IIASA-PC-5

International Institute
for
Applied Systems Analysis

PROCEEDINGS
OF
IIASA PLANNING CONFERENCE
ON
MEDICAL SYSTEMS

August 6 - 8, 1973

Schloss Laxenburg
2361 Laxenburg
Austria

The views expressed are those of the contributors and not necessarily those of the Institute.

The Institute assumes full responsibility for minor editorial changes made in grammar, syntax, or wording, and trusts that these modifications have not abused the sense of the writers' ideas.

TABLE OF CONTENTS

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Agenda

Research Planning Conference

on

Medical Systems

6 August to 8 August, 1973
Park Hotel, Baden (bei Wien), Austria (Conference Room on 4th Floor)

Chairman: Dr. William B. Schwartz, Professor and Chairman, Department of Medicine
Tufts University School of Medicine
Boston, Massachusetts, U.S.A.

6 August

9:00 - 9:30	Welcome and introductory talk about IIASA and about purpose of the Conference by the Director, Professor Howard Raiffa.
9:30 - 10:00	Introductory talk by the Chairman about the organization of this Conference. This presentation will raise questions about suitable approaches to: A. in-house research at IIASA; B. international conferences supported by IIASA; C. cooperation between IIASA and national and other international institutions.
10:00 - 10:30	Summary of previous conferences by the Director (Participants are requested to complete and return the questionnaire before the afternoon session resumes. The answers to the first question about professional backgrounds will be collated and distributed to the Conference members.)
10:30 - 11:00	Coffee
11:00 - 12:15	Presentation of Opening Statements by Conference Participants
12:15 - 2:00	Lunch

6 August

2:00 - 3:00	Presentations by Conference Participants (continued)
3:00 - 5:30	(with coffee break from 4:00 - 4:15)
	Discussion of Research Issues will begin. This discussion will continue until Wednesday noon and will include a consideration of certain of the additional items proposed by the participants.
6:00 - 7:00	Cocktails, Park Hotel
7:00	Dinner, Park Hotel

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7 August

9:00 - 5:30	Continued discussion of Specific Research Issues
	Intermissions:
10:30 - 11:00	Coffee
12:30 - 2:00	Lunch
4:00 - 4:15	Coffee
7:00 - 9:30	A "Heuriger" get-together. Bus transportation will be arranged to bring the Conference Participants and wives to an informal dining establishment where local Austrian wine is designed to foster international relationships.

* * *

8 August

9:00	Departure by bus from Park Hotel to Schloss Laxenburg
9:30 - 12:30	(with coffee intermission)
	Continued discussion of Specific Research Issues

12:30 - 2:00 Lunch (picnic) and tour of IIASA facilities

2:00 - 5:00 A revisit to topics A, B and C listed by the Chairman on page 1 of the Agenda.

* * *

Further Remarks:

1. Participants are invited to express their main observations and proposals, as well as afterthoughts, through written statements which will be reproduced and distributed as far as is possible to all Conference Participants and attached to the minutes of the Conference.

2. No attempt will be made to arrive at a formal set of Conference recommendations. The minutes will reflect all views presented. The Chairman of the Conference, the Director, the Deputy Director, and other research scholars of the Institute will make use of the opinions advanced in formulating a proposed research program in medical systems for presentation to the November meeting of the Council.

Minutes
Research Planning Conference:
MEDICAL SYSTEMS

The Preliminaries

Introduction to IIASA

Professor Raiffa opened the conference and expressed his hope that it would rapidly shed its formality and would evolve into a frank and open airing of viewpoints, opinions, and controversies.

To encourage such exchange, the minutes of the conference will reflect the varying sentiments of the participants but will avoid attribution of positions. Any written statements from participants will be welcome and shall be included in the final proceedings. The minutes will be distributed among the participants present and the council members.

Professor Raiffa gave a short history of IIASA, beginning with the original idea by President Johnson for better coordination of scientists around the world. The twelve founding member countries signed the charter in October, 1972 in London and at the same time selected Laxenburg to be the site of the Institute. The Institute now is well on its way and hopes to have thirty resident scientists by September 1973, sixty by September 1974 and ninety by September 1975. Presently, it faces such problems as the devaluation of the dollar, the scarcity of housing, and the want of convenient transportation.

The Institute will offer three essential services:

- an in-house library connected with libraries in Vienna and abroad,
- an information distribution system, and
- computer facilities.

After Professor Raiffa's welcoming words, all participants introduced themselves and their specific interests.

These minutes were prepared by Dr. Mark Thompson and Mrs. Ulrike Bigelow.

Opening Remarks by the Chairman

Professor Schwartz in his opening remarks noted some skepticism voiced during these introductions regarding systems analysis. The term originated with optimal development of weapons systems and is now out of favor in the United States. Instead, "policy analysis" is widely used. A good way of thinking of policy analysis is as applied common sense --especially in resource allocations problems. All societies have to face problems of resource limitations and are constantly confronted with difficult choices among available alternatives. While it is true that there has been much bad systems analysis in the U.S., it should not be abandoned but but rather improved.

In applying policy analysis, a sharp distinction must be made between policy analysis and decision making. Policy analysis may define the goals and examine ways to achieve them. Often the decision makers present problems which turn out not to be the true problems at all. It is then the task of the policy analyst to point out what the true problems are, to establish their boundaries, to redefine the task at hand, and to arrive at a new set of goals.

The chairman voiced his reservations about IIASA studies of methodology. Only when methodology becomes a constraint should the Institute fall back on such studies. Real world problems are more important, and it is precisely such scholarly studies of complex problems done in a vacuum which have given systems analysis a bad name. Analysts and decision makers must stay in close contact with each other.

What are the constraints IIASA faces? The chairman urged IIASA to take consideration of problems inherent in the Institute's set-up which are bound to arise. He enumerated four such problems:

- acculturation of scholars with widely diverse national backgrounds,

- interdisciplinary communicational breakdowns,

- attaining the critical mass required to tackle successfully a research project, and

- the problem of continuity due to the relatively rapid turnover of IIASA scholars.

To forestall these constraints from becoming crippling, the chairman suggested that seminars be held months in advance for members of groups coming to the Institute. In this way, a group identity can be established and a groundwork for future communications can be laid before any work begins.

Case studies and critiques of previous analysis and of their implementation could be valuable IIASA activities. One such inquiry might investigate why computers have failed in hospital information systems.

The Institute should establish a theme on which five or six people can work--each within his own discipline but each contributing to the resolution of the larger problem. To reach critical mass, collaboration with other institutions may be essential.

In closing, the chairman asked conference members to suggest possible specific in-house projects.

Previous Research Planning Meetings

Professor Raiffa briefly reviewed the previous conferences. He felt that many good ideas had emerged from the conference on water resources. It was agreed to work on a monograph on the state of the art of applied systems analysis --to write a detailed report on the art of systems analysis on water systems and resources; to do retrospective case studies on such river systems as the Vistula, Trent, and the Delaware estuary; to work on a feasibility study for a large river system such as the Danube; and possibly to study a concrete nearby problem such as the eutrophication of an Alpine lake. Presently, two new conferences are being negotiated: on the design and management of the Tennessee Valley Authority and on global modelling.

Concerns similar to those voiced by the chairman came up at other conferences. The conference on large organizations also dealt with the problem of critical mass and the necessity of methodologists cutting across several projects. At the energy conference it was pointed out that simply because an urgent problem exists, IIASA need not necessarily be the right place to deal with it. A problem of this type was felt to be thermal heat and the possibility of climatological changes. The urban and regional systems conference discussed IIASA in terms of a sophisticated clearing house. In such a role IIASA would expedite the interchange of data, unpublished research materials, and computer software. Possible research projects suggested at this conference were: efficient control of such municipal services as solid waste disposal; national settlement policies, and planning of new towns.

Initial Reactions of the Participants

Professor Bogatyrev expressed his pleasure at the quality and scope of the research program under discussion. Topics considered for IIASA in-house research must be selected according to a) their significance and b) their feasibility and tractability to the methods of applied systems analysis. He spoke about projects of particular concern to him.

1) Control of public health care and information - In his task of having to forecast health care delivery up until 1990, Professor Bogatyrev came up against a lack of usable hard data and felt an urgent need for systems analysis in the area of population statistics. He recommended that IIASA in-house research be divided into two spheres:

a) clinical and physiological investigation of man on all levels, beginning with the cell, and focusing upon such problems as cancer and cardiovascular diseases;

b) organization, planning, and control of public health care delivery, e.g., multiphasic screening for which an empirical data base has already been established, but which still lacks expert multi-factorial analysis by applied mathematicians.

2) Emergency health care control - In a big city, rapid transportation and hospitalization in emergencies can no longer be controlled without mathematical programming. In Moscow alone, 600 ambulances stand idle at noon, simply because the number required was based on the peak hour demand realized at midnight.

3) Planning of health care delivery - Many conflicting factors make their influences felt--for instance, acute diseases require shorter hospital stays now, but there are an increasing number of elderly and chronically sick patients. Systems analysis could play a useful role in forecasting and managing these problems.

4) Mathematical modelling of demographic processes and their impact on health care delivery in various countries - Demographic processes must be investigated on more advanced mathematical levels to facilitate health services planning.

In closing, Professor Bogatyrev urged close cooperation between IIASA and WHO and a collaborative distribution of research spheres between them.

One member found the agenda too ambitious. IIASA should cut down rather than add to the list of research themes, avoid duplication with other organizations, and take a hard look at the unique capabilities of systems analysis. He recommended a) that IIASA be a sophisticated clearing-house, to collect, evaluate, and disseminate information, b) that it concentrate on short-term, realizable objectives, c) that it overlap research on several projects such as medical aspects of water resources and energy, and d) that it collaborate closely with other organizations.

In reaction to Professor Schwartz's definition of systems analysis, a participant pointed out that it enjoys no monopoly in applying common sense and in fact represents an offshoot of operations research. Professor Schwartz said that he perceived a difference between operations research and policy analysis. With operations research the exact goal is known beforehand, whereas with policy analysis the initial goal may not be the final goal which is analyzed. Professor Raiffa disagreed, feeling that systems analysis and policy analysis are not so precisely defined or contradistinguished from other disciplines. He reviewed the difficulties of deciding on a name for the Institute. There is a great discrepancy according to vintage and country as to the meaning of systems analysis. This limited ambiguity in fact facilitated the adoption of the present name of the Institute.

Another member liked the idea of a clearing-house, but wanted to know what it really meant. He suggested that "meetinghouse" might be a better concept as it would differentiate IIASA from other organizations such as WHO.

He proposed a) that IIASA break down the main areas of health into subsystems and consider how other human activities, such as sports, contribute to human well-being, b) that IIASA look into the interrelations of sciences and their possible hierarchical order, and c) that IIASA study the higher level interconnections among work performed now exclusively within various agencies, such as FAO, or WHO.

One speaker voiced his concern that the agenda seemed relevant to developed countries only and pointed out that problems of developing nations are also susceptible to technical methods. The agenda description of a possible study into resource allocation he found to be at once too specific and too general. He hoped instead that an actual operational system for a specific country would be examined.

The attention of IIASA was called to the fact that inputs other than resources and medical care contribute to man's well-being and that any research must keep these factors in mind.

Another member addressed himself to the use of computers in health care systems which should relieve physicians from administrative chores and should also provide a high standard of information for the planning and forecasting of health services. He would like to see IIASA turn its attention to: integrating the medical information of various health establishments, standardizing health information, establishing minimal and optimal systems of health information, developing systems to monitor the consumption of prescription drugs, and better integrating computer equipment into the health services.

Drs. Atsumi and Kaihara described the present shortage of manpower in computer applications in Japan and a growing concern about the dangers of violating patient's privacy through mechanized information systems. A survey of health care systems of the NMO's could be the beginning of a cross-cultural analysis of health care delivery which should yield a set of universally applicable descriptive terms.

Dr. Fleissner described a project studying the delivery of health care in which his group, from the Institut fuer Hoehere Studien is currently involved. They are particularly interested in the influence which the social hierarchy and the political system have upon health care. Dr. Fleissner expressed hope that IIASA and IHS could cooperate to resolve methodological problems.

One participant said that IIASA should strive to tackle those projects which cannot be done elsewhere and which require international cooperation. In-house cooperation between the various projects and cooperation with other organizations should greatly benefit research done at IIASA. Agencies such as WHO, FAO, and UNESCO should be coordinated to study such international problems as the inequitable distribution of health manpower resulting from the patterns of migration by educated people. Policy changes resulting from systems analysis may best be brought about by international agencies. IIASA could be the focal point for studies to determine what mix of personnel should perform health services; what are the most cost-effective modes of health training; what health facilities are needed in different parts of the world. Such health problems do not lend themselves to solution by individuals or even by individual countries. IIASA as an international and multidisciplinary agency is ideally suited for the task.

The question of manpower and continuity for IIASA projects was raised. Professor Raiffa replied that a stay of two to three years is planned for project leaders, and that young people coming straight from the university might stay for as long as three years. To avoid creating a brain drain while attracting first rate scholars, many scientists will come to IIASA for short periods or will visit IIASA periodically as "permanent itinerants."

A rudimentary voting process was held to determine the priority of specific research issued for discussion at this meeting. The results of this voting are given in the accompanying document "Specific Research Issues for Discussion."

One member argued that the problem of resource allocation was not common to all social systems. If IIASA decided on in-house research in this area, it might encounter problems resulting from the impossibility of making comparisons between different economic systems. In response, it was pointed out that money represents only a small fraction of the total resources. No society can avail itself of unlimited resources, and all countries face such decisions as the determination of the necessary numbers of hospital beds, doctors, and other medical personnel. It is precisely the differences of approach to these problems which will yield interesting comparisons and enable countries to learn from one another.

One participant saw an inconsistency in discussing resource allocation before a measure of health status is available to make the problem tractable. Other participants felt that the statistical work on health status measurements already performed at WHO was an adequate foundation for research into resource allocation. IIASA may well be the place to make good use of the vast collection of WHO data.

Specific Research Issues

Health Status and Multi-Phasic Screening

More methodological work is needed before reliable health status indices can be established. Subjective criteria resistant to quantification--as the relief of pain, anxiety, or itching--should perhaps be given greater attention than heretofore. To put the relevant quantities in perspective, we note that if cancer were cured, the total life expectancy would increase by four to six months. It seems likely that relief from discomfort which could benefit many individuals throughout their lifetimes would constitute gains of the same magnitude as the cure for cancer.

Professor Schwartz hoped that participants would discuss substantive issues on both the input and output sides in the context of possible research projects for IIASA. He expressed special interest in preventative medicine and multiphasic screening.

Measuring health status will require more work on key problems in methodology. IIASA could pursue problems arising from conflicting objectives and multiple criteria. The policy problems of health status in regard to technological forecasting and adaptation comprise another possible project. Since complete objectivity will not be possible, subjective measurements will have to be introduced. There is at present a lack of collected data on social indices. Such indices can be developed from medical records which, in the U.S. experience, have been shown to be important factors for predicting the future course of a patient.

In working out a health status index, the quality of data and the improvement of medical terms and definitions should be major concerns. For IIASA to become involved in this, however, would require close cooperation with hospitals and other organizations.

The pressing need for health status measurements has prompted all previous research planning conferences to express hope that the medical conference would give attention to this area.

In the area of voluntary and involuntary risk taking--smoking, alcoholism, automobile speeding, and so on--difficult conceptual problems are raised. We may be looking here for technological fixes to sociological problems. Many accidents may be subconscious or conscious suicides which no guard rail could have prevented. Risk taking as part of human life can never be eliminated, but one has to separate health from unhealthy risk taking.

One participant suggested the introduction of a concept of morbidity episodes to measure the efficiency of health care. He noted that one fourth of all morbidity episodes filter into the professional record-keeping system. Without using professional disease categories, a person's health could be defined in his social context: how he himself feels and how he appears to his family and work acquaintances.

Again, participants were reminded that research suggestions must be within the realm of possibilities of IIASA. While, for example, the control trial approach to detection of hypertension is worthwhile, it is too comprehensive a task in which to involve the Institute. IIASA could, however, make specific contributions by looking at the way screening mechanisms are laid out, showing how better to use computers in information processing, and using mathematics in prediction.

An area for IIASA research could be the elimination of a contradiction in modern medicine: the combination of quantitative methods and subjective evaluation of results. IIASA might seek to adapt and extend mathematical techniques so as to reduce the subjective latitude in medical decision making. One participant described a way in which structured analysis was successfully applied to a compulsory screening clinic. It was proven that the number of required clinical visits was more than twice the optimal frequency of screening.

One member suggested that IIASA contribute to preventive medicine by working out a standard format for the evaluation of preventive activities. It might enumerate and elucidate the crucial parameters of mean number of visits before finding an active case; the cost of each visit; and the cost of care. Taking these indicators into account, IIASA could develop modes of statistical analysis for the evaluation of screening procedures.

The following criteria for projects to be accepted by IIASA were proposed:

- high chance of success
- high chance of usefulness of output
- short completion time
- small staff needs
- multidisciplinary approach
- interest to many countries.

The chairman again pointed out the need for an investigation of multiphasic screening. For diseases of low incidence, screening has now become prohibitively expensive. Another factor to be considered is the relatively high incidence of false positives. Of 1,000 people screened for cancer of the colon, 1 true positive versus 100 false positives were found. This causes such mental anguish that it must be added as a serious consideration when weighing benefits against cost. Experience in the Soviet Union supports this view, where 1,000 screenings resulted in 200 positives, but only 2 true cancers.

Since the introduction of multiphasic screening in the USSR, many people are being treated for diseases for which they previously did not seek medical care. Economic analysis shows that multiphasic screening has definite benefits realized through early disease detection and subsequent effective treatment. Whether or not these outweigh the costs and disbenefits, is not yet clear. One negative factor is the psychological damage done to patients who were found to suffer from incurable diseases such as leukemia. To improve multiphasic screening, it was suggested that systems analysis be used

- to develop mathematical models of diseases to calculate future incidence
- to determine the influence on health status of many more factors than are used now
- to develop a generalized mathematical health status index
- to determine the degree of risk caused by undetected diseases.

Voluntary multiphasic screening in Japan has been too costly and has realized disappointing benefits. A study examining the value of information obtained from each test could be useful.

Certain ethical problems are inherent in handling the information obtained through multiphasic creening. False positives may occur, possible treatments may entail various types of risks, and decisions must be taken whether to inform the patients about incurable diseases. IIASA could apply an inter-disciplinary approach to such new ethical questions. By quantitifying perceived risks and trade-offs and values, it may help patients, doctors, and societies to make more rational decisions based upon their individual value judgements.

Professor Schwartz urged that IIASA use multiphasic screening data as a basis for improving policy decisions by public health officials. He felt that early detection of many maladies--one exception is hypertension--had not yet proven its value. The following negative effects must be considered:

- detection of incurable diseases,
- psychological trauma to patients, and
- frequent false positives.

Even if multiphasic screening were costless, it could not be considered an unambiguous boon.

It was suggested that IIASA hold an international conference on health status. In-house study should enumerate its components and describe the effects of various inputs. An important goal would be to relate health status to many environmental variables which would assist other sectors of Institute research.

Planning, Analysis, and Management of Health Care Systems

Professor Schwartz introduced this subject with a sketch of the situation in the United States, where many of those responsible for public health have no experience in systems analysis and no understanding of modern management techniques. A concerted effort to educate decision makers and to structure the decision making process may now be well worthwhile.

If health care services are found indeed to comprise a unified system in need of management, it must be approached as a multi-professional operation. Health professionals are traditionally trained in individual patient service and not in management. It was proposed that IIASA establish a library of already existing health care models beginning with the Austrian model already available and a Canadian model to be supplied later. The applicability of industrial management information models to health systems also merits investigation.

The training of planners and managers in health care systems faces the obstacle of a great resistance to change in the profession. IIASA could work on an analytical approach to health care management and tailor it to the curriculum level for medical students.

In response to this suggestion, Professor Raiffa said that it had been decided early on that IIASA would not be able to get involved in giving training courses. Its educational role will have to be limited to proposing curricula and possibly developing teaching material. At the conference on design and management of large organizations the idea of coordinated Ph.D. theses for cross-cultural comparisons had been favorably received. If such comparisons were done on the hospital and health care level, a fruitful joint project might result.

The use of computers in health care systems poses many unresolved problems. The mathematical formalization of information is often too diffuse to be useable; a minimum volume of information needed for different levels of management has to be determined; quality and effectiveness indices have yet to be developed. Hospital management and emergency care systems in big cities could be studied by IIASA as initial components in a more embracing health information system.

The development of systems analysis for management information systems should give priority to their application in medical situations. A start has been made in this direction in Japan, and the Japanese participants assured IIASA of their desire to cooperate.

IIASA was seen as the natural place to adopt a systems approach to health, to develop simulation models, and to resolve such methodological problems as the integration of data collection and standardization, diagnostic algorithms, and therapeutic techniques. Existing analytical models should be standardized internationally so that they can be tested with data from different countries. While IIASA could not engage in data collecting on a large scale, it could make use of the vast accumulation of health data at WHO and at the UN and give it a more analytical perspective. The Institute is in an ideal position to see the whole picture through a cross-cultural, wide-angle lens.

A warning was sounded not to engage in too technical projects but leave this to the universities. Technical matters could be discussed by experts in many fields during conferences at IIASA called for this purpose. Health related activities could be studied and integrated through intersectoral modelling.

The place of health care in the total national system and the activities it should include might be investigated by IIASA. In view of the constantly rising cost of health care, IIASA should seek a definition of health expenditures on an international level to be used for comparisons. A specific IIASA project could be a sensitivity analysis of cost reductions designed to arrive at the optimal portfolio of expenditures and investments in health care.

One participant asked who the ultimate client of any IIASA analysis would be. The Institute faces the dilemma of thirteen or more potential clients to which it cannot possibly relate at once. It can only address itself to solving prototype problems of general enough interest which can be useful to various societies. Participants argued that the Institute ought to avoid pursuing purely scholarly matters and must achieve policy impact.

Professor Raiffa agreed with the main thrust of this argument but voiced his interest in the study of methodological problems. One example of a concrete problem that might prove a valuable focus for IIASA research is the control and eradication of hoof and mouth disease in Austria and neighbouring countries.

One participant responded that IIASA should not pursue a concrete area by itself but should instead identify systems questions such as what is health and what is the natural state of the environment.

Another member argued that concrete projects similar to a study of the epidemic of hoof and mouth disease were precisely suited to the capabilities of IIASA. Solution of this policy problem requires an expert familiarity with epidemiological systems models, their limitations and applicability. This is exactly the type of expertise IIASA should maintain and offer. Should problems of political organization arise, these could be studied by the organization systems team at IIASA. IIASA would have to display political finesse in dealing with the Austrian Health Ministry. Nevertheless, if the political problems did not prove overwhelming, the proximity of the problem, the availability of data, and the importance of finding a solution could render the study of hoof and mouth disease highly valuable both to the Health Ministry and to IIASA. Good work of this type would engender demand for similar applied research of the Institute.

The recent outbreaks of diseases thought to be under control--such as cholera--have intensified the policy debate among the alternatives of improved sanitation measures, preventive vaccination, and treatment. One member suggested that while IIASA could not tackle this problem alone, it could apply systems analysis to studies undertaken elsewhere.

Health Information Systems

Professor Schwartz opened the discussion telling of the new pessimism in the United States about grandiose hospital information systems. Vast sums of money have been spent with disappointing results. The general experience has been that the system breaks down as soon as the computer experts leave. The investment in hospital automation has been disproportionate since hospital contact makes up only five percent of patient care. The achievements of health information systems merit careful review. Marginal analysis may be valuable in indicating which facets of these systems are expendable and in determining the appropriate size and complexity of the optimal system.

Physicians' resistance to change and the lack of training in modern health information methods severely limit the effectiveness of hospital automation. One participant felt that the debacle at Massachusetts General Hospital derived from a lack of cooperation. A technological breakthrough to simplify procedures may make computerization more convenient and thereby more palatable to medical professionals. Another stumbling block is the need for drastic adaptive re-programming when an operational system is transferred to another hospital. Moreover, there is a great disparity in language between medical records and computers. IIASA could develop minimum requirements for health records so that they can be easily translated into computer input formats. Possible cross-cultural surveys on information handling may reveal technologies different from and better than those used at present in any country.

The chairman suggested that the long-term cost of computers to society should be investigated. While computers ought to be saving personnel, they never do, simply because the demand for data quality rises as soon as the cost of information processing goes down. The burden of supplying information to the voracious system comes to outweigh any advantages of more rapid access to records.

The disenchantment with automated health care systems has not yet reached Japan where their promise is still seen as bright and where it is hoped that the disappointing experiences elsewhere will serve as guides to prevent their repetition.

A critical international survey upon the application of computers in hospitals was seen to fall within the realm of IIASA projects. One participant, however, doubted the Institute's ability to build a model information system because of the great differences in traditions, languages, and economic and social systems in the different countries.

The question of confidentiality of medical records was discussed. It was proposed that IIASA survey the technical and ethical problems arising from the use of medical records where individuals have to be identified and yet their privacy must be protected. Some participants viewed the technical side of such a project as unsuitable for systems analysis and as merely a problem of computer expertise.

Medical Research

Professor Schwartz suggested that the discussion deal with issues arising from biomedical and related research with long-term benefits. He acknowledged that difficult intertemporal trade-offs exist between the long and short terms, but alleged that no country has an explicit, rational policy for reaching decisions on research strategies, tactics, or targets. Value judgments play a great role in such decisions and will hinder the complete rationalization of the decision process. Yet, Professor Schwartz pointed out, every time any country makes any allocation to biomedical research it is invoking de facto its own value structures. He argued that systems analysis can go far toward eliminating the inconsistencies of the structures and toward enabling the decision makers better to sense the difficult trade-offs implied, but often forgotten, in their policy choices.

One participant responded that inadequate mathematics were not at all the stumbling block, but that the power of specific individuals often was the deciding factor in resource allocation for a specific area of research.

At present little research is devoted to improving health care delivery. If it were viewed as a major industry, one might be able to determine how much should be spent to improve such an organization. This suggestion met with skepticism. One member pointed out the virtual impossibility of separating the costs of research, patient care, health care delivery, and teaching. A $2 million study is underway now in the U.S. to develop methods to separate teaching from research and service costs. Participants felt, however, that even if this could be done, the task of deciding on the final resource allocation would always be burdened with value judgments. A possible alternative might be to consider the problem as one of manpower allocation, on a project by project basis.

Professor Raiffa reported that the management of research and development concerns many projects at IIASA. Especially in the energy project, the problem of the multi-value nature of inputs and outputs in evaluating benefits will have to be faced. IIASA will look into the methodological problems of research and development, but he was not sure whether this would also be done in the biomedical area.

Mathematical Modelling of Physiological Systems

The discussion shifted to mathematical modelling of physiological processes. Participants related their experience that many computer application projects fail because they do not use sufficiently sophisticated tools. Perhaps such modelling would not be a suitable project for in-house research, but instead a topic for IIASA conferences. Specific problems such as cell differentiation might be posed whereupon the Institute could support a symposium to consider mathematical modelling approaches toward a better comprehension of the phenomena.

It was proposed that IIASA prepare a handbook on physiology from a systems analytic point of view. A series of conferences should be structured around the multidisciplinary creation of this handbook, Some members objected, saying that IIASA is not a medical school and should not pursue purely physiological research but should be guided by considerations on the policy level. Moreover, any work in physiological modelling would take a minimum of five years. The function of models in medicine is to provide a teaching tool and to link the real world with the laboratory and research. IIASA was not thought to be equipped to carry out such work.

Professor Raiffa supported the idea of writing a handbook, but reminded the conference that IIASA's main direction should be policy oriented systems analysis. Within the inherent constraints, IIASA can organize research done elsewhere and bring together specific groups of people working on the same problem. In the same way that Cornell hosts a gathering of scholars in probability theory each summer, IIASA could become the announced home of people in the area of mathematical models. One or two generalists on the staff could then coordinate in-house interactions.

Impact on Health Care of Expensive, High Technology Discoveries

The addition of only two major new discoveries, the artificial kidney and the artificial heart, have created a potential burden of $3-4 billion per year on the U.S. health bill which means that seven to eight percent of the total U.S. health care cost could be devoted to a relatively small number of people. Moreover, a large portion of the health care manpower will be tied up at the expense of less visible groups of illnesses.

Professor Schwartz asked participants how their nations were resolving the policy problems posed by the new technologies.

Discussion revealed that the projected cost of artificial organs in Japan has reached an estimated 3 trillion Yen per year. The question of priorities of prosthetic versus other research is becoming critical.

Members spoke of a perceived technological imperative: if there is a way to prolong a life, it must be implemented regardless of cost. However humane and appealing this rationale might appear, it obscures the difficult problem of allocation. The visible patient requiring an artificial organ to survive is often saved at the expense of ten invisible, statistical lives that would have been saved if the money instead had been allocated to a vaccination program. It was argued that through intensive medical intervention a patient no longer lives a "natural life." His survival moreover transmits his weaknesses through the human gene pool to magnify the problem for succeeding generations.

One participant pointed out that the health care costs of developing countries could be covered for ten years with the amount needed to pay for the use of high technology prosthetic aids for three months in the United States. Another participant agreed that while at present the cost of such technology as dialysis is prohibitive, the long term cost of prosthetic devices will eventually decrease.

In dealing with high technology medicine, the dilemma arises pitting humane versus social interests. Most of the spectacular advances in medicine such as organ transplants, medically supported pregnancies, artificial organs, and resuscitation present a burden on society, but who would dare to advocate their abandonment? This was felt to be an issue for religion and ethics and not within the scope of IIASA research. The question was raised whether human values can at all be subject to systems analysis.

It was suggested that IIASA pursue social cost accounting of high technology medical advances. The actual cost, monetary and human, of the prolongation of life through correction of spina bifida, for example, may well be too high. A broader look at life in terms of quantity weighed against quality may here be necessary. A cross-cultural study upon the handling of pain was suggested as a possible IIASA research topic.

Finally, the role of applied systems analysis may be to set up a decision framework within which the values of societies and individuals are handled in consistent, rational manners to achieve problem resolution.

Demography

Medical treatment and demographic shifts interact with and influence each other. It may be useful to develop models to capture these interactions and to facilitate the improvement of medical policies that affect, or are affected by, demographic movements. IIASA would not be able to do any detailed demographic work, but might keep track of migrations and other population changes through cooperation with other agencies. Demographic factors may also be incorporated within other IIASA research projects--especially the urban systems project.

Emergency Medical Care

As emergency medical care becomes more and more unmanageable, it was felt that systems analysis could develop a design for management to be used in many countries. IIASA could initially concentrate on one aspect of emergency care, such as coronary care ambulances.

Resource Allocation

Each society faces resource constraints. Professor Schwartz felt that systems analysis should play a role in choosing among the trade-offs involved in the allocation of resources.

Perhaps the systems approach should commence with an embracive concept of the quality of life which should be maximized. Such a concept should take into account all the social indicators considered by various parties to make up "the good life." Efforts of specialists to maximize one subsystem--their organ--must be resisted.

The two most important resources, manpower and health care facilities, are inequitably distributed in most countries. University hospitals in cities attract the greatest number of physicians. IIASA could look into the categories of manpower needed to provide primary care. Another feasible study would examine the factors which induce health practitioners to work at a given place. This study could investigate how these factors might be manipulated to improve the distribution of health manpower.

One participant suggested that systems analysis in the area of psychosomatic illnesses could lead to an effort to educate people how to be healthy. IIASA could study the cost effectiveness of such an intensive education campaign.

It was argued that the social benefits of health are not quantifiable and that the policy choices must necessarily be subjective and dependent upon the circumstances. A study on personal value structures and on the modes of aggregating them to guide allocation decisions was judged worthwhile. Another participant acknowledged that any study touching upon value judgments would encounter many difficulties. He thought, nevertheless, that a good start in this area would be to examine public expenditure decisions to discover their underlying value structure.

Planning Biological and Medical Systems Research for IIASA

Interaction with other IIASA Projects

Complex Use of Water Resources. In connection with the water resources project, it was suggested to study:

- public health
- sanitation
- water supply
- sewage
- the creation of medical problems through man made dams, as schistosomiasis and hepatitis
- traces of pollutants in water supply -toxic pollutants, hormonal trigger pollutants, and psychologically disgusting pollutants

- food supply and nutrition.

Urban and Regional Systems. Themes connected with the urban and regional project were:

- solid waste disposal
- industrial pollution
- air and noise pollution
- airport siting
- balancing of waste disposal across different media
- impact of urban development on health.

One speaker felt that in this area, IIASA should concern itself with large interactions by means of simulation models. The Vacouver Regional Model--originated by C.S. Holling who will be spending the coming year at IIASA--is a possible prototype for inter-project research.

Energy Systems. The energy project of the Institute will depend greatly on medical cooperation for such problems as assessing acceptable toxic levels and adequate experimental methodology for such assessments. Certain recommendations in the existing regulations on the minimum acceptable dosage of radiation have been based on the concept of risk. However, no risk-benefit ratio has yet been established nor has a rigorous examination of risk/cost trade-offs been undertaken. In this area as well as in that of psychological effects, the energy and medical projects at IIASA will need to cooperate closely.

Systems analysis might be used to look at the interaction of the many pollutants which contribute to the total body burden. The goal of such a study could be to describe mathematically the levels and combinations of toxins constituting various degrees of risk and impairment to the human body.

Members did not think that IIASA would be able to carry out fundamental research on linkages of pollution levels and health effects. Nevertheless, it could reexamine, evaluate, and summarize work already done at the epidemiological and clinical levels. The contribution of IIASA would be to recast the findings of this research into forms more useful to policy makers.

One participant suggested that IIASA help establishing air quality criteria. This would require the consideration of diverse factors and a decision on the minimum number of subsystems to include. It would also present difficulties in interfacing various models--for instance, econometric with epidemiological models. Another member made a plea that IIASA strive to determine the acceptable pollution levels in all media. He urged that the Institute consider the soft data of psychological effects as equally important as those more easily quantifiable. A successful study here might lead to the publication of IIASA guidelines for allowable pollutants. Another member warned that such a project would risk embroiling the Institute in political quarrels.

One speaker mentioned that public health confronts the constant danger of correlations being phrased in terms of effects. Critical analytic inquiry is required to determine just which statistical relationships justify classification as cause and effect. Such an inquiry could clarify many issues in the current debate over social experimentation. IIASA could study the phenomenon that public awareness and the consensus for action arise more frequently from rare catastrophic events than from statistical analysis.

The United Nations is presently experiencing difficulties in arriving at a set of social standards. It was argued that systems analysis could pull together all the constraints and objectives relevant to the decision process and then define what is understood by the standard. Although it is not always possible to differentiate clearly between constraints and goals, careful analysis should resolve much of the confusion. To cope with the difficult interface between the soft sciences and systems analysis, conceptual problems must be tackled and data must be quantified more adequately. The reigning inter-disciplinary conceptual chaos severely limits successful splicing of complex models.

Interaction with Other Institutions

Professor Raiffa reported that the wide range of problems and the small size of IIASA will make cooperation with other institutions imperative. At present, close informal ties have been established with a small number of scientific bodies both national and international. Members of IIASA may work at other institutes and vice versa. Professor Raiffa asked for suggestions of institutions in the medical area with which IIASA could establish such ties.

Dr. Hogness felt that collaboration with the Institute of Medicine of the U.S. National Academy of Sciences may prove fruitful. As an independent agency, the Institute's primary activities are policy studies on the U.S. health system. Its 211 members include 60 in-house staff of whom 35 are professionals. Its continuing studies cover:

- measurement of health status
- cost of education for health professionals

- implications of the categorical catastrophic approach to health insurance
- implications of the regulatory versus the competitive approach in health systems.

Scientists from various countries engaged in such projects could come to IIASA and exchange views before completing their work on them. The final reports could then be furnished to IIASA for distribution.

The Medical Research Council in the U.K. was suggested as another possible contact for the Institute. Representatives from the Royal Society and the Department of Health and Social Security participate on the Council, the major concern of which is scientific policy.

Mr. Daw urged cooperation between the Institute for Radiation Protection and IIASA in establishing minimum acceptable radiation doses.

Concrete Possible Projects

Aid for the Partially Blind. The discussion moved to a research proposal put forward by Mr. Page concerning the interaction of technology and the treatment of the partially blind. IIASA could do a cost-benefit analysis comparing the use of closed-circuit television devices against the present reliance on Braille. Such a project might follow a conference on the technological aspects of prosthetic devices in this area.

Modelling of Cancer and its Treatment. Dr. Petrovski reported on the use of systems analysis in the investigation of cancer. In his research, the organism was treated as one complex system and it was found that different cancers have remarkably similar mathematical behavior. Figure 1 shows the dependence of tumor mass on time and the narrow margin within which the cancer must be detected and cured. To compare the effectiveness of alternative therapeutic strategies, three systems had to be integrated mathematically: the cell system, the immunity system, and the blood regeneration mechanism. This was done with nine non-linear differential equations on an IC4-470 computer. Figure 2 shows the dependence of optimal control policies upon the time when treatment begins. Systems analysis could be used to compare treatment strategies and the effectiveness of resource allocation. Discussion of such problems at IIASA could open the way for further research.

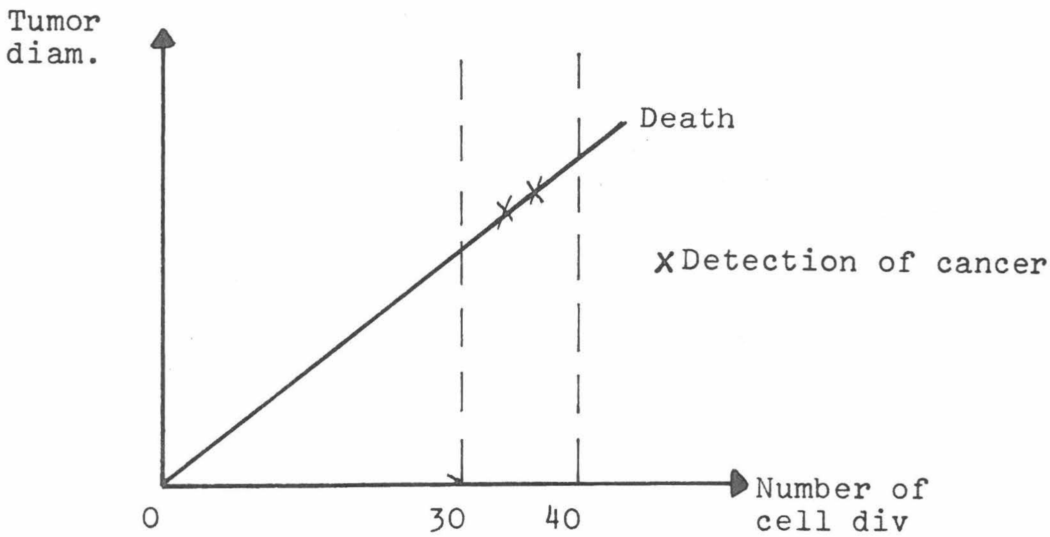


Figure 1
(from the book of N.M. Emman)

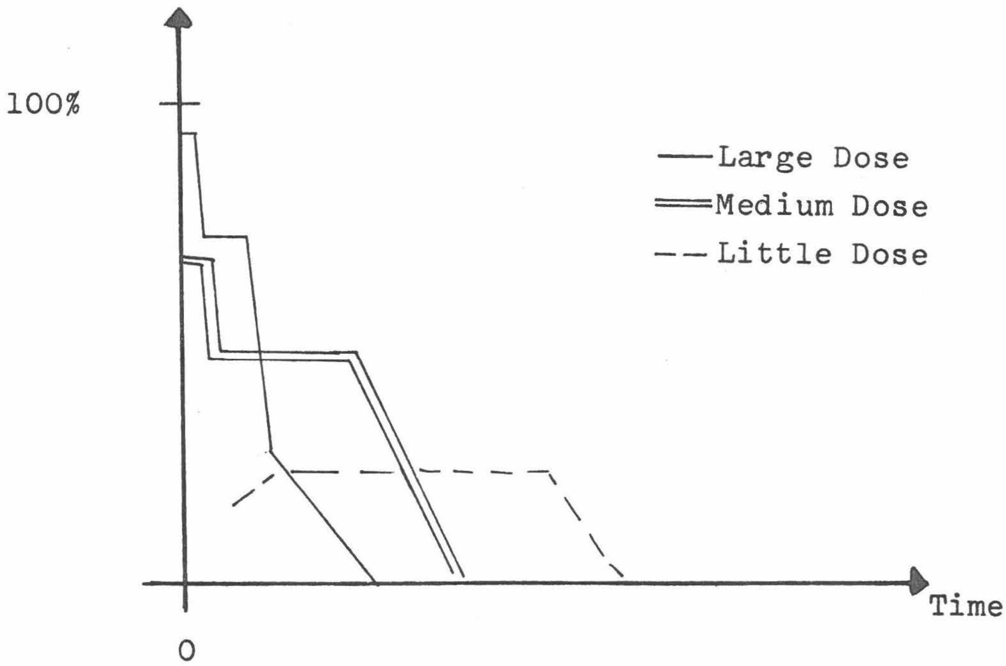


Figure 2
Percentage of Surviving Animals
(experiments with chemico-therapeutical animal treatment)

Physiological Modelling. Dr. Trappl argued that an integrated systems approach to physiological systems could be a valuable component of IIASA research. The brain, for instance, could be studied from the viewpoints of its physical structure, of its capabilities, or of its aspects of consciousness. In response, there was some question on the feasibility of such a project for IIASA. Several teams have already been formed to model the cerebellum and there is an Institute of Brain Research at UCLA. Dr. Trappl described techniques now being used to model human brain processes and suggested that these methods might be extensible to other types of models - as, for instance, urban simulations. Other participants supported the idea of extensibility and felt that a valuable conference could be held to compare the various simulation techniques used in different modelling areas.

Drug Prescription. The discussion shifted to the role of physicians and prescribers of drugs. Drug consumption has become a major problem and one participant felt that the scope of ongoing research on drug purveyance should be broadened to include international comparisons. The possibility should be investigated that the difference in drug use in various countries is a function of their social structures. IIASA could encourage research teams and coordinate cross-cultural studies. The collected data should be standardized. Professor Raiffa said that IIASA could carry out such cross-cultural studies but he favoured research on a micro-observational level--perhaps through orchestrating a multi-national set of doctoral candidates. The central organization would have to ensure agreement upon terminology and a basic compatibility of study objectives.

Participants felt that IIASA must keep in mind the problems of long range research. Professor Raiffa thought that many short term projects will pay for the long term ones in the sense of gratifying the demand for immediate output. It was suggested that IIASA draw up a list of problem areas to be permanently reviewed and kept in mind as possible research themes.

Computers in Medicine. Professor Schwartz opened the discussion on the medical use of computers. Most computer work in clinical care is oriented toward diagnosis. This could eventually extend high quality care through modifications in the training of physicians and a more effective use of allied health professionals. At present, no computer programs deal with risks and benefits in terms of the quality and the distribution of health care. Thus the rapid deterioration of expertise with increasing distance from university hospitals is rarely taken into account. It is not within the scope of IIASA to gather together large groups of scientists for fundamental research. Yet, on the pattern of the ARPA network in the United States, the Institute could create a nucleus for an international network linking computing centers in different countries. It will thereby gain access to ongoing work and will erase the time barrier in information sharing and in the cooperation of scientists dispersed throughout the world. For long distance communications, IIASA could petition governments for free satellite time. These suggestions were strongly supported as ways to unify data bases, to achieve international cooperation, and to circumvent the Institute's budgetary limitations on computer equipment purchases.

Professor Raiffa reported that the Institute's Executive Committee had encouraged IIASA to investigate membership in such networks. The present computer equipment includes a Honeywell-Bull time sharing system which has been installed. At the urging of computer consultants, IIASA will not invest large sums in hardware, but will concentrate on software coverage. Negotiations for mini-computers are under way. ARPA links have now reached Europe and IIASA may soon be connected. Computer connection with the socialist countries is now a viable and appealing option. Foundation support may be forthcoming for satellite-linked television conferences.

Project Organization

The discussion moved to a review of the specific research projects which had been suggested. Professor Schwartz asked how many people should be working on a project, what disciplines and what countries should be represented. Professor Raiffa strongly argued for a cross-cultural and cross-disciplinary balance. The Charter requires that at least two thirds of the scholars be from countries represented in IIASA but the rest may come from non-member countries. It is not necessary that each member country be represented on each project. An acculturation phase for each project--to facilitate interaction between members of different countries and disciplines--and a phase-out stage after completion were advocated. Especially in health care, there is a severe lack of dialogue between the planners and the practitioners which may be overcome with the introduction of pre-planning stages. One member doubted that a project life of one year would be adequate. He argued that data collection will take six months and so will analysis and discussion. More time must then be allocated for model building and writing up results. Therefore, the nuclear participants of a project ought to stay longer at IIASA, ideally for three years.

One participant felt that project staff should get acquainted and build common ground before their arrival at the Institute. For a multiphasic screening project, for instance, the manpower requirement may encompass such specialists as diagnostic clinicians, a biostatistician, an epidemiologist, an economist, a sociologist, a systems analyst, a probabilist, a psychologist, and a health facilities planner. These disparate contributers should not arrive at the Institute without prior contact with each other. Several of them could cut across to other projects. Two years was seen as the minimum time span for a project. After the initial burst of activities, the number of scientists involved will diminish and perhaps only two or three scholars would be required to work full-time throughout the life of the project.

The optimal mix of disciplines working together on any one project will have to be established. To shorten the acculturation period, it was suggested that scholars who already have multidisciplinary experience be given priority.

One participant feared that the Institute programs were too ambitious in view of recruitment and language problems. He urged that the Institute concentrate on such activities as adapting new developments in systems analysis to medical situations.

Professor Raiffa explained that planning at the Institute was still in a state of flux. The number and size of projects have not yet been determined. He has had experience in bringing people together for interdisciplinary work and he has confidence that when there is a specific urgent problem, people can and will pull together. The present strategy of defining overall themes and of pursuing projects with varying life cycles within those themes depends critically upon the guidance provided by project leaders. The Institute must remain flexible, if necessary, to abandon projects which absorb far more resources than their output or potential output justify.

In Closing

The participants expressed their thanks to the Institute, to the chairman, to Professor Raiffa, and to the supporting IIASA staff--praised for their efficiency as well as for their decorative attributes--whereupon the meeting was adjourned.

Specific Research Issues for Discussion

High

1) Health Status

   a) Problem of measurement of health status

      i. Objective criteria--expectancy, mobility, days lost from work (these are the traditional modes)

      ii. Subjective criteria--relief of pain, itching, improved appearance due to effective suturing, relief of anxiety

      Assessment of preferences by means of multi-dimensional utilities

   b) Ways in which health care influences health status

      Influence of:

      i. Control of alcoholism, accidents, environmental pollution, smoking, etc.

      ii. More physicians and hospitals

      iii. Preventive medicine (e.g. multiphasic screening)

2) Planning, analysis, and management of health care system

   a) Training of planners and managers--post graduate training, refresher courses, etc.

   b) Constraints on planning and management in various countries and lessons to be learned by cross-cultural comparisons

   c) Management information systems

3) Health information systems with special reference to housekeeping functions such as pharmacy, scheduling, medical records

4) Medical Research

   a) Assessment of return on investment in biomedical research

b) Cost benefit analysis of return on investment in research versus investment in care (use of discounting techniques)

5) Resource allocation designed to optimize use of resources in delivery of health care.

Medium

6) Impact on health care of expensive, high technology discoveries which permit long term management of catastrophic illnesses (artificial kidney, artificial heart)

a) Influence of payment mechanism on level of resources devoted to particular illnesses

b) Equity

c) Skewing of resource allocation

d) Choice of research goals in light of long term cost to society

7) Demography--population impact on health planning

8) Interaction between policy areas--energy-water-health

9) Interaction with other programs (national and international)

10) Emergency medical care

Low

11) Regulation of the health care industry (quality assurance, certificate of need, length of stay)

a) Impact on quality, quantity and distribution of services

b) Impact on cost of services

c) Influence on behavior of provider and consumer
Note: Cross-cultural comparisons should be particularly useful

12) Impact of cost of health services (including money and time costs) on demand for services

a) Overburdening of the system

b) Modes of equilibration when system is stressed (rationing processes)

c) Equity

13) Computer aided diagnosis and treatment ("artificial intelligence")

Chronological List of Proposals
Brought Forward at the Research Planning Meeting of IIASA on
Biological and Medical Systems

1. Projection of Demand for health services.
2. Demographic effects upon the demand for health care.
3. Control and management of emergency health services.
4. Meta-level interconnections of health-related studies conducted by many international agencies.
5. Improving integration of computer techniques in health care delivery.
6. Standardization of classification in health systems.
7. Computer assisted diagnosis.
8. Improved management methods in the health sector.
9. Systems analysis of health care manpower categories.
10. Management of health care in the municipal context.
11. Cost-benefit analysis of comparative modes of health training.
12. Geographical distribution of health manpower.
13. Effect of pollutants on health.
14. Development of a health status index.
15. Systems evaluation of multi-phasic screening.
16. Improvement of medical information flows in the hospital and the nation.
17. Cost effectiveness comparison of preventive and therapeutic care in specific situations.
18. Measuring the output of the health care system.
19. Studies of risk taking in the health sector.
20. Development and generalization of mathematical models of disease incidence.

21. Mathematical determination of general susceptibility to illness.

22. Collecting an inventory of useful health models.

23. Evaluating health information systems.

24. Inter-sectoral modelling of health phenomena and related activities.

25. Marginal analysis of health expenditures.

26. Consultation on specific policy questions (hoof-and-mouth disease and cholera)

27. Measuring the output of biomedical research as a first step in improving the allocation of research monies.

28. Mathematical modelling of specific physiological processes.

29. Compilation of a handbook of methods and models in quantitative physiology.

30. Epistemological inquiry into health care delivery systems.

31. Ramifications of new medical technologies (artificial kidneys, artificial heart, surgery for spina bifidia).

32. The central nervous system from the perspective of general systems theory.

33. Health considerations in the management of the water supply (schistosomiasis).

34. Establishment of pollutant standards based upon levels of human hazard.

35. Interfacing econometric and epidemiological models.

36. Mathematical models of diseases and their response to treatment.

37. Comparative modelling of physiological processes at different levels of abstraction and from different perspectives.

38. Guidelines for the allocation of scarce resources in the health field.

Medical Application of Computers in Japan

K. Atsumi and S. Kaihara

This report describes the present status of the application of computers in medical care in Japan. The report is divided into two parts. The first part describes the application of computers in hospitals in Japan, and the second part describes the present and future of the medical information system.

The Application of Computers in Hospitals in Japan

The Present Status of Computer Applications in Hospitals

The use of computers in hospitals was started in the middle of the nineteen-sixties in Japan. In those days, however, it was still a trial and the size of computers was small. It took approximately 5 years before the application of computers in health delivery services was more widely accepted. From the beginning of the nineteen-seventies the number of computers installed in hospitals has gradually increased. Some of these are large computers.

The results of a survey performed by the Japan Electronic Industries Development Association in 1972 are shown in Table 1. The data from 1972 and 1973 is incomplete and the actual number will be approximately twice that listed here. The percentage of hospitals with computers, however, is not so high yet, considering that there are 3000 hospitals with more than 100 beds.

When new large hospitals are planned now in Japan, a computer is regarded as an indispensable part of their facilities. Consequently, the number of computers installed in hospitals will be far greater in a few years.

The type of computers installed in hospitals varies. Tables 1 and 2 show the type of computers installed in each year. Minicomputers are more popular, but the number of large computers has gradually increased in recent years.

One of the characteristics of the use of computers in Japan is that there is no shared use of computers yet in medical applications. This is because the data communication lines were not available for private industries, and shared use of computers through telephone line had not been possible. Since the situation is different now, there will be some time-sharing computers used in hospitals in a few years.

The Background of Computer Applications in Medicine

This discussion pertains to the incentives for using computers in medicine in recent years. Computers have been used in medical research for a long time. The computer in research is not included here since this type of use of computers is hardly related to the systems approach to medical care.

We believe that there were two reasons why the computers were accepted in Japanese hospitals. First, a computer is expected to solve the problems in health delivery in Japan. Japanese medical care has been supported by private sectors. Before World War II, the number of hospitals run by public sector, most of which were university hospitals, charity hospitals, or military hospitals was limited. Neither central nor local governments were considered to be responsible for medical care delivery. Medical care was 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 public sectors were built, and local health centres covered the entire area of Japan. The health insurance system was introduced, and every citizen of Japan is covered by this system. Nevertheless, most of the medical care is till in the hand of private physicians in Japan and the health insurance system takes care of only the economical part of medicine.

Accordingly, the delivery of medical care in Japan became more and more complicated. Health centres, government hospitals, university hospitals and clinics are working independently. Some patients complain that there is no way to know which hospitals they should go to when they become ill, or some say that even though they are covered by health insurance, they cannot get any medical care in remote areas away from the big cities.

Recently, a concept came out that we should regard the medical care as a social system and should apply the results of systems sciences to look for the solution to these problems. With the help of the systems approach, the optimum relationship among various medical facilities such as clinics, hospitals, health centers may be found. The same is true for the hospitals, where the interrelationship of various sections of the hospital must be reorganized. Computers are expected to contribute to find the solution to these problems.

Second, computers are expected to help physicians in handling a large amount of complicated medical data. Every year medicine becomes more sophisticated. The amount of information we need to make a certain diagnosis seems to increase year after year. For example, the number of clinical tests we order to diagnose a disease now is twice that ordered ten years ago, to diagnose the same disease. The progress in medical science made the diagnosis more accurate, but it also caused a flood of information. Physicians, sometimes at a loss in this flood, may find computers to be of help. Automated analysis of electrocardiograms is one of the examples of this type of application. Here, computers process electrocardiograms, gather the important information from them, and make a certain decision to give physicians. Some physicians are attracted by the idea that computers may give information which might not have been obtained without computers.

These are the two reasons why Japan is now interested in computers.

The Field of Applications

Table 3 shows the field of application of computers in Japan. The number of hospitals in each field of application is shown in Table 4. At present, administrative application, clinical laboratory, and storage and retrieval of medical records are the three subjects of most wide use. The application to pharmacy or nursing care is still limited probably because these applications require a large computer system.

Organizations which Supported the Development of Computer Applications

The Research and development of computers applied to medicine were first carried out by university hospitals. In the early years, the Ministry of Health and Welfare supported these researchers with a grant. Table 6 shows the research and development supported by the Ministry of Health and Welfare, most of which went to university hospitals. Then industries joined the developmental activities. They cooperated with university hospitals in the implementation of the computer system.

Recently Japan's medical association also became interested in computer applications and joined the developmental activities. The objectives of the Japan medical association is the development of the system applicable to smaller clinics.

The Future of Computer Applications

As shown in previous sections computers have been used in medical care delivery and have made at least a partial success. However, the field of applications is still limited. Computers are more commonly used in the administering field. This is probably because the application is relatively easy and the techniques developed in fields other than medicine can be used with minor modification. On the contrary, the application to medicine itself is still difficult. It may be said that there are no techniques in systems engineering at present which can be applied to medicine.

We need techniques which medicine can use without any difficulties. At present no hospitals in Japan have any future plans based on scientific data because there is no technique available to make such analysis and planning. Currently, there are no computers which can store all medical data. Medical data consist of digital, analogue, descriptive and pictorial data as shown in Table 7. Computers handle only digital and part of descriptive data. But the importance of analogue and pictorial data in medicine cannot be overemphasized.

Table 8 shows the various theories now used in data processing. The theories used to process analogue and pictorial data are not mature enough to be able to be applied to practical medical care. All of these subjects need solutions. We need systems techniques and data processing techniques which can be easily applied to medicine.

The same situation exists for the hardware. At present all computers used in the hospitals are general-purpose computers developed for nonmedical purposes. In the future we may need computers designed specifically for medicine. Table 9 shows some of the requirements of computers applied to medicine. The development of these computers is an important problem to be solved in future.

The Medical Information System

Introduction

To forecast future medical care in Japan, it is important to take into consideration changes in our society as well as the trends of the human's value. It is, however, not so easy to forecast the human's value since it is influenced by various factors as shown in Figure 1. Computerization, technological innovation, development of life science, and new environment are some of the examples of these factors which have a direct influence on human's value.

They also have a possibility to give rise to the evolution of a social system and to give birth to a new culture and to a new philosophy, which, in turn, influence the human's value again.

Welfare, equalization, coexistance of multivalue may be considered as future human's value. These concepts, however, include in itself the idea of continuous expansion and require more resources, while medical resource such as manpower or money is limited. Consequently, the solution to coincide these contradictory concepts is to reorganize all resources as a system with the help of systems sciences.

The Information Society

The Management Information Development Association made a proposal to the "Information Society", which was thought to be a Japanese national goal in 2000. In this report, it proposed the following eleven projects to reach this final goal:

i) Formation of the nation-wide information network

ii) Rationalization of administration

iii) Upgrading medical information system

iv) Computer-oriented education

v) Modernization of health care

vi) Pollution-prevention system

vii) Modernization of distribution channel

viii) Computerization of traffic system

ix) Diffusion of home terminals

x) International cooperation in computerization

xi) Measures to eliminate demerit of computerization

The interrelationship of these projects is shown in Figure 2. The final goal of the projects can be expressed as the building of a computermind.

In this national project, the medical system, together with the traffic system and the education system, is considered as one of the most important social systems. In this medical information system, the following four projects are set as main components: namely, prevention of adult disease, hospital automation, tele-medicine and an emergency medical plan. All of these components are integrated into the national medical information center as shown in Figure 3, which is the final objective of the medical information system.

Characteristics of MIS

Medical care forms a part of the society. Therefore, it can be regarded as a subsystem of the society, which is a total system. This means that medical care is closely related to social needs and social trends as well as to the development of science technology, national policy, national economy, and national education.

When we talk of the medical information system, different people may take different approaches according to the standpoint which they represent, for example, patients, government, physicians, engineers, or enterprise. But the health and welfare of patients must be given first priority as shown in Figure 4.

In other words, the final objective of the MIS must be the improvement of medical care. The MIS is expensive and must be changeable, and flexible, since the desire for better medical care is great. It also must be reliable and have some redundancy. To make the system more effective, it may be advisable to have a modular structure. Figure 5 shows the comprehensive medical care, which is the final goal of the MIS.

Forecast of the Medical Information System

In the past few years several forecasts on Japanese economical, social, and technological problems were carried out by the institutions as shown in Table 10. These forecasts included medical subjects in which the medical information system was always the subject of general interest. In 1969 to 1970, the Electronic Industries Association of Japan made a survey to forecast the future of medical engineering. Figures 6 and 7 show some of the results related to the application of computers, medical data processing, and the medical information system. The dotted line represents the time when the subjects become technically possible, and solid lines represent the time when they will be in practical use.

In 1971, the Science and Technological Agency performed a forecast by Delphi method. Subjects which have a possibility to give a great impact to our society in science and technology were selected for the forecast. The period of forecast was up to the year 2000. The subjects were classified into the following fields: namely, social development, information, food and agriculture, industry and resources, and medical care and health. As noted medical care formed an important section in this forecast. In the section of medical care, 103 subjects were selected, among which 12 were subjects related to medical system. These subjects and the results of the forecast are shown in Figure 8. Table 11 shows the summary of various forecasts performed in Japan as well as in the United States in recent years. According to the results, the research and development of the medical information system will be completed in a subsystem level by the end of the nineteen-seventies, they will start to be used in the nineteen-eighties, and they will be widely accepted by our society by the nineteen-nineties.

Reports and Activities of MIS in Japan

Two subsystems may be, however, delayed in their realization more than expected. One is the network of the organ bank, and the other is the network between medical doctors and home patients. This delay will be caused not by technological difficulties but by the difficulties in social acceptance.

Interest in the medical information system is increasing in Japan. A number of scientific conferences on this subject were held and many reports were published from public as well as private research institutions. (Table 12). The Japan Society of Medical Electronics and Biological Engineering has had annual conferences every spring, in which many papers on computer application or the medical information system were reported. Kansai Institute of Information System sponsored an international symposium on the medical information system (Medis 72) in October, 1972. The titles of the papers presented in this symposium are shown in Table 13. The second symposium (Medis 73) will be held in October, 1973 in Osaka. The main subjects of the sessions will be the regional medical information system and the medical data bank.

It is not only the Science and Technology Agency that is interested in the medical information system in Japanese government. The Ministry of Health and Welfare (MHW) and the Ministry of Internation Trade and Industry (MITI) have published various survey reports related to these subjects. This year, both ministries started national projects to develop a medical information system. The Ministry of Foreign Affairs sponsored the first conference of the South Asian Conference on Medical and Health Information Activities in October, 1972, in Tokyo, in which a national as well as an international medical information system were the subjects for discussion. Other organizations which published the reports related to MIS are The Telegraph and Telephone Corporation of Japan, Japan Medical Association, Electronic Industries Association of Japan, Japan Management Information Development Association, Institute of Information Technology, and Kansai Institute of Information System.

National Projects of the Medical Information System

The national project of the medical information system in Japan will be the cooperative projects of MHW and MITI. MHW will develop softwares of the medical information system and make a plan for their implementation while MITI will take part in the research and development of hardwares. According to the plan of MHW, the regional medical information center will serve as a center for medical care in each region (Figure 9). The central MIS center will function as a kind of "thinktank" to support these regional MIS centers, proposing the basic philosophy of the medical information system, solving the interregional problems, and running the central medical data bank.

The subjects proposed for research and development are as follows.

a) Basic problems

  i) Total plan of MIS

  ii) Development of Technology

b) Regional Medical Information System

  i) Conception of regional MIS

  ii) Development of various information systems in regional MIS

c) Hospital Information System

  i) General problems

  ii) Special problems

d) Coding and thesaurus

MITI started the research and development of hardware which will support the medical care in doctorless remote areas. As shown in Figure10, a regional medical center will be attached to a large hospital of the region and the medical sattelite system will be distributed in small cities, to which terminals in remote areas are again connected. Plans for development in this year are the design of this system and some feasibility study of some technologies such as communication, transmission of images, data processing,and interface between these techniques and medical equipment.

In addition to hardware, an important part in the development of the medical information system is computer software. MITI also made a survey in 1972 about the programs required in the hospital information system, and the content of its report is shown in Table 14.

Medical Care in its Relation to the Medical Information System

The most important question to be answered before the medical information system is implemented, is what is the final aim of medical care. However, this is not an easy question to be answered, since it is related to social economy, education, religion value, etc. From a medical standpoint, the final purpose of medical care is to maintain human individual life as well as species life. The first step may be to solve the contradiction between individual and species life, to maintain individual health and to terminate life at old age. This subject is probably the most difficult subject which was ever given to man. To find the solution may be the final goal of man. Only the research and development of comprehensive medicine will contribute to the answer to it.

Problems to be Solved in the Medical Information System

Economical Problems. The cost of medical care is increasing every year as shown in Figure 11. It expected 3 trillion yen in 1971 and will be more than 3.7 trillion yen in 1972. It is estimated that the MIS will be in wide use in 1980 in Japan. So let us estimate the cost of medical care in 1985. The estimation of total GNP in 1985 is 300 trillion yen. Assuming 6.5% of the GNP is spent on medical care and that 10% of the cost of medical care is spent on medical computerization, the cost for the medical information system will be 2 trillion yen in 1985, that is 2×10^{12} yen.

On the other hand, the cost of medical computerization to realize the proposed plan is 2.9 trillion yen as shown in Table 15. This includes developmental cost and the cost of initial investment of all the information systems such as the emergency medical care system, the telemedicine system, hospital automation, and the health care system. In addition to this, maintenance costs will be required.

These figures suggest that the realization of the medical information system will not necessarily be impossible from economical standpoint.

Manpower. A more serious problem is the lack of manpower. The number of hospitals with 100 to 200 beds and those with more than 200 beds in 1985 will be 2310 and 2340, respectively as shown in Table 16. Assuming that the percent of hospitals with 100 to 200 beds to utilize computers is 15% and that with 200 beds 50%, the number of computerized hospitals is 347 and 1120 respectively, 1467 in total. Assuming the ratio of administrator, system engineer, programmer, key puncher, operator, and general affairs personnel are 1; 1.7; 3.7; 5.0; 2.65; 1.9, the number of total personnel required will be 5483, 35, 392, respectively, and 40, 875 in total.

On the other hand, the lack of system engineers in various fields is estimated to be 40,000 by 1980 (Figure 12). The development of MIS will add the demand of 40,000 system engineers in addition to this. The education and training of system engineers is the most urgent matter at the present time.

Education and Training. One of the difficult problems in medicine is how to evaluate medical care. This sometimes provokes a subtle discussion. Some of the difficulties related to this are as follows.

a) Difficulties in evaluating human life and health

b) Difficulties in evaluating the contents of medical service by patients

c) Contradiction between hospital management and public service to society

d) Complexity in analysis of medical efficiency.

The standard for evaluation of a medical system should be set as a total of management, contribution to society, contents of medical care, research activity as shown in Table 17.

Government Policy. It must be known that there are some oppositions to MIS. They may be summarized as the fear of creating a controlled society, cost over benefit, priority of investment to systematization, and difficulty in workability. The details of each opposition are as follows.

A) Fear of Creating a Controlled Society

a) Problems of the Patient

i) Loss of right to select medical doctor

ii) Restriction on freedom to refuse public health and medical testing

iii) Violation of privacy

iv) Reduction of medical service by bureaucratic medical doctor

v) Decay of patient-doctors relationship

b) Problems of Medical Doctor

i) Restricted freedom in medical care

ii) Loss of autonomy of medical doctor

iii) Decrease of share of medical doctor

iv) Rigidity due to trend to public official from private doctor

v) Fear of shifting to enterprise-oriented system

vi) Law-suit problems occured from opened medical secrets

vii) Confusion due to overflow of redundant information

viii) Decrease of total integrated medical service from result of rigid system

B) Cost/Benefit

C) Priority of Investment to Systematization in Comparison with Investment to the other Medical Problems

D) Difficulty in Workability

i) Economy

ii) Manpower

iii) Education

iv) Difficulty of estimation of medical care

v) Participation of citizen in medical care.

Therefore, the government must run the project only after evaluating these oppositions with the utmost caution. The feedback to the control body of the project is most important, and the plan should be adjusted all the time with flexibility. (Figure 13) Before forming the national policy of the medical information system, more discussions will be required for budget, legislation, education, test and evaluation, research and development of future forecasts, and technology assessment.

<u>Summary</u>

A great profit is expected as a result of implementing the medical information system. The following are some of the problems to the solution of which MIS may contribute:

a) Reduction of the gap between medical need and medical supply

b) Elevation of quality in medical care

c) Realization of comprehensive medicine

d) Solution of remote region problems without a medical doctor

e) Solution of emergency problems in medical care.

The following may be the effect of MIS which a nation can expect:

a) Life elongation

b) Maintenance and enjoyment of health

c) Realization of equality in medical care

d) Reduction of death due to accident and emergency.

However, the following demerits must be taken into consideration:

a) High expenditure

b) Fear of creating a controlled society

   i) Violation of privacy

   ii) Centralization and monopolization of information

   iii) Alienation through labor-saving and automation

c) Negative effect of rigid system.

The most serious question here will be the opposition to controlled society. The details of this are as follows:

a) Prohibition of the use of the individual's files by the administrative agency for other than the intended purposes

b) Prohibition of the perusal and correction of individual's files

c) Prohibition of publicity stating individual's information at the public agency

d) Decentralization of information

e) Public disclosure of information

f) Surveillance of the use of information

g) Right to select to be registered in medical data bank

h) Right to check and correct individual's file

i) Right to participate how to use individual's file

To summarize, we discussed the necessity and problems of the MIS. Since the impact of the MIS to our society is expected to be great, it is most important to discuss this subject among interdisciplinary people from a multichannel view. This is the concept of technological assessment, and this concept must be in the mind of every person who is interested in this subject.

	Large size	Medium size	Small size	Mini	Miscella -neous	Total
1963		I				I
1964						
1965						
1966						
1967		I	I			2
1968	2	I	I	4	2	I0
1969		2	3	5	I	II
1970	I	3	2	I2	I	I9
197I	I	4	4	25	5	39
1972	3		6	4		I3
1973	I			9		I0
Total	8	I2	I7	59	9	I05

Table 1

Size and Number of Computers Utilized in Japanese Hospitals

TABLE 2 COMPUTERS UTILIZED IN MEDICAL FIELDS IN JAPAN

(L : LARGE SIZE COMPUTER
M : MEDIUM 〃 〃
S : SMALL 〃 〃
m : MINI 〃 〃)

BURROUGHS
- L - 2000 (S)

CHUO DENSHI
- CEC - 552 (m)
- CEC - 555 (m)

DEC
- LINE - 8 (m)
- PDP - 8/E (m)
- PDP - I2A (m)
- PDP - I2/20 (m)

FUJITSU
- F - 230/35 (L)
- F - 230/25 (M)
- F - 270/20 (M)
- F - 230/I0E (S)
- F - 230/I0 (S)
- F - 230/I5 LEVEL UP (S)
- F - 230/I5 (S)
- F - R (m)
- F - 33I (m)

HITACHI
- H - 8400 (L)
- H - 8350 (L)
- H - 8300 (M)
- H - 82I0 (S)
- H - 20I (S)
- H - I0 (m)
- H - I (m)

IBM
- IBM 360/40 (M)
- IBM I800/DACS (S)

MITSUBISHI
- M - 3I00/40D (M)
- M - 8I (m)

NEC
- N - 3I00 (M)
- N - 2200/I00 (S)
- N - 2200/50 (S)
- N - 3200/50 (S)
- N - 3200/30 (S)
- N - M4 (m)
- N - I240 (m)

JEOL
- JRA - 5 (m)
- JEC - 5 (m)
- JEC - 6 (m)
- JEC - 7 (m)

TOSHIBA
- T - 5400/30 (L)
- T - 5I00/20 (M)
- T - 4200/F (M)
- T - 3400 (M)
- T - 3000/M (S)
- T - 40 (m)

Application Field	Substance
Diagnosis	Automatic Interviewing to patients, Automated diagnosis, Indication of medical treatment
Clinical examination	Acquisition, analysis and data processing of EEG, ECG, PCG, X-ray film and the other medical information data
Treatment	Automated medical treatment, Automatic monitoring for patients treated with artificial organs
Nursing	Nursing planning, Nursing administration, Indication of nursing performance, Automated nursing scheduling, Automated intensive care units, Automated communication with the other departments
Information retrieval of medical data	Search and retrieval of medical record, health care administration record, medical literatures and documents and the other medical information
Drug	Administration of pharmaceutical effects and side effects on drugs, Drug administration separated by each doctor , Automatic compounding, Stock administration of drugs
Health care administration	Health care administration in and out hospital
Hospital administration	Accounting for outpatients, Claiming for charges to medical insurance, Hospital appointment, Feeding administration, Stock administration, Library administration, Preparation of hospital statistics
Patient monitoring	Computer aided I.C.U. and C.C.U.
Medical research	Simulation analysis.(enzyme reaction, pulmonary system, cardiovascular system, temperature control system, neuron network human vibration system etc.) Data processing of bio-medical data

Table 3. Computer Applications in Hospitals

Table 4

Computer Applications in Japanese Hospitals (4)

APPLICATION	TOTAL	PUBLIC	PRIVATE	MISC.
(I) Hospital Administration				
Insurance Demand	24	8	14	2
Cost Accounting	12	6	6	0
Material Stock Administration	13	2	9	2
Feeding	3	0	3	0
Statistics	10	4	6	0
Outpatient Appointment	4	2	1	1
Bed Appointment	6	3	3	0
Laboratory Test Appointment	2	2	0	0
Hospital Business	8	4	4	0
Library Administration	2	2	0	5
Total	84	33	46	5
(II) Biochemical Test				
Clinical Biochemistry	18	12	4	2
(III) Physiological Test				
Clinical Physiological Test				
ECG Analysis	5	3	2	0
PCG Analysis	3	2	1	0
RI Test	5	3	1	1
Radiation Dosimetry Calc.	4	3	1	0
Image Processing				
X-Ray Film	3	1	2	0
Scinticamera	2	2	0	0
Gamma Camera	1	0	1	0
EEG Research	9	8	1	0
Cardiac Function Research	1	1	0	0
Miscellaneous	9	8	0	1
Total	42	31	9	2
(V) Clinical Chart Diagnosis, Etc.				
Clinical Chart Administration	17	9	7	1
Patient History	1	0	1	0
Rehabilitation	2	2	0	0
Total	20	11	8	1
(VI) Health Care System				
Autoanalysis of ECG for Screening	9	5	2	2
Autoanalysis of PCG for Screening	4	2	1	1
Health Care Administration	4	1	2	1
Health Care System	3	1	2	0
Total	22	9	8	5

Table 5. Medical Facilities Utilizing Computers in Japan

Facility	Uses	Computer
(A) General Uses		
Sapporo Medical College	Claiming for charges to medical insurance, Drug stock administration, Preparation of medical statistics	NEAC 2203
National Cancer Center	Information retrieval of medical record, Automatic analysis of medical data, epidemiologic statistics	HITAC 8300
Keio University Medical Center	Hospital administration	MELCOM 3100/408
Bokuto Hospital	Medical statistics, Stock administration	MELCOM 81
Nippon University Medical Center	Medical record administ-ration	MELCOM 81
Fujitsu Kawasaki Hospital	Claiming for charges to medical insurance, Health care administration	FACOM 230/10 FACOM 230/25
Toshiba Center Hospital	Claiming for charges to medical insurance, Hospital administration, Stock administration	TOSBAC 3400
Tokyo Teishin Hospital	Automated clinical laboratory, Computer aided ICU and CCU	FACOM-R FACOM 230/35
Hitachi Hospital	Medical record administration, Automatic analysis of medical data, epidemiologic statistics	HITAC 8350 HITAC 10
Kanto Teishin Hospital	Total hospital information system(In developing)E.C.G. data communication	HITAC 8400
Tokyo University Medical Center	Medical record administration, Medical statistics	TOSBAC 3400 HITAC 10

(Table 5 Continued)

Tokyo Women Medical College	Hospital administration, Automated appointment system, Computer aided ICU and CCU	FACOM 230/25 FACOM 331 FACOM-R
Osaka Prefectural Adult Disease Center	Analysis of clinical laboratory data, Medical statistics, Computer aided CCU	NEAC 2200/100 NEAC 3200
Tsuchiya Hospital	Claiming for charges to medical insurances, Feeding administration, Medical record administration, Salary accounting	TOSBAC 5100/20
Kodokai Hospital	Claiming for charges to medical insurance, Feeding administration, Medical record administration	TOSBAC 3000/M
Narita Hospital	Automatic analysis of ECG, Salary accounting	TOSBAC 3000/M
Katsumata Hospital	Claiming for charges to medical insurance	TOSBAC 10
Meitetsu Hospital	Medical record administration, Claiming for charges to medical insurance	HITAC 8400
Hiroshima University Atomic Institute	Medical record administration	TOSBAC 4200F
Toyo Kogyo Hospital	Hospital administration, Health care administration, Data processing of biological information	HITAC 8400
Tokyo Jikeikai Medical College	Total hospital information system (being developed)	HITAC 8400

(Table 5 Continued)

Kosei Hospital	Medical record administration Claiming for charges to medical insurance	FACOM 230/25
Aichi Cancer Center	Medical statistics	HITAC 201
Osaka Kaisei Hospital	Claiming for charges to medical insurance	FACOM 230/15
Yonezawa City Hospital	Claiming for charges to medical insurance	FACOM 230/15
Gifu Hospital	Automated clinical laboratory	FACOM-R
Nogawa Hospital	Claiming for charges to medical insurance	FACOM 230/10
Yodogawa Zenrinkan Hospital	Automatic interviewing to patients, Health care administration	FACOM 230/10
Kyoto City Hospital	Claiming for charges to medical insurance	FACOM 230/15
Motojima Hospital	Claiming for charges to medical insurance	FACOM 230/15
Kurashiki Center Hospital	Claiming for charges to medical insurance	NEAC 1240
Yodoi Hospital	Claiming for charges to medical insurance	NEAC 1240

(Table 5 Continued)

(B) Research Uses

Nippon Medical College	Medical research, Automatic interviewing to patients, Automatic analysis of ECG and PCG	OKITAC 7000 FACOM 230/20
Tokyo Medical and Dental College	Medical research, Automatic interviewing to patients	NEAC 2101
Osaka University Medical Center	Medical research, Automatic interviewing to patients	HITAC 10
Okayama Medical College	Medical research	NEAC 2203
Medical Radiation Institute	Medical research	TOSBAC 3400/31
Chiba Medical College	Data processing of radio-isotope data	HITAC 10
Institute of Applied Electronics, University of Hokkaido	Automatic analysis of ECG	TOSBAC 3000/M FACOM 270/20
Naruko Hospital, University of Tohoku	Medical research	FACPM-R
Institute of Defensive Aero-medicine	Medical research, Statistics	FACOM 270/20
Institute of Voice and Speech, University of Tokyo	Speech analysis	PDP 9
Institute of Medical Electronics, University of Tokyo	On-line control of artificial heart	FACOM 331

Table 6. New Medical Technology Development Projects

<u>1964</u>

1) A-D conversion of biological information

<u>1965</u>

1) Hospital automation
2) General purpose medical computer

<u>1966</u>

1) General purpose medical computer
2) System design on hospital automation system
3) Automatic analysis on ECG & PCG
4) EEG data processing

<u>1967</u>

1) General purpose medical computer
2) Hospital automation
3) EEG data processing
4) EMG data processing
5) Clinical applications of simulation techniques

<u>1968</u>

1) Hospital automation
2) Automatic diagnosis of ECG by analogue technique
3) EEG data processing
4) Automation of pulmonary function tests
5) On-line data processing of pulmonary function data
6) Control of paralyzed muscles with information of EMG
7) On-line medical data processing with general purpose medical computer
8) Measurement and analysis of cardio-pulmonary functions

<u>1969</u>

1) Automation of hospital information
2) Graphic display system of general purpose medical computer
3) Automation of pulmonary function tests
4) Automatic reading system of chest X-ray films.

(Table 6 Continued)

<u>1970</u>

1) Screening of cardiovascular diseases
2) Diagnostic logic for ECG analysis
3) Interface for medical data communication
4) Computer analysis of mechanism for cardiac contraction
5) Data processing of biological pulsation phenomenon
6) Medical terminals for hospital automation
7) Multiphasic differentiating apparatus utilizing EMG
8) Identification method for automatic diagnosis in clinical laboratory
9) Filing of medical record
10) Automatic diagnosis of chest X-ray film
11) Programing scintiphotocardiogram

<u>1971</u>

1) Data processing of biological pulsation phenomenon
2) Medical record administration system for out-patients
3) Computer control and identification in clinical l boratory
4) Multi-dimensional automatic analysis of cardiac functions
5) Data communication system in hospital
6) On-line data processing of pulmonary function test data
7) Automatic classification of chromosome with man-machine interaction
8) Medical terminals in medical data communication
9) Automatic diagnosis of myocardial infarction region by graphic display system
10) Automatic analysis of human chromosome
11) PCG screening apparatus in group screening
12) Automatic analysis of serum protein fraction pattern
13) Medical terminals and automatic diagnostic apparatus for medical care system in doctorless villages
14) Automation of peak flow measurement with driving pressure control
15) On-line data processing of scintiphotocardiogram synchronized with cardiac pulsation

Table 7
Classification of Medical Information

(I)	Digital Information	measurement values, etc.
(II)	Analog Information	ECG, EEG, etc.
(III)	Descriptive Information	patient history, examination reports, etc.
(IV)	Graphic Information	X-ray films, pathological images, scintigram, etc.

Table 8. Specifications of Medical Computers

	Computer for Medical Research	Computer for Hospital Automation	Computer for Medical Data Bank
Purpose	Small sized, special computer for on-line medical & biological information analysis	Computer for medical information system in hospital automation	Computer for future medical data bank
Performance	1) A/D converter 2) Basic programs for statictics 3) Display 4) Connectable with transducers	1) TSS 2) Reliability 3) Specialized terminals 4) Connectable with various hospital instruments 5) Connectable with mini-computers 6) Changeable sub-systems 7) Easy maintenance	1) TSS 2) Many on-line terminals 3) Large capacity random access

Table 9

Basic Theory and Medical Application in Medical Data Processing

Medical Information Data Processing	Basic Theory	Medical Application
(I) Digital Information Data Processing		
A) Diagnostic Logic	Likelihood, Bayes, Boole, Multiple Discriminative Funct.	Patient history in health administration, Diagnostic assistance
B) Clinical Statistics Analysis	Statistics	Judgment of pharmaceutical and therapeutical effect
C) Medical Syst.Engineering	Simulation, Waiting Matrix, LP, DP, Game Theory	Health care system, Hospital design
(II) Analog Information Data Processing		
A) Pattern Recognition of Analog Wave	Cluster Analysis	Automatic analysis of ECG
B) Tracer Kinetics	Multiple Compartment Analysis	Renogram analysis
(III) Descriptive Information Data Processing		
A) Information Retrieval		MEDLARS, KWIC, SDI, Information retrieval of clinical chart
B) Narrative Language Data Processing		
(IV) Pictorial Information Data Processing		
A) Image Improvement	Filtering, Enhancement	
B) Pattern Recognition		
C) Measurement		

Table 10. Forecast of Future Medicine in Japan

1. Japan's Economy in 1985
   Japan Economic Research Center, July, 1967

2. Long Term Perspective of the Electronics Industry
   Japan Electronics Industry Development Association, March, 1968

3. Future Perspective in Medical Engineering
   Electronic Industries Association of Japan, September, 1969, April, 1970

4. Forecast of Future Optical Technology
   Committee of Perspective in the Japan Optics Industry

5. "Science and Technology Developments up to A.D. 2000"
   Science and Technology Agency, June, 1971

6. Forecast of Future Technology in 1980
   Magazine of Nikkei Business, July, 1970

7. Long Term Plan of Research and Development of Bio-Medical Engineering
   Japan Society of Medical Electronics and Biological Engineering, July, 1969

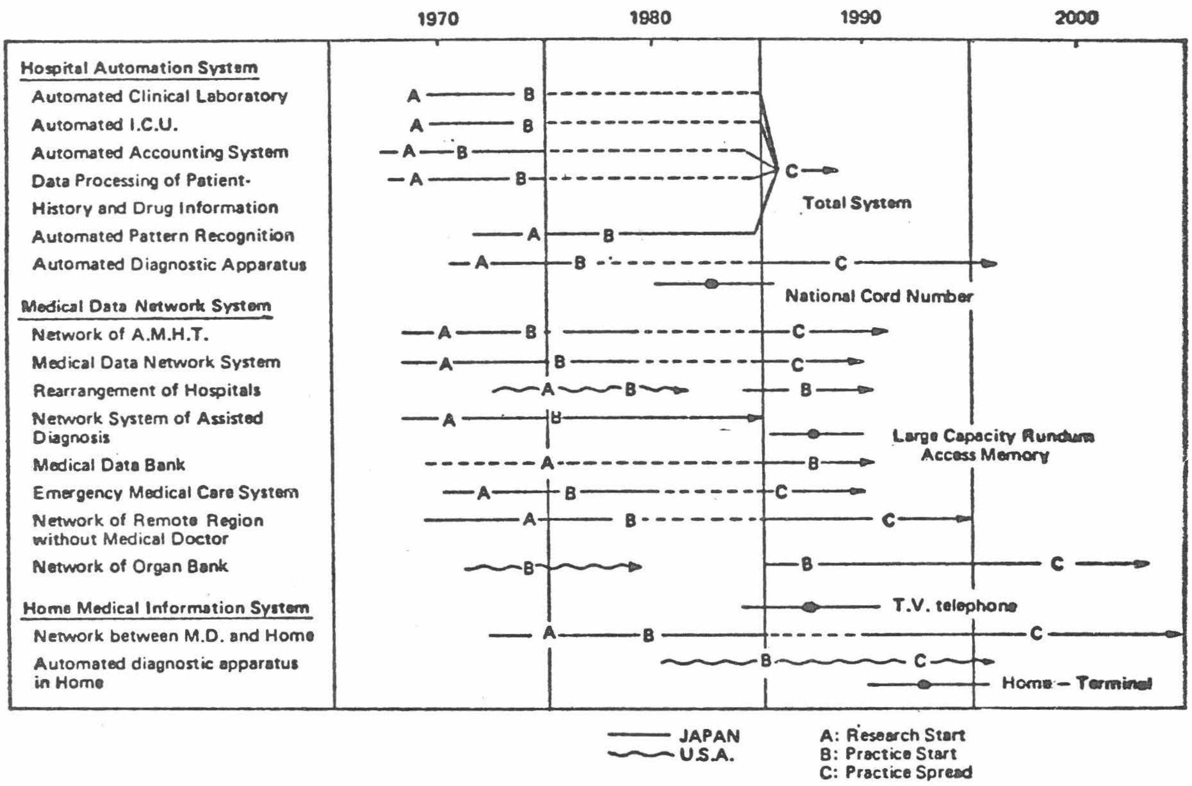


Table 11

Future Forecast of Medical Information Systems

Table 12.

Reports on Medical Information System in Japan

I) Scientific Conference

1) Japan Society of Medical Electronics and Biological Engineering

a) The 10th Annual Conference (Tokyo, April 1971)

b) The 11th Annual Conference (Kurume, April 1972)

c) The 12th Annual Conference (Tokyo, April 1973)

2) Kansai Institute of Information Systems

a) International Symposium on Medical Information System (MEDIS'72) (Osaka, September 1972)

b) International Symposium on Medical Information System (MEDIS'73) (Osaka, October 1973)

II) Government

1) Science and Technology Agency

a) "Science and Technology Developments up to A.D. 2000" (June, 1971)

2) Ministry of Health and Welfare

a) "Applications of Computers in Hospitals" (May, 1971)

b) "Medical Information System" (August, 1972)

3) Ministry of International Trade and Industry

a) Survey Reports on "Systematization in Industrial Activities, ——1) Medical System——." (April, 1972)

b) "Association for the development of Medical Systems and Engineering" (June, 1972)

c) "A study of the Trends in Health Care Systems Development in the U.S.A." prepared in Battelle Institute (March, 1973)

d) "Software on Hospital Information Systems (July, 1973)

4) Ministry of Foreign Affairs

a) "The First So theast Asian Conference on Medical and Health Information Activities" (October, 1972)

(Table 12 Continued)

5) The Telegraph & Telephone Corporation of Japan, cooperated with Institute of Future Technology

a) "Future Applications of Electronics in Medical Fields (I)" (March, 1972)

b) "ibid (II)" (March, 1973)

III) Institutions

1) Japan Medical Association

a) "Community Health Activities" (April, 1971)

2) Electronic Industries Association of Japan

a) "Medical Information Systems (I)" (March, 1972)

b) "Medical Information Systems (II)" (March, 1973)

3) Japan Management Information Development Association

a) "The Plan for Computerization in 1980" (September, 1971)

b) "A Guidepost for Information Society" (October, 1972)

c) Studies on "Medical Information System in remote areas and islands" (June, 1973)

4) Institute of Information Technology

a) Trends of Medical Information Systems in U.S.A. (April, 1973)

5) Kansai Institute of Information Systems

a) Sudies in Medical Information System (March, 1972)

b) Model Desingn of Regional Medical System (March, 1973)

Table 13

SEPTEMBER 29, 1972.

09:30~09:45		Opening address	TARO NAKAYAMA, M.D.
Symposium A:		Hospital Automation and Hospital Information System	
09:45~10:00	1	Hospital Automation in Japan	RYOSEI KASHIDA, M.D.
10:00~10:30	2	Managing of Medical Records Automation	B. G. LAMSON, M.D.
10:30~10:50		Discussion	
10:50~11:05 (Break)			
11:05~11:20	3	Out-Patient Survey and Traffic Simulation Study in a General Hospital (Osaka University Hospital)	TOSHIYUKI FURUKAWA, M.D.
11:20~11:35	4	Automatic Electrocardiographic Interpretation System	EIICHI KIMURA, M.D.
11:35~11:50	5	Computer use in CCU/ICU	YUTAKA NOMURA, M.D.
11:50~12:05	6	Problems on Computer Diagnostic Systems of Phonocardiograms	SHOZO YOSHIMURA, M.D.
12:05~12:30		Discussion	
12:30~13:30 (Lunch)			
Symposium B:		Regional Medical Information System I	
13:30~13:45	1	Present States and Future Problems of Regional Medicine	MASAMITSU OOSHIMA, M.D.
13:45~14:15	2	L' Informatique Medico-Hospitaliere en France	M. LAUDET M.D.
14:15~14:45	3	Health Information Services and The Medical Record Review of Health Information Services in Britain	R.G. ROWE, M.D.
14:45~15:00	4	Experimental Model of Regional Medical Data Bank at Nishi-ku, Yokohama	SHIGEKOTO KAIHARA, M.D.
15:00~15:30 (Break)			
15:30~15:45		Discussion	
15:45~16:00	5	Regional Medical Plan in the Middle Western (Kinki) Region of Japan	AKINA HIRAKAWA, M.D.
16:00~16:30	6	MSS, a Centrally Planned Decentralized Medical Information System in Sweden	W. SCHNEIDER, M.D.
16:30~16:45	7	Design of Health Care System for Remote and Doctorless Area	KAZUO MIYAWAKI, Ph. D.
16:45~17:00	8	Problems Regarding Contribution of Japan Medical Association to Regional Medical Plan	MASATERU FUJISAWA, M.D.
17:00~17:30		Discussion	

(Table 13 Continued)

SEPTEMBER 30, 1972

09:45~10:00		The Medical Stucture in JAPAN	TADASHI TAKIZAWA
10:00~10:15		The Planning in Medical System in JAPAN of Epupmental Development	MASAAKI MINOUE
Symposium C:		Automated Multiphasic Health Testing and Services	
10:20~10:35	1	The Present and Future Problems of AMHTS in Japan	YOSHITAKE IWAI, Ph. D.
10:35~10:50	2	Appraisal of AMHTS in Practical Operation	TORU IWATSUKA, M. D.
10:50~11:05	3	Evaluation of AMHT System and Hardware from from Engineering Viewpoint	MASAO SAITO, Ph. D.
11:05~11:25		Discussion	
		11:25~11:40 (Break)	
11:40~11:55	4	Regional Health-Examination Center (Definition and Function)	TOSHIO UTSUNOMIYA, Ph. D.
11:55~12:10	5	Critical Evaluation of Computerized Medical and Health Care System in Future Intofmation Society	KAZUHIKO ATSUMI, M, D.
12:10~12:30		Discussion	
		12:30~13:30 (Lunch)	
Symposium D:		Regional Medical Information System II	
13:30~14:00	1	Regional Medical Information System II How Information system are employed to Regional Medical Activities in West Germany. with the reference to the Medical System Hannover (MSH)	R. L. REICHERTZ
14:00~14:30	2	The Health Information Sistem in the Region	M. R. ALDERSON, M. D.
14:30~14:45	3	Towards Medical Data Bank in a Hospital and in a Community	AKIRA SASAKI, M.D.
14:45~15:00	4	Medical Information System and a Plan for Regionalization of a Hospital Specialized in Cardiovascular Diseases	ATSUAKI GUNJI, M. D.
15:00~15:30		Discussion	
		15:30~15:45 (Break)	
15:45~16:00	5	Medical Data Bank and Coding System	MITSUHARU OKAJIMA, M.D.
16:00~16:15	6	On-line Computer Diagnosis and Treatment through MAC System	HIROSHI INADA, Ph. D. HIROSHI ABE, M.D.
16:15~16:30	7	Computer Applications of Information Retrieval and Medical Instruction Technology	IWAO FUJIMASA, M.D.
16:30~16:45	8	Application for Medicine in Data Communication System Mainly on Medical Data Communication System Designed by NTT	SUMIO TAKAHASHI
16:45~17:15		Discussion	
17:15~17:20		Closing Address	TSUNEO YOSHIDA, M.D.

Table 14

Problems of Software in Hospital Information System

(M.I.T.I., July, 1973)

1) Introduction
2) Necessity of Hospital Information System (HIS)
3) General Vision of HIS
4) Troublesome Problems to be solved before making Software
5) Problems of Software
   5-1) Present Status
   5-2) Possibility of Standardization
   5-3) Special Characteristics of Software in HIS
   5-4) Terminals
   5-5) Possibility of Universality
   5-6) Estimation
   5-7) Special Situation of Japan
6) Programs of HIS to be developed in Future

Table 15

COST ACCOUNTING OF MEDICAL COMPUTERIZATION IN JAPAN IN 1985

(OUTPUT)

1) EMERGENCY MEDICAL CARE SYSTEM

DEVELOPING = 1.5 billion yen = 15×10^8 (yen)

CENTER FOUNDATION = 19 billion yen = 190×10^8 (yen)

2) TELE MEDICINE SYSTEM

DEVELOPING = 10 billion yen = 100×10^8 (yen)

CENTER FOUNDATION = 150 billion yen = $1,500 \times 10^8$ (yen)

3) HOSPITAL AUTOMATION

DEVELOPING COST = 20 billion yen = 200×10^8 (yen)

FOUNDATION COST = 1.2 trillion yen = $12,000 \times 10^8$ (yen)

4) HEALTH CARE SYSTEM

DEVELOPING COST = 8 billion yen = 80×10^8 (yen)

FOUNDATION COST = 1.5 trillion yen = $15,000 \times 10^8$ (yen)

TOTAL = $29,085 \times 10^8$ (yen)

= 2.9 trillion yen

Table 16

Forecast of Man-power of Computerized Medical Care System in Japan in 1985

SIZE OF HOSPITAL	100 - 200 BEDS	OVER 200 BEDS	TOTAL	RATIO
TOTAL HOSPITAL NUMBER	2,310	2,240	4,550	
COMPUTER UTILITY RATIO	15 %	50 %		
COMPUTERIZED HOSPITALS	347	1,120	1,467	
ADMINISTRATER	347	2,240	2,587	1
SYSTEM ENGINEER	590	3,808	4,398	1.7
PROGRAMER	1,284	8,288	9,572	3.7
KEY PUNCHER	1,735	11,200	12,935	5.0
OPERATOR	868	5,600	6,468	2.5
GENRAL AFFAIRS	659	4,256	4,915	1.9
TOTAL	5,483	35,392	40,875	15.8

Table 17

Standard to Estimate Medical System

A) Management

1) Good Service with Minimal Cost and Minimal Manpower
2) Medical Efficiency
3) Beds Utility Ratio, Patient's Number per One Staff, Operations' Number

B) Contribution to Society

1) Emergency Care
2) Preventive Medicine
3) Increase of Health Level of People in Community
   a) Expansion of Area of Medical Care
   b) Decrease of Waiting Time of Patient
   c) Decrease of Percentage of Contraction and Death

C) Contents of Medical Care (Medical Audit)

1) Medical Care Equipment
2) Hospital Days and Prognosis
3) Examination's Items and Number of Examinations
4) Contents of Treatments
5) Confirmation of the Result of Medical Diagnosis and Treatment (Autopsy, Survey of Left Patient)

D) Research Activity

1) Report on Scientific Conference
2) Autopsy Ratio
3) Research Equipment and Money
4) Library

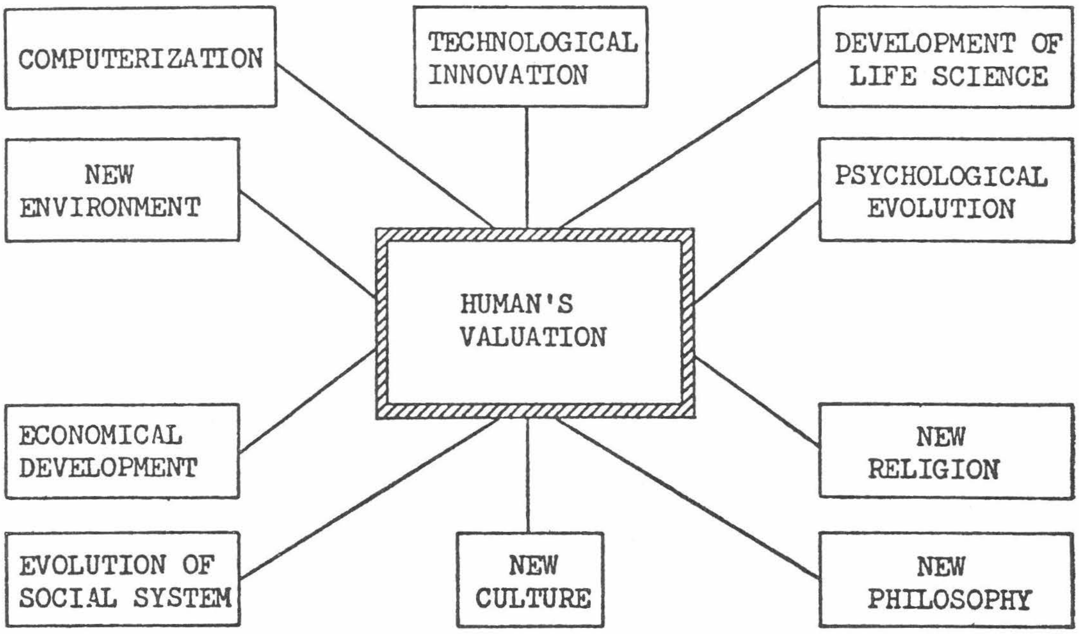


Figure 1
Multi-Factors Influencing The Human's Valuation

Figure 2. Computerization Chart of Society in 1980

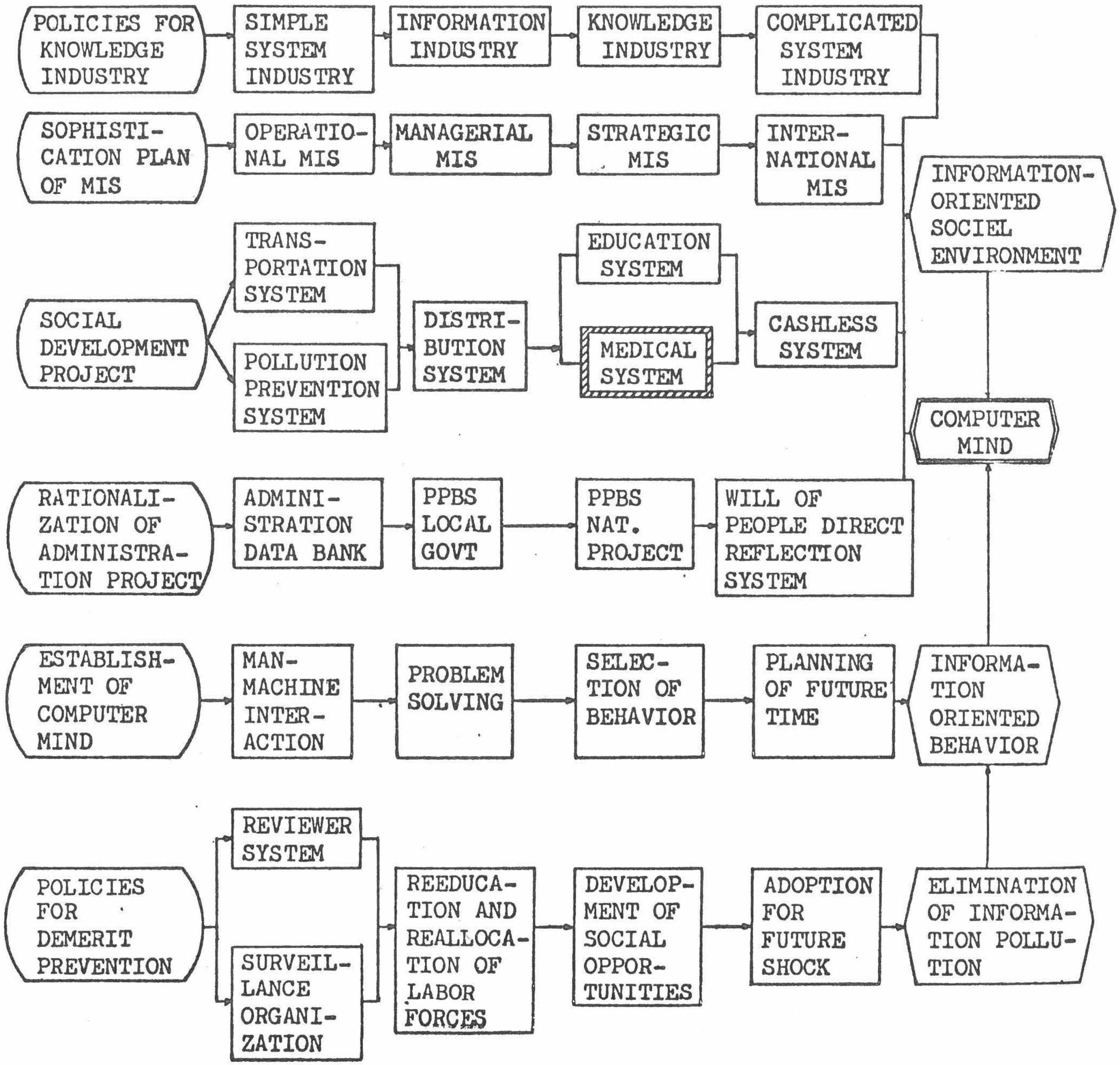
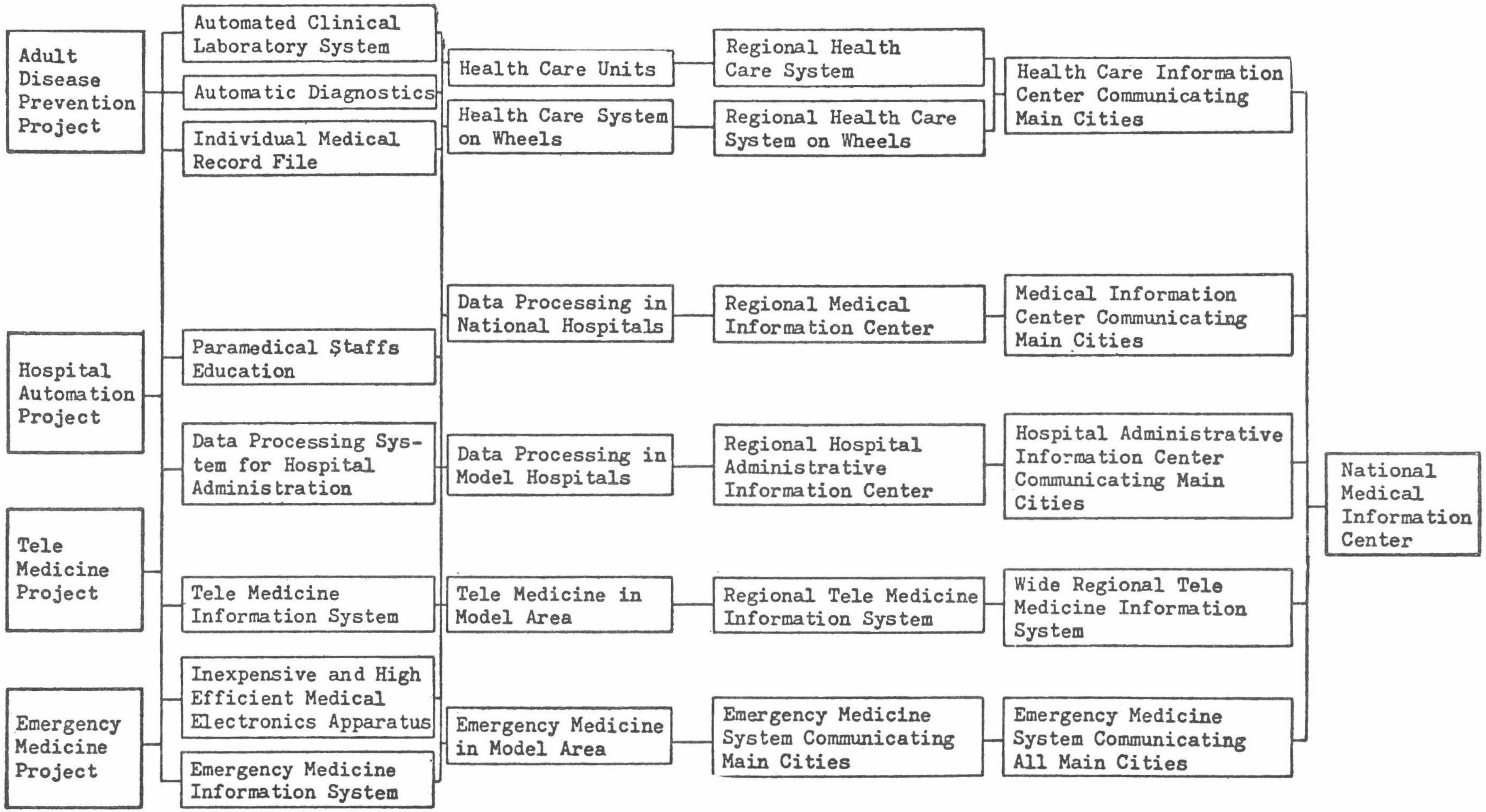


Figure 3. Medical Information System



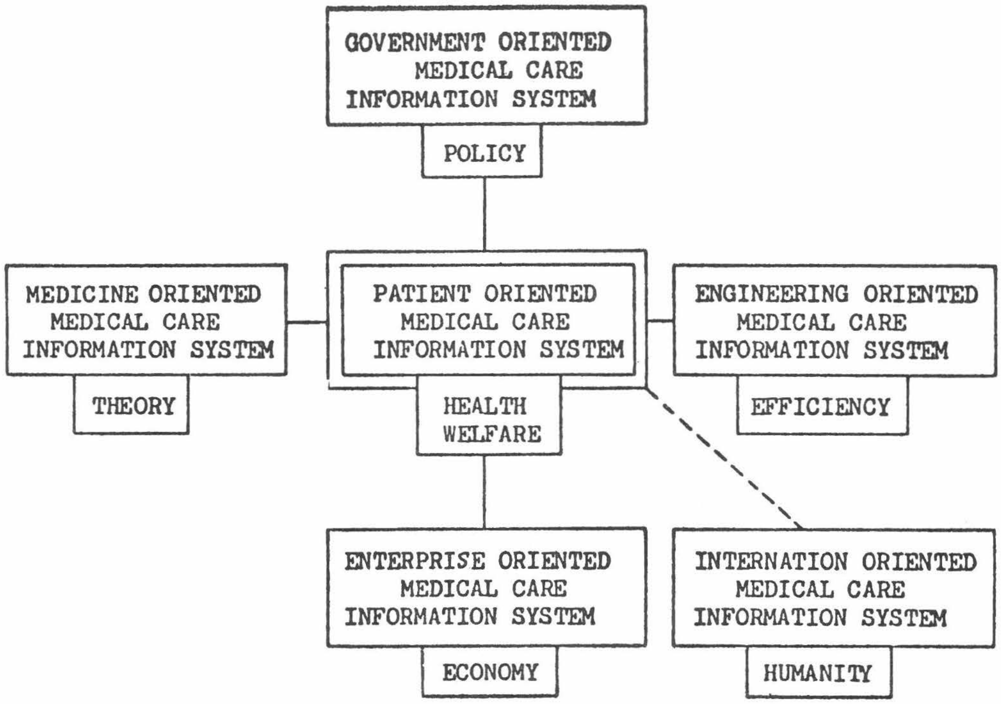


Figure 4

Multi-Aspects for a Medical Care Information System

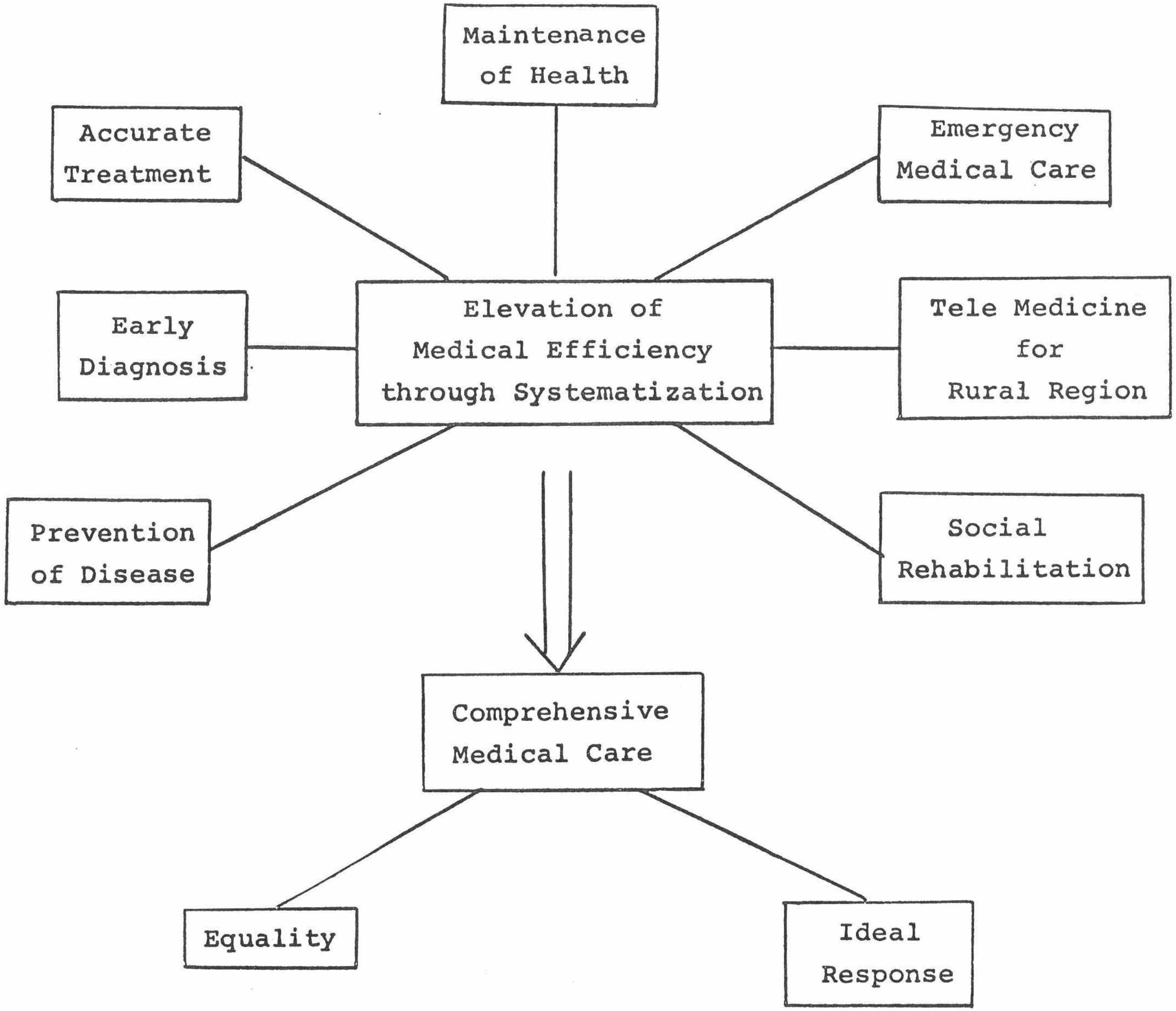


Figure 5. Purposes of Medical Information Systems

Figure 6. Forecast of Medical Engineering (I)

(Electronic Industries Association of Japan, September 1969 - April 1970)

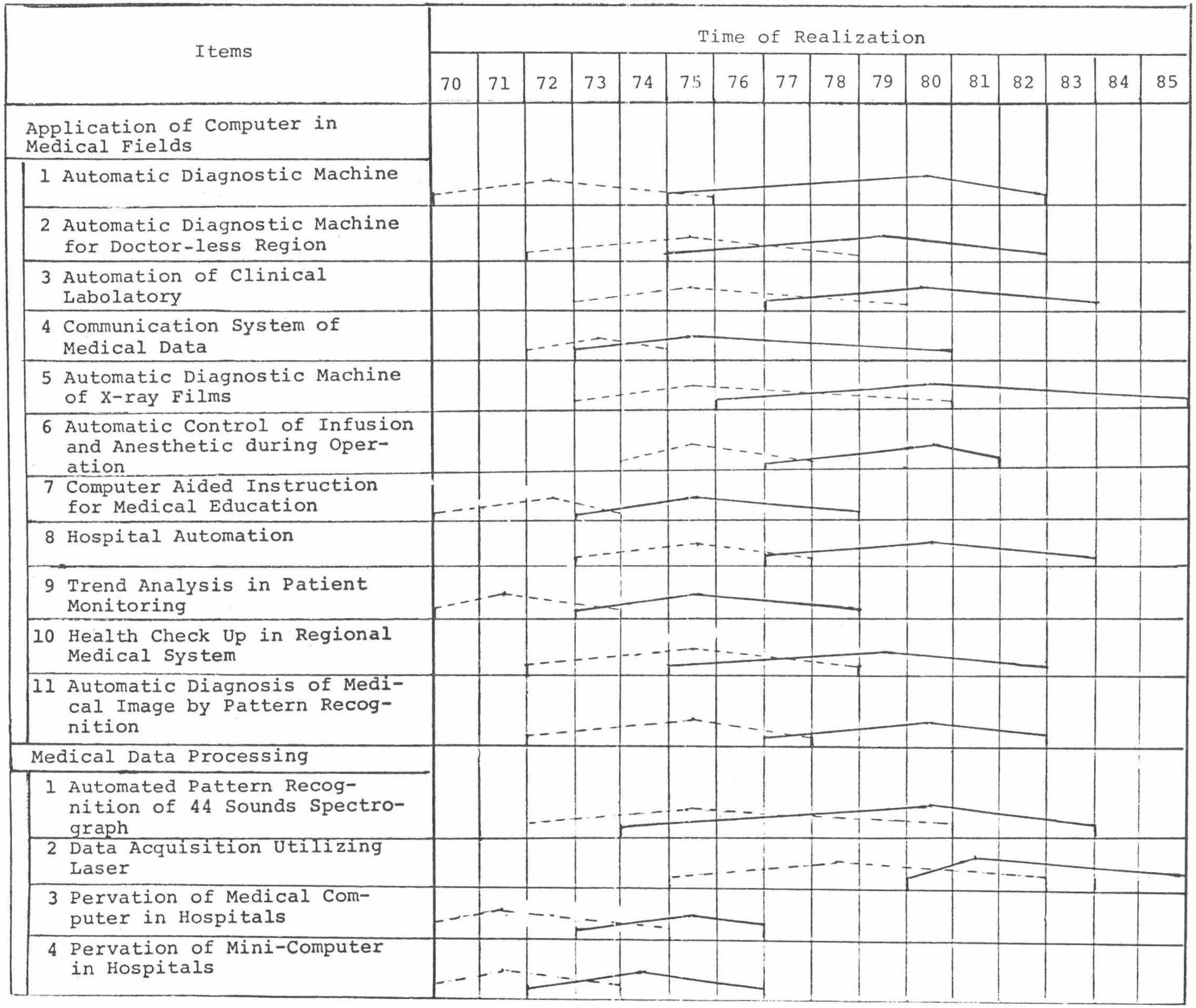
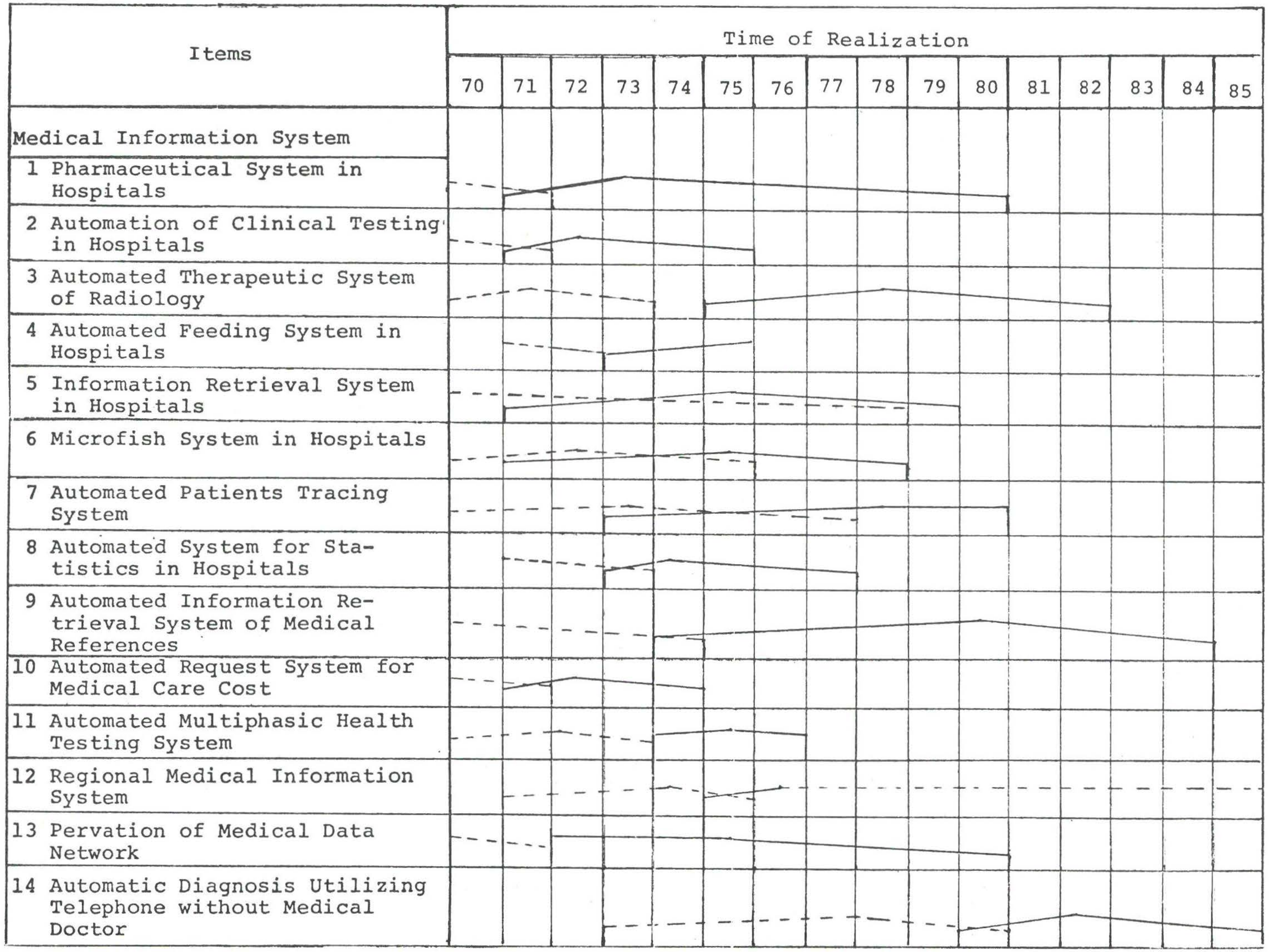


Figure 7. Forecast of Medical Engineering (II)

(Electronic Industries Association of Japan, September 1969 - April 1970)



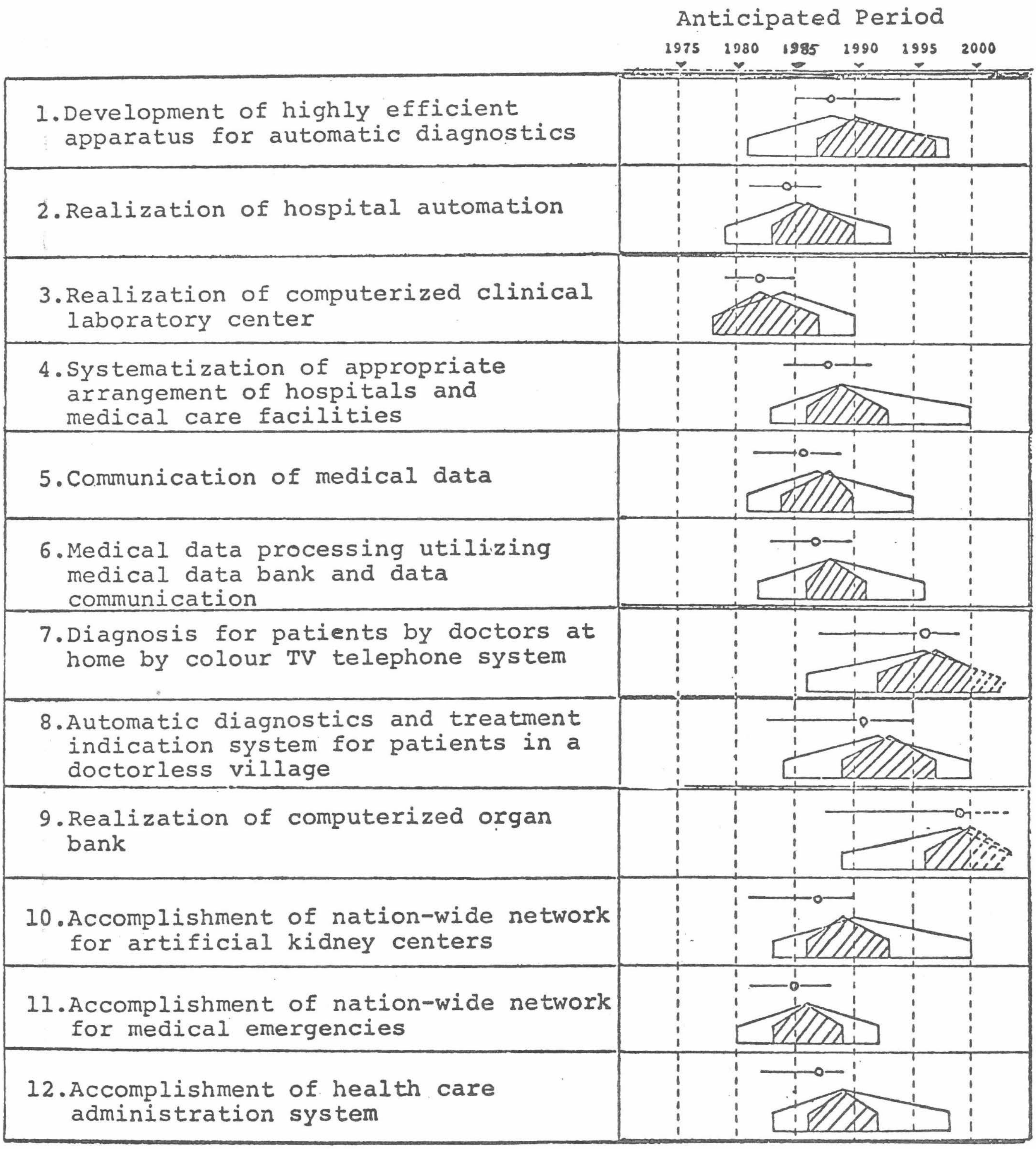
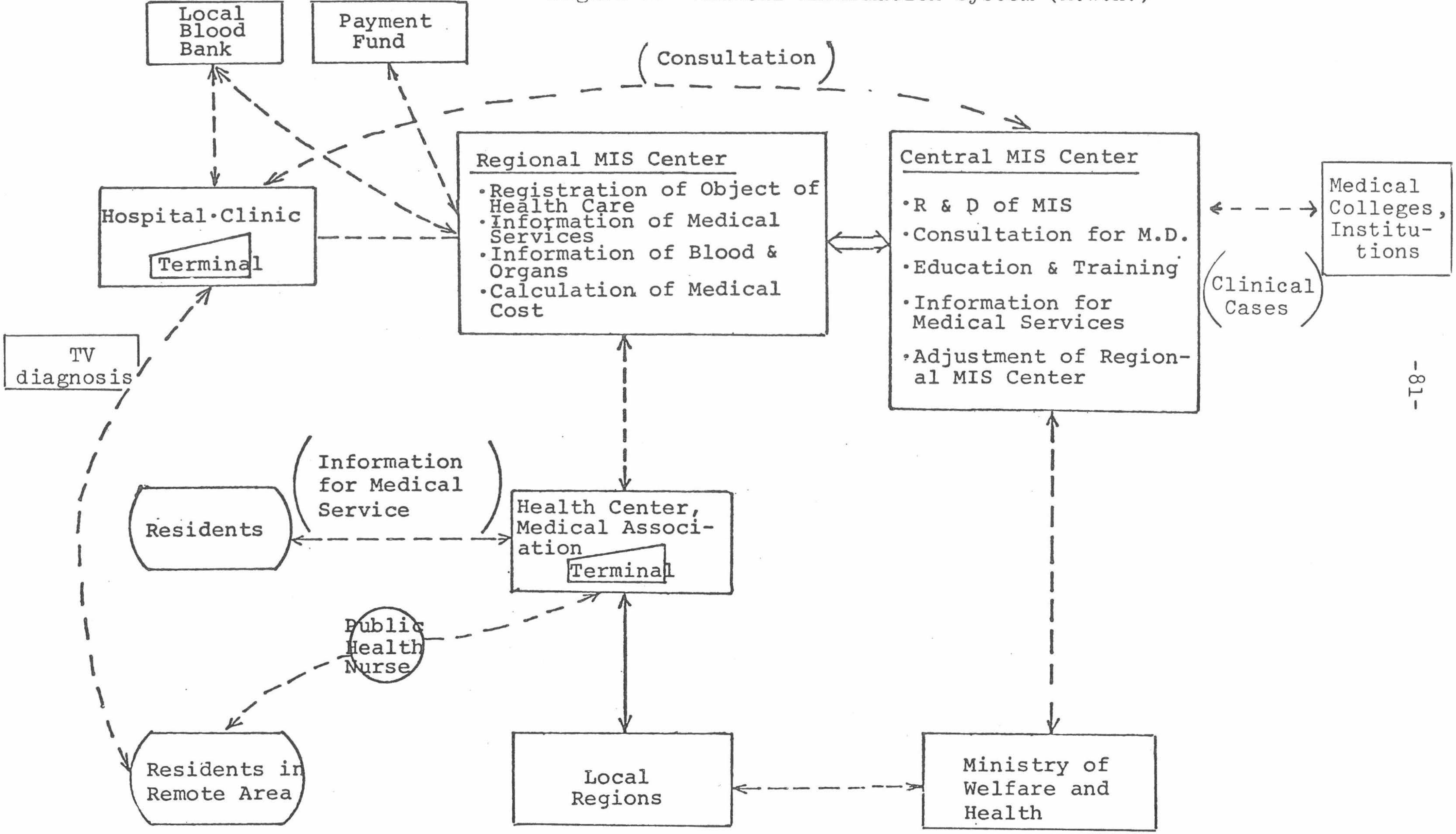


Figure 8. Forecast for Future Medical Systems

Figure 9. Medical Information System (M.W.H.)



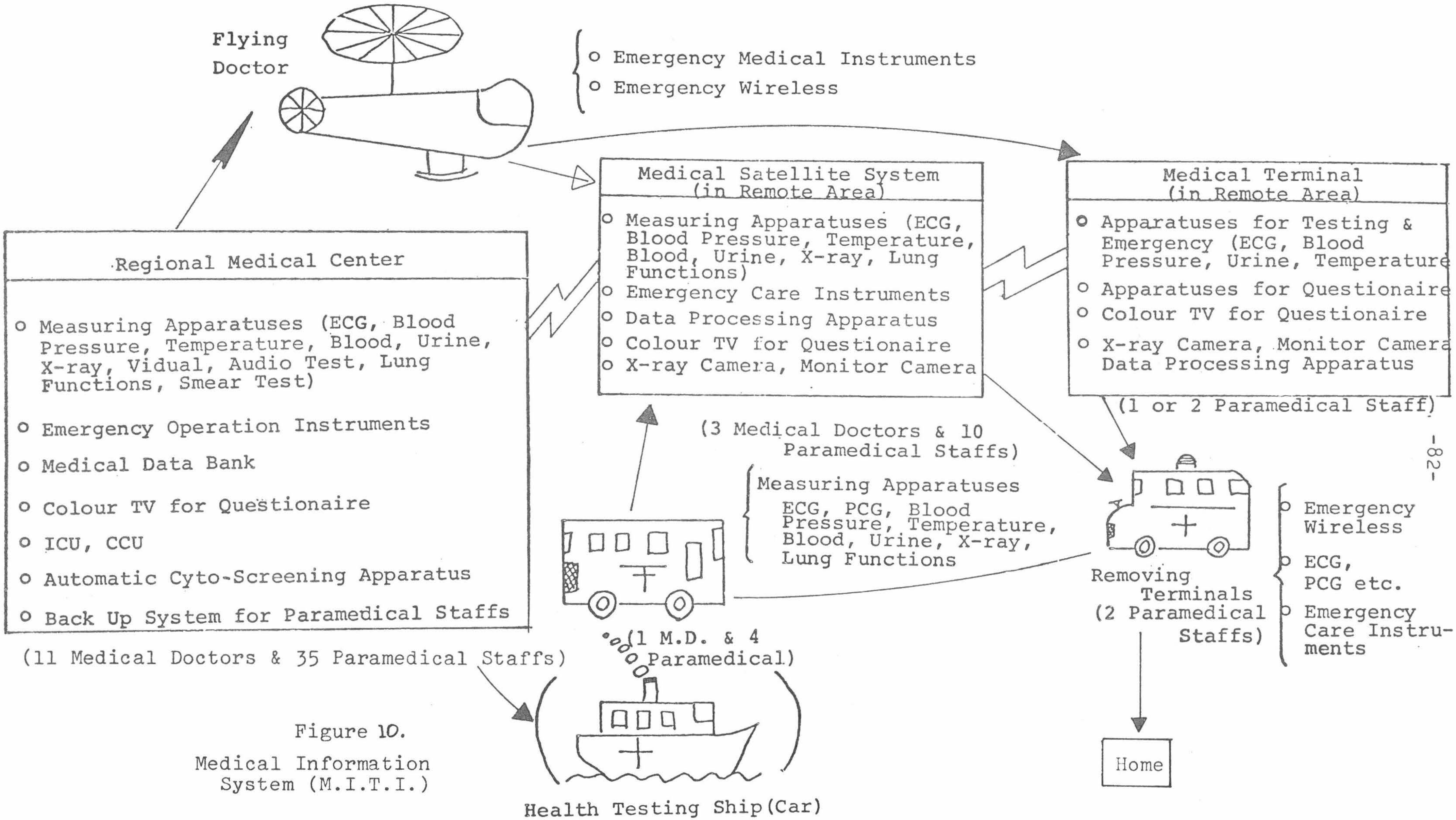


Figure 10.
Medical Information System (M.I.T.I.)

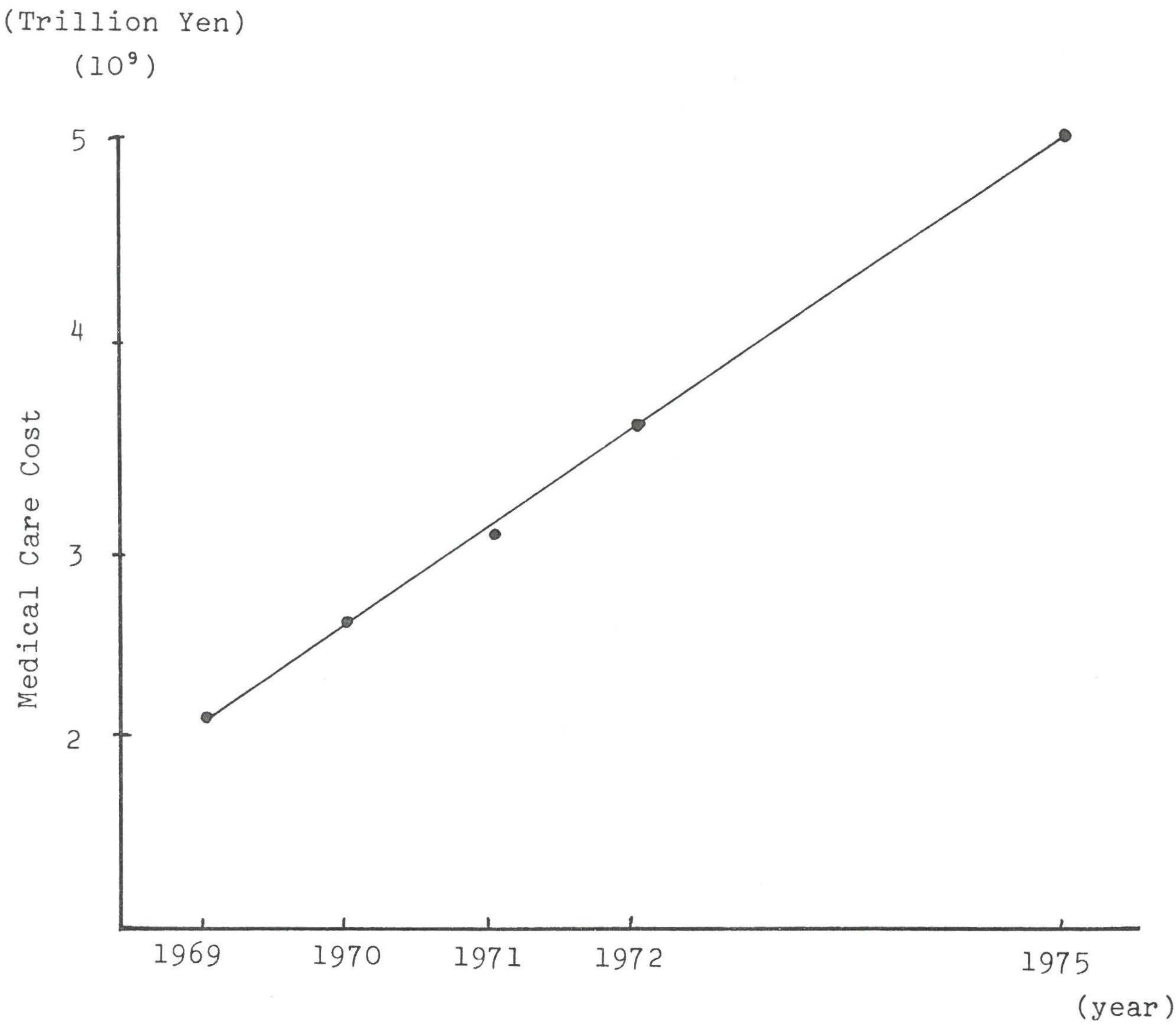


Figure 11. Increase of Medical Care Cost in Japan

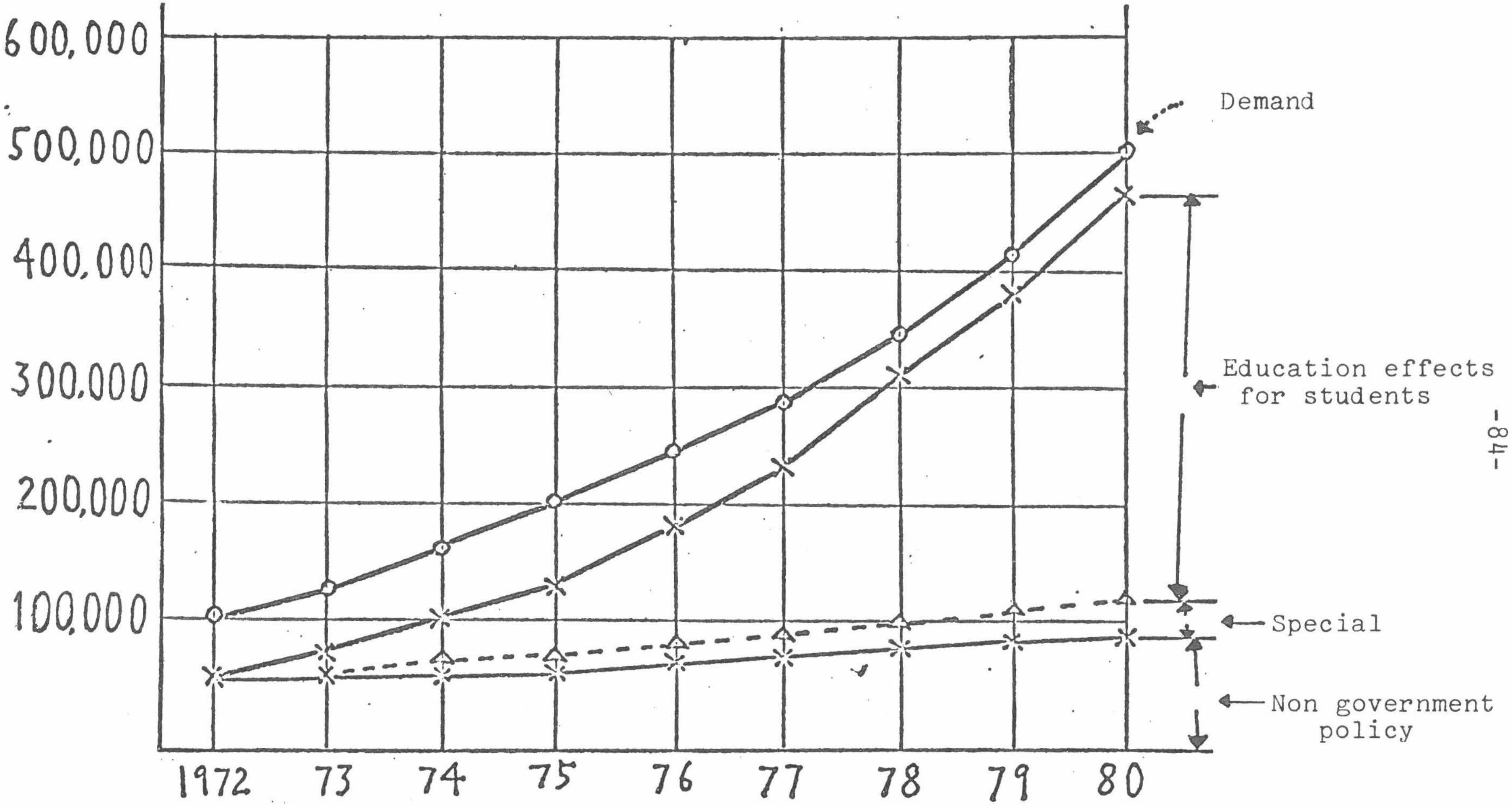


Figure 12. Demand and Supply of Data Processing Technologists

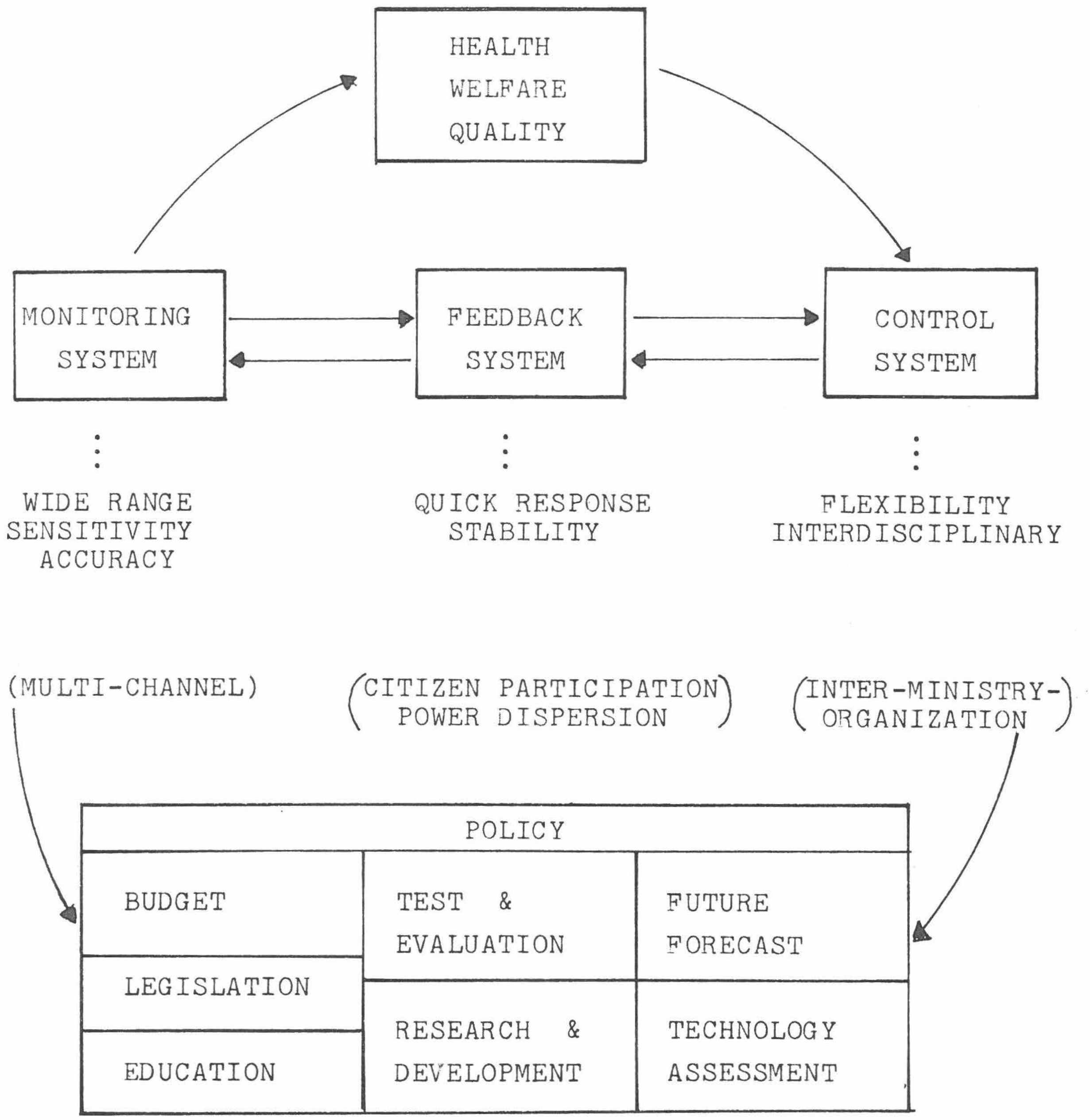


Figure 13. Nation, Society and Government

Personal contribution

N.T.J. Bailey

1. For various reasons I have found it difficult to fit into the general framework of our discussions a number of ideas and recommendations that I would like to give more emphasis to. I am therefore writing these down here, as suggested by Dr. Raiffa.

2. First, I see three distinct levels on which work can be envisaged:

a) the primarily technical level of subsystems, e.g. a given disease or a specific aspect of health care, demography, manpower;

b) the operational systems level, comprising a whole range of subsystems, in which typical features of interaction between subsystems, time lags, feedbacks, etc., are present. This is the level at which regional health authorities usually have to act. There are major problems of organization, intervention, and control facing administrators; and

c) the policy analysis level, dealing with questions of general objectives, goal setting, overall planning.

In my opinion, IIASA should be concerned with both (b) and (c), but not with (a) in any great detail, although of course these subsystems have to be modelled in sufficient detail to provide adequate inputs to level (b). The main responsibility for level (a) lies with individual research institutes, university departments, or perhaps the relevant units of international organizations.

3. As an example, consider communicable disease control. The mathematical modelling of communicable disease dynamics has been developed largely in university departments and other research institutes. In recent years, mathematical models have been used in an increasingly frequent way to understand specific diseases in a field context, particularly with a view to evaluating alternative strategies of control. These applications have been made to diseases like tuberculosis, malaria, typhoid, tetanus, smallpox, etc. Many of these

applications relate to developing countries. But even in developed countries there are difficult problems of the rising incidence and prevalence of venereal disease, for example, or questions of whether vaccination programs for smallpox, say, should be discontinued because they are thought to do more harm than good.

So far, these aspects are mainly at level (a). But as soon as we begin to consider communicable disease control of a number of diseases at regional or national level, and have to take serious notice of a variety of constraints, social, economic, educational, etc., then we are operating on level (b).

4. I would therefore recommend the overall control of communicable diseases--taking into account a wide range of constraints, many of them from outside the health sector--as being a subject worthy of an in-house IIASA project. The same subject could also be treated rather more widely at an international conference. This could give more prominence to technical work at level (a), should review the present state of the art, and should try to indicate specific directions for future work.

5. Another topic which might be worth studying is the organization of health care at a regional level. In some cases, this might incorporate item 4 above as a component, sometimes not. In the U.K., for example, there are many serious problems involving the interactions between hospital care, both inpatients and outpatients, domiciliary care, general practitioners, hospital consultants, medical requirements for hospitalization as opposed to social requirements, availability of specialized and expensive equipment for rare but serious conditions, etc. Similar problems exist in developing countries, though the details are different. Obviously, most individual countries are directly aware of these problems, as is WHO. But little is being done to systematize study of the problems, on level (b), in an adequate systems format.

6. A major activity which also deserves consideration as an in-house IIASA study is environmental monitoring and surveillance. This is receiving increasing emphasis with the establishment of UNEP. One gains the impression that large sums of money are likely to be spent on data collection by different countries and/or different international agencies.

In the health field specifically, data are collected on environmental hazards and pollution and also on mortality and morbidity, but insufficient steps have been taken to relate the two. Naturally, WHO is involved in such work, including information on air and water pollution, health statistics, drug monitoring, epidemiological surveillance, congenital abnormalities, etc. But other agencies, such as FAO, are also involved. Insufficient effort is being directed towards integrating these activities. This is not the responsibility of any one organization except perhaps UNEP itself. IIASA could play a major role in bringing together the various monitoring activities, and helping to relate the collection of data (possibly involving enormous expense) to the overall goals of improving health and exploiting the environment wisely. Also suitable for a conference.

7. The importance of sectors other than health have already been mentioned in connection with the proposals mentioned under items 4,5, and 6 above. Even for health control at a fairly aggregative level--i.e. (c), or between (b) and (c)--it is essential to take into account the relative payoffs between interventions in other sectors: economics, agriculture, industry, education, transport, etc. For example, improved sanitation may improve health indirectly more than the equivalent expenditure on direct health intervention. As usual, the details depend on the country in question.

There is a strong argument for IIASA considering the study of such intersectoral modelling in relation to a suitably chosen area of region of application. Not only are the major features of complex systems present, but it seems difficult for any other institute or agency to mount the appropriate studies on a sufficient scale.

8. Some other comments I would like to make are more of a general administrative of policy nature. For example, the group felt that the needs of developing countries was not a suitable topic for specific discussion. Nevertheless, it seems important that these needs are kept in mind. The promoters of IIASA are at present almost entirely from developed countries so it is natural that their problems should receive the main emphasis. I feel, however, that it is politically desirable, from the point of view of the world image of IIASA, that at least one or two projects should be quite explicitly devoted to developing country problems. In the health field one thinks of such problems as the health difficulties, e.g. schistosomiasis, that may arise as the result of dams and man-made lakes that provide benefits from irrigation.

9. In deciding how many projects should be undertaken by IIASA, there must be sufficient staffing for adequate multi-disciplinary converage and critical mass, as already discussed in the conference. However, having regard for the other areas that must be covered in addition to health, it seems likely that more than one or two projects of adequate size in the latter field would be impossible. Satisfactory choice of one or two projects from the vast range of alternatives discussed may be very difficult. But any appreciable dilution of

effort would be disastrous.

10. Another problem bearing on item 9 is the question of length of contract. I believe that it would be very difficult to run a well-grounded two or three year project if the majority of participants were hired on an annual or short-term basis. This is especially true if the projects are in collaboration with other agencies. Even when things go well, a good deal of time can be spent in preliminary administrative work and planning. Moreover, even the technical staff involved may be engaged in prolonged discussion before an agreed protocol for a study can be arrived at. Even a relatively modest study could entail a year of preparation, a year of investigation and research, and a final year of interpretation, discussion and report writing.

I believe that relatively short term contracts are feasible only when people come to carry out specific, largely theoretical assignments. But when assimilation to a multidisciplinary team is required, plus collaborative work with other agencies or institutes, then some system of renewable three-year contracts would seem, in my opinion, to be essential.

Suggestions for the Procedure to be Used by IIASA in Medical Systems

J. Boukal

Mr. Chairman, Ladies & Gentlemen,

Permit me to express by way of introduction my thanks to IIASA in convening this Medical Systems Conference. This session should be considered an important step in the approach to the coordination and regulation of efforts of member states in the significant problem of medical systems and of introducing computers in the health services. It may be assumed that the adopted recommendations and their incorporation in the plan of IIASA activities will be a great assistance to member states in this complex, extensive and important sphere, which has no analogy in other sections of health activities and which affects all components of the system of health services.

The tasks may be defined as follows:

1) to assess the medical system and its subsystems and the advantages and possibilities which are at present furnished by the use of computers in medical system, in medicine, and in public health.

2) to elaborate recommendations which will serve as a guide for defining the policy and working program of IIASA, and for the further development of IIASA activity in the exchange of information and coordination.

Permit me the following comments upon this program.

We are in a stage when member states develop their efforts to solve extensive problems associated with systemic access to medical system and its subsystems and with computer applications in medicine, in the health services, and in public health. This ensues from the fact that member states also in this way try to face the following factors in particular:

1) The rise of the living standard of the population is also associated with higher demands and requirements not only in the standard of therapeutic care but also in prevention.

2) Expanding specialization of medical branches and technical advances in the examination-investigation of patients is also associated with expanding information on patients and with the need for the physician to obtain as rapidly as possible all required information for his optimal decision for treatment of the patient and for adjusting the patient's working and living pattern.

3) It is necessary to relieve the physician as much as possible of the burden of the administrative work in connection with the expanding volume of medical information.

4) The need is increasing for high standard information for the control and planning of the health services in the period of technical development.

Systemic access in the methods of scientific management in the Czechoslovak Health Services is not a new idea. The principles of the scientific regime are summarized in the health-political records and transferred into the principles upon which the organizational structure of the health system and its functions are based. The conception of the network is hereby asserted as an arrangement of the whole health establishment in the regional system being recommended by the World Health Organization. Each health unit is obliged to have, as an integral part of this system, its optimal location, position, its role in satisfaction of healthcare needs through a rational relationship to the health-social characteristics of the population. From the systemic point of view, it is possible to divide the system of health into the two groups:

1) The system being formed by the Ministry of Health, the institutions of National Health, directly overseen by Health departments, the economic organizations within the framework of the health service.

2) Partial systems and subsystems composed of the health establishments within the framework of the Institute of the National Health and National Committees. Attention is concentrated in the groups upon rationalizing the structure from the organizational point of view and on rationalizing its function as follows:

a) by rationalization of the organizational assortment and by rationalization of the work of the leading employees directing the individual components.

b) by rationalization of the information systems through use of mechanization, automation, and computing techniques.

In the first group the utilization of computing techniques in planning, management and organization predominates. In the second group operation in medical practice predominates.

The extensive problem of automatization in the health services requires a coordinated approach for solution of these problems locally and also on the international level. These conclusions were also reached by representatives at WHO conferences (England 1968, France 1970, Czechoslovakia-Bratislava 1970) and by representatives of the socialist countries at the symposium on the use of computers in Moscow and Berlin 1969.

The conclusions summarized above ensure in the following recommendations for the procedure to be used by IIASA. The project elaborated for IIASA activities in medical systems should include:

a) Conception of the integral system of medical and economic information in the regional system network of health establishments (calculating centers, statistical results, building, projection, standarization).

b) Standardization and unification of information and terminology in an integral information system.

c) Development of basic patterns for planning and management of health services (range and quality of information needed on the individual levels of the management and activities of the health departments). Establishment of the minimum and optimum systems of information indispensable for the management of the health services in various levels and various services (levels: state, region, district, establishments, departments). For example, the CSSR Ministry of Health realizes a regional experiment for an integrated medical computing information system, and the Research Institute of Medical Bionics in Bratislava solves a problem of an information system in a hospital.

d) System of information for the consumption of therapeutic prescriptive drugs (framing, prescription, supplying, planning of production).

e) Health statistics (statistical programs elaborating the common data).

f) The recording system of documentation; the research system of bibliographic data of medical literature.

g) Conception of technical equipment (parameters of computers, the additional equipment, especially the problems of terminals).

Besides the conceptual and perspective solving of system of the health services for implementation, the integral (relatively autonomous) subsystems will form the building blocks of the future integral system, and are not time-dependent on its totality after it is built up.

The solutions of these subsystems bring the projects as soon as possible for immediate application. For example:

- computers in clinical chemistry
- evidence of the blood donors
- screening in pediatrics, gynaecology, onkology
- epidemology evidence
- use of computers in therapy (e.g. radioisotape therapy, monitoring of patients)
- consumption of prescriptions and the invoice of medicaments
- computer-assisted diagnosis
- use of the computers in research work
- use of computers in rationalization of investigation (the method of obtaining and transmitting the information on investigation for the purposes of therapy, prevention, screening, and diagnosis.
- use of computers in the program education.

Furthermore, it is necessary to deal with the legal and ethical aspects of computer applications in the health service (the confidence of the patient to the physician, medical secrets, legal value of the data filed in the computers). It is also necessary to pay attention to the economic value of advantages which will be brought out by the computers on the individual fields of the health services and to what the efficiency would be for the health services in relation to the expenses of using computer techniques.

IIASA assistance to member states should be further expressed in:

1) the solution of concrete tasks of development of automation (for example: consultant groups of specialists, working symposia on medical systems in member states with the participation of IIASA specialists and representatives of member states);

2) the establishment of an information center for member states providing information on projects under preparation and implemented projects and thus ensuring a wide exchange of information, programmes, standards, etc.; and

3) the organization of courses for the special categories of the leading specialists including systems engineering methods in health services.

The application of the rationalization method, of systemic access and application of computers is the *sine qua non* of modern progress, of future developments of medical science in health services, and thus also of the improvement of health care.

Thank you for your attention.

The Impact of Radiological Burden on Health

H.T. Daw
Division of Nuclear Safety and
Environmental Protection

Introduction

The release of radioactive material into man's environment from man-made sources causes some increase in the radiation doses to individuals and to populations. Fortunately, that increase in radiation doses is small, thanks to the stringent radiation protection practice which has and is being implemented at nuclear installations.

99.9% of all radioactive waste produced at these installations is being contained in one way or another. The remaining small percentage, however, is released to the environment only after careful consideration of the pathways which may lead to exposure of man, after ensuring that that exposure will result in doses to individuals and populations well below the dose limits, and after making efforts to keep radiation exposure as low as can be readily achieved. The dose distribution amongst individual members of the public is not uniform, and it ranges from an upper figure for the members of a given group termed the 'critical group' down to a figure which merges with local variations in the natural background. The actual doses received by individual members of the public vary, depending on factors such as difference in age, metabolism, and customs, as well as variation in the environment.

In practice it is feasible to take these sources of variation into consideration by the selection of the appropriate critical group within the population. Such a group should be representative of the individuals in the population expected to receive the highest dose. The appropriate dose limits would be applicable to the mean dose of the group. The selection of the critical group should be such that the group is small enough to be homogeneous with respect to age, diet, and those aspects of behaviour which might affect the dose. Of course, because of the inevitability of some variability within the apparently homogeneous group, some members of the critical group will receive doses somewhat higher; however, at the very low levels of risk implied, it is likely to be of minor consequences.

The exposure of the public from radioactive release to the environment occurs through a variety of pathways, and the radioactive material reaching man gets involved in a variety of processes--biochemical, physical, and biological. Therefore, the material becomes dispersed more widely in the environment, and at the same time it may become re-concentrated by some environmental processes, including biological processes. The result is that radioactive material or radiation exposure occurs to man through complex and intricate pathways. Of course, not all pathways leading to exposure of man are equally important. As indicated in publication 7 of the ICRP, it is important to identify the critical radionuclide, the critical pathway, and finally the critical group of individuals affected.

To evaluate the impact of radiation on the health of man once radioactivity is released to the public domain, it is necessary to estimate the resultant doses to (1) individuals; and (2) populations; and hence to assess the biological consequence to the individual and populations from such doses. For that purpose we need to have biological risk estimates to relate dose and probable harm.

1. Estimation of Population Doses

The ICRP report No.9 indicates that "when whole populations or large sections of populations are exposed, it becomes necessary to consider not only the magnitude of individual's risks but also the number of persons exposed. Even when individual exposures are sufficiently low so that the risk to the individual is acceptably small, the sum of these risks as represented by the total burden arising from the somatic and genetic doses in a population under consideration, may justify the effort required to achieve further limitations of exposure".

Thus, the average population dose must be estimated in order to assess the total number of expected injuries in a given population or to compare the risks of 2 sources of exposure to radiation.

The concept of population dose commitment developed by UNSCEAR is appropriate and can be applied to situations of discharges to the environment from releases from nuclear power plants.

1.1 Concept of dose commitment

The dose commitment can be defined as follows:

"The dose commitment to a given time is ... the integral over infinite time of the average dose rates delivered to the world population as a result of a specific practice ...."

The actual exposure may even occur many years after the release of radioactivity has taken place and may be received by individuals not yet born at the time of the release.

This concept of dose commitment can be made use of in estimating the harmful consequences which might result from the environmental releases of radioactive material as a result of peaceful uses, such as nuclear power plants. Therefore, we can estimate the consequences of a unit practice--for example, the consequences of one mega watt year of electrical energy produced. Thus, the consequences of a unit practice of electrical energy produced from nuclear power plants can, in theory, be estimated by multiplying the dose commitment from that practice by the number of the population exposed to obtain the 'man rad' quantity. The number of the population exposed can be taken to be the geometric mean of the range of N(o) and N(t). The man rad thus obtained would be a measure of the population dose caused by a given practice.

* UNSCEAR supplement No.13 (A/7613) 1969.

It is important to qualify that statement. To use the average dose commitment, multiplied by the average number of the population for a given time period, implicitly implies linearity of the dose effect relationship. Further, the implication is that the time distribution of the dose has no effect on the response. This is a conservative approach, as it allows for no repair, particularly at low dose rates.

To obtain the man rem dose, which is a more suitable measure of the possible harm, it is necessary to multiply the man rad dose by the Quality Factor appropriate to the quality of radiation producing the harm. The man rad dose must also be multiplied by other factors in order to take account of the nonuniformity of the distribution of the dose delivered to tissues and organs.

2. <u>Information necessary to enable assessment of dose commitments from discharges to the environment or the dose to individuals in the 'Critical Group'.</u>

Radioactive material can reach man through a variety of pathways: from inhalation of radioactive material present in the air we breathe; from the ingestion of such material present in our food or water: from external irradiation of our bodies by deposited material, such as ground, water surfaces, sea bottoms, etc.; or from external irradiation of radioactive material in the atmosphere.

The pathways through which radioactive material can reach man are illustrated in Figure 1, Annex 1. The dose to man can be received directly from path (2) by external irradiation and directly from the atmosphere (path 1), as in the case of noble gases and tritium.

To estimate the dose to man resulting from incorporation of radioactive material, the transfer functions from input to the tissue which are relevant to a given pathway have to be known.

For example, in the case of ingestion, we need knowledge of the transfer functions:

P01 = transfer co-efficient function from input to atmosphere

P12 = transfer co-efficient function from atmosphere to Earth's surface

P23 = transfer co-efficient function from Earth's surface to diet

P34 = transfer co-efficient function from diet to tissue

$$\text{The transfer co-efficient} = \frac{\text{The total quantity deposited in a compartment}}{\text{The total quantity deposited in the preceding compartment}}$$

In the case of inhalation, the transfer functions required would be P01, P14, P45.

In the case of external irradiation, the transfer functions required would be P01, P15, and P01, P12, P25.

The total dose from the various pathways would be the sum of doses received through each pathway.

To assess the dose commitment, therefore, it is necessary to know the transfer co-efficient from input, through the various pathways, including the uptake function in the tissue or organ of interest. To estimate the dose to the organ or tissue of interest, it is necessary to know the metabolic characteristics of the radionuclide as well as its physical and chemical characteristics. The estimation is based on the "reference man". The reference man biological parameters are indicated in the report of ICRP Committee 2. The latter report, however, deals with the adult standard man only. The forthcoming publication of reference man by the ICRP includes the biological parameters for reference man, child, and woman.

The various pathways of radionuclides in the environment can be schematically represented by Figure 2, Annex 1, which shows the coupled compartment system.

The determination of the dose in a 'critical group' from a critical radionuclide through a critical pathway can be much simplified, as in the case of radioiodine which is released to the atmosphere, deposited onto grass on the ground, eaten by a dairy cow, and consumed in milk by infants and children. Figure 3, Annex 1, shows the coupled compartment system for that case.

The behaviour of the radionuclides in the environment, therefore, renders itself amenable to the Systems Analysis Modelling. The SAM approach is applicable to planned releases and unplanned releases whether for single radionuclides or for a multiplicity of radionuclides. The system is also applicable for continuous releases or single releases. Of course, a special case of the SAM would be the continuous release of a radionuclide through a certain pathway which attains equilibrium condition. This special case is often referred to as the concentration factor model (CFM), where an equilibrium is assumed between the rate of discharge and the steady state concentration of radioactive material in the environment, e.g. ^{131}I discharged from a stack, deposited in grass, and grazed by the cow.

Using these models, it would be possible to assess the average dose to individuals in a critical group, the dose commitment to populations, or the dose to any sector of the environment if we want to undertake some ecological studies.

To come back to the concept of dose commitment, the UNSCEAR has calculated dose commitments for the gonads, the bone marrow, and the endosteal cells.

If the dose distribution amongst the exposed population is not uniform, then the average dose, i.e. the per caput dose, may be largely due to the exposure of individuals which are for biological reasons not at risk. This is the case, for example, with respect to the genetic effects if the exposure takes place to individuals who are not expected to be able to produce children. Also, in the case of exposure to the aged, the late biological effects may not be made manifest, due to the shorter life expectancy.

This effect can be taken into account by introducing weighting factors to take account of the life expectancy in the calculation of the mean average marrow dose, to derive a leukaemia significant dose. However, this has not been the practice of UNSCEAR who, for leukaemia risk evaluation, have calculated the per caput mean marrow dose.

On the other hand, in the calculation of the genetically significant dose, weighting factors have been introduced to the per caput mean gonadal dose to take account of the child expectancy of different groups of the population.

2.1 Difficulties and uncertainties in the assessment of dose commitments

The population dose can be assessed as described earlier if adequate knowledge of the quantity discharged is available, as well as the knowledge of the transfer co-efficients involved in the pathways of interest. The dose commitment can also be assessed in theory by a directed monitoring programme for the level of radioactivity in food, drinking water, or air. However, there are practical difficulties, amongst which are:

i Considerable uncertainty exists with respect to the transfer functions and parameters in the model. This is because, often, simplifying assumptions are made which may not be realistic.

ii The monitoring programme is not really geared to detect very low activities in the medium. It is mainly to ensure that the radiation protection rules and recommendations are respected. In addition, the interpretation of the measurements is difficult because of radioactivity due to fallout. The fallout radioactivity is considerably larger than the radioactivity released from nuclear plants.

Sources of global exposure which result in environmental contamination are the noble gases ^{85}Kr and Tritium. Though these are produced in the nuclear reactor, they are released to the environment from the fuel processing plants. Assuming the world population to be 3.5×10^9 at the year 1970, the dose commitment from these noblegases is shown in Table 1, Annex 2.

To put the picture of the nuclear industry in perspective, Table 2, Annex 2, includes estimates of worldwide average dose commitments from man-made environmental contamination and natural background.

The table is from UNSCEAR report 72, vol.1. It includes dose commitments from atmospheric weapon tests and from the utilization of nuclear explosions for peaceful purposes (cratering experiments). As can be seen, the dose commitment by the year 2000 will be extremely small compared to the annual exposure from natural background. Nevertheless, methods are available and technological developments are taking place for the containment of ^{85}Kr and for the minimization of the release of tritium which are the main contributors to the worldwide population dose commitment from gaseous releases.

In conclusion, if transfer co-efficient functions are allocated to each pathway in and out of the various compartments, the dose commitment of a population or average individual doses of a 'critical group' can be estimated.

2.2 The impact on health

To assess the risk to an individual exposed to radiation or to assess the possible upper limit of the number of cases which might suffer the deleterious effects of ionizing radiation, we need to have 'risk estimates'. The risk to an individual or the number of cases in a population estimated using the risk estimates would be in all probability an upper limit. This is because the estimate is based on conservative assumptions inherent in the concepts of dose commitment and risk estimates; thus, the risk or the actual number of cases of harmful effects can be anything from zero up to the assessed upper limit.

2.3 Possible biological consequences of exposure of individuals and populations to radiation resulting from the operation of nuclear power plants

2.3.1 General

To detect the incidence deleterious effects at levels near the average natural background is a formidable statistical undertaking which is not practical. Only by inference from higher doses and high dose rates is it possible to arrive at some estimation.

It is considered that the exposure to levels within the natural background fluctuations represents a small risk compared with other hazards in ordinary life, so that the non-trivial benefits obtained would outweigh by far the harm which might result. However, to make such decisions, it is important to be able to estimate the probabilities and frequency of occurrence of such harmful effects. Admittedly, these estimates are based on many uncertainties; nevertheless, they provide adequate guidance for decision making and comparative guidance for selecting from alternative options of technological development. At the same time, these estimates would promote better public relations.

It is important to emphasize here once again the overall requirement of radiation protection, namely to avoid all unnecessary exposure and to keep necessary exposure as low as is readily achievable, taking into consideration social and economic factors. This implies that, even if the benefit outweighs by far the harmful effect, every reasonable effort must be made to reduce the exposure.

As you know, the exposure of ionizing radiation may produce harmful effects in the individual exposed. These effects can be acute effects which occur after exposure to high doses ofradiation. Acute effects become manifest in a matter of weeks after exposure. These effects are not expected to occur except in accidental exposures. The late effects become manifest after a latent period of tens of years, and they are the late somatic effects and the genetic effects.

The late somatic injuries include the induction of malignant conditions such as leukaemia and some types of cancer (cataract of the lens of the eye). The mechanism underlying the induction of leukaemia and certain types of cancer by radiation is not known. In experiments the induction has been established after high exposures. In extrapolation of the dose effect relationship, it has been assumed that the relation is linear and has no threshold. Thus, the exposure even to a small dose of radiation carries with it a small probability of malignancy induction.

The hereditary effects resulting from gene mutations or chromosomal changes are manifested in the descendants of the exposed individual. The effect may be of any degree from mild to lethal. A lethal effect is eliminated rapidly through natural selection, while a less harmful effect tends to linger from generation to generation for long periods of time. Radiation protection aims not only to protect the individual but also to protect society in future generations from an unwanted increase of individuals with mutated genes. Thus, the genetic dose should be limited as well as the individual dose.

2.3.2 Risk estimates

Risk estimates were suggested by the task group of the ICRP* in 1966 and also about the same time in the UNSCEAR** reports. Recently, UNSCEAR 1972 up-dated its risk estimates in its report***. The risk estimates quoted here are based on that report.

Spermatogonial gene mutation

1. Recessive mutations

   a. high acute irradiation: 100-5000 recessive mutations per rad per million

   b. low acute doses or chronic low dose rate exposure: 30-1500 mutations/million/rad

Oocyte gene mutations

   a. high acute doses for females conceiving shortly after irradiation: 200-10,000 recessive mutations per rad/million

   b. low doses: 60-3000 recessive mutations per rad/million

   c. chronic exposures: 10-500 recessive mutations per rad/million

It is important to note that in man, if conception occurs after a long period after exposure to irradiation, the frequency of mutation approaches zero.

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* Report of the task group on Committee I of the ICRP on the evaluation of risks from radiation - Health Physics Journal 1966 - pages 239-302

** UNSCEAR supplement No.14 (A/5814) 1964 and supplement No.14 (A/6314) 1966

*** UNSCEAR 1972, Vol.II - Effects

2. Dominant gene mutations

The dominant gene mutations are expressed in the 1st generation of offspring of the irradiated population.

The rate of induction of dominant visible mutations in the human male exposed to low doses of radiation is 2 per rad per million descendants.

Chromosome aberrations

A large number of spontaneous miscarriages, congenital malformations, and mental and physical effects is due to chromosome aberrations. Down's syndrome is associated with an increase in chromosome 21.

From a radiation protection point of view, at present we can identify the important chromosomal aberrations as:

a. Translocation
b. Other forms of aberration

a. Translocation

Translocation from animal experiments (mouse) indicates malformations or early prenatal death. A balanced translocation, i.e. where there is neither gain nor loss of genetic material by the exchanged segments, does not usually lead to a detrimental effect in the individual carrying them. However, in the individual carrying balanced translocations, half of the offspring are likely to have translocations in an unbalanced form.

The present state of information suggests that many of these non-balanced zygotes (fertilized ova) will die in the early stages of pregnancy and that they will lead at most to a missed menstrual period. The percentage which will survive to produce abnormal newborns will not be more than 6%. Thus, the risk estimate would be one to two additional defective babies per million per rad of paternal exposure at low doses or dose rates. The estimates for maternal exposure are not likely to be more than that.

b. Other forms of chromosomal aberrations

Information gathered from mouse experiments seems to indicate that the other form of chromosomal aberrations, i.e. gain or loss of chromosomes, is less apt to be transmitted from generation to generation after irradiation of the male. Natural selection will eliminate the aberrant reproductive cell through death of the cell. The irradiation of female cells, however, at low doses and dose rates gives an estimate of 8 additional zygotes 0 per million, most of which will die in utero; those surviving will be sterile. Loss of other chromosomes is also associated with early uterine deaths and therefore would not constitute a significant risk to live born children. Gains of chromosomes may occur after irradiation, especially of females, but information is lacking.

In general it is possible to state that gene mutations are induced at higher frequencies than chromosome aberrations and that gene mutations tend to persist much longer through many generations than chromosome aberrations, which are eliminated after a few generations.

Risk estimates relative to spontaneous incidence of genetic diseases

About 4% of all live born children suffer from various genetically determined diseases. UNSCEAR estimates that the natural incidence of hereditary disease maintained by receiving mutations is 30,000 per million live births.

The irradiation of the male by low chronic doses would increase the mutations to about 300 per rad of million males exposed. Up to 20 of these new mutations would contribute to the incidence of hereditary disease among the immediate descendants, while the remaining new mutations' contribution will be distributed over many subsequent generations of descendants.

UNSCEAR 1972 report, vol.II, summarizes the genetic risks of induction of different kinds of genetic damage in man per rad at low doses or after chronic exposures. This table is reproduced in Annex 2 as Table 3.

Risk estimates for radiation carcinogenesis

The information about incidence of malignancy in man is based upon studies carried out on the survivors of Hiroshima and Nagasaki, and upon other human epidemiological studies. The latter include the incidence of malignancy in an American group of early radiologists and patients irradiated for medical purposes. These include surveys of thyroid cancer in children irradiated for thymic conditions, spondylitic patients, and children irradiated in utero in the course of X-ray examination of the pregnant mothers. Human data are also available for the induction of lung cancer by radon and its daughter products in some underground mining operations.

Risk estimates for leukemia

The information available indicates that the frequency of increase in incidence after radiation exposure occurs after a few years' post exposure, and that after 25 years the frequency tends to return to the normal frequency in the absence of radiation. At high doses (more than 500 rads) radiation-induced leukemia frequency tends to decrease as a large number of cells which would have turned leukemic are probably destroyed by irradiation. During the 25 years post exposure from whole body irradiation, observation of high dose rates of 50-500 rads reveals 15-40 cases of leukemia per rad per million exposed.

Risk estimates for lung cancer

The Hiroshima data suggest that lung cancer has been induced by 30 rads of external γ irradiation delivered at high dose rates. Whether or not lung cancer tends to subside after a period of time is unknown. However, UNSCEAR states that, taken at face value, the data indicate that from 10 (at 250 rad) to 40 (at 30 rad) cases of cancer per million exposed develop during the first 25 years after exposure to high dose rates.

Risk estimates for breast cancer

The breast cancer mortality data at Hiroshima suggest a risk of 6-20 cases per million per rad in the first 25 years after irradiation among women exposed to between 60 and 400 rads. This may be an underestimate of the total yield.

Risk estimates for thyroid cancer

The risk estimate is about 40 cases per million per rad over a period of 25 years. The estimate has a large margin of uncertainty.

Other types of malignancies

Other types of malignancies taken together also show an increase after exposure to radiation. A tentative estimate of 40 cases (other than leukemia, thyroid, breast and lung cancer) per rad per million over a period of 25 years after exposure to 250 rads is given by UNSCEAR. It is not known how many cases can develop later than 25 years post exposure.

The risk estimates as mentioned above have to be qualified:

1. They are based on information obtained from exposures of at least tens of rads, delivered at high dose rates. These irradiation doses are much higher than those expected from environmental exposure, either from internal or background radiation.

2. Animal experiments suggest that chronic irradiation is usually less carcinogenic than if the same dose is given in a single exposure. Thus the risk estimates given above are probably an overestimate for risks which might be received from environmental sources.

3. For internal contamination, the sources of information are few. The miners are exposed to radon and radon products in high concentrations in some underground mining operations. Very high incidence of lung cancer has been reported, but the radiation exposure is in the high range, at least a few hundred rads of alpha radiation.

3.3 Effects on the immune system

UNSCEAR concludes that it is unlikely that any appreciable effects on the immune system can result from exposure to radiation in doses less than tens of rads. Exposure to 100/rad (whole body) would affect the immune system and can induce lower resistance to infection. At exposure of 200 rads (whole body), the depression of the immune system causes an increased risk of death from infection.

A summary of the risk estimates per 10^6y rad is shown in Table 4, Annex 2.

In summary, the risk estimates given are presented in Table 5, Annex 2, indicating the probable total cases over a period of 25 years per million population exposed per rad. To this should be added the genetic risk. As a rough guide, which is probably a conservative figure, the total genetic damage over all time resulting from the exposure of 10^{-6} parents to one rad would be 300 cases out of which about 7%, i.e. 20 cases, would be expressed in the 1st generation. If the effects in the 1st generation are considered equivalent, from the individual's point of view, to the somatic injuries incurred by him, the total somatic and 1st generation injury would be about 200 detrimental cases per million per rad.

DISCUSSION

From the foregoing, we can see that the total risk for an individual of one rem $= 10^6 \times 200 = 2 \times 10^{-4}$. Let us look more closely at what that means with respect to an individual member of the public who lives near a nuclear plant.

Individual members of the public

In Table 6, Annex 2, *F.D. Sowby calculates the average lifetime risk of death for selected causes.

* F.D. Sowby. Some risks of modern life, IAEA STI/PUB/261 (1971) p.916

The actual exposure of individual members of the public from nuclear power plants is only a few per cent of the dose limits for members of the public. If the risk estimates were applied to this exposure, the individual's risk would be negligibly small. Suffice it here to say that the exposure risk to an individual living near a power plant for an entire year is less than the radiation exposure risk incurred by one journey across the Atlantic by present-day jets.

As mentioned earlier, the assessment of risk would involve the assurance not only that the individual risk is small, but also that the group risk is small. The previously cited recommendations of the ICRP* indicate that "when whole populations or large sections of populations are exposed, it becomes necessary to consider not only the magnitude of individual's risks but also the number of persons exposed. Even when individual exposures are sufficiently low so that the risk of the individual is acceptably small, the sum of these risks as represented by the total burden arising from the somatic and genetic doses ... in any population under consideration may justify the effort required to achieve further limitations of exposure".

To enable such assessments, the concept of dose commitment and the associated man rem are to be considered as explained before. Information about approximate total population gonad dose in man rem resulting from public radiation exposure due to radioactive waste disposal of nuclear power plants in the UK is shown in Table 7, Annex 2. It is evident that the man rem dose would result in a negligible upper estimate of induction of deleterious effects. The table also shows the maximum exposure, resulting from the release of radioactive waste to the environment, of an individual in terms of ICRP recommendation dose limits. As can be seen, at most it is

* Paragraph 45 ICRP - Publication 9

only a few per cent of the maximum permissible dose. It would suffice here to quote the conclusion of the recently published UNSCEAR report* about the effects of radioactive releases of the nuclear industry in terms of exposure of populations:

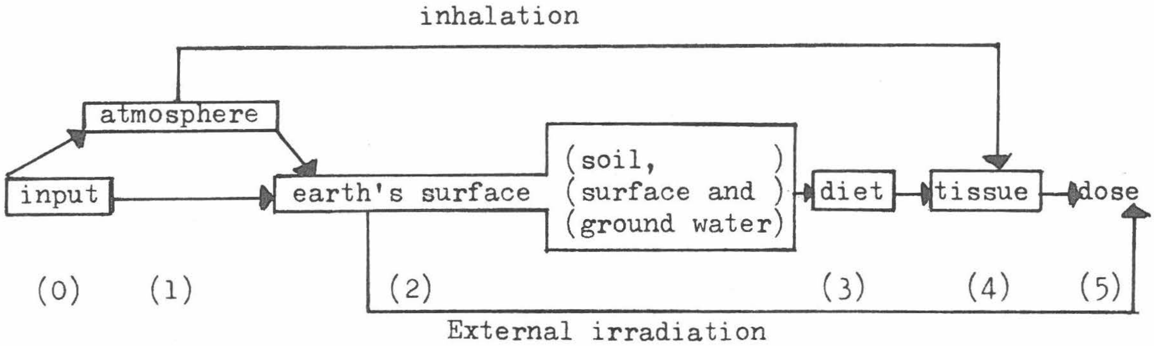
"... one year of electric power production at the 1970 rate and at the assumed rate for the year 2000 would involve doses corresponding to about five minutes and one day of natural background respectively".

* UNSCEAR 72 - paragraph 406 page 73, vol.I

ANNEX 1

Figure 1

Pathways Through Which Radioactive Material can reach Man



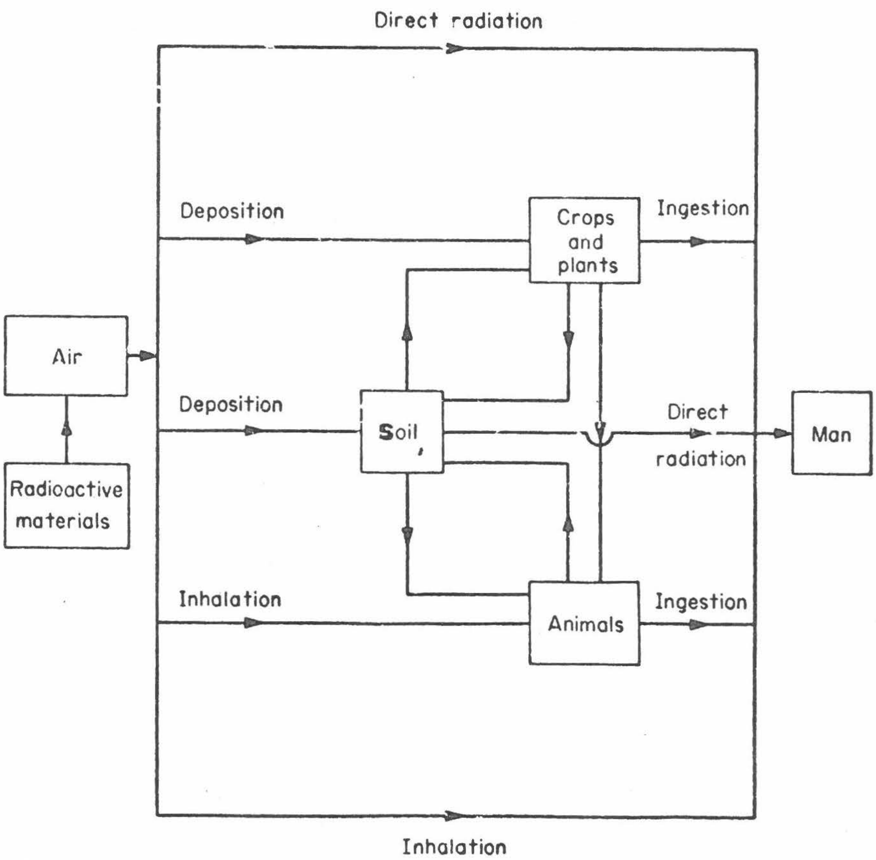


Figure 2 Simplified pathways between radioactive materials released to atmosphere and man.

ANNEX 1 contd.

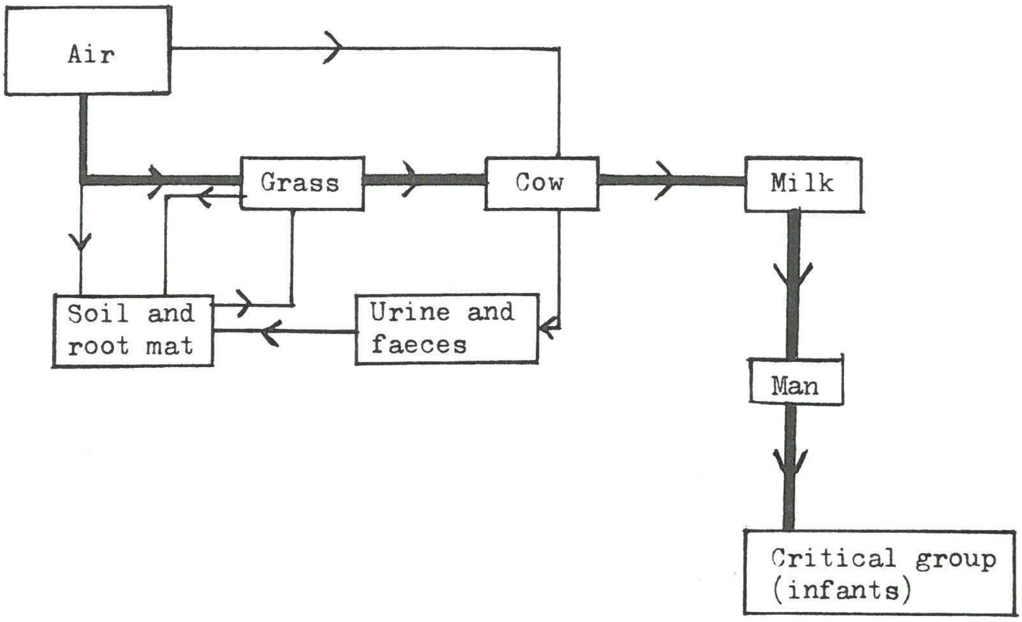


Figure 3. Transfer Pathways for ^{131}I Between Air and Milk.

ANNEX 2

TABLE 1

Summary of Estimated Dose Commitments Resulting from Discharges of Radionuclides by the Nuclear Fuel Processing Plants*

	Source of radiation	Relevant tissue	Number of individuals concerned	Dose commitment, average to individuals concerned per unit of power generated by thermal reactors (rad $(MW(e)y)^{-1}$)	Population dose commitment per unit of power generated by thermal reactors (man rad $(MW(e)y)^{-1}$)	Dose commitment to the world population per year of generation of electricity: At the 1970 generation rate (rad)(GW(e)y)	Dose commitment to the world population per year of generation of electricity: at the estimated rate for the year 2000 of 2,150 GW(e)y[b] (rad)
					GLOBAL DOSES		
Fuel reprocessing plants	^{85}Kr	Gonads	3.5 10^{9}	3.1 10^{-11}	1.1 10^{-1}	3.0 10^{-7} (9.7)	4.5 10^{-5}
	^{3}H	Whole body	3.5 10^{9}	4.4 10^{-11}	1.5 10^{-1}	4.3 10^{-7} (9.7)	1.6 10^{-4}

*Data from Table 75 UNSCEAR 72 vol. 1.

TABLE 2 ESTIMATES OF WORLD-WIDE AVERAGE DOSE COMMITMENTS FROM MAN-MADE ENVIRONMENTAL RADIATION AND ANNUAL DOSES FROM NATURAL BACKGROUND

	Dose commitments (mrad)				
			Electrical power production[c]		
	Atmospheric tests[a]	Cratering experiments[b]	1970	2000	Annual doses from natural background[d] (mrad y^{-1})
Gonads					
External	84	$1.7\ 10^{-2}$	$4.5\ 10^{-4}$	$0.5\ 10^{-1}$	72 (79)
Internal	35	$0.6\ 10^{-2}$	$4.7\ 10^{-4}$	$1.6\ 10^{-1}$	21 (22)
ROUNDED TOTAL	120	$2\ 10^{-2}$	$9\ 10^{-4}$	$2\ 10^{-1}$	93 (100)
Bone-lining cells					
External	84	$1.7\ 10^{-2}$	$4.5\ 10^{-4}$	$0.5\ 10^{-1}$	72 (79)
Internal	95	$0.6\ 10^{-2}$	$4.7\ 10^{-4}$	$1.6\ 10^{-1}$	20 (20)
ROUNDED TOTAL	180	$2\ 10^{-2}$	$9\ 10^{-4}$	$2\ 10^{-1}$	92 (99)
Bone marrow					
External	84	$1.7\ 10^{-2}$	$4.5\ 10^{-4}$	$0.5\ 10^{-1}$	72 (79)
Internal	76	$0.6\ 10^{-2}$	$4.7\ 10^{-4}$	$1.6\ 10^{-1}$	17 (17)
ROUNDED TOTAL	160	$2\ 10^{-2}$	$9\ 10^{-4}$	$2\ 10^{-1}$	89 (96)

[a] Dose commitments resulting from atmospheric tests carried out before 1971 (table 45). For ^{14}C, only the doses accumulated up to year 2000 were taken into account. The total dose commitment to the gonads and bone marrow due to ^{14}C is about 140 millirads, and that to cells lining bone surfaces is about 170 millirads.

[b] Dose commitments resulting from peaceful nuclear explosions conducted before 1972 (paras. 304, 306 and 307).

[c] Dose commitments per year of generation of electricity (1970 or 2000); summation of data in table 75.

[d] Taken from table 20. Estimates of the 1966 report are given in parentheses.

ANNEX 2 cont.

TABLE 3 RISKS OF INDUCTION OF DIFFERENT KINDS OF GENETIC DAMAGE IN MAN PER RAD AT LOW DOSES OR AFTER CHRONIC EXPOSURES

End point	Expected rate of induction per million: Spermatogonia	Expected rate of induction per million: Oocytes	Expression in F_1 per million conceptions after spermatogonial irradiation
1. Recessive point mutations	1,500[a] (36)[b]	Very low -	30-75 (1-2)
2. Dominant visibles	2	-	2
3. Skeletal mutations	4	-	c
4. Reciprocal translocations[d]	15[e]	Very low	2 congenitally malformed children, 19 unrecognized early embryonic losses and 9 recognized abortions[f]
5. X-chromosome losses	Very low	8	8 early embryonic losses and/or abortions
6. Other chromosome anomalies	Very low	-	Very low
Total genetic damage	1,521[g] (57)[h]		
Total genetic damage[i]	300		6-15[j]

Note: dashes indicate that inadequate or no information is available.

[a]Estimate based on mouse specific locus data.

[b]Estimate based on the per genome rate for recessive lethals induced in mouse spermatogonia.

[c]Included under (1)

Table 3 contd.

[d]Figures apply to low-dose X-irradiation. Estimates for chronic gamma-irradiation are 50 per cent lower.

[e]Balanced products.

[f]For low dose x-irradiation; for chronic gamma-irradiation, figures should be halved.

[g]Obtained by adding 1,500+2+4+15 in the column.

[h]Obtained by adding 36+2+4+15 in the column.

[i]Relative to spontaneous incidence of genetic diseases among live-born, based on an estimated "doubling dose" of 100 rad.

[j]In terms of incidence of genetic disease among live-born.

ANNEX 2 contd.

TABLE 4 SUMMARY OF RISK ESTIMATES

Irradiated population[a]	Radiation quality[b]	Mean dose or dose range (rad)	Observation period[c]	Type of data[d]	Sex	Age of exposure[e]	Risk per 10^6y rad[f]
				Leukaemia			
H	GN	60	5-25	Mt	MF	AC	0.7
H	GN	400	5-25	Mt	MF	AC	2.0
N	G	10-400	5-21	Mb	MF	AC	1.6
S	X	300-1,500	(5.5)	Mt	M	A	1.2
P_1	X	0.2-20	0-10	Mt	MF	F	10
P_2	GN[g]	25	0-10	Mt	MF	F	NE
				Thyroid cancer			
HN	GN[g]	25-200	5-20	Mb	M	AC	1-2
HN	GN	25-200	5-20	Mb	F	AC	2-4
I	X	50-600	(16)	Mb	MF	C	2.5
				Breast cancer			
HN	GN[g]	150	13-21	Mb	F	AC	2-4
H	GN	60	5-25	Mt	F	AC	0.3
H	GN	400	5-25	Mt	F	AC	1.0
N	G	20-400	5-25	Mt	F	AC	0.7[h]
T	X	600-3,000	(17.5)	Mb	F	AC	1-6
				Lung cancer			
H	GN	30	5-25	Mt	MF	AC	2.3
H	GN	260	5-25	Mt	MF	AC	0.6
N	G	20-400	5-25	Mt	MF	AC	NE
S	X	80	(10.5)	Mt	M	A	3
				Other types of cancer			
H	GN	30	5-25	Mt	MF	AC	NE
H	GN	260	5-25	Mt	MF	AC	2.5
N	G	20-400	5-25	Mt	MF	AC	NE
P_1	X	0.2-20	0-10	Mt	MF	F	10
P_2	GN[g]	25	0-10	Mt	MF	F	NE

[a] H = Hiroshima survivors; N = Nagasaki survivors; S = ankylosing spondylitis patients; P_1 = children irradiated pre-natally for medical reasons; P_2 = children exposed while in utero to A-bomb radiation; I = infants irradiated in the cervical region; T = tuberculosis patients.

[b] G = gamma rays; N = neutrons; X = x rays; GN = mixed radiation.

[c] Years elapsed between exposure and beginning and end of follow-up period or, in brackets, average duration (years) of follow-up.

[d] Mt = mortality; Mb = morbidity

[e] A = adults; C = children; F = foetuses

[f] NE = no excess or no statistically significant excess.

[g] No neutron RBE applied to calculate dose

[h] Based on the over-all excess among those exposed to known doses > 10 rad (average 113 rad).

ANNEX 2 contd.

TABLE 5

Detrement	No. of cases 10^{-6} rad^{-1} over a period of 25 years
Leukaemia	15 - 40
Thyroid cancer	40 - 25
Breast cancer	6 - 20
Lung cancer	20 - 40
Other types of cancer	~ 40
TOTAL	≈ 185

TABLE 6 AVERAGE LIFETIME RISK OF DEATH FOR SELECTED CAUSES

Cause of death	Risk as a percent
Car accident	0.2
Rail accident	< 0.01
Air accident	0.02
Use of oral contraceptive	0.06

TABLE 7*

Central Electricity Generating Board

Berkeley/Oldbury	External dose	< 0.3	< 0.1
	Fish/shellfish	< 0.1	< 0.1
Bradwell	Oyster	0.1	0.002
Dungeness	External dose	≪ 0.1	< 0.1
	Fish	≪ 0.1	< 0.1
Hinkley Point	External dose	0.1	< 0.1
	Fish/shellfish	0.2	< 1
Sizewell	External dose	≪ 0.1	< 0.1
	Fish/shellfish	≪ 0.1	< 0.1
Trawsfynydd	Lake fish	3	< 0.5

* Radioactivity in surface and coastal waters off the British Isles - 1970 M.T. Mitchell - Technical Report FRL8, December 1971.

Statement

H.T. Daw

It is important to emphasize that the SAM approach forms a basic conceptual framework of thought in the field of radiation protection. It cuts across many areas which have been extensively debated in this meeting. Mathematical models at the physiological level are essential for the calculation of such derived working limits such as the Maximum Annual Permissible Intake or Derived Concentration limits in air or water. They are also important to evaluate body and organ content from excretion rates. The model is important in evaluating releases to the environment. In addition, inherent in the radiation protection philosophy which is based on a non-threshold linear relation between dose and effect, the cost-benefit analysis approach is required and is now being further developed. These are only a few of the broad areas of interest in the field of radiation protection. As Prof. Raiffa indicated that good cooperation exists between IIASA and the Agency in the energy field. It would be desirable, therefore, to emphasize the need for cooperation between IIASA and the Agency in the field of radiation protection as well, and to extend that cooperation to other interested international bodies particularly the ICRP and WHO.

NOT TO BE QUOTED*

On the Social Rationality of Health Policies

J-P. Dupuy

Measuring the Output of Health Activities

Introduction

It was tempting to give this paper a different title, like "Social Indicators in Health Care," or "On the Measurement of the Efficiency of Health Care Systems." But this might have proved confusing at a conference where these subjects are treated in other papers under similar headings, but having naught else in common with the approach here adopted.

Yet the basic problem is the same. In the field of health, as in all other fields of economic and social life, it is one of the economist's tasks to "allocate scarce resources to alternative uses," to quote a well known phrase. To do so, he needs a composite indicator of results. Take the case, for instance, of how much resources to allocate to the fight against cancer and to providing the country with artificial kidney machines; nothing meaningful can be said about this without a common measure for aggregating the effects of these two different activities. Once such indicators are available, it remains to assess the efficiency of the various possible activities which it is proposed to combine in proportions to be determined. The efficiency of an activity is defined, quite simply, as the level of performance achieved thereby as measured by the chosen indicator or indicators. The problem of allocating given resources between different activities so as to maximize total performance thus becomes a classical problem of programming.

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* This paper will soon be published by MacMillan and Co. in the proceedings of the International Economic Association Tokyo Conference on Economics of Health and Medical Care, in a volume called: "Economics of Health and Medical Care."

We know that on certain assumptions (convexity, in particular), this problem can be decentralized at the level of individual activities by attaching a value to the indicator. If the latter, for example, is expressed in terms of the number of human lives saved, we arrive at the familiar concept of the "value of human life." [1]

It follows that to construct indicators of results is the first thing economists, or planners generally speaking, must do prior to any attempt at rationalization. The idea which it is hoped to develop in this paper can be summarized as follows. The only result indicators habitually used in the field of health are based on mortality and morbidity rates, but while these certainly refer to manifest outputs of the health care system, they do no represent the whole of the aims actually pursued by the agents of that system. In other words, to work out a purportedly rational health care system on the basis of these indicators alone would be tantamount to imposing on it an extrinsic rationality. Would it not, in these circumstances be better to try to discover the real aims consciously or unconsciously pursued by those who make up the health care system? Surely, it is with reference to these real aims that we should judge the performance of the system and define rational policies, and not with reference to indicators expressing no ones's aims.

Most of the literature on the economics of health, whether explanatory or normative in intent, seems to take a highly technical view of medical treatment. Most frequently, we find two implicit assumptions. One is that none but "technical" effects--a patient's life saved or prolonged, pain relief, improved physical comfort--can follow from health activities, the other that all health activities rest on technical decisions. If, for example, a doctor prescribes drugs for his patients, he is supposed to be guided solely by a technical consideration, namely, the effective achievement of desired technical effects. For the economist, this is obviously a convenient view, since it enables him to apply familiar lines of thought in the field of health care. But to regard a physician, or more generally speaking, anyone who takes decisions which affect other people's health, as a mere technician suggests a disregarding of an important peculiarity of health care. Contrary to the assumptions of the classical consumption model, in the field of health the person who takes decisions is generally not the same as their beneficiary, and furthermore, under any kind of national health scheme, neither is the same as the person who foots the bill. The preferences of the final "consumer," the patient, are supposed to be unaffected by the existence of the physician, inasmuch as the latter's sole aim is to apply his technical knowledge to the satisfaction of these preferences. But this view of the doctor/patient relationship seems to owe less to reality than to what psychoanalysts mean by rationalization, namely, the reasons by which an individual, when asked to explain his behaviour, spontaneously justifies it while concealing its true motivation. A mere glance at the psycho-sociological and sociological literature on the subject suggests that in health decisions the purely technical aspect is not the only relevant one, and that the doctor/patient relationship is actually much more complex. It will be shown below that the fact that the person who makes decisions and the person who benefits from them are not the same introduces a new and specific dimension into health problems, and that this alone offers the key to any real understanding of the rationale of behaviour in this field.

Health Expenditure Appears to Make Only a Slight Impact on the Overall Technical Health Indicators

The first reason which throws some doubt (but no more than that) on the assumption that the usual performance indicators--that is, crude mortality and morbidity rates--really do represent the sole aims of the health care system is that the results, as measured by these indicators, are very modest indeed [8].

Take for instance the effect of health activities on a crude mortality index like life expectancy. We all know that one of the aspects of health problems which cause concern in industrial countries is the feeling that there seems to be no relation between the rate of increase of resources spent on health care and progress made towards lengthening life expectancy or reducing the death rate.

In France, as in nearly all other industrial countries, medical consumption is increasing faster than most other consumption, even though the rates of increase differ for different components (in France, between 1950 and 1964, the quantitative annual increases per head were 12.4 per cent for medicines, and 6.0 per cent for medical services and hospitalization).

However, this growth of health expenditure is matched by a distinct deceleration of life expectancy gains. An average Frenchman born in 1825 could expect to live 39 years; the figure increased to 47 years in 1900 and to 71 years in 1966. In the countries most advanced in the health field, life expectancy lengthened on the average by 4 years every ten years during the first half of the twentieth century, but during the fifties the gain declined to one or two years in the leading countries, and since 1960 progress has been slower still [16]. The situation in France is typical in this respect. In forty years, from 1932 to the present day, life expectancy at birth rose from 55 to 68 years for men and from 60 to 75.5 years for women. Until 1960, life expectancy for both men and women increased regularly by some six months every year. Since 1960 the curve has been tending to level out, more markedly so for men than for women. The annual increase in life expectancy for women is now only one month, and for men the figure has been oscillating around 68 years since 1965. The fact of higher male mortality, incidentally, is common to all industrial countries, but seems more pronounced in France than elsewhere.

More precise figures can be found in the mortality tables by age and sex. They reveal striking differences during the last forty years in the decrease of death rates for different age groups: the decrease was very sharp for children, considerable for young people and adults, but less marked for the over-fifties, especially men. It can be calculated that during these forty years the fall in infant mortality alone was responsible for 20 to 30 per cent of the rise in life expectancy at birth. At present, this same factor accounts for 33 per cent of female, and for 50 per cent of male life expectancy gains.

Around the years 1955 to 1960, the mortality tables show a clear break in mortality trends for all ages above 5. Until 1955, mortality rates fell very rapidly, but now they tend to level out or even to increase; for men between 15 and 24, for instance, the death rate is increasing by 2 per cent annually [4].

Disturbing as they are, these facts obviously do not justify the conclusion that medical expenditure is "ineffective" in reducing mortality, if only because factors other than medical consumption affect mortality, and affect it adversely. Accidents, nutrition, smoking and the way of life in the broadest sense (including, in France, too much drinking) certainly are exercising mounting influence on health and human life in the rich countries. The pathological pattern, too, is changing under the growing impact of certain types of diseases, like chronic degenerative diseases (metabolic, vascular and respiratory), cancer, mental illness, not to speak of accidents and violent death. The common feature in this apparent diversity of diseases and causes is that they are all linked to a complex and interdependent set of factors, the so-called risk factors, which are correlative to the way of life in developed countries.

It would seem, then, that the attainment of a given mortality level requires more and more medical care in order to offset increasing incidental morbidity. If we want to push the analysis further, we must, therefore, explain mortality trends in terms of the separate parts attributable to medical consumption and to the environmental and way-of-life variables. Some studies have been made in this direction mainly in the United States. The results provide presumptive evidence, inasmuch as, at the average level of the different variables in developed countries, mortality changes in time and space are influenced far more by environmental and way-of-life variables than by medical consumption as such, which seems to make little difference [17]. In France, for instance, a recent study by L. Lebart showed that departmental differences in mortality rates can be explained for the most part by alcoholism. Once this effect is eliminated, we are left with a very weak negative correlation between mortality and expenditure on medical care [14]. For the United States, a study by R. Auster, I. Leveson and D. Sarachek [2] shows a distinctly adverse effect of the income variable, which, at high values, is assumed to express an unhealthy way of life -- a diet that is too rich, cars that are too fast, sedentary and harassing jobs, etc. But there is no need to dwell on this point here, since it is dealt with in the very interesting paper Professor V. Fuchs has prepared for this Conference [10].

However, the slight impact of health activities on an indicator of the quantity of life will come as no surprise to those who regard it as the primary task of modern medicine to secure for people a certain "quality of life." Just because of the prevailing new pathological pattern, medical activities should in any case have much more sophisticated effects than merely to prolong life expectancy, to wit, they should help patients to live with a minimum of discomfort. Along the same line of thought it can be argued that doctors will tend to minister not only to the sick, but to the healthy as well (e.g. tranquillizers or aesthetic surgery). What we need for the future, the argument continues, is to establish criteria based on morbidity and on the concept of the "quality of life," however little statistical information there may be at present to work with.

This certainly seems a very useful approach, provided two conditions are met. First, due allowance must be made for the fact that, unlike mortality, the "quality of life" cannot simply be defined in terms of physical characteristics, but that psycho-sociological factors play an important part in it, as we shall see presently. Secondly, this last observation must not be allowed to serve as an excuse for shelving the problem of the measurement of the efficiency of medical care.

Admittedly, morbidity statistics are at present still altogether inadequate, since morbidity to a large extent defies observation. If an individual is ill without realizing it or without seeking help from the medical system, his ailment remains unknown and is not recorded statistically. Morbidity can be observed only if it finds expression in the consumption of medical care. Even then it may be statistically elusive, mainly because the production and distribution centres of medical care are so dispersed--at least in France.

However, this is not the chief obstacle for an economist in charge of allocating scarce resources. To this end he needs overall indicators, as we have seen. Even with perfect factual knowledge of morbidity, he still would have to define a common measure, or at least a common scale, for all types of morbidity.

Such few indicators as have been proposed so far do not seem satisfactory. There is an American suggestion, for example, to use an overall health indicator called "healthy life expectancy," which is total life expectancy less time spent bedridden or in hospital. But this indicator takes no account of the seriousness of the illness (greater or smaller risk of death), of the degree of disability, of the extent to which the trouble is chronic or otherwise, or of the degree of suffering, and hence gives no clue to the value of medical care the sole effect of which is, for example, to improve the patient's comfort.

More recent studies go further in this direction, e.g. some of the reports prepared for this Conference [15,21]. The fact remains that the hypothesis that the primary aim of health activities in highly industrialized countries is to improve the quality of life is, for the time being, neither proved nor disproved. We simply do not have the necessary data, nor, what is more important, any usable conceptual tools.

In any event, my own view, as stated in the Introduction, is that, while it is certainly necessary and useful to try and work out an overall technical health indicator based on mortality and morbidity, such research is nevertheless insufficient in that it neglects a major part of reality, as we shall see in the following section. This neglect, incidentally, may well be the cause of the difficulties encountered.

Logical Criteria Systems Other Than the Maximization of an Overall Technical Health Indicator

Let us assume that it has proved possible to work out an indicator of a population's state of health, and that that indicator takes account of the quantity of life and of morbidity, including the physical comfort of patients. At once, we are led to suspect that a health policy designed to achieve, with given resources, maximum performance in terms of such an indicator would be very different from what is actually done now.

To prove the point, the rationale of medical decisions may usefully be compared with the repair and maintenance decisions which would be appropriate if it were a matter of using given resources for obtaining maximum performance from a set of industrial machinery (that is, raising to its highest value an indicator integrating in the machines' life-span the quality of their performance at each moment according to their "state of health"). We sense intuitively that these two types of resource management have little in common.

This, no doubt, is why a French economist and humanist, Bertrand de Jouvenel, said that "whereas an economically rational approach would cause priority to be given to the care of persons whose health can be most improved, a social spirit demands that the most seriously ill should be looked after first." [17] Without claiming that health decisions entirely obey this "social spirit," it may be assumed that they are influenced by it and come somewhere between the dictates of economic rationality and those of the social spirit. The demands of the latter, as will readily be appreciated, are contrary to management geared to the maximization of any overall indicator of technical performance.

To return to our example of industrial machinery, it can be shown that there exists an age limit beyond which it is preferable to reduce, or indeed stop, all maintenance and not to repair any breakdown. The resources so saved are more efficiently employed in additional maintenance and more thorough repair during the early years. In more general terms, before any decision is taken regarding the extent of repairs when a machine breaks down, one should ask oneself what will probably happen once the damage is repaired; the decision will depend on how much risk there is that the machine will break down again in the future. Clearly, this type of resource management would universally be considered inadmissible with reference to human health. Nobody would ever be in favour of stopping all care to old people above a certain age. Nobody would ever question the legitimacy of care for the dying. No doctor would ever ask himself whether or not to treat a young man of 20 for bronchial pneumonia, just because at that age there is a high risk of dying in a motor accident. The doctor knows only too well that death is stronger than he, and that one illness is followed by another; nevertheless he will go on treating each illness as it occurs, and society would not wish it to be otherwise.

A good many other decisions and types of behaviour may well appear inconsistent or irrational to an economist intent on maximizing an indicator of technical performance. Compare, for instance, what I shall call "immediate or primary" health situations and those "at one stage removed." In the first case, decisions affecting an individual's health are taken by himself with respect to various aspects of his life (his different consumptions, his choice of career, the employment of his leisure, etc.). Persons who are well informed about the health consequences of their choices try to reconcile the conflicting claims of their health and those of other satisfactions, and health is not always the winner (in economic terms: the preordering of preferences is not necessarily lexicographically in favour of health, and there is a finite marginal rate of substitution between the weight assigned to health and to other satisfactions). A person may, for instance, deliberately choose an occupation he knows to be trying for his nerves, but which carries prestige, or he may take risks which give him social status, etc. Achilles, remeber, preferred a brief life of glory to a long and unworthy one. Now, if such an individual should find himself in the situation of a patient in relation to the medical system, in other words, if his health becomes someone else's responsibility (we call this a "health situation at one stage removed"), we find a very different type of behavior dictated by very different preferences. Lay literature and economic research agree that in such a case health becomes the overridingly important commodity, that "health has no price" (in other words, health comes first in the order of preferences). Medical consumption does in fact seem to be barely influenced by classical economic variables such as price, income (except at very low income levels) or the degree of social protection [18]. Neither the patient, nor the doctor nor anyone else would wish less than the utmost to be done to restore the patient's health; if it is technically possible to do so, it must be done whatever the cost.

An economist comparing these two types of situation may well be tempted to bewail the inconsistency of human behavior and will be reminded of other inconsistencies--the environment is polluted and then has to be cleaned up, holes are dug only to be filled in again, etc.

Yet other things look "irrational" when one compares health situations at one stage removed with those at two stages removed. The former, it will be recalled, are situations involving a personal relationship between a person (or persons) performing a health activity and the person (or persons) benefiting from it, which implies that both are identified. By a health situation at two stages removed we mean one where no such relationship exists, because one or both of the pair, decision maker and beneficiary, are unidentified. Cases in point are preventive action aimed at a statistieal population (like, in the case of road safety, getting rid of a black traffic spot), or the effects of better public hygiene on the health of the population, etc. There is obviously no strict line of demarcation between situations of these two types. They overlap. Take, for instance, progress in the fight against cancer. Here we have on the one side a statistical population of potential cancer victims; this is very close to a health situation at one stage removed, in so far it represents a clearly understood message of comfort from society to itself. Inversely, progress in so-called predictive medicine will increasingly lead doctors to attend to individuals who are not really ill, but who, in the light of some of their physical characteristics (such as weight, height, age, sex, blood pressure, cholesterol level, smoker or non-smoker, etc.) run a calculable risk of falling victim to predictable diseases within a predictable period. This is obviously an intermediary situation between one involving an identified victim of a disease and one involving a statistical population. Health situations at one stage removed and at two stages removed are merely the two extreme cases of a whole series of situations along a scale of intensity of personal relations between decision maker and beneficiary of the decision.

So much for definitions. Now, if the aim is to maximize an indicator of "technical" performance, health situations at one stage removed would seem to be far too greatly favored compared with those at two stages removed. In the first case, as we have seen, everything happens as though "health had no price." With respect to the second, the economists who invented the concept of the value of human life have shown that, whether we like it or not, any given preventive action does involve rejected (unaccepted) expenses--which means an implicit decision not to save certain (statistical) lives. Human life and health do, after all, have a finite price (just as in immediate or primary health situations), and this is responsible for an apparent distortion as between health situations at one stage and at two stages removed.[1] Take the example of safety and of the number of lives that could be saved if part of the resources devoted to the safety of astronauts or to rescuing a climber trapped on a cliff were devoted to the prevention of traffic accidents. The same sort of reasoning applies to health. Morbidity in economically developed countries can be attacked in three different ways: by curative medical intervention, generally at a late stage in an ailment's development process, when acute symptoms or complications occur; or by preventive intervention at the stage of a medical check-up; or by direct action on the risk factors. Some experts think that this last method is much the most effective with reference to a purely technical objective. It certainly would require the organization of health policy to be thoroughly overhauled, and would, for example, involve joint policies in several fields now largely outside the scope of existing health systems, as well as the training of dual-purpose experts who are half doctors and half town planners. Yet this method is neglected at present to the benefit of preventive and, even more so, of curative medicine.

It looks like another case of the same type of distortions.

Yet another circumstance is bound to appear irrational to our economist. This is that in different health situations at two stages removed, very different values are implicitly assigned to the technical performance indicator (say, a human life saved). Any transfer of resources from one sector to another should, therefore, at given resources, improve the overall performance of the indicator concerned. Relevant calculations have been made in France, though not in the field of health itself (where calculations are complicated by the fact that the effects of most preventive action are not confined to mortality, so that there is no simple choice between cost and years of life), but in the field of safety. These calculations have led to rather startling estimates: "everything happens in France at the moment as though a human life were worth, respectively $30,000 in a road accident, $100,000 in an accident at work in a large public company, and $800,000 in an air crash." [19]

The Implicit Rationality of Health Activities and Their Non-Technical Outputs

"Inconsistent behavior, irrational decisions!" A little humility would befit the economist, as we suggested in the Introduction. Before passing judgment, he would do well to try and understand and explain the behavior and the decisions concerned. He might find some implicit rationality hidden in them.

Actually, there is an implicit rationality, and it can be perceived easily enough if we look for what is common to all the cases mentioned above in which, at given resources, a transfer of resources would result in better performance than we have at present, in terms of a crude mortality-morbidity indicator. Any such transfer would lead to the replacement of a certain number of current health activities by others more effective with reference to the indicator, but of weaker psychological impact. Consider, for example, care for a dying person. This care, which can be very expensive, does have technical effects, that is, effects on the mortality and morbidity indicators. But these effects may be minute: the person concerned may live a few days longer, and suffer a little less. Undoubtedly, these expenses, which society fully approves whether or not their technical effects are at all appreciable, play another role as well: they demonstrate to the dying, and even more perhaps to his family and friends, not to speak of the doctor himself, that everything possible is being done for the patient and that he is not alone in his last ordeal. Similar considerations apply to the care for the very sick: the more seriously ill they are, the more the very act of caring for them is reassuring and clear evidence that medicine concerns itself not only with people easy to cure.

Generally speaking, it can be argued that any health activity (and more broadly, any activity concerned with the safety and preservation of human life) has, simultaneously,[2] technical and non-technical effects. The technical effects are so called because they are directly connected with the physical and technical properties of the means employed, and they consist in a prolongation of life, relief of pain, and improvement of the patient's physical comfort. The non-technical effects, on the other hand, are not directly connected with the physical properties of the means employed, but rather with their psychological property of signifying something. Their significance may vary; at the level of generality of this discussion, we have to distinguish two dimensions. (In the second part of this paper, on the consumption of medicines, these notions will be discussed in more detail.) Health activities may have, first, a reassuring effect by signifying the retreat if illness and death, and second, an emotional effect (felt by the doctor, the patient, and others) by signifying that the doctor takes responsibility for the patient [12]. There would, of course, be no point in distinguishing technical and non-technical effects if they were proportional, that is, if the patient's sense of security and his feeling of the doctor's taking personal responsibility for him were commensurate with the technical efficiency of the means employed. But this is not so. Health activities may well be equivalent in their technical effects and yet have very different significative powers, or non-technical effects.

Let us consider, for example, the sense of security. Psychologists know very well that situations of equal objective insecurity may be lived through in very different ways, and may generate very different feelings of insecurity and anxiety (e.g. fear when travelling in a car or an aircraft). In the field of health, the sense of insecurity experienced in the face of some symptoms of illness may have very little to do with the latter's real gravity. Sociological surveys have shown that some people considered seriously ill from the point of view of medical science remained quite unconcerned, and that others were deeply worried by the most benign symptoms [11], which they regarded as the revealing signs of some constitutional weakness and as a foreboding of the inescapable approach of death. Psycho-sociological factors amplify subjective insecurity to a greater or lesser extent. One of the principles of these factors is attention to the body. This is known to vary considerably according to social categories. The limit beyond which an individual feels his physical condition to be impaired ranges from a cut finger in the case of a coal miner to dental caries in the case of a young lady. Medical attendance itself seems to increase the attention paid to the body. As L. Boltanski, a French sociologist, writes: "The practice of consulting doctors increases the number of known diseases, that is, diseases named and established as such; it also enables morbid symptoms to be classified more accurately and hence causes people to perceive them more readily and to pay more attention to them. The end effect is to raise the subjective chances of illness, and, ipso facto, medical consumption." [3]

Because the state of health and the degree of anxiety felt are relatively independent of each other, actions with equivalent effects on technical indicators may have very different reassuring effects. Publicity devoted to spearhead advances in medicine (heart transplants, cancer research, etc.) is a good deal more reassuring than the construction of sewers. The same applies to the prescription of drugs as compared with advice regarding the general way of life. It is even possible for a positive effect on a technical health indicator to be associated with an alarming psychological effect. A case in point is a system of compulsory medical screening for the early detection of certain diseases, which "inevitably has the result of lowering the tolerance level for morbid sensations by creating a new, more reflexive and apprehensive attitude to the body." [3] The opposite is equally true: to smoke, drink, take drugs, or eat too much may be means of making people feel more secure and of fighting off anxiety at the price of impairing their health [12].

Let us now consider the other non-technical output of medical activities, which is connected with the quality of the relationship between the person who makes a decision and its beneficiary, and concerns primarily the latter, but also the former as well as third persons. Here again, equivalent technical outputs may be associated with emotional outputs of widely differing effect. It is certainly more gratifying for the doctor if he can bring a baby back to life in the maternity ward, and will give the mother a much stronger impression that "something is being done for her," than if he simply attends to prenatal check-ups of expecting mothers. With reference to our definition of health situations, there is a general presumption that the emotional output will be much larger in situations at one stage removed than in those at two stages removed or in immediate or primary situations.

The non-proportionality of the technical and non-technical effects of health activities creates a situation of conflict between these effects, in the sense that a non-zero weight attached to one type of effects causes, at given resources, part of the performance achieved by the other type of effects to be sacrified. This conflict would appear in an entirely different light if activities having technical effects were distinct from those having non-technical ones, for then there would be conflict only at the level of the distribution of total resources between the technical and the non-technical sector. To be sure, there exist means specifically applied for non-technical effects and devoid of any direct[3] technical effect; examples are a doctor's bedside manner, the kindness of what he says, or the attention with which he listens to what the patient has to say (none of these are free, since they use up that very scarce resource which is the doctor's time). But generally speaking, as we have seen, most medical activities exercise simultaneously both technical effects and, thanks to their significative property, non-technical effects.

At this point we begin to discern a certain internal rationality in medical activities, a certain consistency at least in qualitative terms. Everything comes to pass as if a deliberate balance were struck between the weight assigned, respectively, to non-technical and to technical effects, the former being undoubtedly those which play a central part in the definition of what we called earlier the "quality of life," the "comfort" of the patient as well as of the doctor and third persons. If we look again, one by one, at all the activities which we have mentioned and which in the light of short-term economic rationality might appear "unprofitable," we realize that while these activities certainly have mediocre technical effects, their significative effects are outstandingly strong, and stronger at any rate than those of such other activities as would have to be substituted according to the criterion of technical efficiency. Examples are the care given to those who are seriously ill as against those who can recover easily; treatment of actual disease as against disease existing only in probability; action concerned with identified individuals as against a statistical population; and action in fields where the sense of insecurity is strong as against those where it is weak. Everything in effect happens as though the members of society were assessing the value of the performance achieved by non-technical outputs. We may conclude that even though, at present, the technical marginal efficiency of health activities varies greatly in different cases, there does exist, at least in qualitative terms, a tendency towards equalization of their social marginal efficiency, including non-technical outputs.

Let us return to the apparent inconsistency that in health situations at one stage removed everything happens as if "health had no price," whereas it clearly does have a price in all other situations. We now see that this social norm is not the expression of a lexicographic order of preferences between health (in the physical sense of the word) and other satisfactions, in which health comes first, but has to do with the type of performance obtainable by the use of technical means for emotional outputs--in plain words, the quality of the doctor/patient relationship. Take for instance a simple case where the significative power of the means employed (the significance being that the doctor assumes responsibility for the patient) is linked to their technical efficiency,"[4] which we call x. Designating by the variable X_1 the performance obtained with respect to the state of health in the technical sense of the word (mortality-morbidity indicator), we can write

$$X_1 = X_1(x) \quad , \quad \frac{dX_1}{dX} > 0 \quad . \qquad \text{(a)}$$

The relation between x and X_2, X_2 being a variable representing the performance obtained in terms of emotional output, the quality of the doctor/patient relationship, is very different. In this case x acts as a sign, and the performance on X_2 depends not on the absolute value of this sign but on its relative place in a scale of signs. We have to do not so much with efficiency as with the greatest possible efficiency. In other words, what counts is the gap between what the doctor could do and what he actually does. Let us designate by $\overline{x}$ the maximum efficiency possible at a given state of technology and with a given supply of equipment. We can write

$$X_2 = X_2(x,\overline{x}) \ , \quad \frac{\partial X_2}{\partial \overline{x}} > 0$$

$$\frac{\partial X_2}{\partial \overline{x}} < 0 \qquad \text{(b)}$$

This is what is really meant by the norm, "health has no price." This norm does not purport to establish a lexicographic order of preferences between X_1 and other satisfactions; it does mean that when a doctor takes decisions regarding a patient, decisions which can always be considered as the use of existing techniques and equipment (giving the word "equipment" a very broad sense, including, e.g. the number of doctors, their training, etc.), any failure on the doctor's part to make the utmost use of existing means would incur strong censure (bad performance X_2) as unwillingness to assist a person in danger. But it must be added that in any event the doctor's action is conditioned and limited by prior choices regarding techniques and equipment, $\overline{x}$. Necessarily,

$$x \leq \overline{x} \ . \qquad \text{(c)}$$

Choices regarding $\overline{x}$ may be made by conscious decision or not, but they are certainly made, and they are different in nature from decisions concerning the use of means. Unlike the latter, they are concerned not with flesh-and-blood patients, but with statistical populations.[5] They are choices in a health situation at two stages removed, where health has a price. In other words, the level of $\overline{x}$ results from weighing the cost of $\overline{x}$, $c(\overline{x})$, against the value $pX_1(\overline{x})$ of the technical benefit associated with $\overline{x}$.

In concluding this section, let us return for a moment to our starting point, namely, the observation that health expenditure seems to have precious little influence on crude technical indicators of the state of health. Small wonder, we can now say, for this is not the result which, implicitly, is desired. We may add that, paradoxically, a health policy which, at given resources, carried out such transfers of resources as are necessary to improve performance in terms of an overall health indicator would be regarded as much less reassuring, and hence less efficient, than present policy, even though on the average,people would live longer and would be afflicted by less disease.

From Technical and Non-Technical Outputs to a Rational Health Policy

Now that we have uncovered the implicit rationality underlying behavior and decisions in the field of health, can we affirm that all is for the best in the best of all possible worlds? Or on the contrary, must this rationality be judged to be..."irrational?" It is time to switch from a strictly explanatory to a more normative point of view.

To begin with, there is a temptation to be resisted. It would be wrong to think that only the technical output of health activities should be taken into account, and that, consequently, there is a case for any transfer of resources likely to improve performance with reference to these indicators alone. In any event, advocates of such a policy would stand little chance of seeing it put into effect, given what we have seen above. But we may ask in the name of what principles and what ethic we should be required to assume that people's sense of security and freedom from anxiety, and good personal relations have no weight at all in comparison with their state of health in the physical sense, whereas individuals themselves patently do attach importance to these factors of their well-being and show it by their behavior. Such a view would, in plain words, be altogether technocratic. We reject it, and in what follows shall take it for granted that any health policy must be judged by its impact on all outputs, technical and non-technical alike.

A more constructive approach is possible. One suggestion is that the non-proportionality of the technical and non-technical effects of health activities is at the root of this problem of choice, and if such be the case, it is because of distortions which make things appear different from what they really are. It might be useful, then, to try and reduce these distortions and make the non-technical effects of health activities match their technical effects. It is perfectly possible that people are simply misinformed about the real efficiency of various health activities. On the one hand, for example, the press makes much of certain spearhead medical techniques, and this publicity gives people a strong impression of the real possibilities of curative medicine. On the other hand, for example, the press makes much of certain spearhead medical techniques, and this publicity gives people a strong impression of the real possibilities of curative medicine. On the other hand, there is a deplorable lack of information and studies concerning the impact of the environment and of people's way of life on their health. It is suggested that such distortions might be straightened out by health information campaigns, or better, by real health instruction for the population at large. And it might be well, too, to take a hard new look at certain power relationships, with particular reference to the power which doctors, such as we know them at present, wield in all matters concerned with health.

Measures along these lines would certainly do much to lessen the conflict between the technical and the non-technical outputs of health activities and thus, at given resources, make it possible to obtain improved performance from the first without detriment to the performance of the second. But there is no hope of removing the conflict completely, for at least two reasons.

The first reason is that, leaving aside the time it would take so to refashion individual attitudes, they could never be changed radically enough. The psychological impact of bringing a new-born baby back to life, to return to our earlier example, would always remain bigger than that of new regulations increasing the number of prenatal check-ups. In other words, when the difference in the non-technical effects of two activities with equivalent technical effects is connected with a purely physical factor, such as whether the decision maker and the beneficiary (or beneficiaries) of the decision are, or are not, identified individuals and in each other's presence, then this difference simply cannot be reduced to zero [13]. Do what you will, an optimal policy taking account of all the technical and non-technical outputs of health activities will never resemble the management of a set of industrial machinery.

The second reason is that, even though the non-technical effects are linked with technical ones, it still remains a fact that the relational output X_2 is influenced not by the absolute value of technical efficiency, x, but, as we have seen, by the relative value of x with respect to $\bar{x}$. Choices regarding $\bar{x}$, which are those of prime interest to health planners, thus appear in a very different light according as performance is assessed in terms of X_1 alone, or in terms of X_1 and X_2. Any increase in $\bar{x}$ has nothing but advantages so far as X_1 is concerned, since a higher $\bar{x}$ makes room for higher values of But to increase $\bar{x}$ has, to some extent, adverse effects of X_2, because the impact of any given x on X_2 diminishes when $\bar{x}$ rises (because of the inequality $\frac{\partial X_2}{\partial \bar{x}} < 0$). This is a psychological cost which is associated with any technical innovation in the medical field and corresponds to the frustration felt by all the people who cannot benefit from this innovation. Here we have another irreducible source of conflict between technical and non-technical effects.

Let us imagine that appropriate measures have been taken in order to minimize the conflict between technical and non-technical effects. Nevertheless, there will still be some conflict. The problem then is to compare the equilibrium state of the health system with an optimal state, the optimum being defined with reference to the whole set of outputs, both technical and non-technical. We can provide an at least qualitative answer on the evidence of the inequality $\frac{\partial X_2}{\partial \overline{x}} < 0$. This psychological cost, which we shall call the "psychological obsolescence" of the technical qualities x, may formally be characterized as an externality of psycho-sociological nature, since any decision to vary $\overline{x}$ entails a change in the social utility of a given x. Such a decision therefore also alters the choices based on any x, without, of course, any deal being actually struck. There is clear evidence of an interdependence between two decision levels, x decisions and $\overline{x}$ decisions. It is hardly surprising, therefore, that the equilibrium position can be shown to be distorted with respect to the optimal position. More precisely, at the equilibrium position too many resources are allocated to research and development for new techniques, and not enough to the broader application of existing ones [7]. It follows that, in theory, there is a case for action designed to bring the present situation closer to an optimal situation. The same considerations suggest an explanation for the growth of health expenditure much more satisfactory than those usually advanced at present, which all take account only of technical factors [8]. We shall not dwell on these points here, but refer the reader to the theoretical works quoted as well as to the second part of this paper, which deals with the consumption of medicines.

But our final arguments also suggest another way of improving the present situation, that is, of using given resources to enhance the performance of certain outputs without detriment to that of the others. It follows from what has been said (and this will be seen more clearly in the case of medicines) that to bring technical means to bear on problems of human relations leads to bad performance in terms both of technical and of non-technical outputs (the equilibrium is not optimal). We may ask whether it would not be better to devise specific means for dealing with problems of reassurance and personal relations, and reserve technical means for technical purposes. Such an approach would certainly do much to clarify the situation, but it would equally certainly run counter to strong tendencies in industrial societies, where people regard technical progress as the answer to all their problems, though most of these problems have to do likewise with human relationships or with the anxieties of living. We shall discuss this question in more precise terms in connection with the consumption of medicines.

The Consumption of Medicines in a System of Private Medical Practice.

So far the discussion has kept to a very general level and may have appeared somewhat abstract. It will now be illustrated by an analysis of a specific case, namely, the consumption of medicines in a system of private medical practice (which in France, means that the patient freely chooses his doctor and on a fee-for-service basis. This is a subject on which an interdisciplinary study was carried out under the auspices of the Centre de Recherche sur le Bien-être (CEREBE) in Paris [9]. The research team, which includes economists, psychosociologists and sociologists, based its findings on a wide-ranging bibliographical analysis as well as on field observations. Using non-directive techniques, the team interviewed some hundred physicians, patients and executives of pharmaceutical firms, and also observed cases of doctor/patient relationships. The principal results of this study are briefly summarized below. (The text which follows is a summary of an article published in May, 1973, in the review, Projet [5].)

The Facts and the Questions They Raise

It has been argued in the first part of this paper that any attempt at rationalizing a social system should be preceded by an effort to understand how it works. In the matter of the consumption of medicines, value judgments are often passed on the basis of a very summary and unsatisfactory analysis of the relevant facts. One of these facts is that drug consumption displays one of the fastest growth rates in the whole health care field (in France, its annual growth in the long period is about 16 to 17 per cent, at current prices); this growth is currently justified, if not explained, on the basis of purely technical considerations, whereas precisely known facts suggest that other factors are involved as well.

There is no gainsaying that the pharmaceutical industry produces a rich harvest of innovations, witness a growth rate of 16 to 17 per cent in the consumption of its products. This growth rate may be considered as the sum of several other growth rates, concerning respectively: 1) the number of entries into the medical system (consultations and visits)--+6 to 7 per cent annually--not to be discussed further here; 2) the number of products per prescription, of which little is known but which is probably close to zero; and 3) the average price of medicines prescribed and purchased in the unit period--probably as high as 10 per cent annually, and thus accounting for more than half the rate of growth of expenditure on drugs. In its turn, the high rate of increase in the price of drugs has two causes:

a) Every new drug is more expensive than the one it replaces. This has invariably been so in the past and continues to be so, because a higher price is authorized, if indeed not provoked, by a certain number of institutional factors, such as price control (a fixed price for old products and a range of prices for new ones), or the conditions of eligibility for reimbursement by the Social Security System.

b) The renewal rate of the pharmacopoeia is extremely rapid. Products emerge, replace others which disappear from the market, and after an average life of ten years are in their turn driven out by new products; of the medicines now on the market, 70 per cent are less than fifteen years old, and almost half of the industry's turnover is attributable to products less than five years old.

Innovation, therefore, is an essential factor in the growth of expenditure on drugs. But does innovation necessarily mean technical progress? To begin with, not every "novelty" is *a priori* as good as another, for the term covers a multitude of very different things. Novelty can mean a genuine scientific discovery which enriches therapeutics by a new class of active molecules, or it can mean an existing drug in altered dosage, form or packaging, or with new instructions for use, and indeed it can mean merely a change of name. Something like 250 new pharmaceutical products are launched on the market every year and replace cheaper ones; it certainly looks as though the overwhelming majority of them must be placed on the lowest rungs of the scale of innovations. The point can be proved by American figures, there being reason to think that the French situation is very similar. Between 1948 and 1966, 7,563 articles were launched on the market in the United States (which means, on average, 420 each year); of the total, 1,785 were new pharmaceutical forms of existing products, and 5,778 were new products. The latter consisted of 676 new therapeutic substances, 3,757 combinations of known substances, and 1,345 products launched by a new manufacturer but identical with products already on the market. As regards the 676 new substances, more than half of them were merely new salts or derivatives of some already known molecule. In all, less than 5 per cent of new drugs launched in the United States during the 18 years in question can rightly be described as genuine major innovations.

These figures will come as no surprise to anyone who knows what sort of research the manufacturers pursue. Most often it is ultra-empirical research, which consists in synthesizing the greatest possible number of molecules and testing them systematically for their activity. This is a lengthy and very complicated process, and also a very expensive one. As Professor J.M. Pelt says [20]: "Failing any guide line, chemists and pharmacologists proceed by systematic testing of thousands of molecules, like a locksmith devoting all his efforts to making thousands of keys, each better than the one before, in the hope of opening a lock he does not know. The more complicated the lock, the less are his chances of stumbling by accident upon the right key. One ends up by wondering whether it would not be better to dismantle the lock and then make a key that fits." And in effect, this kind of haphazard, costly and uncoordinated research is the very opposite of genuine fundamental research, which would start out with the "biochemical lesion" at the bottom of an illness and then try to find ways of treating it.

In any case, there is reason to think that innovation is really a constraint which pharmaceutical manufacturers impose upon each other, rather than a freely chosen aim which furthers their interests. Every manufacturer knows from experience that if he does not bring out novelties his products will be driven from the market by his competitors' new products. Every one of them is thus forced to innovate and to go in for the kind of research described above, which certainly has the merit of encouraging innovation, though perhaps of doubtful quality, but does so at the cost of making shockingly poor use of the brainpower at hand. In short, it seems that in the present state of the pharmaceutical industry each single manufacturer acts according to his own best interest, given the behavior of all the others, but that it would be in the best interest of all manufacturers to break out of this situation and adopt other arrangements better for every one of them, not to mention the interests of pharmaceutical research, public health and the Social Security System. Economists are familiar with this kind of situation of non-optimal equilibrium. The problem is to discover what type of interdependence is responsible for the gap between equilibrium and optimum.

The facts described above are not open to doubt. But how can they be explained? Why is it that these new products, so many of which apparently merely duplicate existing ones, are commercially so successful as to lead to such a situation? The answer no doubt lies in the market, which in this case is rather peculiar in that it consists of all the doctor/patient pairs. Two opposing kinds of explanation are often put forward. One of them, which, needless to say, is the one upheld by the pharmaceutical industry, is that in the light of the most recent biochemical theories even the slightest change in an existing molecule may have therapeutical implications. It is, of course, true that in matters, say, of metabolism or sensitivity to a foreign body, individual reactions vary very greatly; hence, it is argued, a great many similar products need to be available so that doctors can adapt the treatment to each individual case. The weakness of this argument is to suppose that doctors are expert enough, and sufficiently competent and immune from non-technical considerations, to be able to make such fine distinctions regarding the pharmaco-dynamic activity of the drugs they prescribe. As will be seen presently, such an interpretation is invalidated by the facts.

Detractors of the pharmaceutical industry suggest an altogether different explanation. Manufacturers, they suggest, can do what they like with doctors, they swamp them with a flood of publicity material, and make them take all this sales talk about doubtful innovations for pure gold. But doctors are not puppets any more than they are omniscient experts. It can be shown that the success of new drugs can in fact be ascribed to their having considerable social utility for patients and doctors alike. But it is not "technical" utility in the sense of deriving from the drugs' pharmaco-dynamic activity; rather, it has to do with the significative function of medicines in the doctor/patient relationship. And this links up with the considerations developed in the first part of this paper.

The Functions of Medicines in the Doctor/Patient Relationship

Whatever afflicts patients, whether they have had a road accident or suffer from high blood pressure, have cancer or are neurotic, they turn to a doctor in the hope that he will relieve their pain and cure them, which is a technical problem; but they also want help in their state of anxiety. This need for help derives from the patients' feeling of insecurity, which, as we have seen, is up to a point independent of the real gravity of the disease concerned. A patient expects from the doctor an attitude and a manner which make it quite plain that he takes genuine responsibility for the case. Depending on their social standing, patients may expect mutual trust and understanding, or fatherly devotion, but in any case a technical, detached attitude is not welcome. However, these expectations are highly ambivalent, since they are likewise concerned with outstanding technical competence.

Patients never tell the doctor in so many words that they need this kind of help. Two kinds of repressive factors come into play. One is the defence mechanisms by which an individual safeguards the unity of his ego by putting the blame on the body and, with it, on the exogenous character of the illness. The second has to do with social conformism. Society, and above all its physicians, certainly take an extremely narrow view of disease and accept it as such only if it shows every sign of being a mere temporary deviation independent of the sufferer's will.

When people want help from a doctor, therefore, they express their need in purely somatic terms (or, at best, if they belong to the higher socio-cultural classes, in terms of physical treatment of psychical disabilities). Doctor and patient can then agree that things must be put right. But it must be realized that the technical means which the doctor can bring to bear on the satisfaction of the patient's needs have two functions; they should solve the technical problem involved in the patient's illness, but also should in roundabout ways respond to his need for help by making it plain that the doctor is taking charge.

Among these technical means, the prescription of drugs has the immense advantage of making very little claim on the doctor, psychologically and in terms of his time. One of the essential roles of medicines in the doctor/patient relationship is that they are a sign of the doctor's attention. This is a very widespread phenomenon in our society, and can be observed in all cases when one person takes a consumption decision on behalf of others. An example which at once comes to mind is a mother's decision of what to buy for her children by way of clothes, food, toys, etc. However much the popular saying may assert that a gift itself counts less than the spirit in which it is given, the fact remains that what one gives bears direct witness to the attention one devotes to the recipient. A gift having a social or economic value too remote from what one might normally expect in the light of the resources and means of the donor will meet with disfavor. This sign of attention to others may, incidentally, be addressed as much, if not more, to oneself than to the beneficiary concerned; this is certainly true of a mother's decision concerning her baby, which is quite incapable of appreciating these decisions in terms of the social values which make up society's image of a good mother. Much the same applies to medicines. It certainly is the doctor's bedside manner, his listening to the patient and giving of himself, in short, the judicious administration of what is sometimes called the "doctor treatment," which demonstrates medical comprehension so far as the patient is concerned; but given that the issue is confused by the two parties' underlying agreement on technical means, this demonstration would signify little if it were not materially buttressed by the "gift" of a prescription. To some extent a prescription means for the doctor himself that he is doing his best for the patient. By prescribing such drugs as he judges to be the most effective, the physician proves to himself that he is sparing no effort on behalf of his patient's health, and thus enables him to forget that so far as his personal contribution is concerned, and more particularly his time, he certainly does attribute a finite value to other people's health.

If a patient is to feel that his doctor is taking genuine and full responsibility for his case, evidence of comprehension is not enough. The patient must have also confidence in the doctor's ability to take over technical responsibility as well, that is, in his technical competence. But this, in many cases, seems to be somewhat uncertain, or at least is felt by the doctor to be so. Perhaps the reason is that so many people nowadays require treatment for ill-defined diseases with vague and volatile symptoms, or perhaps it is that medical practice is changing as a result of the introduction of drug treatments whose effects are described in terms of easily observable symptoms and clinical signs, so that physicians themselves need not proceed to an etiological diagnosis. This question need not be discussed here. What is certain that general practitioners themselves state that a large proportion (between 60 and 90 per cent) of the patients they see suffer from what doctors call psychosomatic or functional disorders. What do doctors mean by these terms? Surely not that these patients are malingerers, that there is notning organically wrong with them, for every doctor can cite cases of a tumor he eventually diagnosed in a patient long regarded as a "purely functional case." No, doctors use the word functional precisely when they are incapable of diagnosing a complaint as precisely as they would wish. It is their way of evading responsibility by declaring the trouble to be of psychic origin.

Be that as it may, once again drugs are the answer, for in this case the prescription signifies the doctor's ability to take appropriate action. "If I'm telling you to take such and such tablets, it follows that I know what's ailing you," he seems to be saying as he writes out his prescription, and this in itself absolves him from making tests or taking the decision to advise the patient to see a specialist or go to a clinic, which might be taken as a sign of incompetence. One can go even further and assert that the prescription, or rather its length, its cash value, the complicated name of the medicines and their novelty for the patient convey to the latter the message that he did well to consult the doctor, that his case needs medical treatment and that he would clearly not have managed to get well by himself. A patient of independent mind will thus feel less sorry not to have relied on self-medication. But the medicine can do still more for the patient. It not merely shows him that the doctor knows what ails him, but communicates to him this "knowledge" in place of the doctor himself, who would often be hard put to it to make an etiological diagnosis and communicate it to the patient. This essential function of communication falls to the manufacturer's directions for use, which are often drafted with an eye to patients as much as to doctors, but in any case are couched in the language of the drug's therapeutic uses and of the symptoms observed. When the patient buys a medicine and unwraps it at home, he will discover, or find it confirmed, that he suffers, say, from high blood pressure or has some "hepato-biliary malfunction."

Psychological Obsolescence and the Outmoding of Medicines

So much for the signicative functions of medicines with respect to patients and also, perhaps primarily, to doctors.[6] The doctor thus appears in a certain sense as a "consumer" of drugs, and pharmaceutical manufacturers are in no doubt about it.

Let us now see whether and how knowledge of these significative functions can help us to understand some of the seemingly inconsistent facts mentioned earlier.

A doctor and his patient, as we have seen, come to a sort of tacit agreement on a set of technical steps to be taken, even though in part something quite different is at stake. If, therefore, a drug is to perform well with respect to the non-technical aspects of the doctor's and the patient's satisfaction, it must signify technical efficiency. This meaning may be conveyed, in some cases, by the possibility of side effects which suggest that the drug may be dangerous, or sometimes by the high price of the drug, but most often simply by its newness, a symbol of progress and hope.

But to the extent that the drug acts as a sign, its performance depends, as we have seen, on the relative position of this sign on a scale. In order to obtain good effects, therefore, it is not enough for the drug to signify efficiency, it must signify the greatest efficiency. Let us take a simple example. All general practitioners and rheumatologists know that aspirin is of effective help in rheumatic diseases. But if today a doctor prescribed such an old, familiar and banal drug, after so many new products have succeeded each other on the market since aspirin was first introduced, patients would feel that the doctor was not paying enough attention to their case, or even that he refused to accept responsibility for it (except if the doctor's reputation is so high as to reassure the patient without any further need to prove medical competence; such a doctor can prescribe aspirin.) So far as the doctor is concerned, this would certainly not be the best way of demonstrating his competence and his ability to help. Without such non-technical dimensions in the doctor's and the patient's attitude the whole thing would be incomprehensible; aspirin would be regarded as a reasonably effective drug for the case, and it would be prescribed. But if we do take account of the non-technical effects of drugs, then we realize that their performance in terms of the doctor's and the patient's non-technical objectives diminishes with the appearance on the market of a new drug which is more effective or at least believed to be so. To the extent that novelty alone is taken to signify effectiveness, the mere appearance of a new drug is enough to destroy part of the power of older ones. This is precisely what was meant by the term "psychological obsolescence" as used in the first part of this paper (the significative characteristic x being the novelty of the product in its therapeutic category, and $\overline{x}$ referring to the latest product introduced on the market).

Evidently, the psychological obsolescence of old drugs encourages their displacement by new ones. So does what we shall call the psychological outmoding of drugs. Medicines "wear out," in the sense not of any loss of pharmaco-dynamic activity in the course of time (though this can happen, too), but of an erosion of their signicative power. Two reasons for this come to mind, each connected with one of two non-technical functions of drugs. In the first place, a drug has the function of demonstrating the doctor's competence. No physician could go on prescribing the same drug for six years without impairing the collective image of continuous progress in therapeutical science. This component of psychological outmoding is an offspring of psychological obsolescence, for it is precisely the experience that old products become obsolescent which creates, in the mind of doctors and patients alike, the image of technical progress and hence causes psychological outmoding. In the second place, a drug signifies that the doctor is taking charge of a case. All patients need this kind of help, but to the extent that any drug's response to this need is not direct, but roundabout, it is hardly surprising that its significative power is brief, "that this same flower that smiles today, tomorrow will be dying." The same happens in all cases when people think consumption will answer a problem of another kind: once acquired, the desired object only too often suddenly proves quite unattractive. If a patient feels misunderstood or neglected, he will transfer his dissatisfaction to the medicine prescribed, and he will think either that it is worthless or else too potent and hence dangerous. Doctors are usually very sensitive to this kind of complaint, and in their turn will be quick to prescribe another drug instead, provided of course there is a supply of new ones to choose from.

Now we can see why the market for pharmaceuticals has such an unquenchable thirst for innovations. Manufacturers must meet this demand, for any who fail to do so would quickly be swept off the market. Innovation is needed to offset the destruction of the older product's performance, yet this very destruction grows with an increase in innovations--a vicious circle which shows up the full absurdity of the system. Nor is this all. Since in these conditions technical progress simply is not fast enough to provide enough signs of progress for the needs of doctors and patients, there is room for the appearance and commercial success of spurious novelties and minor innovations. While these may contribute little or nothing from the point of view of pharmaco-dynamic activity, we can see now that they do renew and revive the significative power of pharmaceutical products. The costs of course are high all along the line--from research and development through experiments and tests to sales promotion.

The Question of Overconsumption of Medicines

From the above analysis, the following conclusion may be drawn. On the average, the pharmaco-dynamic power of drugs grows less fast than the resources used in their production. How much of an average annual rise of say, 10 per cent in the price of drugs is due to genuine progress, and how much to the effort required for producing signs of progress? There are no serious econometric studies on this subject, and no precise answer is possible therefore. But the facts we have recalled in the first part of this paper regarding the overall efficiency of health expenditure as measured by technical indicators suggest that genuine technical progress accounts for only a small proportion.

Another, corollary, conclusion may be drawn. In a system of private medical practice, expenditure on drugs actually prescribed by doctors is always much higher than would correspond to the purchase of less expensive drugs of equivalent pharmacodynamic effect. This excess expenditure is attributable to the costs of developing, testing, and promoting various spurious novelties, not to speak of forgone productivity gains on products with short market life expectations. The amount involved must be considerable.

Must we, then, conclude that there is waste, overconsumption? One answer has to be ruled out straight away as unacceptable, as has already been stated: it cannot be said that drugs which duplicate older ones are devoid of social utility, and most certainly such an assertion may not be made without trying to find out first why such drugs are so successful. Nor, however, can we conclude that the existing situation is the best possible one. Drugs appear to be a distinctly inefficient means of obtaining good results with respect to those essential, though non-physical, aspects of doctor and patient satisfaction which have here been discussed.

We are led to ask the following question. Would it not improve the situation if it were possible to remove the present confusion which causes means designed to meet technical requirements to be used also for dealing with problems of human relations? The answer is certainly in the affirmative so far as technical performances within the scope of the health care system are concerned. If drugs had none but purely technical effects, psychological obsolescence and outmoding would vanish, and pharmaceutical manufacturers would have no reason to oblige each other to innovate at all costs and would thus be free to devote time and resources to fundamental research. There would be clear gains in the field of biochemical knowledge and of the development of really new products, and gains also with respect to the use made of this knowledge and these products. A doctor trying to find the drug most appropriate for the technical problem involved in treating a patient would no longer be sidetracked by considerations extraneous to this technical problem.

There remain the non-technical aspects of the doctor/patient relationship. Here the problem is to substitute something else for drugs in the functions they now discharge so badly. The task will not be easy, and certainly this is not the place even to try and outline a solution. But one thing seems obvious, though there are few to recognize it. To tackle the problem of medicines in France is a matter not so much of altering the conditions of production in the pharmaceutical industry (though this may be a useful stage), as of transforming the rules of the game whose name is medical practice. It will readily be appreciated that a satisfactory solution of the problems discussed in this paper, problems which concern doctors and patients alike, will require radical changes in the conditions of medical training and practice. Medical students will need psychological training, the teaching monopoly of hospitals will have to be abolished, genuinely medical post-university teaching will have to be organized by some agency having no connection with the pharmaceutical industry, the status of the general practitioner will have to be upgraded and the manner of his remuneration revised. These are just a few items in the list of necessary reforms.

Footnotes

[1]In the sense that the marginal (not the average) cost of saving a life is very different in the two situations--very high in the first ("health has no price") and medium in the second.

[2]In economics, we would speak of joint outputs.

[3]The word "direct" must be stressed, because actually psychic and somatic factors are so closely interwoven (witness e.g. the placebo effect) that good performance in non-technical outputs may in itself generate a positive technical effect.

[4]This is in fact a simple case, for in reality the significative characteristics of the means employed may be quite different, e.g. their novelty, their cost, etc. (see the discussion of the consumption of medicines in the second part of this paper).

[5]However, there are cases where the choice of safety or health equipment is made in conditions similar to those of the choice of the level of its use when there is an accident. In the case of astronauts, for instance, their safety equipment is designed for a very small and well identified population. The whole range of intermediary cases is obviously possible.

[6]To avoid any misinterpretation, it should be made clear that to highlight these significative functions in no way means to deny the real pharmaco-dynamic activity of drugs, nor the real physical relief they bring. But for a proper understanding of drug consumption, it is necessary to take account not only of the technical effects of medicines, that is, those linked to their pharmaco-dynamic activity, but in addition also of their significative effects are produced by one and the same medicine, whether it be an antibiotic or a tonic, a heart stimulant, or a tranquilizer.

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A Simulation Model of the Austrian Health System
(A Progress Report)

P. Fleissner

Some General Remarks

This study is only one element of a larger project on "Health-Maintenance in Austria," initiated by the Chancellor of the Federal Republic of Austria, and carried out by an interdisciplinary team at the Institute for Advanced Studies, Vienna.

Conventional projects in the health sector are short term or medium term oriented and/or are optimizing one or more subsectors, e.g. hospitals. As a side condition they take the existing social order for granted. They do not deal with the associated modes of illness formation and do not reflect the fact that different social structures will show different patterns of health/illness conditions. They are looking at the health system as a highly professionalized and bureaucratically specialized subsystem of society, with once and for all fixed goals.

The task of our project is:

- to show the performance of the health system in dependence of the prevailing capitalistic structure of the Western world,
- to develop alternative perspectives, and
- to initiate a large scale public discussion to promote the evolution of the Austrian health sector.

To draw a clear picture of the ideas of the team we first decided to construct causal loop diagrams. But step by step we tried to test our hypotheses by empirical data and, if statistically accepted, we translated them into mathematical equations. Now we are finishing a rather big simulation model, consisting of five subsectors (Figure 1).

1) The health maintenance sector
2) The political subsystem of the health sector

3) An econometric model of the Austrian economy
4) The subsystem of reproduction of labour
5) The population subsystem.

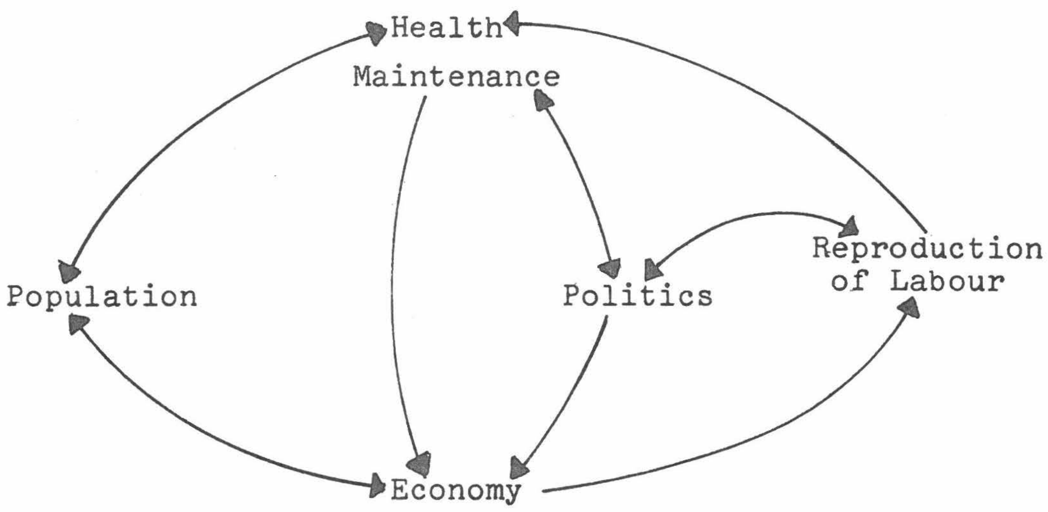


Figure 1. The Interconnections between the Subsectors

Of course, this mathematical model is only a very restricted and rough mirror of the philosophy and theory behind it.

Central Features of the Model

The Health Maintenance Sector

Because of the fact that social order will result in a certain structure of social classes we tried to divide population into subsets:

1) by sex,
2) by age (children, working people, elder people), and
3) by occupational status (workers, employees, farmers, self-employed, others).

For these social classes we derived subjective/objective indicators of well-being. Here we used the pre-professional concept of "morbid episodes" (ME). We tried to get some empirical evidence on this topic. It seemed to us that although the material standard of living is raising, the ME are increasing. Our hypothesis was strengthened by the observed stagnation of life expectancy in Austria and in many other Western countries. On the other hand, comparing social classes, we found very different numbers of ME; therefore, we made ME dependent on socio-economic conditions (average income, labour intensity, pollution, educational level, etc.) of each class. In the model these conditions are results of the economic and reproductive sectors.

Only about one quarter of the ME are handled by professional health institutions as regular disease. As professional indicators for illness we chose statistics for sick-leave, hospital stays, and mortality, if possible divided by sex, age and occupational status. Unfortunately statistics very often use different classifications, therefore creating additional problems. Nevertheless we could find out that workers are two times as much on sick-leave as office employees, another indicator of unequal health conditions.

On the data base 1955-71, we estimated following equation

$$N_t = .938\, N_{t-1} + .084\, g_t + .364 \qquad R^2 = .912$$
$$\qquad (8\%) \qquad (48\%) \qquad (238\%) \qquad D.W. = 2.183$$

where N is Annual number of medical certificates, and g is the growth rate of Austria GNP. This equation gives us evidence for the heavy influence of the economic system on health behaviour.

Figure 2 shows the main structure of the health subsystem. Underlined words stand for subsectors.

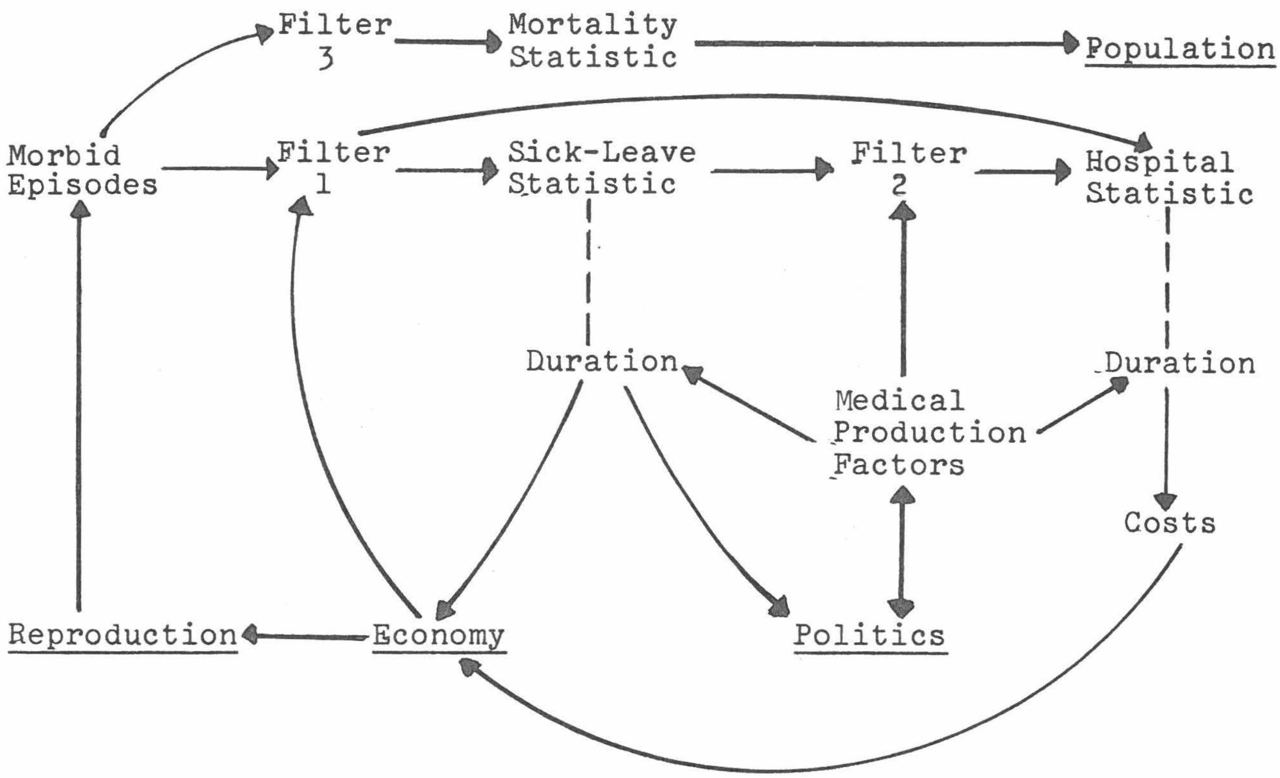


Fig. 2. The Health Maintenance System

The Political System of the Health Sector

Here we are trying to endogenize political conflicts on certain issues (doctor's income, equal health supply, extension of non private ambulances, etc.). We are representing conflicts by a very simple mathematical model

$$\Delta I = \left(\sum_{k=1}^{m} w_k \cdot P_k \right) \cdot (1 - |I|)$$

I = Indicator of the state of the political issue, range: -1...+1,

P_k = Political Power of interest-group k, represented by socio-economic indicators,

w_k = weight of the power P according to the overall political situation,

m = Number of conflicting groups, and

1 -|I|= Damping factor, holding I between -1 and +1.

Usually a change of I will change the structure or structural coefficients of the model, followed by changes of socio-economic conditions, resulting in changes of P_k, resulting eventually in an other short term equilibrium in political terms.

The Economic Model

This subsector consists of a nonlinear simultaneous system of thirty-four equations: each of them is either tested econometrically on the data base of 1954-1970, or is ex ante a definition equation. We chose the rate of profits as the central variable of the model. If it is falling--because of higher taxes, higher wages, lower profits, or higher capital stock, etc.--prices for investment or consumption goods are raising, after a certain time lag public expenditures will rise, bettering the conditions for private capital formation.

A very simplified structure of the model is represented in Figure 3. (A complete list of equations is available at request).

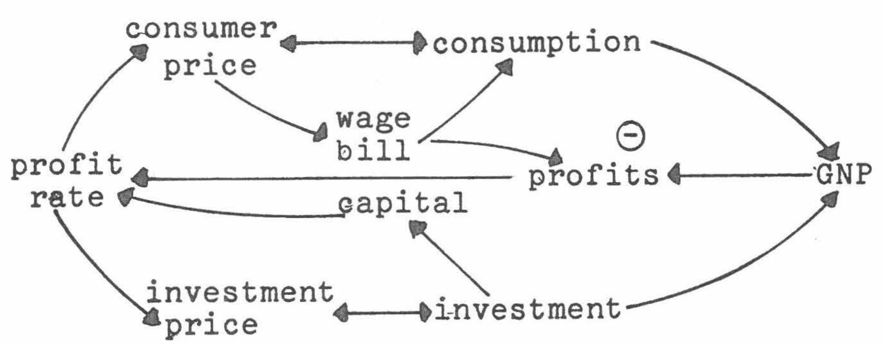


Figure 3. Simplified Structure of the Economic Model (foreign trade and the public sector are excluded)

The Reproduction of Labour

This sector is highly dependent on the economic subsector. From this part of the model consumption structure, educational level, private and public traffic possibilities and an ecological indicator are derived.

The Population Model

Bases on Austrian census data (1961) a simple dynamic version of population behavior was developed. It includes birth and death-rates. Birth-rate is governed by the growth of GNP and by labour income. The death-rate is a result of the death-rates of the different social classes. The number of workers is determined by a labour-market equation. The population sector is a crucial one for long term planning problems and could have heavy influences on economic development.

Preliminary Results of Simulation

Simulation runs were executed at the "Wirtschafts-und sozial wissenschaftliches Rechenzentrum" Vienna, on UNIVAC 1106. At this time the sectors 3 and 5 are already finished; sectors 1 and 4 are at work. Sector 2 will be modelled afterwards.

Comments on Activities at IIASA

D. Koch-Weser

I would like to comment on the types of activity which should be going on at IIASA. In general--be they defined as Applied Systems Analysis, Policy Analysis, or even, as Dr. Reid suggested, Operational Research--only those projects should be undertaken, which are not feasible for one individual alone or even for a small group on a local or national level. IIASA projects should require international and/or inter-disciplinary cooperation.

Prof. Raiffa this morning outlined essentially four types of activity:

1) undertaken in-house by IIASA people alone,

2) undertaken by IIASA people in cooperation with others and directed toward a local problem,

3) undertaken by IIASA people together with other international organizations and other groups on problems, which transcend national borders and are beyond national capability, and

4) functioning as a clearing house, communication center, organizer of international meetings.

I will comment briefly on each of these four types:

1) In relation to strictly in-house projects one would be worried about such issues as necessary intellectual mass--particularly if the limited staff of IIASA will be engaged in a multitude of projects in many fields--short employment, etc.

On the other hand, one would imagine that there would be great usefulness in inter-and multi-disciplinary projects, which would combine the expertise of various in-house scientists. We heard this morning about a number of areas in which IIASA will be active, and for every one a health related component can be identified. To name just a few:

Project	Medical Component
Water resources	Schistosomiasis Hepatitis Other medical problems of pollution
Municipal and other administration	Health services administration Sanitation problems
Urban and regional planning	Health aspects of crowding (tuberculosis, etc.)
Environmental systems	Medical problems of pollution (lung disease), etc.

This in-house cooperation on such inter-and multi-disciplinary problems by scientists with different professional, cultural, political backgrounds, would be very worthwhile.

2) Attention by IIASA to clearly local (and national) problems should be limited to those which, either by serving as a model or by producing data applicable to international issues, transcend local (and national) importance.

To give just one example, outside of strictly health issues, I would rather see IIASA pay attention to the Danube, the Amazon, the Rio de la Plata, the Mekong, which serve as resources and problems to many countries, than the Vistula and the Delaware, even though I recognize that there are political constraints and difficulties of magnitude.

So I would favor local and national projects only if they are definitely having an impact on the international health scene.

3) Cooperation of IIASA with international government and private organizations should, in my opinion, have a very high priority, as, if I understood him well, Prof. Rapoport already has said. Again, just to give a few examples:

Organization	Topic
FAO	Nutrition
UNESCO	Education and training
IAEA	Medical problems of atomic energy production
WHO	Too many to list

Let me elaborate a little more on one problem, which could very well be the target of a IIASA collaborative study: The totally inequitable distribution of all types of health manpower is probably the greatest impediment to the development of rational health services, not only in the developing countries, but very much in the industrially advanced countries.

The crowding of physicians into cities, to consider one category, is a national problem, but has led to an increasing migration from some countries (donor countries) to other countries (recipient countries), with some countries (England, France, et.al.) serving in both camps, receiving from India, Pakistan, and Africa, and donating to primarily the U.S. The problems of shortage in the donor countries and of quality in the recipient countries are compounded by social, economic, political, and psychological superimposed and causative problems and can only be studied on a multi-disciplinary and international basis, if one hopes that certain policy changes in many countries can be expected.

Data are abundantly available on many national and international (WHO) levels, but multi-disciplinary analysis is badly lacking and would be, in my opinion, a project of high priority for IIASA, certainly as a collaborative project with WHO or other organizations.

This problem, as well as many others in the health care delivery field, such as health facilities location in different socio-economic and cultural settings and the cost/benefit relationship between preventive and curative care, perhaps in one specific disease (tuberculosis, cholera, etc.) would lend itself very well to a multi-national and multi-disciplinary approach for which IIASA seems to be particularly well suited. In my opinion, most would be done best in collaboration with other organizations using their data and/or expertise and superimposing the IIASA capability.

There might be, particularly in the first years of the Institute, an advantage in projects, which promise relatively short-range results. This does not exclude that these projects, following one another, would lead to a long-term and broad goal with possible important policy changes.

4) The role of IIASA in serving as a clearing house, communication center, and organizer of international, possibly multi-disciplinary, conferences in the field of applied systems analysis is undisputed. IIASA might also provide consultations to individuals, groups and organizations.

As a general conclusion, I would like to see IIASA as a very high level (scientifically), not very large research organization, which in addition to its own work (in-house) would be very active in a cooperative way in applied systems analysis research, organization of conferences, etc.

Notes re: Point (5)
Study of the Inequitable Distribution of Health Manpower and Health Facilities

D. Koch-Weser

Two of the most important resources to be allocated are the health manpower at all levels (physicians, nurses, public health workers, auxiliaries, etc.) and the physical facilities (hospitals, ambulatories, rural clinics, etc.).

In relation to health manpower a study on the sociological, economic, and cultural causes for migration and consequent crowding into cities could be undertaken.

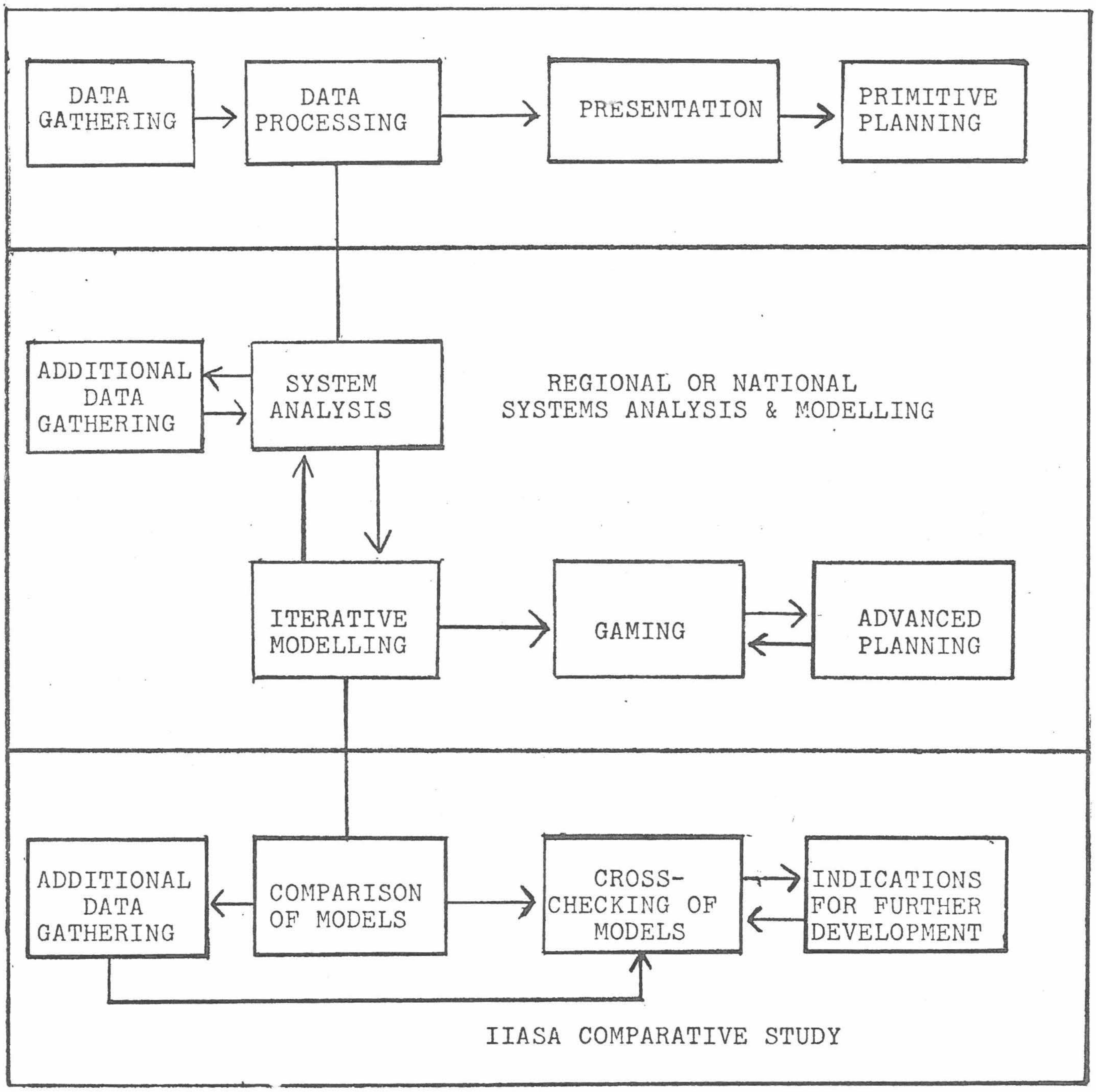
A similar study could be performed on the migration of physicians for instance from England to the U.S.

Another possible study is on the location of health facilities, which seem to be located more according to the "needs" and convenience of the providers, that is around medical schools for research and teaching purposes, than according to the needs of the consumers. This study should be part of the general work on urbanization and urban planning.

Again, more rational decision about these allocations only can be reached by an analysis of demographic, sociological, economic, political, and public health factors, a multi-disciplinary task for IIASA, probably as part of the investigations on urbanization, management, and others.

Management Information Systems

J. Miedzinski



Note: The bottom right-hand square could contain the development of a metamodel, as suggested by Dr. Milsum

Systems Analysis and its Role in the Delivery of Health Care

J. Milsum

Introduction

The delivery of health care has grown in an unsystematic way from its early basis of privileged physician-patient relation for the affluent and hazardous charity hospital for the poor. The growth has been dramatic in that the power to cure sickness and prolong life has greatly increased as a result of advances in biomedical science and technology. In consquence a significant proportion of Canada's Gross National Product is now spent in this sector, some 6% or a total of $6 billion depending somewhat on the definition of health care expenditures.

The evident inequities of health care delivery have forced socially responsive societies to legislate for universal and equitable access to health care. In Canada this process has been relatively slow and variable because provincial autonomy over the health care field has made it difficult for any federal-provincial consensus on priorities to be reached. There have been three landmark developments in successive decades which, while themselves being clearly well-intentioned, have contributed historically to the present difficulty in achieving a systems approach. First, in the forties the new national health grants to the provinces emphasized the establishment of public health programs. In unfortunate consequence these tended to separate the activites of prevention of illness and promotion of health from that of caring for the sick. As discussed in a companion paper [1], these activities should be closely integrated. Second, the hospital insurance program of the fifties tended to establish hospitals as the pre-eminent site for medical care, since the services were "free" both to the patient and the physician seeking the admission. Third, the medical services program in the sixties, legislated for universal free access to physicians, without either ensuring an appropriate increase in their number to meet the inevitably increased demand, or providing a mechanism to pay other health professionals for providing some at least of the services. In the wake of these reforms it is now generally agreed that a systems approach is necessary to the design of an appropriately structured health care delivery system. The broad and more philosphical outline of this has been sketched in the companion paper [1]. In this paper we suggest how systems analysis may be fruitfully applied.

Modelling the System

A basic task in applying systems analysis to health care delivery is to generate an appropriate model of the system. In general, however, any model should be designed to represent only a particular part of the total system complexity, since unneeded complexity would only obscure the working of that part being studied. There is usually a correlation between the level of detail included and the part of the frequency spectrum covered by the model. Thus in health care system, "macro-models" are concerned with the overall working of the system, in terms of reaching objectives and matching resources and demands, during time intervals of months and years [2, 3, 4]. They are therefore especially useful for planners. However, it should be noted that the time delay in changing the supply rate of medical specialists is from five to ten years. Unfortunately, this time span is not too much less than the limits within which projections from the model can be viewed with confidence due to uncertainties about future technologies and biomedical research breakthroughs. Thus specific projections from these planning models must be accepted only with some reservations, but the models can still be very valuable in mapping out variations in responses due to changes in management strategies, morbidity and demographic parameters, etc.

At the other end of the frequency spectrum, "micro-models" are typically concerned with the working of such subsystems as emergency wards and ambulance services [5, 6, 7]. As such their natural time units are minutes through days. Micro-models are thus necessarily stochastic in nature and an important part of their performance output concerns queue behaviors. In comparison, macro-models with large temporal and spatial aggregation can often be modelled by using averaged non-stochastic "flows" of consumer demands and resource services through the system.

A regional health care systems model [3, 8] will be used here to exemplify some of the procedures. As shown in Fig. 1 there are some five basic processes or sub-models necessary to describe the system.

1) Incidence of illnesses generates flows of consumers demanding service from the system. In detail this involves separate sub-models of population and incidence/prevalence rates. Further, these state variables must be aggregated into conveniently small groups of age, sex and illness. In the MEDICS model of the Quebec health care system [8] there are currently 10 age groups and either 18 or 36 illness groups. The systems analyst must make a rather arbitrary definition

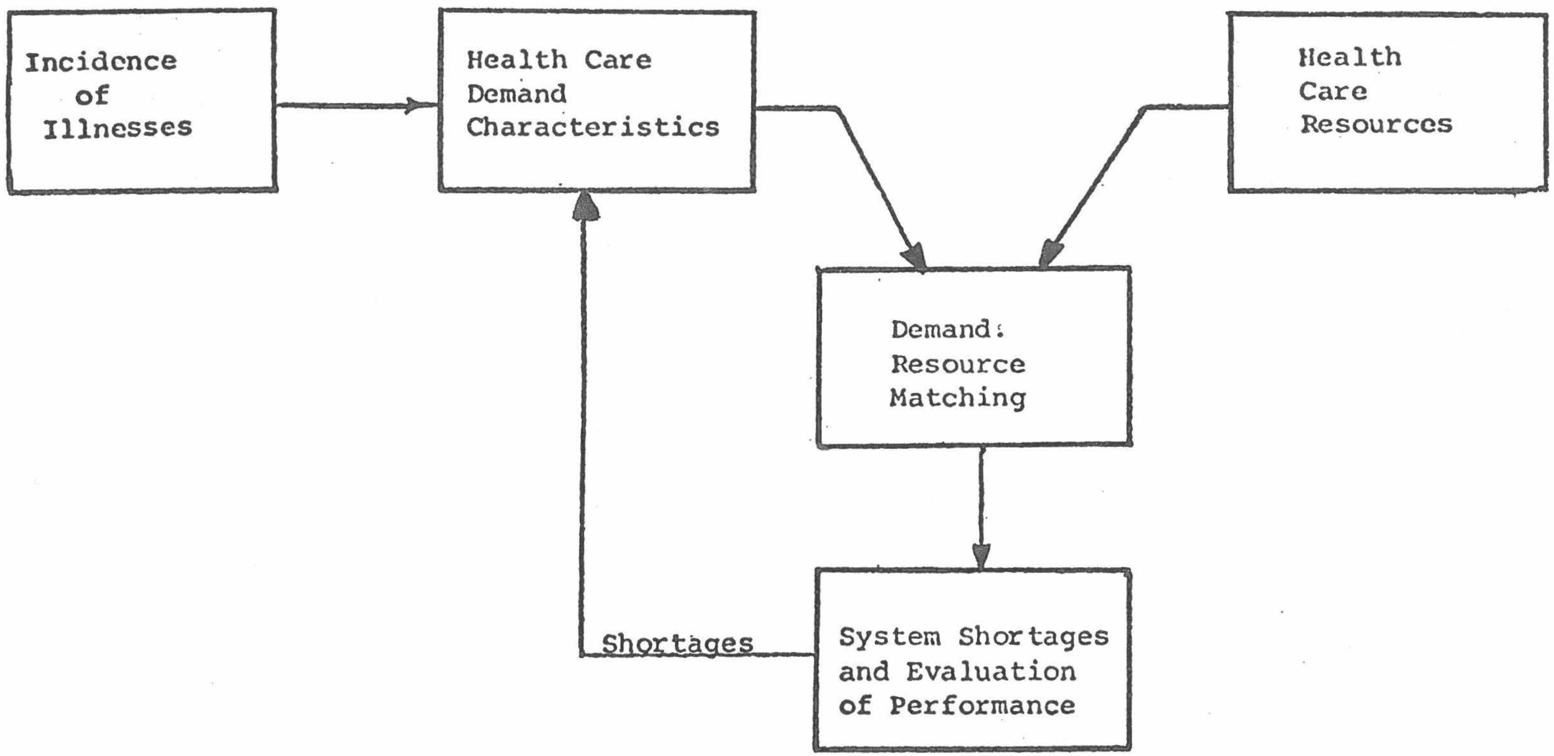


Fig. 1 Basic Flow Diagram for Macro-Model of Health Care System

of illness episode during each time unit, and it may be convenient to separate acute and chronic episodes within a given illness aggregation.

2) Health Care Resources. This generates the flow of resources available in the system. Each flow results form combining a "demographic" model of each resource with its utilization rate. The extent of disaggregation needed among professional specialities and equipment will correlate to some extent with the disease groupings, and in the MEDICS model numbers about 30.

3) Health Care Demand Characteristics. This function converts the flows of patients with illnesses to their corresponding demands upon the system's resources. The analyst must choose whether the dimensions of the demands upon resource flows will be, for example, specialist visits per unit per illness, and bed-days per unit time per illness, or whether they will all be expressed in a common dimension, notably $ of resource per unit time per illness. Each approach has its advantage.

4) Demand-Resource Matching. Here is modelled the key process of the health care system. It is particularly difficult to represent since the real system works largely through individual encounters on a time basis of hours; the model on the other hand works more typically through averaging large population on a time basis of months or more. The model requires an explicit statement or algorithm describing how priorities are to be accorded, whereas the real system clearly has many implicit priorities. Nevertheless, plausible algorithms can be proposed and, to some extent at least, can be validated through checking out the model's operation on real data. Mathematical programming, in particular linear programming, offers a direct scheme suitable for computer simulations, but more heuristic allocations can be easily implemented.

5) System Shortages and Evaluation of Performance. The greatest modelling difficulty perhaps lies in generating explicit functions to represent health care system performance. Shortages, that is the failure to treat illnesses in a given time period, represent one obvious and sensitive public measure of bad performance, and must in any case be fed back into the system for treatment in the next time period. More generally, however, measuring system performance adequately depends upon developing health indicators [1].

For micro-models there will be many differences of modelling detail, especially in incorporating stochastic variations in flows and Markovian-type transitions of health state from one period to the next. Emphasis in measuring performance may shift to the worst performance possible in terms of queuing times, rather than the description of average performance.

Management and Control

The processes of the health care system model described in [2] are uncontrolled or open-ended as described so far. However, control strategies are now being sought by the various governments, as managers of the systems. Fig. 2 represents the negative-feedback configuration, and indicates that management interventions may affect all of the processes. The morbidity flows of patients with illness may be significantly modified; for example, they would initially be increased by strong maternal-child welfare or dental programs. On the other hand, good education programs in nutrition would hopefully reduce some morbidity flows quickly. The resources can be directly affected by educational support programs and by the priorities accorded various health care facilities. However, since there is typically a signficant time delay before the changes become effective, it is important to be able to explore the response dynamics through computer simulation of the model. The health care demand characteristics can be changed in many ways, notably here by the introduction of different techniques for delivering health care, for example, through a health care team and/or through community health centers. In practice the problem is to estimate the extent of these changes quantitatively. Many other management interventions are possible, and can be tested by computer simulations.

Optimization

The aim of systems analysis and computer simulation should be to generate a better system, and ideally an optimal one. This aim is difficult to fulfill because adequate health indicators to represent the benefit side of the necessary cost-benefit analysis are lacking. The conceptual scheme necessary is suggested in Fig. 3, which shows an extra feedback loop, generating changes in management structures and parameters. The performance indicators include the health indicators as outputs of the system and the various costs. The aim of this second loop is to move the system adaptively toward an optimal performance, but in a much slower time scale than that of the system's "real-time" management. A reasonably general model for assessing cost benefit aspects of competing health programs is outlined in [9].

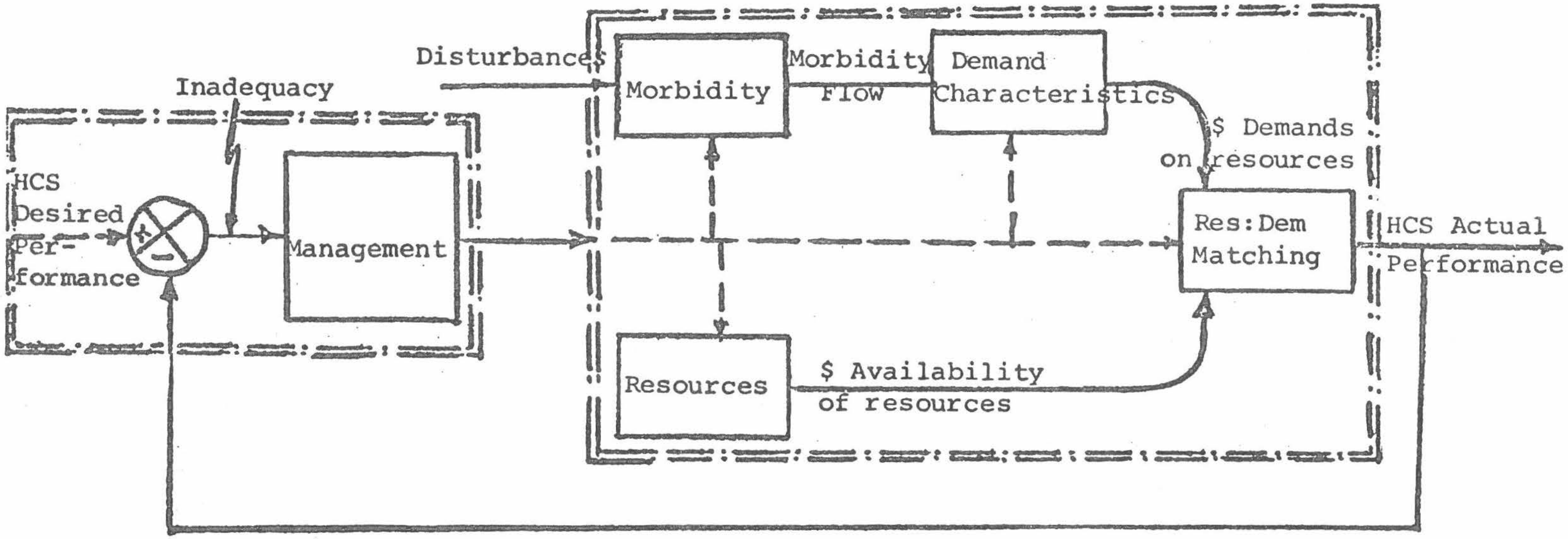


Fig. 2 Management Influences on HCS Operation

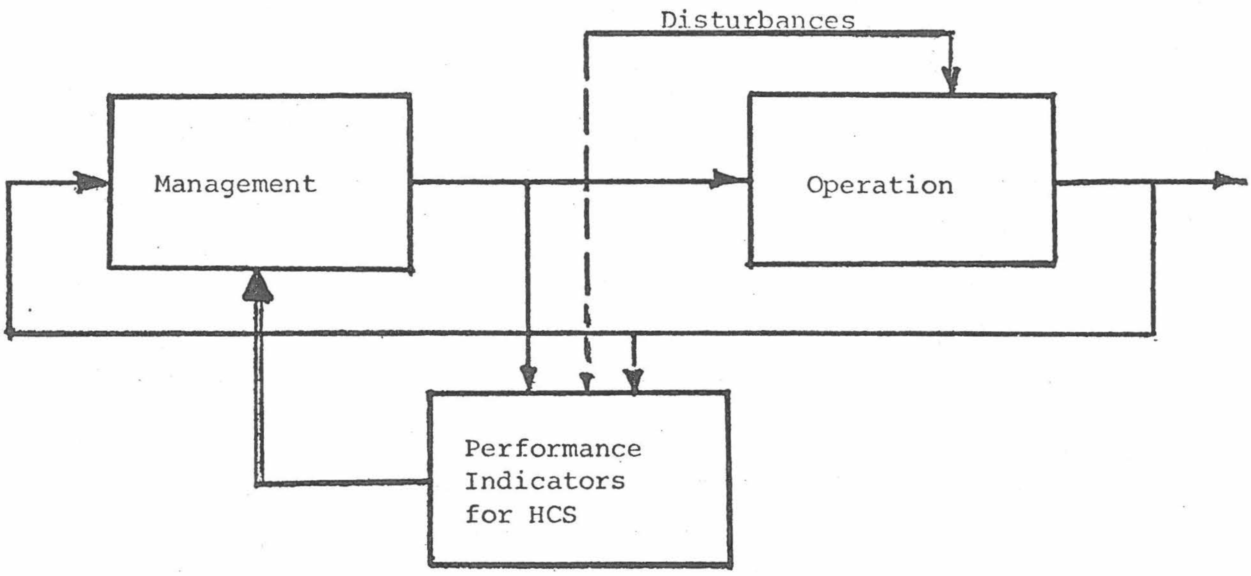


Fig. 3 Optimization Configuration for Health Care System

Implicit in the optimization concept is the necessity for subsystems to operate optimally, within hierarchically imposed constraints. The "informational affluence" potentially available through computerized health information systems would permit the constraints to be minimized and much local striving for the optimal to be encouraged. In detail, systems analysis will undoubtedly indicate a greatly expanded role for biomedical engineering and information technology.

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Comments Upon IIASA Medical Systems Research

J.H. Milsum

Notes regarding Point (2): Planning, analysis and management of Health Care Systems (HCS)

Basic problems of definition and scope are:

(i) what activities are to be defined within the HCS

- sick care (of course)
- preventive care (generally also included)
- promotion of health--there are many factors which affect health, e.g. nutrition, recreation, exercises, public sanitation; costs may only be partly attributable to HCS.

(ii) given reasonable agreement on how to define HCS expenditure, then in any case it is expanding at rates which will soon be unacceptable (12-20% say, per annum), so that the percentage of the GNP will continually rise beyond the present rate of approximately 5% up toward 100%!

Therefore, IIASA could ideally try to generate:

(i) a meta-model of HCS imbedded in the national system

- this model to be applicable to many countries based upon having different sets of parameters

(ii) sensitivity studies with this model to establish marginal benefits/costs of increasing/decreasing the part allocated to the HCS

- assuming of course that any variation in resources allocated would be applied in the most appropriate area, so that the HCS remains optimal within each constraint.

<u>Notes re: Gaming with HCS Simulation Models</u>

J.H. Milsum

We note that in many areas (aeroplanes, industry, military) gaming has proved highly valuable--aeroplanes worth $20 million can be crashed without loss, industries can go broke, etc. Especially in HCS (health care systems), where there is often divided authority between health professionals, institutional administrators and patients, there would seem to be particular advantage in developing a gaming philosophy of practice.

Such HCS models may be simpler than desirable, but they can still incorporate most major interactions, and also some interactions with other major IIASA systems (energy, water resources, etc.). The gaming would also fit in well with the idea of individuals and groups coming to IIASA for short to medium term periods.

Some Notes on a Possible Study on Close-Circuit T. V. Systems for the Partially Sighted

J. Page

Introduction

1. There are several eye defects which, while not normally resulting in total blindness, make it impossible for the individuals concerned to read, write, or do other work of a manipulative nature. Most such conditions affect the retina and optic nerve structure, and are therefore not treatable either by surgery or spectacles, etc. In some cases these conditions are present from birth, in others they appear later in life: in any case, those affected must learn Braille as the only means of reading. An important group of such conditions are characterized by the inability of the eye to obtain useful information, at any magnification, from the normal degree of black/white contrast obtainable by daylight or by artificial light sources. In some cases these difficulties are enhanced by a considerable restriction of the visual field. It has been demonstrated particularly by Genensky and his co-workers at the Rand Corporation* that in a significant number of cases the twin problems of magnification and contrast improvement can be dealt with satisfactorily by electronic means using a close-circuit TV camera/monitor screen to provide adequate magnification and contrast enhancement. Equipment based on this research is commercially available, but at a rather high price level; moreover, it seems that such equipment has not been thoroughly evaluated by opthalmologists in most countries. Probably, these are the reasons why it is not generally prescribed as a standard aid for those who could perhaps benefit by it.

2. Thus, we appear to have a situation in which a relatively simple application of new technology could improve the quality of life of a substantial but unknown number of individuals: whether these applications are being adequately exploited, is open to question.

3. An analysis of the situation, viewed as a system, might therefore result in useful policy guidance to those concerned with the administration of medicare programmes, and education of visually handicapped individuals including infants and children. The results might also be useful to

* See Advances in Closed Circuit TV Systems for the Partially Sighted, Rand Report No. R-1040-HEW/RC

those concerned with more clinical matters. While it can not be claimed that such a study could be regarded as a major contribution by IIASA to Bio-Medical Systems Analysis, nor that it is likely to produce interesting new concepts in the techniques of systems analysis itself, the problem is concrete finite, and has a good prospect of producing useful results. In considering such a suggestion, it may be worthwhile to try to arrive at some indication of the number of people likely to be affected. Genensky has estimated that some 800,000 Americans (out of a population of 180 million) could benefit from CCTV systems of the kind he and his colleagues have developed. When extrapolated to the total population of the developed countries--which as a first assumption might well be assumed to have the same pattern of totally blind to visually handicapped to total population--the probable number of potential beneficiaries of such systems could be regarded as not insignificant.

Alternative System Description

4. The system studied by Genensky is essentially the interaction of possible paths for engineering development and the subjective operational requirements of a sample of visually handicapped people. For example he has considered alternative equipment design involving on the one hand, fixed camera systems with the text to be viewed placed on an X-Y platform, being moved in two dimensions by the subject. On the other hand, an alternative design is a moveable camera which scans automatically by electro-mechanical methods the reading material being kept stationary.

5. A further illustration is the development of the so-called "electronic window" by which the image projected on the monitor screen is restricted to that of the line being read, a system refinement necessary for many of the subjects tested. It is understood that the Rand team are extending their work into other areas of engineering development/ subject needs, for example, CCTV systems for classroom instruction of the partially sighted, modifications to the basic design to enable the partially sighted to undertake manipulated work, etc.

6. Other researchers are similarly active in other countries and it might be of value, to compile a catalogue of what has been done so far by whom, naturally calling upon the considerable experience of Genensky and his colleagues in the subject as a whole.

7. It seems reasonable however, not to attempt to duplicate the existing research and development efforts in this particular system description, but one area might deserve some consideration. This concerns the peculiar relationship between the need for magnification coupled with the need of better black/white contrast noted as a characteristic of some of the eye conditions for which CC T.V. systems can be used. It is entirely possible that, in less severe cases, the required level of magnification and contrast enhancement can be obtained by optical devices used under conditions of high, but even illumination. It would be interesting to gather information on such systems which although of much more limited application (in terms of the subject population) than CC T.V. might form a useful and very cheap alternative.

8. A second system can be described which may be of more interest as a minor Bio-medical project for IIASA; in such a system, CC T.V. developments could be regarded as a new technological factor in a social economic situation. In advanced societies, medicare or Social Security programmes exist to help disabled individuals and a sub-set of these individuals are that proportion of partially sighted or legally blind people who could benefit from CC T.V. systems. Whether or not the cost of such assistance is met from taxes or by insurance premiums, or a mixture of both, it represents a real cost to the community. Moreover, in advanced societies, the need to be able to communicate by reading and writing is of great importance, not only socially, but also economically and in particular from the employment point of view. To a first approximation the cost to the community of this form of disablement may be measured by the sum total of social insurance payments made to this particular part of the disabled population, although a more sophisticated calculation could be imagined in which one attempts to compute the net loss to the GNP by taking salary levels into account.

9. In examining the cost to the community of this form of partial disablement, one might also compare the cost of CC T.V. systems to the cost of other possible alternatives. The practical alternatives in many countries is the use of Braille: for adults, the ability to read Braille is both a social aid, and to a lesser extent provides employment possibilities, depending on the availability of text books and other reading materials in this typography. For children, it is one of the main means by which they can receive an education. An analysis of the available statistics on the teaching and use of Braille, followed by an elementary cost/benefit analysis of Braille and CC T.V. systems as an aid to the partially sighted would form an important part of the study.

10. To complete the picture, it is necessary to mention a third system, of which the other two discussed above are sub-systems. This third system is constituted by the interaction of the totally blind population and the technology available to assist them. For example, a device has been developed in which the material to be "read" is scanned electronically, the signals being fed to a sensing pad with which the subjects hand is in contact. The subject actually feels an impression of letters and words being imprinted, as it were, on his hand, thus enabling him to read printed matter in normal typography, without the need for translation into Braille characters. In addition to this type of device, the possibility (at least theoretical) of connecting the visual perception areas of the brain with some form of external electronic scanner has been suggested as a long range target in investigating quasi-physiological methods for replacing normal sight.

Choice of Research Strategies

11. If IIASA were to become active in this sub-field of Biomedical Systems Analysis, it is suggested, with the exceptions noted above (review of existing work, possible utility of purely optical devices) that it would not be profitable to undertake research in the first of the systems described above. However, it is obvious that any IIASA study in this area must draw heavily on the work of Genensky and his colleagues, and therefore some form of close collaboration between IIASA and the RANDSIGHT project seems essential, together of course with similar projects in other countries. Beyond this however, a broadly based investigation of the second system would seem appropriate to IIASA's mission: particularly if the proposed study could be organized on an international basis, so as to provide data which the various national agencies would find useful in their own spheres.

12. Consideration of the third system should be delayed until work on the second system has proceeded to the point at which useful results can be expected.

Outline of Proposed Study

13. The following points are not intended as a formal plan for the study but are an illustration of the phases in which the work could proceed. The study must in any case be preceded by a definition stage in which sources of information and statistics should be examined in detail so that it is then possible to establish a proper study plan, including an assessment of the efforts required.

14. Phase One - Project Definition

It is impractical at the present stage to indicate a detailed study plan for this possible IIASA project. Indeed, the project itself must be preceded by a definition phase in which it is defined, thus enabling an estimate in terms of effort and time required, to be made. At the end of the definition phase it will be possible to present the material for a decision on a continuance of the project, and it may well be that the work done during this phase will suggest substantial modification of ideas for the project as envisaged now. Except for the remarks under definition phase, the notes below should not therefore be regarded as in any sense constituting a formal study plan. They may however serve as an illustration of the kinds of activity which may be foreseen as project requirements.

15. Phase One - Definition

This may be broken in several areas:

i) Analysis of Available Statistics. It seems probable that the definition phase would indicate a number of countries for which adequate statistical information was available, but possibly these data would be non-uniform in character. In addition to enlisting the cooperation of WHO and that organization's contacts in the IIASA member countries it would clearly be desirable to enlist the active cooperation of individual groups in the countries concerned who were active in the analysis of their own medicare/social security systems. It is even possible that such groups could be directly associated with the project.

ii) Pathological and Clinical Aspects. In Genensky's sample of 120 subjects some six main types of visual disorders were identified as responsive to CC T.V. aids, and he has developed a series of measurements, including a simple lightbox test to give a rapid indication of probable efficacy of CC T.V. systems in individual cases. While it is not IIASA's role to carry out extensive clinical trials, nevertheless there is a great deal to be said for broadening Genensky's sample in close association, of course, with appropriate organizations in the member countries. The Royal National Institute for the Blind in the U.K. and its analogues in other countries might contribute to this part of the study.

iii) Alternatives to CC T.V. Systems. This relates specifically to an objective comparison of Braille and CC T.V. systems as aids to the partially sighted. A particularly important part of this section of the project would be concerned with the education of children born with eye defects and of course the re-training of adults who developed conditions resulting in partial blindness later in life. In this area also, it goes without saying that the study should be carried out in association with appropriate national organizations.

17. Phase Three - The Possibility of Extension

Finally, in concluding the study of what was called the second system (see paragraph 8 above) the feasibility of extending the work into the third system area, the inter-relation of technological development and the totally blind population should be examined.

Additional Comments

G. Sacerdoti

I will try here to give some of my comments and ideas in writing, as a late contribution to the setting up of IIASA.

1. I understand from the conference discussion that the Institute needs a) some short term studies that will show results in a reasonable amount of time, and b) a long range program to give IIASA a role to stand on its own.

2. For the short term studies I share Dr. Hogness' criteria and Prof. Raiffa's opinion on a project which could interest several fields simultaneously. For instance the study of the water system could be considered simultaneously from the point of view of:

- water resources
- municipal systems
- medical systems (essential preventive care)
- ecological systems.

Another short term subject that I consider quite fruitful would be the study of management of emergency medical services in big cities. My organization is working on this theme--in particular on cardiologic emergency services: intensive care units and related ambulance services. There are very interesting considerations to be made on:

- where to place the units
- where to place the ambulances
- how many of both
- how much personnel
- cost/benefit analysis
- medical and urban aspects.

3. For the long term I would suggest without any doubt the subject of resources allocation. It is by far the most important because it will force doctors, administrators, and planners to work together and tackle the real issue from which most of the others depend. In my organization we are also

working on this subject, but with great difficulty, because the problems are very wide and require many professional skills.

The conference discussions on this matter were quite lengthy on the first day. Then this point was dealt with in a rather subdued way, for political reasons I suppose, but it kept coming up again and again. In fact five of the fifteen topics listed for priority were only part of the general theme of resources allocation, for example:

Topic 2 - Planning

Topic 4 - Medical Research

Topic 6 - Impact of expensive technologies

Topic 5 - Resources allocation

Topic 10 - Emergency medical care.

4. If I may, I would like to suggest what IIASA should not consider in its plans:

a) Training courses (on its own, it may participate with its professional members in some other Institution's courses).

b) Medical Information Systems.
This is not a matter for system study but rather of organization and software implementation. It is not yet ripe, not only in the medical field but also for industrial companies. I know this field very well from my present job in the health organization. It requires a lot of practical work and it should be carefully avoided by IIASA.

c) Study of computerized medical records or special languages for medical applications.
Also in this case is not a systems problem; much preparation is necessary in order to have doctors describe their problems in a prcise way.

Before closing this comment, I would like to point out that, in my view, all subjects in this sector of "medical systems" belong to two big categories:

a) health organization problems, and

b) medical problems.

The first group is closely interrelated with all the other systems that IIASA plans to study; it is broadly socio-economical with technical inputs. The second category is composed of less related arguments; it is very technical, difficult but narrower.

Proposal for Specific Research Topics of IIASA

B. Schneider

IIASA research activities are focused upon methodological problems of policy making. The best way to do such research is to choose specific application problems and try to solve them. Of course, it is important to discern problems which are urgent and of general interest but also treatable by systems analytical methods.

In medicine one such problem is the analysis and improvement of information and information handling. It is well known that in the last ten years tremendous efforts have been undertaken introducing computers in medicine. But these efforts failed, at least with respect to integrated medical information systems (either hospital information systems or general medical information systems). In my opinion, this failing cannot sufficiently be blamed upon a lack of trained personnel for medical computer applications, upon infeasibility of computer equipment for use in hospital, or upon psychological reasons. One of the intrinsic reasons for this failing is, in my opinion, the lack of sufficient knowledge of the structure, validation, interrelations, flow of data, and information in medicine. Therefore research in this field--which may be called medical informatics--is one of the urgent needs for future computer applications in medicine and for an improvement of the quality, effectiveness, and management of health care systems.

One of the most interesting problems in this connection is the development of policies for design and handling of medical management and medical information systems. This would be a suitable research issue for IIASA. From the point of systems analysis, study of medical management and information systems would provide opportunities for an overall insight into the functions, constraints, and improvement possibilities of health care systems. A systematic analysis and improvement of these informational systems is the best approach for a better understanding and improvement of health care systems. Therefore an applied systems analysis of this topic is of important general and international interest. The information system approach is relevant to the other activities of IIASA and has numerous connections to other research areas (for example, municipal systems and regional planning, ecological modelling and control).

In more detail, an applied system analysis of medical management and information systems must include the following topics:

1. <u>An analysis of medical information and data handling</u>

This means a semantic analysis of medical data and medical terms, an information theoretical analysis of medical data (especially patient record data) and data flow; methods for objectification and validation of medical data and terms especially for obtaining improved health status indices; a study of the interrelations between medical data and environmental data (e.g. socio-economic data) to get better ideas of the health structure and rise factors, a study of the regulation function of medical data looking at the information system as a cybernetic system.

This analysis must be done in cooperation between IIASA and medical centers involved in these problems.

2. <u>An analysis of the health care management system</u>

This analysis should not be restricted to management tasks in the narrow sense, e.g., hospital management, health screening management, etc., but also to management tasks in treatment, that is systems analysis of diagnostic and treatment procedures, integrating these procedures into general management systems and so on. The main goal of this study should be the development of policy strategies for design of management information systems in health care. This project could operate primarily as an in-house project of IIASA, but cooperation with some outside medical centers would be of great value.

3. <u>The analysis and design of health information systems</u>

This analysis should 1) point out the interrelation between the organizational structure of health care systems and information systems, 2) show the possibilities of improving health facilities by improving the quality of health information, and 3) develop policy strategies for introducing computers in health care systems and medicine. Specific problems are the system analysis of data bank systems, medical conversational systems for man-machine dialogues, etc.

The project could be primarily an in-house project of IIASA.

Brain Research and its Implications for IIASA: A Brief Sketch

R. Trappl

When studying complex systems, it is very often necessary to break them into subsystems or sometimes even arbitrarily chosen sectors, to analyse these subsystems and then to "interface" their models. There is only one living system, which we can approach from three different aspects, the methods of analysis of which are very different. This system is therefore interesting from two points of view. First, the results of its analysis are of great importance for most of the sciences, and more, for mankind. Second, it offers a unique opportunity to develop and to test system analytic procedures, since finally the models of three levels have to fit together, more they have to approximate each other.

This system, the brain, can be studied from three different aspects:

1) the aspect of nerve cells, nerve nets, the structure of the brain, its discernible parts and their connections,

2) the behavior of the animal or man, i.e. the input-output relations of the system and its spontaneous activity, and the time course of both, and

3) it can be studied from the "inside," by introspective methods using our consciousness.

One aspect--the level of single nerve cells and nerve nets--shall be treated in more detail, though only a brief survey is possible. Nevertheless, this should enable to see how many different methods of analysis have been applied and how fruitful a comparative study of these methods might be. The studies on this aspect can be divided into three groups, depending on the number of elements:

1) single nerve cells,

2) moderately elementary nerve nets, and

3) nerve nets for "higher" functions.

The analysis on all these three levels leads, depending on the kind of analysis applied, to two different kinds of models:

a) equivalent models, and

b) isomorphic models.

While an equivalent model is describing only the input-output relation of the system under study--neglecting its structure--the isomorphic model exhibits a structure which can be mapped by a one-one relation with the structure of the original system, at least this kind of mapping is intended.

The most prominent isomorphic model of single nerve cells is the model for the axonal transmission of nerve signal by Hodgkin and Huxley [11] consisting in a partial differential equation of second order. Recently, the results on synaptic transmission by Eccles [5]were used by Jeansomme and Weaver [12] to establish five ordinary differential equations which describe the transsynaptic propagation of the axon potential. However, they simulate a neuron with only one input and one output: Since about 10,000 presynaptic neurons "synapse" with single large pyramidal cells in the neocortex of the brain, the difficulty of simulating the overall behavior of only one single nerve cell is evident. Besides this, even such a model would neglect other ways of information propagation like the fast axonal transport of chemical substances described by Ochs [16].

Concerning the Hodgkin-Huxley model [11], it is interesting to note that another explanation of the action potential was given recently by Zeeman [23], based on the cusp catastrophe theory by Thom [19].

Owing to the just mentioned difficulties, it was necessary to develop equivalent models of the single nerve cell, which therefore had to be of probabilistic nature. Quite a lot of models of this kind have been developed; Moore, et. al., already in 1966 described 18 of them in their review of neuronal models [15], and several others have been developed meanwhile. These models can be:

1) purely mathematical-statistical,

2) software, or

3) hardware models, namely electronic models.

While the first ones are mostly of theoretical interests (and this mostly not to neurophysiologists), the software models consist in a description of the behavior of a "neuron" the study of which demands actual computation. Famous hardware models are the "artificial neuron" by Harmon [10] having five excitatory and one inhibitory input and one output, or the more elaborate model of the Bionics Laboratory of the Polish Academy of Science, developed under Gawronski [9]. Recently, integrated circuits have been used for modeling neurons, e.g. by French and Stein [9]. For a simple reflex only few neurons are needed. Equivalent models of elementary nerve nets were, besides the ideas of Descartes [4], first developed by W. Grey Walter [21] in his different kinds of "tortoises" showing unconditioned ("machina speculatrix") and conditioned ("machina docilis") reflex(es). The most elaborate model is the "complete" model of the conditioned reflex by Angyan, Kretz, and Zemanek [1]. Equivalent models might seem to be obsolete nowadays, since nobody any longer wants to show that a simple animal or human behavior can be electronically simulated without having an "Entelechia" or an "Elan vital" at hand. However, these models serve an important heuristic purpose by enabling us to test completeness and consistence of non-formal theory. It is said that when developing the just mentioned complete model of the conditioned reflex even a highly developed theory like the Pavlovian reflexology proved to be incomplete in some, and even inconsistent in one respect.

Models of single nerve cells can be put together to build isomorphic models of elementary nerve nets: Depending on the kind of single cell models, these nerve net models will be either hardware or software models. Hardware models are expensive and not flexible, concerning the parameters of the single nerve cells (though in the Gawronski model [9] parameters could be changed) and the connection between these cells. Furthermore, it is difficult to record what is going on, when and where in the model. Software models are cheap (if the price of the EDP equipment is not taken into account), very flexible and record its own states on demand. However, there is a great drawback: They are slow. For example, if a nerve net with 10,000 neurons is simulated, the subroutine NEURON (or whatever its name) has to be called 10,000 times, its parameters set in (perhaps 10), all complex curves which are easily realized by resistors, condensors and coils have to be computed by Chebyshev series, and all that to compute the state of the whole nerve net say 1 millisecond later. There is now an increasing trend to switch over to hybrid computations, and it will be very interesting to see when sociologists will find their "world models" too elaborate to be simulated on "slow" digitial computers.

Equivalent models of higher nervous functions or of more complex structures of the nervous system include A.I. like pattern recognition (Minsky and Papert [14], problem solving, or manual tracking, models of eye movement (Vossius [20]). These models describe only the input-output behavior of the system under study (man as such, or the relevant subsystem CNS) some take even into account conscious processes, e.g. Colby [3] in his neurosis model or Ernst and Newell [7] with their GPS. However, there were attempts to build isomorphic models of higher nervous functions, though hardly models in which conscious processed could play a major role. Examples are retinal models (Eckmiller [6], Yamaguchi [22], and others), models therefore of a structure whose modes of operation are at least more known than that of other parts of the brain, models of the area striata of the occipital lobe (Kigan [13]), the cerebellar cortex as timing organ (Braitenberg [2]) or as a special purpose neuromal computer (Sabah [18]) and others. The way of analysis is usually the following: It is first a structure consisting of more or less "artificial" neurons proposed which is able to explain a certain kind of behavior, and second this structure is matched, or better, mapped with the known structure of a certain part of the brain. However, when viewing histological structures of the brain, even the more regular structure of the retina in a scheme developed by Polyak [17], it can be easily seen that nearly all possible structures which could explain a specific kind of behavior (and there is an infinite number of such structures) can be matched with a given anatomical/histological structure. Progress is expected to come from microelectrode studies where multiple microelectrodes are used to record simultaneously the activity of several nerve cells at the same time, in a rather well known structure or using animals like the sea hare (Aplysia californica) with rather simple, big ganglions.

This short and, quite naturally, superficial survey should give a feeling how many different ways of analysis have been applied in the study of nerve nets and how profitable, therefore, a dialog of people working in these fields with each other, having the aid of systems analysis might be. Moreover, concerning the different simulation methods used by neurophysiologists, economists, and sociologists, it does not seem too unreasonable that an interdisciplinary exchange of ideas might not only aid in the study of the brain, but also help the research of the social scientists.

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