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A Model for the Integration of Health and Nutrition Planning

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A Model for the Integration of Health and Nutrition Planning

Hector Correa and Wafik A. Hassouna

I Numerous applications of mathematical techniques for decision-making to the administration of health facilities are available, covering a wide variety of questions dealing with localisation of health care facilities, use of personnel, inventories etc. (4). Only in references (1) and (3) is the selection among different methods for the prevention and cure of disease considered. Only very restricted problems are studied. In reference (1) the problem of choosing between prevention and treatment of one disease in such a way as to minimise deaths is studied. The method is applied to the determination of a method for minimising the number of deaths produced by whooping cough. In reference (3) the approaches that should be used to minimise the losses caused by tuberculosis are considered, particular attention being given to ambulatory care and hospital care.

In this paper we shall discuss the problem of choice between prevention and cure of several diseases. The fact that the incidence of disease and the final outcome depend upon the nutritional conditions of the population will be taken into consideration. As an example, the approach will be applied to the problem of minimising infant and child mortality in Egypt.

II In this section, the problem of choosing between improvement of the nutritional conditions of a population or of preventing or treating the diseases suffered by that population, will be put in a form that can be

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analysed by means of linear programming techniques.

Several simplifying assumptions are used in the model to be presented. The problems caused by the passage of time will not be considered; some observations about the possibility of avoiding this limitation will be made later.

Nutrition will be introduced as an element influencing resistance to disease and, if a person becomes sick, influencing also the final outcome of the illness. It will be assumed that there is one 'satisfactory' or acceptable nutritional level, and that under the conditions prevailing at this level, precise morbidity and mortality rates can be defined. With this information, it is possible to determine the optimum allocation of resources in a health plan.

In principle, a person can deviate from 'satisfactory' nutritional conditions in an infinite number of ways. For each of these deviations, different morbidity and mortality rates prevail.

The current nutritional status of the population could be either the satisfactory one or any of the infinite number of unsatisfactory ones. The current status will be explicitly considered only if it is unsatisfactory. It will be assumed that the precise values of morbidity and mortality rates corresponding to this current unsatisfactory level of nutrition are known. Finally, it will also be assumed that by making certain expenditures per person it is possible to supplement the diet of the population so that it will achieve the 'satisfactory' nutritional level. With the explicit consideration of satisfactory and current unsatisfactory nutritional conditions of the population, the question of optimum allocation of resources among better nutrition and prevention or cure of disease can be studied in detail.

The analysis will be restricted to the case in which a health and nutrition plan is designed to combat three diseases. It will be assumed that there is only one method of prevention and one method of treatment for each of them. These assumptions greatly simplify the presentation of the model and the data needed. However, they can easily be dispensed with if necessary.

Perhaps the most difficult question in any type of planning, and particularly in health and nutritional planning, is the specification of an appropriate objective function. It will be assumed here that the objective is to minimise deaths. If necessary, this objective function can easily be extended in order to consider other types of losses such as number of days of sickness, etc. The basic problem in this case is to specify the basis for comparison of – say – days of sickness with death.

To formalise the model, let N denote the population considered as reference for the health and nutrition plan, N_{ij} be number of persons with nutritional conditions

i = 1 current
i = 2 satisfactory

and prevention status

j = 0 none
j = 1 against disease 1 only
j = 2 against disease 2 only
j = 3 against disease 3 only
j = 4 against diseases 1 and 2
j = 5 against diseases 1 and 3
j = 6 against diseases 2 and 3
j = 7 against diseases 1, 2 and 3

A first condition that must be satisfied is

$$N = \sum_{j=0}^{7} \sum_{j=1}^{2} N_{ij} \qquad (1)$$

The number of cases of disease k among persons with nutritional condition i (to be denoted with B_{ik}) is

$$B_{ik} = \sum_{j=0}^{7} \alpha_{ijk} N_{ij} \qquad (2)$$

where

α_{ijk} morbidity rate
nutritional condition i = 1, 2
preventive care j = 0, 7
disease k = 1, 3

As observed, only one treatment is assumed to be possible for each disease. However, this does not mean that every patient has to be treated. Actually, one possibility open to a decision-maker is not to treat some or all the patients suffering from a particular disease. Denoting with T_{ikm} the number of persons with nutritional conditions

$i = 1, 2$, disease $k = 1, 3$ who should be treated ($m = 1$) or should not be treated ($m = 2$), the following constraint is obtained:

$$B_{ik} = \sum_{m=1}^{2} T_{ikm} \quad (3)$$

The number of deaths of patients suffering from the three diseases becomes

$$D = \sum_{m=1}^{2} \sum_{k=1}^{3} \sum_{i=1}^{2} \delta_{ikm} T_{ikm} \quad (4)$$

where δ_{ikm} mortality rate for persons with nutritional conditions $i = 1,2$, affected by disease $k = 1,3$ and treatment $m = 1,2$.

Equations (1) to (4) 'explain' the number of deaths, but do not deal with the resources needed to reduce that number. To consider this element, let τ_{ijkm} denote resources of type $m = 1, \ldots, M$, needed per person for $i = 1$ prevention and $i = 2$ treatment, for persons with nutritional level $j = 1, 2$, and for method k of prevention $k = 0, 7$ or disease treatment $k = 1, 3$; and with H_m total resources of type m available. Then the following constraints can be defined:

$$H_m \geq \sum_{j=1}^{2} \sum_{k=0}^{7} \tau_{1jkm} N_{jk} + \sum_{j=1}^{2} \sum_{k=1}^{3} \tau_{2jkm} T_{jk} \quad (5)$$

In the example below it will be assumed that $M = 3$, i.e. that three resources are used to prevent or cure disease. These resources are doctors' services, nurses' services and financial resources. As a consequence τ_{ijk1} will be measured in minutes of doctors' time per patient, τ_{ijk2} in minutes of nurses' time per patient, and τ_{ijk3} expenditures per patient.

With the notation above, the problem of integrating health and nutritional planning reduces to that of minimising (4) subject to the constraint in (1) to (3) and (5).

In the model presented so far, nutrition appears simply as one possible way to use the resources available to improve the health conditions of the population. However, it can also be used to study the impact of deficient nutritional conditions on morbidity and mortality. For this, it is necessary to compare the number of deaths when the population enjoys satisfactory nutritional conditions and when it does not. The first alternative is simulated in the model, assuming that the cost of satisfactory nutritional conditions is zero, and the second assuming that it is so high that none of the resources available should be used for them. Nutritional costs between these two bounds will show the impact on deaths of using some resources to improve nutrition and some to prevent or treat disease.

III The model presented in Section II will be applied below to planning of health and nutrition for infants and children in the United Arab Republic (Egypt).

As observed, two nutritional levels will be considered. The three diseases to be included are bronchitis, diarrhoea, and measles, which together cause 90 per cent of the deaths of children between 0-4 years of age.

Better housing and clothing are considered to be the preventive measure against bronchitis, a sanitary water supply against diarrhoea, and vaccination against measles.

The data required on morbidity and mortality rates, use of resources, and costs were estimated, using information from different countries, different governorates of the UAR, and the opinions of health officials in that country. Data were collected in such a way as to reflect the conditions existing in 1970-1973. These data are presented in Table 1.

Doctors' and nurses' time did not appear to be a scarce factor in any of the analyses made on the basis of these data. This was true even without assuming that additional time could be obtained by using some financial resources for the purpose. Therefore, in the following analysis attention is paid only to restrictions imposed by scarce financial resources.

Tables 2 to 4 make it possible to study the influence on morbidity and mortality of satisfactory and unsatisfactory nutritional conditions. They are obtained by assuming, firstly that the cost of satisfactory nutrition is zero, i.e. that the current nutritional conditions of the population are satisfactory, and secondly, that the cost of improving nutritional conditions is so high that no resources should be used for this purpose, because greater reduction of morbidity and mortality can

Table 1

United Arab Republic:
Data Used to Specify Optimum Allocation of Resources
for Integrated Nutrition and Health Plan

No.	Equation Description	Constant	N_{10}	N_{11}	N_{12}	N_{13}	N_{14}	N_{15}	N_{16}	N_{17}	N_{20}	N_{21}
13.10	Objective		0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	Constraints											
13.7	Population	5000 =	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
13.9	Disease 1, no nutrition	0.=	0.051	0.017	0.045	0.051	0.015	0.017	0.045	0.015	0.	0.
13.9	Disease 1, nutrition	0.=	0.	0.	0.	0.	0.	0.	0.	0.	0.0390	0.013
13.9	Disease 2, no nutrition	0.=	0.350	0.750	0.400	0.850	0.400	0.750	0.400	0.350	0.	0.
13.9	Disease 2, nutrition	0.=	0.	0	0.	0.	0.	0.	0.	0.	0.300	0.700
13.9	Disease 3, no nutrition	0.=	0.700	0.650	0.680	0.90	0.630	0.085	0.090	0.085	0.	0
13.9	Disease 3, nutrition	0.=	0.	0.	0.	0.	0.	0.	0.	0.	0.650	0.600
13.11	Doctors' Time	90000≥	0.	0.	0.	2.0	0.	2.0	2.0	2.0	0.	0.
13.11	Nurses' Time	180000≥	0.	3.0	3.0	3.0	5.0	5.0	5.0	7.0	5.0	7.0
13.11	Financial	R ≥	0.	7.15	1.0	0.018	8.15	7.168	1.018	8.168	c	c+7.15

No.	Equation Description	Constant	N_{22}	N_{23}	N_{24}	N_{25}	N_{26}	N_{27}	T_{111}	T_{112}	T_{211}	T_{212}	T_{121}
13.7	Population	5000 =	1.0	1.0	1.0	1.0	1.0	1.0	0.	0.	0.	0.	0.
13.9	Disease 1, no nutrition	0.=	0.	0.	0.	0.	0.	0.	−1.	−1.	0.	0.	0.
13.9	Disease 1, nutrition	0.=	0.0344	0.039	0.0115	0.013	0.0345	0.0115	0.	0.	−1.	−1.	0.
13.9	Disease 2, no nutrition	0.=	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	−1.
13.9	Disease 2, nutrition	0.=	0.350	0.80	0.87	0.70	0.35	0.30	0.	0.	0.	0.	0.
13.9	Disease 3, no nutrition	0.=	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13.9	Disease 3, nutrition	0.=	0.610	0.070	0.600	0.075	0.075	0.075	0.	0.	0.	0.	0.
13.11	Doctors' Time	90000≥	0.0	2.0	0.0	2.0	2.0	2.0	0.	25.	0.	25.	0.
13.11	Nurses' Time	180000≥	7.0	6.0	10.0	10.0	10.0	12.0	0.	32.5	0.	32.5	0.
13.11	Financial	R≥	c+1.0	c+0.018	c+8.15	c+7.168	c+1.018	c+8.168	0.	6.15	0.	6.15	0.

R = 2000. 5000, 10000, 15000, 20000, 25000
c = 0., 0.10, 0.15, 0.20, 0.50, 1.0, 2.0, 5.0, 10.0

be obtained by using the resources in other ways. Table 2 shows that approximately 40 per cent of the deaths of infants and children could be avoided if their nutritional status were satisfactory. Tables 3 and 4 show how the financial resources should be used. The fact that the pattern in the two Tables is identical is a consequence of the assumption implicit in the data that a satisfactory nutritional status reduces in an approximately proportional way all morbidity and mortality rates. It is likely that this assumption – acceptable for the three diseases being considered – will not hold true in the case of other diseases. For this reason, it should be empirically verified in each specific case.

Table 2

UAR: minimum number of deaths per year among 5000 infants and children with different nutritional status and health expenditures

Health Expenditure E£ per year	Nutritional Status Satisfactory	Non-satisfactory	100 (a) (b)
2000	238	362	65.7
5000	75	134	55.9
10000	37	61	60.7
15000	34	57	59.6
20000	31	52	59.6
25000	28	47	59.6

In the model in Section II, nutrition appears as one of the alternative ways to use the human and financial resources available. This makes it possible to study the influence on the number of deaths of different levels of expenditure needed to raise the current nutritional status of the population to a satisfactory level. The results of this analysis appear in Table 5. Increasing nutritional expenditures when part of the resources are used for better nutrition simply means less resources for other uses in health care. As a consequence, the number of deaths increases. Finally, the position is reached where the cost is too high to justify any expenditure on nutrition. This conclusion might seem surprising. However, it simply means that more lives can be saved with one monetary unit used, say, for vaccination than with one unit used for improving nutrition. The reason for this is not that the life-saving properties of nutrition have been reduced, but that their cost is too high.

Table 3

UAR: number of children that should receive preventive measures and number of patients that should be treated to minimise children's deaths (assuming satisfactory nutritional conditions)

	Case No. I	II	III	IV	V	VI
Children in Population	5000	5000	5000	5000	5000	5000
Financial Resources Available (Egyptian Pounds)	2000	5000	10000	15000	20000	25000
Minimum Number of Deaths	238	75	37	34	31	28
Number should receive no Protection	0	0	0	0	0	0
No. should receive protection from 1	0	0	0	0	0	0
No. should receive protection from 2	0	0	0	0	0	0
No. should receive protection from 3	5000	5000	0	0	0	0
No. should receive protection from 1-2	0	0	0	0	0	0
No. should receive protection from 1-3	0	0	0	0	0	0
No. should receive protection from 2-3	0	0	4784	4065	3346	2627
No. should receive protection from 1, 2, 3	0	0	216	935	1654	2374
Patients of 1 that should not be treated	195	131	0	0	0	0
Patients of 2 that should not be treated	2310	0	0	0	0	0
Patients of 3 that should not be treated	350	350	0	0	0	0
Patients of 1 that should be treated	0	63	168	151	134	118
Patients of 2 that should be treated	1690	4000	1739	1703	1667	1631
Patients of 3 that should be treated	0	0	375	375	375	375

IV Perhaps the most important limitation of the model given in II and III is that it ignores the consequences of the passage of time. Fortunately, no conceptual modification of the model is needed to deal

Table 4

Number of children that should receive preventive measures and number of patients that should be treated to minimise child deaths (assuming current nutritional conditions)

	Case No. I	II	III	IV	V	VI
Children in the population	5000	5000	5000	5000	5000	5000
Financial resources available E£	2000	5000	10000	15000	20000	25000
Minimum number of deaths	362	134	61	57	52	47
Number should receive no protection	0	0	0	0	0	0
Number should receive protection from 1	0	0	0	0	0	0
Number should receive protection from 2	0	0	0	0	0	0
Number should receive protection from 3	5000	5000	0	0	0	0
Number should receive protection from 1 and 2	0	0	0	0	0	0
Number should receive protection from 1 and 3	0	0	0	0	0	0
Number should receive protection from 2 and 3	0	0	4880	4156	3432	2708
Number should receive protection from 1, 2 and 3	0	0	120	844	1568	2292
Patients of 1 that should not be treated	255	237	0	0	0	0
Patients of 2 that should not be treated	2559	0	0	0	0	0
Patients of 3 that should not be treated	450	450	0	0	0	0
Patients of 1 that should be treated	0	18	221	199	178	156
Patients of 2 that should be treated	1691	4250	1994	1958	1922	1885
Patients of 3 that should be treated	0	0	449	446	442	439

with this point. However, the notation becomes rather complex, in particular if attention is paid to the fact that different preventive measures have different periods of validity. For this reason, no attempt is made here to present the mathematical formulation of the model. Preliminary computational exercises are also excluded, because only

financial resources might not be sufficient to guarantee the availability of human and physical resources. The reason for this is that the model in II and III deals with only one of the many alternative uses for the human and physical resources considered. In fact, doctors, nurses, housing and clothing, and the resources needed to educate the personnel and to produce the physical goods have many uses. As a consequence, the assumption that those resources can be obtained at fixed prices might not hold.

In a general model, the process of educating the human resources and producing the physical ones would be endogenous to the model. The real capacity for education and production would determine their availability.

In conclusion, it is useful to observe that, except for the problems associated with the definition and evaluation of a social welfare function, the theory and the mathematics needed to construct a general socio-economic planning model are available at the present time. The initial efforts that have already been made will bear fruit in the near future.

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