The Application of Operational Research in Developing Countries

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INTRODUCTION

In the past century the developed countries have undergone two technological or industrial revolutions: the first involved mechanization (the use of machines to replace man as a source of physical work), and the second involved automation (the use of machines and computers to replace man as source of mental work, as source of control). Many developing countries are still in the early stages of the process of mechanization and have yet to make a real start in the process of automation. they will have to make rapid strides in both processes in order to bridge the gap between them and the developed countries, or even to prevent the gap from widening. Either of the two processes requires not only technological knowledge, but also managerial capability to utilize such knowledge effectively. For all developing countries the advent of planned development invariably entailed new tasks beyond the administrative capabilities of their governments. Only a few administrators in these countries have the opportunity to keep abreast of new Operational Research Techniques. This is certainly one of the main reasons why Operational Research has up to the present not been very successful in helping developing countries.

Problems concerning optimum allocation of scarce resources, rational use of the limited number of trained personnel (especially scientists and technologists), determination of areas of natural resources exploration, design of better systems of inventories and supplies, replacement and maintenance of public assets, effective sequencing and controlling of multiple construction activities, large-scale food distribution, effective coordination of transport and communications, satisfactory movement of mails, removal of traffic congestion in the cities, efficient use of port facilities, export promotion and marketing are some of the typical problems that are readily amenable to effective solution through the use of Operational Research. However, what is of utmost importance is the need of a large-scale development plan which will help an underdeveloped country's advancement by increasing real national income which in turn will improve the standard of living and decrease unemployment.

CAPITAL REQUIRED FOR DEVELOPMENT

Development of a nation depends mainly on the capital available for investment and how well the investments are made. The capital must come from external and/or internal sources. Usually external aid is not likely to provide all the capital required for development. Besides, in many cases, there is no adequate planning of the use of this aid money. For example the United States gave aid to Peru and made no restriction on the use of the money given with the result that the money was divided among the various activities and no activity received enough to solve its problems and become self-sufficient. Some of the activities had to be abandoned. The same happened in India and other countries. This shows that preliminary Operational Research studies can be exceedingly valuable on the uses of aid money. Internal aid, that is increased capital from within, can be accomplished by reducing the rate of increase of consumption, by increasing the rate of increase of production and by the intelligent allocation of the resources of the country.

Reduction of the rate of increase of consumption may require either a reduction of the rate of growth of the population or a reduction of per capita consumption. However, it is necessary to treat with scepticism the argument that "in order to create a surplus it is necessary to reduce consumption rate by a cut in the population increase". There obviously must be a reduction in the rate of growth of consumption but not by a cut in population. For the very fact that capital can be bought by raw material exports which are very labour-intensive, implies there is a surplus over the consumption. This means that labour creates more wealth than it consumes, assuming it is well employed. In the case where population control is necessary it has been found that the problem is very big and too many obstacles are in the way. In many over populated countries there is no social security and when a person gets too old to be able to go on working he would need financial support from his children and therefore children become an economic necessity. Apart from the work by Balakrishman and Camp[1], little has been done by operational researchers in this field. Operational Researchers have to work with behavioural scientists in order that a solution to this problem can be found.

The problem of economic development is essentially a question of how much the productivity of a country can be increased and what use of resources should be made. This question calls for an efficient development plan. Most of the work done by operational researchers in developing countries deals with such plans. Early work in this field has been carried out by Mahalanobis in the fifties and by Hanssmann, Bhende and Burton in the sixties.[2]

THE DEVELOPMENT PLAN

We shall see how mathematical models can be built for a development plan by considering the models by Bhende and Hanssmann.

Bhende presents a linear programming model (of moderate size) for project selection. The approach is to make a tentative goal for national income, translate it into the targets for each category of final commodity, and minimize the capital required to achieve these targets. Thus, two steps are taken: (i) determining the general rate of economic development the country seeks to attain, (ii) select the various key sectors which are of prime importance to the economy and which need government intervention. Then various departments should be asked to design projects for the expansion of these sectors. Close estimates of the input and output in a specific project should be prepared.

The objective function is:
"To minimize the total capital required for the Development Program", ie

$$\sum_{j=1}^{n} c_j y_j$$

subject to

$$\text{(a)} \quad \sum_{j=1}^{n} a_{ij} x_j + M_i - E_i \geqslant b_i \qquad (i = 1, 2, \ldots, m)$$

$$\text{(b)} \quad \sum_{j=1}^{n} a_{ej} x_j \leqslant L$$

$$\text{(c)} \quad \sum_{j=1}^{n} x_j f_j + \sum_{i=1}^{m} M_i m_i - \sum_{i=1}^{m} E_i e_i \leqslant D$$

$$\text{(d)} \quad x_j^p \leqslant 1$$

$$\text{(e)} \quad E_i \leqslant D_i$$

$$\text{(f)} \quad x_j, b_i, M_i, E_i \geqslant 0$$

where

c_j = the capital investment for the jth activity
x_j = the jth activity
a_{ij} = the amount of commodity i produced by the unit of jth activity
M_i = the amount of commodity i imported from the foreign market
E_i = the amount of commodity i exported to the foreign market

b_i = the projected future requirements of commodity i
a_{ej} = the amount of labour required for the jth activity
L = the total labour supply
x_j^p = the jth project activity which cannot exceed unity level
D_i = demand for commodity i in the foreign market
f_j = foreign exchange required for unit of jth activity
m_i = cost in foreign exchange for importing one unit of commodity i
e_i = revenue in foreign exchange earned by exporting one unity of commodity i
D = the exchange deficit permitted in the period considered.

An illustration of how the model can be used is given by Bhende: a problem with 25 constraints, 17 various projects, 5 import alternatives for some of the commodities, 6 export activities for some prospective commodities, 13 artificial variables and 25 basic variables was solved by the IBM FORTRAN 1620. Some recommendations for guiding the policies, as suggested by the solution are made. Sensitivity analysis is also taken into account.

In Hanssmann's approach a large-scale linear programming model is formulated, then a heuristic ranking procedure solution for the problem is given. Hanssmann proposes an approach that takes into account conflicting objectives, sequential decision making, and the coordination plan. The formulation of the program is an follows: each year projects are started. They are selected from a project list which is a collection of all proposed schemes worked out by the individual ministries. After the selection has been made, the ministries continue to work out new schemes so that next year's list consists of new projects and the old projects not previously started. The yearly project lists are assumed to be somewhat identical. These are obtained by a duplication of the characteristics of the presently available list. A planning horizon of, say, ten years is introduced; then a tentative ten-year plan is laid out by selecting projects from the ten identical lists. The first year's part of the total plan is implemented. One year later, the whole process is repeated, using the new master project list and a new planning horizon of ten years that is shifted by one year into the future. Restrictions are imposed to ensure economic, technological and social feasibility.

The problem is: what should be maximized when we have conflicting objectives such as national product, employment, education, health and housing. We use the efficient surface method: we choose to maximize one objective only, national product say, and keep all other objectives at fixed satisfactory levels of achievement. The procedure is repeated for different sets of fixed levels and the result is summarized in a list of efficient compromises (efficient surface) which is presented to the decision makers for selection of the fixed compromise.

For the mathematical formulation, let us suppose there are m projects to be considered for the next ten years.

Let Z_k = 1 if project k is selected.....(1)
0 otherwise

A development program may be described as a vector

$$(Z_1 \ldots, Z_k \ldots, Z_m)$$

where $Z_k = 0$ or 1. Let there be n commodities and services that are of interest for final consumption and for the requirement of the projects and let i = 1, 2, ...n designate the various categories.

Let h = 1, ..., L denotes conflicting objectives and let a_{hk} be the contribution of project k to objective h. Then the level of achievement of objective h will be

$$A_k = A_{h0} + \sum_k a_{hk} Z_k$$

In order to construct a point of the efficient surface, we prescribe fixed values V_h for say, all but the first objective

$$A_{h0} + \sum_k a_{hk} Z_k = V_h \qquad h = (2, 3, \ldots, L) \ \ldots(2)$$

The problem now reads

$$\max A_1 = A_{10} + \sum_k a_{1k} Z_k$$

with respect to the decision variables Z_k, subject to (1) and (2), and the economic, technological and social constraints (not given here symbolically) which ensure feasibility. Repeat the maximization for a number of vectors V_h in (2).

No attempt is made by Hanssmann to solve the problem by linear programming: the number of variables and restrictions is too large. However, an approximate method of solution is developed through the ranking approach.

IMPLENTATION STAGE

Unfortunately, the implementation stage of the results of a research project is rarely reached in the case of the developing countries. The usual dependency of the projects on the particular administrations which have supported them on the one hand and the very frequent change in political governments on the other, have as a result the interruption of many processes of development, one of which is the research process. This is what happened, for example, to a project by J.C. Papagiorgiou who tried to apply operational research in the

development of a new stock control and distribution system of fertilizers in Greece[3]. After a draft report was submitted to the administration of the Agricultural Bank of Greece which had supported the project, a political change came and the new administration being hostile to the old, adopted a hostile attitude to the projects of the old administration as well, and the results of this research project were never considered for implementation. In this way, this project, like so many others carried out in developing countries, had an unhappy end.

CONCLUSION

Experimentally, the Operational Research techniques have been used in national development planning in a number of countries including India, U.A.R. and Venezuela. However, many difficulties have been encountered. Amongst the many difficulties the following are most common:

(a.) in developing countries data necessary for mathematical models for planning are often inadequate or incorrect; the importance of good estimation has been emphasized by Bhende and Hanssmann in the formulation of their models,

(b.) in order to make certain models manageable, it is often necessary to make simplifying assumptions, some of which may be untested or incorrect,

(c.) the models themselves may be inadequate or incomplete and therefore are not suitable for indicating desirable courses of action,

(d.) the use of mathematical models in planning often leads to too much emphasis being given to quantitative (rather than qualitative) aspects of planning.

Besides these difficulties there are those regarding the integration of human, social and political factors in operational research models. such difficulties, expected as they are, should not foster a negative attitude to the potentialities of the operational research techniques. Difficulties are not impossibilities. The question is rather one of overcoming such difficulties. It is essential to identify those specific problems of developing countries that are particularly suitable for the use of operational research as well as to show how operational research can solve them better than the traditional techniques. A question often arises whether operational research is too sophisticated for the developing countries. But, then, the problems of these countries do require more than simple techniques. Thus there is the need to use operational research techniques more effectively in developing countries than in industrially advanced countries. It is with this in

mind that the United Nations has convened an interregional seminar on the use of operational research and modern management techniques in the public services of developing countries in October 1970 in Washington.

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NOTES:

1. Balakrishman and Camp (1965).
2. Mahalanobis (1965), Bhende (1964), Hanssmann (1961) and Burton (1969).
3. Papagiorgiou (1969).

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