Pan American Health Organization

ADVISORY COMMITTEE ON MEDICAL RESEARCH

Seventh Meeting

Washington, D.C., 24-28 June 1968

Item 4 of the Agenda

OPPORTUNITIES FOR OPERATIONS RESEARCH IN THE HEALTH SERVICES

Ref: RES 7/6
23 May 1968

PAN AMERICAN HEALTH ORGANIZATION
Pan American Sanitary Bureau, Regional Office of the
WORLD HEALTH ORGANIZATION

Washington, D.C.

Opportunities for Operations Research in the Health Services*

In this presentation, I shall touch on four topics: a description of what operations research is; a statement of PAHO problem areas seemingly amenable to operations research techniques; a concept for an operations research position within the Department of Research Development and Coordination which would function primarily as a liaison between PAHO and the university-industrial medical operations research complex in the United States; and some examples of my own research interests, purely to illustrate how such a technical collaboration with various organizations might be established.

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1. Description of Medical Operations Research

Operations research may be described in terms of the types of problems that normally fall in its domain, the type of personnel who normally work on these problems and the types of methodology which are typically used to solve the problems.

The problems of operations research involve the better (if not near optimal) use of resources in the military, economic, and health fields.

The approach to the problems is mathematical modeling and solution, ordinarily expedited by judicious interplay of ideas among a multi-desciplinary team. The operations researcher creates the model from the information supplied by the other team members and solves it, most often with the help of a digital computer. Typically operations researchers have extensive background in industrial engineering, mathematics, and economics.

The methodologies normally included in the curriculum are:

(1.) Mathematical Programming (especially linear, quadratic, and dynamic programming)

(2.) Queuing Theory (or waiting line theory)

(3.) Inventory Theory

(4.) Graph Theory

(5.) Theory of Games

(6.) Probability and Statistics

(7.) Techniques for forming PERT charts

Mathematical programming typically is applied to minimize the cost function associated with maintaining a level of performance, or to maximize the level of performance subject to spending only a certain amount. Cost might be dollars spent on a program, performance, the mortality, morbidity or health resources utilization of a population. Variables might involve acquisition and maintenance of para-medical personnel, equipment, beds, floor space and laboratories in the medical units of the region of interest.

The queuing model enables calculation of numbers of elements in a queue, and the average waiting time and average service times for these elements, give the type of queue, i. e., give the distribution of arrivals, the rules under which they queue and the methods under which they are served. For example, given some statistics about eye disease, and the times for various operations, queuing theory might be applied to calculate the number of operating rooms and in-patient beds required for an ophthalmology department in a medical unit.

Inventory theory represents mathematically the rate of stocking and usage of supplies and determines the amounts which should be ordered at various times in order to minimize losses due to overstocking (e. g., spoilage, use of space) and losses due to understocking (e. g., not having an item when required). Such mathematics have been applied to the distribution of blood and plasma, the stocking of pharmacies, and the stock-piling of radio-pharmaceuticals.

Graph theory abstracts the input, output and throughput relationships of a system. Graph theory has been applied to economic planning models to delineate which resources and procedures are required to determine a given output.

Theory of Games investigates the optimal strategies of players involved in payoffs to each other which depend on the actions or moves of the players. Some of the mathematics applies to a game between a "human" and "nature" where the payoffs involve the cost of sickness and death and money spent to ward them off, and the strategies involve diagnostic testing and therapeutic actions.

Chance is involved in almost every operations research problem, so that knowledge of probability and statistics is indispensable.

PERT is a method of scheduling the performance of an activity(e. g., building a hospital) in terms of its components (e. g., finding the land, buying the land, the architectural plans, the construction of the buildings, the interior decorating, the specification of equipment, securing the equipment, specification of personnel, securing the personnel, etc.). The order of the tasks and expected distribution of the time to carry them out are used to generate the so-called critical paths which are then examined with improvement of the overall scheduling in mind.

2. PAHO Problem Areas Seemingly Amenable to Operations Research Techniques

2.1 Suggested Areas for Immediate Investigation

a. Cost efficiency studies: setting levels of programs and meeting these levels with the right 1) throughput, 2) para-medical personnel, c) allocation of clinics, d) mix of treatment, and e) automation.

b. Measuring the impact of malnutrition in terms of morbidity, mortality, mental illness, disability, and economic loss.

c. Standardizing rural water programs; measuring the impact of water purification and pollution control in terms of geographic and ethnic variables so that resources may be intelligently allocated.

d. Standardizing the definition and measurement of dollars spent on health services, morbidity, mortality, and water purification so that statistics involving these variables are valid.

2.2 A Preliminary Proposal for a Study on Cost Efficiency

For any PAHO program against sickness, an ascending scale of costly activity, (to be taken as oversimplification, of course) may be suggested:

education
decrease in mortality (emergency clinics)
decrease in morbidity (periodic screening)
decrease in susceptibility (public health actions)
eradication of mortality (universal gross treatment)
eradication of morbidity (intensive care)
eradication of cause of sickness (preventive public health actions)

Presumably, acquisition of each successive level demands a greater outlay of resources than that required for attainment of the previous level. Also such a categorization implies that going beyond one objective level but not reaching the next may represent some useless expenditure; roughly, one should spend sufficient resources to attain a level, but effort beyond this level--but insufficient to reach the next one--may be largely wasted.

Given a level aimed at, one should attempt to determine the amount of screening and treatment likely to be required to attain it. Beds, physicians, paramedical personnel, equipment, and medication should be related to number of patient contacts expected to achieve the health level. That is to say, a throughput rate and average medical demand per patient "entry" should determine the number of medical units and their staffing level.

Decision-making models should aid in the selection of treatment where there are trade-offs as in malaria (spray, mix of pills to minimize resistance of strains, etc.), poliomyelitis (those taking vaccine may infect those who do not), and tuberculosis (pills versus costly intensive care).

Good history-taking and good epidemiological records cost money which may or may not be justified by anticipated beneficial effect on the particular project. Dispensable supplies may be more expeditious but introduce secondary infections. Automated blood chemistries, e.g., modeled after existing Automated Laboratory Data Systems, are examples of hardware that function today and that could conceivably be cost-effective in certain Latin American settings.

There is no implication in this description of a cost efficiency outlook that such methodology is used to any degree in the United States today but that it will most likely be used in the future. Such an analysis of efficiency in delivering a level of service may be especially pertinent in Latin America where the desirability of careful resource allocation may be even more important than in the United States.

2.3 Other Studies Suggested in Discussions with PAHO Staff.

A. Environmental Health

(1) Mass produced water purification and sewage systems.

An industrial engineering study might isolate and then develop the procedures and equipment which are normally fixed for most rural water work, e.g., permission of the village authority, surveying, organization of manpower, fixed mechanical components, maintenance manuals.

(2) Urban water purification and water pollution control.

A mathematical programming approach to resource allocation is envisioned where independent factors might include water flow, terrain, present pollution, density of population, and current epidemiology, and dependent factors might include projected epidemiology, (e.g., decrease in dysentery), projected pollution (decrease in sewage, industrial wastes, and pesticides), and psychological, sociological, and economic impacts. The object, then, is to place water projects locally in such a way as to maximize the benefits to a region.

(3) Total planning study of the La Plata River Basin: an analysis of socio-economic, health transportation and energy factors to deduce which combination lead to the quickest development of the region.

B. Malaria Eradication

(1) Factor analysis of present treatment strategies versus indigenous variables and past treatment strategies is recommended.

Independent Variables	Dependent Variables
Rainfall	Present strategies
Density of population	sprays
Type of housing	drugs
Socio-economic factors	presumptive treatment
Past strategies	radical treatment
sprays	mass treatment
drugs, singly or in combination	a) by mouth b) by injection
Type of parasite	larviciding
P. falciparum	
P. vivax	
Money available	

(2) A cost benefit study is needed of the utility of the final stages of eradication.

C. Communicable Diseases

(1) A decision-making model is needed to determine the best treatment strategies (leprosy, malaria, poliomyelitis, and tuberculosis).

A Bayesian model can be applied to determine when further signs and symptoms should be collected and to estimate the best treatments, given cost of errors of both kinds--treating the healthy, not treating the sick.

(2) Priority studies: To develop an index of the criticality of a disease in a population, perhaps similar to the Q index developed by the Bureau of Indian Health / U. S. Public Health Service, which is a weighted sum of the mortality, plus the inpatient, outpatient, and disability days imposed by a disease class.

(3) Cost Efficiency Studies: an investigation of throughput rate (number seen and for how long) of a clinic versus its efficacy. Also the setting of levels of a program each of which is associated with a required amount of resources.

(4) Study of information-gathering, with emphasis on the appropriateness of indicators:

One should develop methods for determining the adequacy of a set of indicators;(e. g., Is the best linear predictor of mortality and/or morbidity and/or resources utilization, available from the indicators, sufficiently good?)

One should also be able to drop useless indicators; (e. g., Can a small subset of the indicators predict the total set of indicators reasonably faithfully?). Using common sense, 872 indicators associated with leprosy were reduced to just 70 with little loss of information.

(5) Meta-evaluation of PAHO: A study of the efficiency of field operations, determining, for example, the toll taken by red tape.

D. Health Promotion Services

(1) Analysis of the efficiency of existing delivery systems: Industrial engineering talents might be applied to plant layout, time and motion studies, disposable versus non-disposable items, inventory control, supply, billing and accounting.

(2) Development of methodology for deciding how much PAHO assistance should go into various programs versus required matching funds.

(3) An analysis of the best distribution of dental clinics, the desirable throughput rate, and the economically optimal blend of paramedical personnel.

(4) A determination of the cost-effectiveness of periodic visits of children to pediatric clinics as a function of the time between visits.

(5) A study of the cost effectiveness of health education (how much propaganda, posters, and pictures are really needed).

(6) A viable definition of "rural" and "urban" as a weighting of density of population, communications, distance from services, per capita income, farming, and attitudes.

(7) A study of the correlation between mental disease and nutritional defects.

E. Health Statistics

(1) A study of the improvement and possible automation of medical records.

(2) A follow-up on urban mortality studies to deduce multiple causes of death and causes of sudden death.

(3) Determination of the "real cost" of malnutrition to a society (mortality, morbidity, mental illness, lack of productivity, etc.).

(4) Standardization of estimates for costs, water supply, resource utilization, and per capita income.

3. Concept of the Operations Research Position as a Liaison Between PAHO and Current Research Activities in Universities and Industry.

In creating an operations research activity within PAHO two disparate approaches might be considered. One approach would involve the acquisition of a multi-disciplinary team capable of significant self-contained problem solution. Such a team could usually contain operations research, industrial engineering, statistical, social survey, economics, computing, and bio-medical engineering personnel. As such it would function as a formidable research unit comparable to those in large university settings and non-profit research institutes of the United States. To a degree, this approach, of accruing a critical mass of technical people capable of attacking wide-scale problem areas, is the approach being followed in Geneva by the Division of Research in Epidemiology and Communications Science.

Within PAHO I believe an alternate, viable approach, demanding less initial expense, and capitalizing on PAHO's location at Washington, D. C., would be to choose a single operations researcher who could operate as a clearing house for available useful research and development projects already in operation in the United States.

The sizeable operations research activity in the Public Health Service and The National Institutes of Health, at Georgetown and Johns Hopkins Universities, in systems analysis firms such as Booz Allen Hamilton, Rand, Arthur D. Little, etc., is immediately accessible within the area. Of course, all the enormous effort throughout the country represents an ultimate resource.

4. Illustration of Technical Collaboration Among Research Activities That I Might Expedite

As an example of an integrated network of collaborative studies that might be instigated, I list, in Table 1, a number of research endeavors now being carried on in the United States, with which I am personally familiar, and which have strong indications of being useful to PAHO. This set of examples is purely illustrative.

Concerning the application of automation in general, whether it be in medical records, automated laboratories, multiphasic screening, billing and accounting, or research, any of the following organizations might be contacted depending upon the appropriateness to the application.

1. General Electric Mednet Project
   Jordan Baruch, Director
   Watertown, Massachusetts

2. IBM Hospital Information System
   R. E. Taylor, Director
   Watertown, Massachusetts

3. Lockheed Hospital Information System
   Lockheed Missiles and Space Company
   K. T. Larkin, Director
   Sunnyvale, California

4. Systems Development Corporation
   H. H. Wilson, Director
   Santa Monica, California

TABLE 1

Program	Agency	Comments
Health Services Research	Operations Research, Hopkins Medical Care and Hospitals, Hopkins	Quadratic Programming [1]
Computer Aided Screening (Diagnostic)	Operations Research, Hopkins Pathology, Hopkins	Bayes Theorem [2]
Outpatient Department Record Automation	Operations Research, Hopkins Ophthalmology, Hopkins	Information Retrieval [3]
Hospital Planning	RAND	Linear Programming [4]
Water Pollution	Travelers Research Center	Simulation [5]
Drug Monitoring	Booz Allen Hamilton for FDA	Statistical [6]
Automated Analysis of Electrocardiograms	Instrumentation Field Station (Public Health Service)	Computer-Aided [7]
Automated Blood Chemistries	University of Missouri Medical Center	Automated Laboratory Data Systems [8]

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[2] "Medical Diagnosis Using Bayes Theorem", by Thomas L. Lincoln, M.D. and Rodger D. Parker, Spring, 1967, Health Services Research.

[3] "Organic and Functional Disorders of the Retina", an outpatient clinical research project under the National Institute of Neurological Diseases and Blindness conducted by George Weinstein, M.D. and Rodger D. Parker.

[4] "A Quantitative Approach to Health Care Planning", by J. C. Clayton and R. M. Gurfield, April 3, 1968, RAND Corporation, Santa Monica, California.

[5] "A Computer Simulation Model For Use In Water Data System Planning and Management", July 1967, Final Report to the Water Resources Division, U.S. Geological Survey, Department of the Interior, Contract 14-08-0001-10448 by The Travelers Research Center Inc., Hartford, Connecticut.

[6] "Surveillance Product Sampling and the Drug Monitoring Program", Preliminary Draft, December 8, 1967, to the FDA, Contract number CPR-11-5260 from Booz Allen and Hamilton, Washington, D.C.

[7] "Pilot Program for Automated Analysis of Electrocardiograms", by Doyle Darragh, Instrumentation Field Station, PHS, 2121 K Street, N.W., Washington, D.C.

[8] Computer Center, University of Missouri Medical Center, Don Lindberg, M.D., Director.