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EVALUATION AND OPERATION RESEARCH AS MEANS FOR MEETING SERVICE OBJECTIVES AND IMPROVING METHODS OF HEALTH CARE DELIVERY : OPERATION RESEARCH

by

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The application of scientific and mathematical methods to management problems is relatively new. These methods were first employed in relation to military problems during World War II, and have since spread to industry and commerce to such an extent that operations research is nowadays an established part of management in large industrial and commercial concerns.

In recent years, health administrators have become increasingly aware of the value of managerial methods in health planning, health problem solving and operation research in the delivery of health services. The adaptation of industrial and other applications of the newer analytical and managerial techniques for use in the health fields is at an early stage. Academic training in medical schools and schools of public health is gradually being modified, especially at the post-graduate level, to include operations research. However textbooks on the subject are not, as yet, available. There is also a universal shortage of teachers who are able to present research methodology, few standard models that teachers can use, and resistance on the part of health professions educators to modify traditional training programmes. But as Grundy and Reinke observe, "Managerial practices based on analytical techniques are here to stay and will become routine in the health services of most countries well within the professional lifetime of the present generation of post-graduate students".[1]

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(1) Grundy, F. & W.A. Reinke, Public Health Practice Research and Formalized Managerial Methods. Publ. Hlth. Papers No.51, WHO, 1973, p. 174.

HEALTH PRACTICE RESEARCH

Before defining operations research, it would be necessary to define health practice research and the systems concept.

Health Practice Research - may be broadly defined as the formalized investigation of some aspects of the organization and administration (including the management evaluation) of health services in relation to objectives and socio-economic circumstances. Its main purpose is usually to achieve the optional use of a system for the delivery of health care and other health services, to show where and how improvement might be made, and to help in the development of health planning and research methods. It is usually concerned with providing solutions to a particular problem, and is characterized particularly by

(1) a system orientation;

(2) a multidisciplinary approach, i.e. one not limited by the artificial boundaries between different disciplines;

(3) the use of the scientific approach conceived in terms of models, objectives and feed-back, i.e. the use , as far as possible, of formalized and objectivized investigatory and decision-making procedures; and

(4) the explicit statement of aims or objectives in precise terms, whenever the evaluation of results is contemplated.

Of these, the fourth is fundamental. It is impossible to prepare an itinerary for a traveller who has not decided where he wishes to go; it is meaningless to inquire if he has reached his destination if he has no particular destination in mind.

The special contribution of these newer methods in health practice is, therefore, in the formalization and objectivization of procedures, most of which have already been widely used in health administration on empirical or intuitive basis. They must be viewed as a complement to, but not as a substitute for the well established statistical, budgetting and accounting methods.

Because the business of health services is to promote health care in a social setting, the position of health practice research is intermediate between those of the biomedical and the social sciences; because health services form part of a larger system, it is also an aspect of public administration.

Systems Concept

A health care system is an example of a system designed by man for fulfilling a human purpose and subject to human control, and consisting of a combination of human and material resources. Like other social systems, it permits freedom of choice between alternative courses of action that, by modifying its structure and functions, change its operation so that its output approximates more closely to the predetermined objectives.

An aggregate of health centres, and hospitals can usefully be regarded as a system for some purposes, though it is clearly a sub-system of a comprehensive health system, which itself is a sub-system of a larger politico-social system. Therefore, the relationships would be viewed as a hierarchy of systems and sub-systems.

In ascending order of complexity, the systems studied in health practice research comprise :

(1) the individual components of a health service or some particular aspect of these components;

(2) the health service in its entirety;

(3) the health service and its components in relationship to socio-economic and other factors. Thus, for obvious reasons, health practice research is multidisciplinary in character.

A basic system may be depicted as consisting of

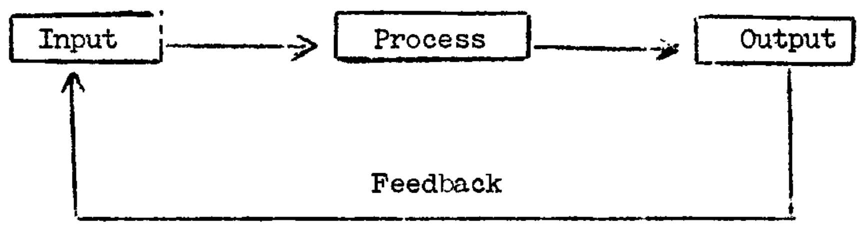
(1) inputs (persons needing health care);

(2) process (health care delivered by services);

(3) outputs (treated patients); and

(4) feedback (effects of processes on future inputs), operating within a number of constraints such as buildings, equipment, geography and population.

This system as represented diagrammatically is the prototype operational system.



Operational sustems are, therefore, characterized by processes that serve to translate inputs into outputs or results. Typically, some of the inputs are uncontrollable disturbances, whereas others are subject to control. Thus, the administrator of a hospital has little control over patient needs, but can control, in large measure, the staff input to the service process.

Control over inputs is inevitably subject to constraints in terms of money, manpower, facilities or time available.

The fact that a process exists for converting inputs into outputs (or results) suggests that alternatives are usually available. For example, two hospitals or health centres may differ markedly in the way their services are organized and delivered.

The assessment of results involves value judgements, which may be difficult to make. Elements of uncertainty pervade the entire system, from the type and magnitude of the problems that arise (patient admissions) to the possible effectiveness of alternative treatments (survival rates). Uncertainties of outcome are especially frustrating because of the dynamics of most operations; not only are immediate results indefinite, but those results usually lead to further decisions that yield equally uncertain results.

Therefore, operations research techniques are largely concerned with means of dealing with resource constraints, the assignment and maximization of values, and the appraisal of alternatives in an uncertain, dynamic environment.

Systems Analysis - as applied to health practice is an approach rather than a rigorous method. It refers to any formal analysis whose purpose is "to suggest a course of action by systematically examining the objectives, costs, effectiveness and risks of alternative policies or strategies - and designing additional ones if those examined are found wanting. It is an approach to or way of looking at complex problems of choice under uncertainty; it is not yet a method" (definition proposed by E.S. Quade).

Scope of Health Practice Research :

The scope of health-practice research is rather wide. Priority areas were identified by a WHO Consultant Group in 1968, and are listed below. This list is not fully exhaustive, but gives an idea of the kind of problem that health practice research deals with :

(1) Manpower - personnel utilization, especially in health centres and systematic studies of the education and training needed by different categories of personnel in the health care team;
(2) organization of health care services;
(3) utilization;
(4) major problem areas studies to identify the best lines of attack on major problems, such as nutrition, specific diseases, and family planning;
(5) quality of health care (evaluation);
(6) cost (cost-effectiveness and cost benefit studies);
(7) terminology; information and research systems; indices; statistical methods;
(8) need-demand; health care provision and the need-demand relationship;
(9) community response studies; factors influencing acceptance of services.

OPERATIONS RESEARCH

Definition

An operation can be defined as a set of interdependent or interacting activities that are necessary for the occurrence of a desired outcome; both activities and outcome can be treated as defined variables in this set of activities.

By operations research is meant any formalized quantitative analysis whose purpose is to improve efficiency in a situation where "efficiency" is clearly defined. Typically, operations research is used to optimize an objective function that is defined in quantitative terms.

When the optimization method is used, the usual objectives are either to provide a given level of service in the most economical way, or to provide the best service with the given resources, i.e. to indicate what service should be provided and how this can best be done with the resources available.

Operations research does not necessarily require the use of special techniques, and does not exclude the use of managerial and planning procedures. "With this qualification, operations research can be said to be the use of the scientific approach in the study of operations".[2]

Operations research may be contrasted with systems analysis. The latter is usually concerned with problems in which the difficulty lies in deciding what ought to be done, not simply how to do it most efficiently. Both systems analysis and operations research have to deal with practical problems of choice or decision, but with a difference. Systems research is concerned mainly with the strategy of choice, operations research with the tactics. Only rarely are the problems fully understood in either case, but they are more completely specified in operations research than in systems analysis. The models used in operations research, though often tentative as compared with those of pure science, are more circumscribed and better defined than those used in systems analysis. When objectives are unambiguous, criteria precisely defined and data adequate, the models of operations research are quantitative and incorporate quantified relationships. Typically, they are mathematical in form and employ optimization techniques that are rarely feasible in systems analysis.

Objectivization of Decision-Making[3]

Two broad categories of administrative decisions can be distinguished : (a) policy decisions; and (b) operational or managerial decisions.

Policy Decisions - these involve the definition of objectives that commit an organization to some overall purpose, and usually involve a choice between conflicting aims.

Priority decisions are a sub-class of policy decisions. They are concerned with the items listed below :

(1) establishing a time order for various programmes and with such matters as coverage (e.g. local; regional; national; industrial groups; social groups)

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(2) Ibid p.41

(3) Ibid p.42

(2) need-demand rankings (e.g., vulnerable groups)

(3) economic ratings relating to an overall allocation of resources.

The above answer questions such as when and for whom something should be done and broadly, the means to be employed.

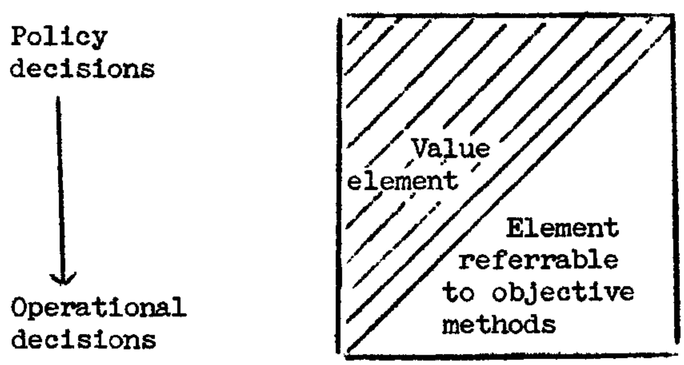
Operational Decisions - are also concerned with timing and coverage, as well as with cost and efficiency, but with the difference that they are taken in the context of the policy decisions they are intended to implement.

In the final analysis, all decisions depend on value judgements or on the allocation of priorities - policy decisions more evidently so than operational decisions - and no information system or analytical technique can alter this fact. For example, in optimization procedures it appears superficially that decisions on ways and means are entirely formalized and value-free. However, it turns out that this is so only because a value-dependent decision to optimize in some regard has been taken for granted.

Although in theory complex managerial alternatives can be reduced to a sequence of two-way or yes-no decisions that can be handled by a computer, it remains true that the ultimate responsibility for making decisions rests overtly or covertly on some individuals or groups.

Therefore, in all decision-making there is a value element that, though it varies greatly in importance, no conceivable procedure can eliminate entirely. It tends to be large in policy decisions and small, or even negligible, at the operational end of the scale. This is shown in the diagrammatic presentation below.

The value element in the decision spectrum *



* Grundy & Reinke, 1973 (Fig. 9, p. 43, WHO 20746)

The aim of rationalizing the decision-making process is to reduce the value element (shaded area in figure) to a minimum i.e. to maximize objectivity, by means of analytical methods.

Complete objectivity in decision-making is probably an unattainable ideal. However, decision-making can be systematized and substantially rationalized by reducing it to an orderly sequence of steps or stages, as follows :

(1) the classification of the problems and objectives involved;

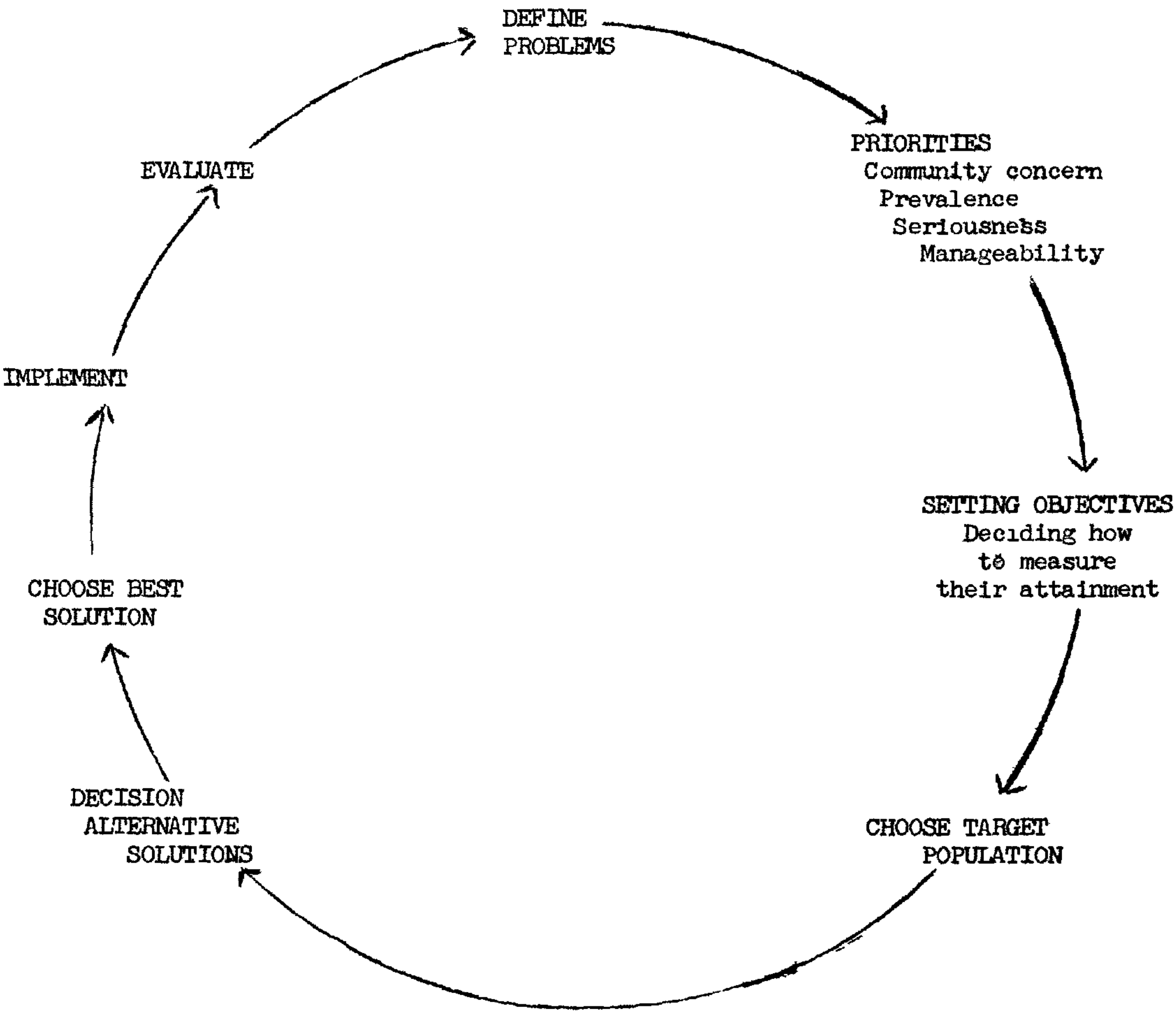
(2) the definition of alternative approaches and means, based if necessary on trials,

(3) the collection of relevant information about the alternatives;

(4) a comparison of the advantages and disadvantages of each, giving special consideration to feasibility and the time factor in the assessment of probable benefits i.e. to the relative weights to be assigned to short-term and long-term benefits;

(5) the evaluation, at intervals, of the results of implementing decisions, and the use of feedback for modifying and adjusting subsequent action.

Evaluation is not only a formal review of operational experience, but also an element in the feedback on which subsequent decisions are partly based. almost invariably, both policy and operational decisions are provisional not final. As decisions are made in sequence, later decisions are likely to be affected by the observed consequences of earlier decisions. The process of decision-making and evaluation in problem-solving is, therefore, a continuous one as shown on page 9.



Bryant's problem-solving cycle, 1971

USE OF MODELS : THE SCIENTIFIC APPROACH

The use of a model of some sort is the basis for each application of an operations research technique. Because of their versatility, lack of ambiguity, and ease of manipulation, mathematical models are the ideal, but this ideal is frequently unattainable in health practice research.

Real situations are invariably so complex that it is essential to simplify to select and isolate certain features of reality, to develop a more or less idealized situation, and then to construct a model that represents this idealized situation and also, to some extent, certain features of the real situation.

The model is thus a symbolic representation of an idealized system. It resembles but does not purport to be a replica of the situation it represents. It stands for the structural and functional attributes of that situation, not for its substance, and precisely on this account it helps us to visualize what is going on in the real world, brings hidden relationships to light, and provides a basis for logical operations that enable implicit relationships to be made explicit. It enables us to see how things hang together, how our concepts are related to each other; it enables us to discover patterns that are not apparent from the everyday inspection of events.

Main Characteristics of a Model

As a minimum, any model must satisfy the conditions listed below (Golding, 1968) :

(1) convey information (not always quantitative);

(2) illuminate appropriate variables and their relationships to each other, including factors of uncertainty or chance;

(3) provide a structure for analysis or simulation;

(4) be an abstraction of such a character as to allow manipulation without misrepresenting the real situation.

Types of Models

Models are said to be figurative when they are diagrammatic or geometric in form, or non-figurative when they assume a mathematical form. They are classified as follows :

(1) deterministic, when the parametres are constant or vary in a predictable manner; or

(2) stochastic, when their magnitude depends partly on chance, or when the model takes account of variability, e.g. rates of arrivals at clinics, rates of hospital admission, and queue formation.

Alternatively, models may be described as :

(1) static, when the magnitudes of the parametres are independent of each other, and vary in a way that does not alter with time, or

(2) dynamic, when this is not so; such models take account of changing circumstances and the manner in which decisions will affect or be affected by these circumstances.

Finally, according to the purpose they serve, models are said to be :

(1) descriptive;

(2) predictive; or

(3) prescriptive.

The descriptive model displays in convenient form the essential characteristics of the idealized system it represents. The predictive model provides a basis for deductions (extrapolations either in time or range of representation) that can be compared with observations in the real world. The prescriptive model is used to indicate what should be done to achieve or approach a stated objective. A single model often combines two of these functions, or all three of them.

Formation and Use of Models in Health Practice Research

The place of model-making in relation to the scientific approach to practical problems involving health planning and management decisions, and reasoned, goal-directed actions, may be best conveyed by the steps that follow :

(1) the idealization or conceptualization of the probler ;

(2) symbolization - the construction of a model that represents the idealized problem;

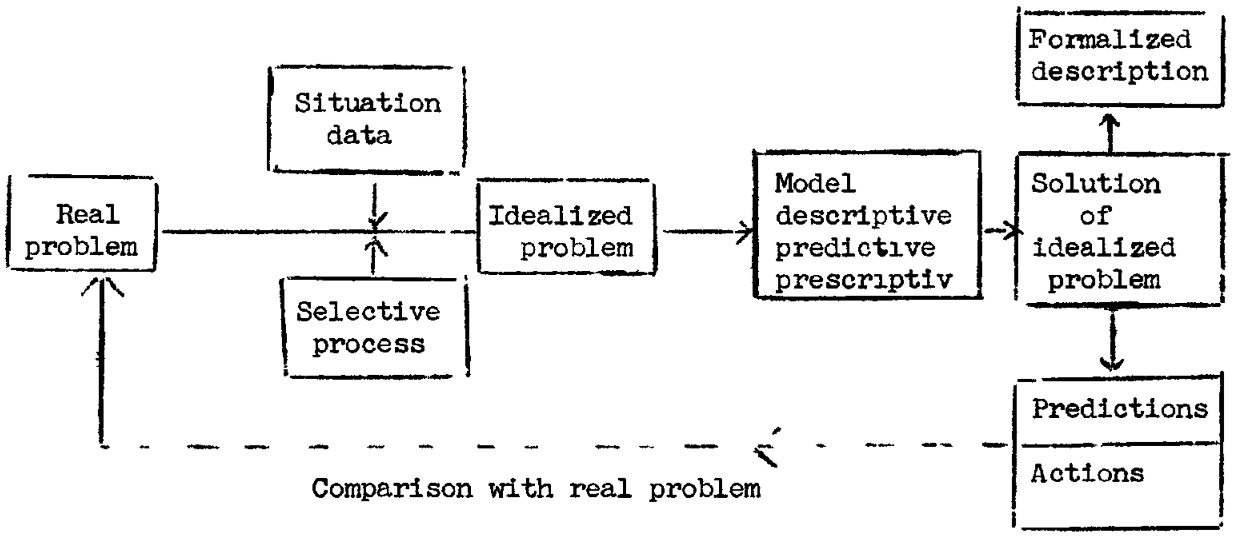
(3) manipulation of the model - the performance of logical operations on the model so as to find a solution to the idealized problem;

(4) evaluation - testing the ability of the model to represent the real situation by comparing model-based predictions with real observations, or by comparing the results of model-based actions with real world objectives;

(5) the formulation, in some instances, of generalizations or hypotheses that become the starting point for a new investigation.

In practice, many subsidiary steps are involved at every stage of the sequence. The right questions (or hypotheses) have to be selected (in such selection a good deal usually depends on intuition), situation data have to be examined, and variables rigorously defined and, whenever possible, quantified. Trial runs to demonstrate feasibility, adequacy and the suitability of the method are often needed, and the final stage in every project is the interpretation of results in the light of existing knowledge of the subject and related theory.

The above mentioned steps in the scientific approach, utilizing a model, are presented in the diagram below.



Diagrammatic representation of the scientific approach, utilizing a model Grundy & Reinke, 1973 (Fig. 8, p. 40, WHO 20745).

<u>Examples of Models</u>

<u>Figurative Models</u> : are notational devices that use boxes and arrows, or nodes and arcs, to represent the essential elements and relationships of complicated situations.

(a) Flow charts, which display sequences or relationships without reference to time or other quantities, are the simplest example of a figurative model (see Fig.1).

(b) Network analysis, in which an arc represents an activity, and a node its completion (event), so that a time factor is introduced. The best known form of network analysis is PERT (Programme Evaluation and Review Technique). Network analysis provides a basis for the planning, scheduling and controlling of complex, non-repetitive projects (see Fig.2).

(c) Ecological model or state-transition model, which relates a state by rates of transition from one state to another, leading, in some instances, to a set of equations that can be solved by mathematical operations (differential calculus or by method of finite differences) (see Fig.3).
Graphs and diagrams commonly used in health practice, such as disease incidence graphs, population pyramids, and epidemic curves are also primarily figurative models, though, like the PERT network and the state-tansition models, they may lead to arithmetical and other mathematical operations.

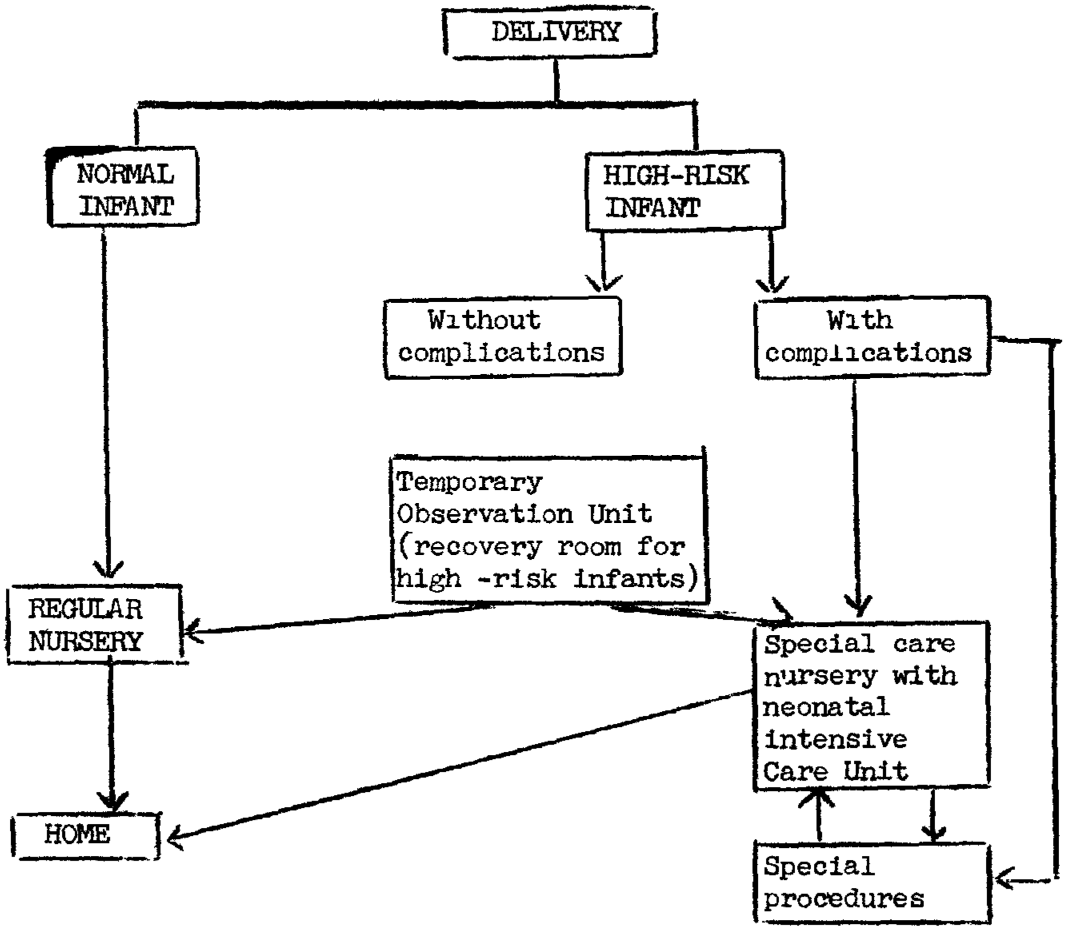


Fig. 1 Flow Chart of Optimal Newborn Care
Grundy & Reinke, 1973 (Fig.4, p. 34, WHO 00221)

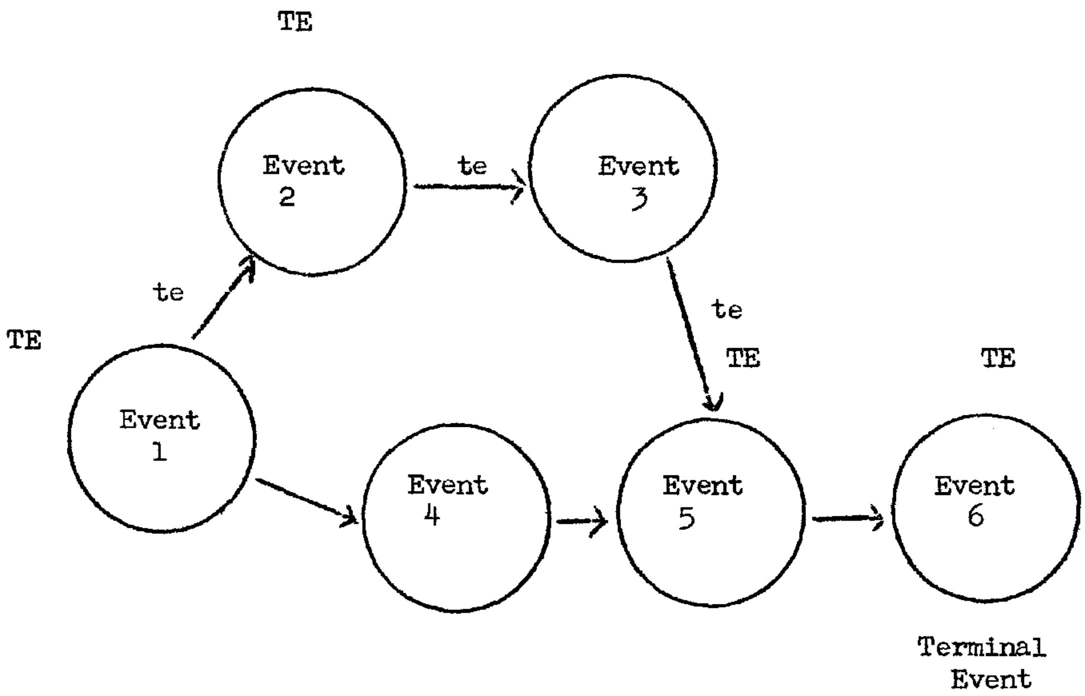


Fig. 2 Network Model
Grundy & Reinke, 1973 (Fig.5, p.35, WHO 20743)

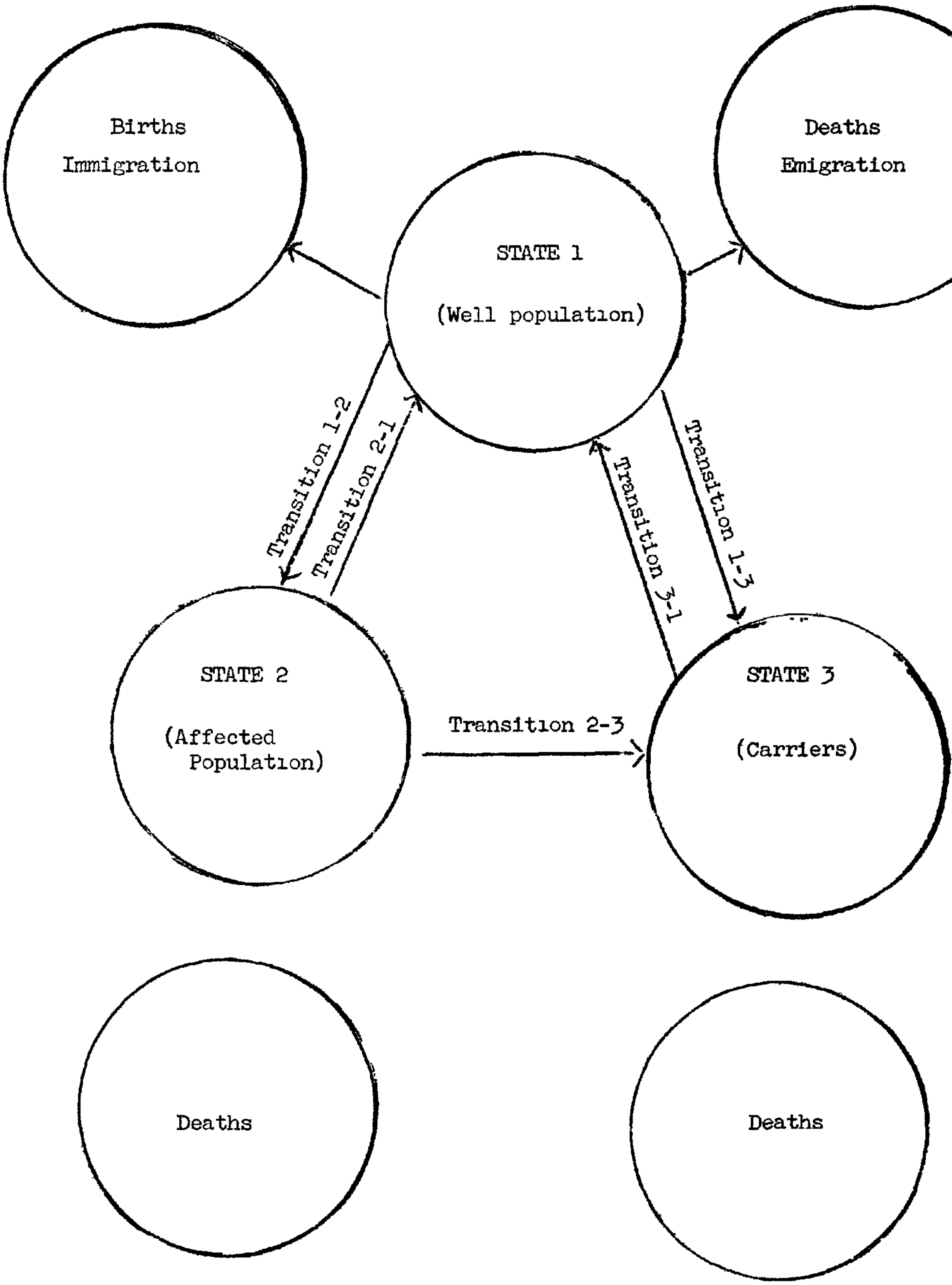


Fig. 3 Diagram of ecological model
Grundy & Reinke, 1973 (Fig. 6, p.36, WHO 20792)

Mathematical Models - are of several prototypes - a) inventory model; b) linear programming; c) prediction : queueing; d) simulation; e) decision analysis; and f) dynamic programming; etc. An example of inventory model will be considered here. (For examples of other mathematical models see Grundy & Reinke, 1973, Chapter 2, pp. 46 - 80).

The inventory model is a prototype deterministic model. The aim is to determine the optimal ordering policy for an inventory item, such as a drug or immunization agent. Like other mathematical models, because of its formalism, the inventory model is highly versatile. It enables precise, quantitative relationships to be expressed unequivocally for the purpose of prescribing an optimal course of action. Moreover, complicating chance factors that fall short of precise quantification can be incorporated into the model.

For example, small orders will keep the cost of carriage l v, but if for each time an order is placed, regardless of its size, a certain administration cost will be incurred. The problem is to determine the ordering policy that minimizes the sum of these costs : the inventory model makes use of the equations listed below to reach the optimal course of action during the period of concern for the administrator.

C_T = total cost.

C_1 = cost of carrying one inventory unit.

N_1 = average number of units carried.

C_o = cost of placing an order.

N_o = number of orders placed.

Then :

$$C_T = N_1 C_1 + N_o C_o$$

If U is the number of units issued, and Q the quantity ordered at any time, then $N_1 = \frac{Q}{2}$, and $N_o = \frac{U}{Q}$. It follows that :

$$C_T = \left(\frac{Q}{2}\right)C_1 + \left(\frac{U}{Q}\right)C_o$$

C_T is minimal when $Q = \sqrt{2U \frac{(C_o)}{(C_1)}}$

This example of the inventory model illustrates the importance of precise definitions, the explicit recognition of the essential factors in a problem, and the manner in which these factors are related to each other and to the objective.

The inventory model may also be applied to recruitment and training of health personnel.

ANALYSIS OF HEALTH CARE DELIVERY SYSTEMS

Comprehensive analyses of health care delivery systems are virtually non-existent, because of the multiplicity of factors and the diversity of units of measure involved. Ideally, we should be able to compile a list of community health problems and to relate them to the available resources in terms of the specific services provided. In practice, however, this is not easy.

For example, the patient with a problem sees it from the viewpoint of his "complaint", whereas, the health professional thinks of it as a diagnostic category. The problems identified vary from such non-specific entities as "cough" or "fever" to diagnosed cases of "active tuberculosis". Moreover, the translation of health problems into "needs" for specific health services is by no means unambiguous, e.g. the difference in care in the case of a short-lived low grade fever and a fever lasting for one or more weeks and associated with persistent cough.

In the case of resources, the difficulty arises in attempting to disentagle the enormous number of service mixes and organizational arrangements that might be derived from these resources (e.g. doctor-hours, nurse-hours, X-ray units, etc.).

Despite difficulties, however, it is clear that services provide the common denominator whereby health problems and resources can be related in a comprehensive systems analysis. In assessing these services, we should not be limited by traditional organizational boundaries, such as paediatrics, obstetrics, or public health. It has proved to be more informative to base the analysis on functional categories, such as child care, family planning, medical relief and mass control of communicable diseases. Within each functional area to be investigated, the specific activities of the various personnel categories can then be portrayed with respect to health problems in question.

The time devoted to the various functions might be analyzed as shown in the table below. Such a table shows, for example, the current distribution of well child care activities among different types of professional personnel, and would enable the time devoted to such care to be compared with the level of care required, as indicated by the demographic and other evidence of community need. The table also shows the distribution of total health effort relative to available manpower.

In addition to the descriptive insights provided by the table, it might also have predictive and prescriptive uses. The ultimate aim might be to vary functional emphasis in accordance with the distribution of needs, and to prescri an optional reallocation of effort among the various professional categories, transferring responsibilities, whenever possible, to less highly qualified personnel.

ANALYSIS OF TIME DEVOTED TO VARIOUS FUNCTIONS BY DIFFERENT CATEGORIES OF PERSONNEL

Functions	Time devoted by :						
	Family and friends	Indigenous practi-tioners	Auxiliary sub-pro-fessionals	Nurses	Physicians	Existing functional balance	Functional balance based on need
Well child care							
Family planning							
Medical relief							
Mass control of communicable diseases							
Etc							
Effort by individual category							
Manpower available							

ECONOMIC ANALYSIS

Economic analysis is a necessary constituent of health planning. Estimates, budgets, cost accounting and other financial methods are as necessary for controlling and evaluating the performance of health services as they are in other fields. Economic analysis is an accepted tool for resource allocation, and can also shed light on problems of utilization.

The main areas common to economics and health practice include :

(1) budgetary and other financial controls and evaluation methods;

(2) cost-effectiveness and cost-efficiency measurement;

(3) cost-benefit approaches.

The first of these is well understood.

Cost-effectiveness measurement is a method of comparing the costs of achieving an agreed objective in different ways, while cost-efficiency measurement is a method of comparing the costs in two or more enterprises providing similar services, or in a single enterprise at different times.

The cost-benefit approach is a method of comparing the cost of providing a service with the gain accruing, or likely to accrue from it (i.e. the net estimated gain). Though useful in making policy decisions, it often involves arbitrary assumptions and leads to controversial conclusions. Cost-benefit methods have been useful for demonstrating the economic soundness for certain health services and, especially, of mass campaigns for the control of certain communicable diseases; of immunization, family planning and nutritional programmes, and of occupational health services. Applied to health care services in general, their value is doubtful.

Where accounting systems are adequate, the cost of establishing, maintaining, or extending health services can be estimated without difficulty, provided that agreement is reached on the items to be included; the cost of supplementary diets, for example, can be charged to health or to some other account. The demonstration of benefits that are unequivocally attributable to the operation of a health service is, in contrast, a more intractable and, in some cases, an impossible problem. This is true even if the benefits considered are limited to such items as increases in working-life span, reductions in working time lost because of sickness, and reduced need for health and allied care, all of which can be expressed in monetary terms.

Especially, if the quality of human life, community morale, social stability, and similar items that cannot be expressed in this way, are included.

Moreover, so far it has not been feasible to correlate costs and results with any confidence, since improvements in general levels of health are rarely attributable exclusively to better health services. They are often the result, for example, of rising standards of living. The use of the cost benefit approach is, therefore, hampered by difficulties in measuring the effects of health programmes, but this is not the only limitation. Many health care services, e.g. those for the severely physically or mentally disabled, are patently unsound in economic terms. Cost-benefit in the health field must, therefore be seen as one of the bases for decision-making but not as a sufficient foundation, in itself, for policies and programmes. It can be used in the evaluation of programmes and services, and can sometimes demonstrate the economic value of health services. The improvement of health is not purely an economic objective, however, and many of the benefits resulting from health services cannot be measured in financial terms; the provision of such services, even if there is no demonstrable economic gain, may nonetheless, be highly worthwhile on other grounds.