OR Modeling and Public Policies in Bangladesh: Implementation Challenges

Shams Rahman
Logistics and Supply Chain Discipline, School of Management
RMIT University, Melbourne, Australia

Abstract

Over the last three decades a large number of Operations Research (OR) studies in the context of developing nations have been published. Many of these studies deal with public policy issues. Using OR case studies in the context of Bangladesh health and agriculture sectors, this study investigates the development process of these models and identifies the challenges for implementing the results of the models.

Keywords
Agriculture, Bangladesh, Health, OR Models, Implementation challenges.

1. Introduction
Operations research (OR) is little known in Bangladesh in either the academic or the business areas. However, some OR studies have been carried out in Bangladesh. However, there is a great concern about the ways in which OR models are developed and applied in Bangladesh. This study analysed a number of public policy related OR projects in the context of Bangladesh health and agriculture sectors which were modeled as linear programming (LP), non-LP to mixed-integer programming and combinatorial optimisation problem. It was found that the recommendations of many of these studies have not been implemented. This is not due to the lack of solutions, but is often the result of inadequate acceptance of some of these solutions. Allowing OR to serve those who take decisions may improve the chance of acceptance; however, it is no guarantee for implementation. The objective of the study is to assess the development processes of the OR studies and identify the challenges for implementation of the solutions of these studies.

2. OR Studies in Bangladesh Agriculture and Health
After an extensive literature search we have identified twelve OR studies which addressed the policy issues in the context of Bangladesh agriculture and health. Of these studies eleven studies belong to the agriculture sector and one belong to the health sector. Agriculture is the most important sector in Bangladesh; it is therefore not surprising that most of the studies are related to agriculture and agricultural development. These studies were published in the international and national journals.

2.1. Studies in the Agriculture sector
Studies in the agriculture sector have been classified into three broad categories. These are;

- Water management
- Food production, and
- Food grain distribution and storage.

A brief discussion on each category is given below.

a. Water Management
Four studies which belong to this category deal with water management issues such as net water requirement, investment policies in irrigation, long-term irrigation planning, and water resource planning.

i. Simulation study of crop water requirement
When natural sources of water, e.g. rains, together with the available soil moisture cannot meet the water requirement of crops, the difference can be met through irrigation. In this study Chowdhury, Huq and

Hassan [1] developed a simulation model to determine the level of irrigation required in different parts of Bangladesh over a planning period of one year. The model considered that the need for crop water would depend on the following parameters

1. Total rainfall.
2. Available soil moisture.
3. Evapotranspiration.
4. Percolation.

The parameters such as rainfall and available soil moisture can be considered as input and evapotranspiration and percolation as output of the system. Thus the amount of water required for crop during any time period will depend on the differences of input and output. The model is applied to a project area consisting of 18 Upazillas (as Upazila comprises an area of approximately 250-300 square kilometres) in Bangladesh. Using data on soil properties, rainfall, available soil moisture and considering ponding depth the model calculates the requirement of water for 13 different crops and cropping patterns cultivated in that project area and demonstrates the consequence of inadequate moisture on the crop yield.

The model was developed as a part of the study undertaken by the Master PIan Organisation, Ministry of Irrigation, Drainage and Flood Control, Government of Bangladesh.

ii. Evaluation of investment policies in irrigation

The study by Smith [2] reports on the experience of using several decision rules to evaluate investment requirements and economic returns in designing irrigation projects in Bangladesh. In some respect, the study is similar to the one discussed earlier (Chowdhury, et al. [1]), which is formulated as a linear program. In this case, however, a stochastic programming model is constructed.

The stochastic model has not been solved optimally. Instead, by applying chance-constrained programming, deterministic equivalents to the probabilistic water requirement constraints were derived and using decision rules good sub-optimal solutions to the problems were obtained. These decision rules are:

1. Zero-order rules.
2. Linear rules.
3. Piecewise linear rules.

The solution of the model using these rules produces two sets of decisions to optimise the benefits from an irrigation project. These are related to investment and operating decisions. The operating decision variables considered in the model are amount of groundwater pumped and delivered (removed) to (from) the project area, amount of stir-face water diverted from the river to the irrigation fields and area sown to crops. The chance-constrained programming model, using zero-order rules, executes the investment decision only. Operating decisions are considered to be invariant from year to year. In the case of linear and piecewise linear rules however, the model treats operating decisions as stochastic policies to be determined by the model solutions. The model was applied to an irrigation project in Bangladesh considering five different crops over six decision periods. The comparison of the solutions using different decision rules indicated that the investment decisions are not significantly affected. For example an adoption of the project configuration suggested by the two-piece rules would lead to a savings of about 1% in construction costs compared to the linear solutions. The savings are even less when the zero-order solution and the two-piece solution are compared. However, the model is useful for computing benefits for comparison with other projects.

iii. Simulation for irrigation planning

Chowdhury [3] reports on the experiences of using a micro-computer for simulating an optimisation problem which involved allocation of funds among alternative investment schemes in irrigation planning in Bangladesh. The problem is formulated as a linear programming model for a planning period of 20 years with constraints on the budget, availability of ground-water and sustainability of a particular irrigation scheme in the form of operation and maintenance costs. Its objective function maximizes the total benefit (in terms of increased yield) achievable by bringing non-irrigated land under different irrigation schemes. However, the model turned out to be a large one, involving 18000 decision variables and the LP was not solved directly. A simulation approach was used instead.

The result of the model showed the change in the land pattern under different development schemes and the related increase in the foodgrain production over a 20 year period. It demonstrated that development would cease after about 15 years which would indicate a saturation point in land development. The time period of 15 years could be changed by varying the budget constraint. These flexibilities give the model an ability to meet the short and long term targets of the country within the perspective of development.

iv. Water resource planning model

Shahabuddin [4] presents a land allocation model for use in water resources planning in general, and in analyzing water sector investment for agricultural development in particular. The model would serve as a tool for framework planning through screening and sequencing of alternative investment modes, and in identifying viable investment options in different regions. This LP-based model is meant to analyze alternative strategies for long term development of water resources in Bangladesh. In particular, the implications of alternative investment strategies underlying different projections are analysed in terms of their contributions in achieving foodgrain demand supply balance over the next twenty years.

b. Food Production

A total of five studies which belong to this category deal with food production issues such as food production under different constraints, production of crops in terms of nutrient contribution, optimal cropping pattern, new seed and income distribution, and planning for fisheries.

i. The Bangladesh agricultural model

The Centre for World Food Studies (CWFS) at the Free University of Amsterdam has constructed several simulation models for the analysis of food production and distribution in developing countries. The Bangladesh Agricultural Model (BAM) (Rebelo [5]) is one such model. By dividing the population into 10 groups depending on their occupation, land ownership status and residential location, the model essentially traces the effects of alternative policies on these socio-economic groups. The BAM is a complex model consisting of three main components supply, ex-change and agriculture. The model may be summarised as follows. In the supply part of the model, each of the 10 groups draw up their own production plans on the basis of several factors: price expectation, knowledge of technology and availability of land, labour, capital, livestock etc. These factors lead them to choose, out of wide range of production activities, the combination promising the best return to them.

At the end of the production process (which is assumed to take one year), all producers, i. e. each of the 10 groups, supply their commodities to the market. Here the suppliers are confronted with the demands of each socio-economic group and an interchange takes place. The government can intervene in this process through its financial and market policies. The interaction of supply, demand, external trade and government interventions results in to setting of prices for all commodities. These in turn determine incomes and their distribution, the purchasing power and the food intake of each socio-economic group. At the same time, these prices have an impact on the price expectations for the next year, which guide production plans. At the end of the exchange process, adjustments take place in the resources available to each group, thus setting the stage for the new production plans and for supplies to enter the market in the next year. The model has been applied in comparative static analyses of various issues: alternative levels of fertilizer subsidy, alternative policies on flexible food rationing (a type of national ration scheme directed towards the lower income socio-economic group), short run impact of trade liberalization measures and the stabilization of the Bangladesh jute market. The model has been used to support the preparation of the Third Five-Year Plan (1985-90) and the Perspective Plan (1985-2000) (Rebelo [5]).

ii. Nutrition model for Bangladesh

The Bangladesh Nutrition Model (Rahman and Clarke [6]) is a simple linear programming model which minimizes the cost of imports or maximizes the value of exports, under nutritional requirements. The decision variables considered are the type of crop or cropping pattern to be produced in different parts of the country. The model was applied at village and regional levels. Two villages, Shitalpur and Kulia-Durgapur of Khulna District were considered for the village level study. The country was divided into seven homogeneous regions for the regional level study. Taking into consideration the malnutrition situation in Bangladesh, three problems were considered.

1. The constraints were to satisfy the requirements of two dietary components: energy (calories) and protein. It was assumed that all arable lands, defined to be those that are used at any time of the year for cultivation, are available throughout the year.
2. Problem 1 was repeated with constraints on nutrients and vitamins.
3. In the final problem, the assumption that all arable lands are available throughout the year was released. Instead, it was assumed that inadequate irrigation and flood control technologies limit the amount of land available during winter and summer months to that currently being used.

It was evident from the results that both villages could achieve nutritional self-sufficiency if problem 1 and 2 are considered. In the case of problem 3 only Kulia-Durgapur could achieve self-sufficiency. It is however, interesting to note that the net value of exprots from Kulia-Durgapur is approximately equal in value to the net aid requirements in Shitalpur. This emphasises the distribution aspect of the nutritional problem. It indicates that acting together both the villages could achieve self-sufficiency even if only the existing land areas utilized in winter and summer season are available for cultivation. However, self-sufficiency for the regions can only be achieved with the current population level, provided there is full flood control and effective irrigation policies. This conclusion does not come as a surprise, since flood control and irrigation are the two most important factors affecting agricultural activities in Bangladesh.

iii. Cropping pattern selection

Clarke [7] discusses a case for crop rotation and diversification that is entirely unrelated to soil depletion, environmental or market uncertainty and factor-requirements-smoothing. Instead a case for crop rotation and/or crop diversification is established purely on the basis of the fact that crops take different periods to mature and have different yield properties when planted at different dates during a year. Thus through time we show it may be rational for farmers to diversify and rotate crops simply because such policies allow farmers to 'pack' the optimal sequence of crops onto land so as to maximize intertemporal returns.

iv. Determination of fisheries benefits

Mathematical optimization techniques have been in use for some time in the context of fisheries management problems. Several authors [8-13] have developed programming models for economic optimization of mixed fish stocks, multiple marketing strategies, allocation mechanisms or development strategies for fisheries. Ahmed [14] developed non-linear programming model to determine the benefits obtainable from the inland capture fisheries of Bangladesh. First a based model was developed and the functions and parameters of the base model were estimated by deriving non-linear catch-effort and cost functions as well as rice responsive demand functions using both primary and secondary data. Results of NLP (linear programming) solution of the base model suggest that the inland fisheries of Bangladesh are capable, under optimal conditions, of generating a total net benefit of Bangladesh Taka (BDT) 1383 million per annum (US$1= BDT38), most of which (96%) accrues as producer surplus. Under the optimal allocation of total fishing effort the model shows a 13% reduction in overall fish catch with 54% less effort. Sensitivity analysis, through variations of fishing effort, shows that the incorporated variables (e.g. catch, cost, benefit and shadow price) change in line with theoretical expectations. The implication of these results for management is that a reduction in effort would be required in order to generate a greater net economic benefit from the riverine fisheries. Such reduction should be specific to individual fishery and/ or fishing grounds.

v. Seed-fertilizer-water control

Smith [15] reports on a study which employed linear programming models to examine the objective conditions constraining farmer adoption of a new seed-fertilizer-water control technology in Bangladesh. Equal access to the technology and a static set of factor endowments are initially assumed. It is then demonstrated that realistic assumptions of differential access to inputs and a dynamic view of class formation processes illustrate the incompatibility of existing social relations and the new seeds.

c. Food Grain Distribution and Storage

Two studies belong to this category of agricultural activities deal with issues such as grain distribution and storage policies.

i. The Bangladesh grain model

In 1974-75 a team of Danish experts participated in a nation-wide logistics project which was initiated by the government of Bangladesh and funded by the World Bank. The purpose of the study was to recommend the solution-both technically and economically-to the country's grain supply and storage problems. The study resulted in an extensive report of five sections. The Bangladesh Grain Model is the third section of the report (Pruzan [16]). A large scale mixed integer programming model is used to define the number, size, and location of grain storage facilities in Bangladesh. It was possible to vary the assumptions regarding supply and demand of foodgrain and transportation and handling systems. The aim was to select Major Storage Facility (MSF) sites and a distribution system. It was formulated as a network flow problem. The grain is considered to flow from surplus areas and outer anchorage, if imported-through MSFs to deficit areas-and to outer anchorage, if exported. However, due to the size of the network (approximately 600 vertices and 6000 arcs) and the number of fixed cost elements (approximately 200), a single optimal solution was not identified. Instead a set of solutions (under different assumptions) was proposed. The model output suggested several recommendations with respect to the location of sites for MSFs and their capacity and the allocation of demand points to these MSFs. The major recommendations of the study were implemented in stages.

ii. Foodgrain import and storage policy

Berlage [17] reports on an OR study purpose of which is to demonstrate the use of stochastic dynamic programming models concerning import and storage policy. The model presented takes explicitly into account the stochastic character of foodgrain production and the imperfect substitutability of imported for domestically produced foodgrain. Furthermore, in contrast to one-period models they are based on the sequence of beginning stocks, import ordering, production, local procurement and releases from stocks, and beginning stocks in the following year. Stocks in these models are the result of the stochastic character of local rice production and of the fact that, to a large extent, imports have to be ordered before production is known. The working of the models was demonstrated for different growth rates of rice production.

2.2. Health Sector

Health delivery system development

Rahman and Smith [18] describe the problem of finding suitable sites for further health facilities in a rural area in Bangladesh. The objective is to improve accessibility of people to the health care system given the existing set of facilities. As is frequently the case in developing countries, the activities designed to develop and improve differing sectors of the infrastructure are often ill-coordinated and poorly integrated. As a result, decision-makers may make their own decisions about locating new service facilities. Often, as has been the case in Bangladesh, these decisions are taken at a relatively low level, by officers of local government or by elected leaders in a region, or by a combination of these. In the absence of any formal analysis and generation of alternatives, the final decision may be made on political or pragmatic considerations. As a result the decisions are very often far from optimal. This paper is concerned with decisions about where to site facilities which would improve access to health care. Ultimately, better health care will enhance many sectors of a regional economy, and so the decision about where to invest in new or better resources is important for reasons other than providing health of the population. In this paper, the role of location-allocation modeling in developing countries is considered, and the specific Bangladeshi problem is considered as a maximal covering location problem which is solved by an efficient heuristic method. A summary of these studies are given in Table 1 and Table 2.

Table 1: Category of studies and their sources

Study category	Authors	Source
Water Management	Chowdhury et al.[1] Sahabuddin [4] Smith [2] Chowdhury [3]	Journal of Management, Business and Economic The Bangladesh Development Studies Management Science
Food Production	Ahmed [14] Clarke [7] Rahman & Clarke [6] Rebelo [5] Smith [15]	Aquaculture and Fisheries Management European J. of Operational Research The Bangladesh Development Studies Journal of Operational Research Society The Journal of Development Studies
Distribution and Storage	Berlage [17] Pruzan [16]	The Bangladesh Economic Review European Journal of Operational Research
Health delivery system development	Rahman & Smith [18]	Journal of Operational Research Society

Table 2: Category of studies and the types of models

Study category	Authors	Type of Model
Water Management	Chowdhury et al.[1] Sahabuddin [4] Smith [2] Chowdhury [3]	LP – Linear Programming LP – Linear Programming Chance-constrained Programming
Food Production	Ahmed [14] Clarke [7] Rahman & Clarke [6] Rebelo [5] Smith [15]	NLP- Non- Linear Programming LP – Linear Programming LP – Linear Programming LP – Linear Programming LP – Linear Programming
Distribution and Storage	Berlage [17] Pruzan [16]	DP - Dynamic Programming MIP- Mixed Integer Programming
Health delivery system development	Rahman & Smith [8]	Combinatorial optimisation

3. Implementation Challenges

Bangladesh lacks basic communications and service facilities such as health and education in the rural areas where about 90% of its population live. Half the population has a deficient calorie intake and more than 80% are deficient in important nutrients. Over 60% of the population is illiterate. Enrollment in primary schools is 55-60% of age groups and dropout rates are high.

Industry is small in Bangladesh and contributes less than 15% to its GDP. Among industries jute, textile, paper and newsprint, sugar and fertilizers are important. Like the agricultural sector, the performance of the industrial sector is considered to be poor even compared to many less industrialised countries. This is due to inefficient production and poor quality management. The nation has a few proven mineral resources of which natural gas is the important. At present it is being used for power generation and in the fertilizer factories. Putting together these facts and figures, it is not difficult to identify some of the factors which affect the decision making process in Bangladesh. These factors are as follows

- Low levels of infrastructure.
- Shortage of financial resources.
- Shortage of skilled human resources.

Sagasti [19, p. 121] has noted that "the most important reason for promoting the use of management sciences in general and OR in particular, in under-developed countries, is that the general lack of resources, particularly human and financial, imposes the urgent need for using them more efficiently". Since Bangladesh is characterised by such a lack of resources, it will be evident that for Bangladesh optimal utilisation of available re-sources is an urgent necessity.

However, it was found that the recommendations of many of the OR models (discussed earlier) developed for addressing the public policies in Bangladesh have not been implemented. This is not due to the lack of solutions, but is often the result of inadequate acceptance of some of these solutions. Considering OR as (soft) technology, it has been suggested that for successful implementation, OR models must be appropriate to the local context, i.e.,

- Appropriate for the local people who will implement it,
- Close to the local culture where it will be implemented, and
- Relevant to the local issues.

It is important that more emphasis has to be given to the *people* and *culture* of the context while developing and implementing OR models. Thus, the following two necessary steps must be taken for implementation:

- The involvement of local analysts from the beginning by attachment to the OR project team, irrespective of whether or not the project was initiated locally. Here, *local* means familiar with culture and organisational setting of the project as well as the economy, education and geography of the region. The successful implementation and completion will depend on the knowledge and experience of such local people.

- Effective communication with local decision-makers to demonstrate the benefits of using the OR approach. Again *local* is used to indicate a wide familiarity with the context of the problem. The development of potentials of any decision, according to Moos and Dear [20], are to be evaluated by various groups in any society: politicians, influential individuals, bureaucrats and ordinary citizens. These groups form what they call 'the dialectic of control'. The amount of power commanded by these groups within the dialectic of control varies. In most developing economies the ordinary citizens possess no power in the decision making process. In the absence of any formal analysis, in this case OR modeling and generation of alternatives by the bureaucrats/ planners (decision makers), the final decisions are taken by the politicians and are generally far from optimal.

Both these steps are to be considered as an integral part of any OR project in a developing economy. Step 1 is necessary to allow for a successful transfer of every phase of the planning and the model for further use; step 2 is required for acceptance of the implementation and diffusion of OR ideas amongst planners in the society. Majority of the studies discussed in this paper have not followed these two steps.

Reference

1. Chowdhury, I. G, Huq, M and Hassan, A, 1988, "A simulation study of crop water requirement", Proceedings of the Bangladesh Economist Association Bi-annual Conference, 14-16 July, Dhaka.
2. Smith, D. V, 1973, "Decision rules in chance-constrained programming: some experimental comparison", Management Science, 19, 688-702.
3. Chowdhury, I. G, 1986, "A simulation model for micro-computer", Journal of Management, Business and Economics, 12, 262-270.
4. Shahabuddin, Q, 19, "The investment analysis model: an application to water resources planning in Bangladesh", The Bangladesh Development Studies, 15 (3), 63-81.
5. Rebelo, I, 1986, "Economy-Wide Models for Developing Countries, With Emphasis on Food Production and Distribution", Journal of Operational Research Society, 37 (2), 145-165.
6. Rahman, S and Clarke, H. R, 1991, "A Nutrition Model for Developing Nations with Special Reference to Bangladesh", The Bangladesh Development Studies, 19 (3), 83-98.
7. Clarke, H. R, 1989, "Combinatorial aspects of cropping pattern selection in agriculture", European Journal of Operational Research, 40, 70-77.
8. Quirk J.P. and Smith V.L., 1970, "Dynamic economic models of fishing". In Economics of Fisheries Management: Symposium (ed. by A. Scott), pp-3-32. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Canada.
9. Anderson L.G., 1975, "Analysis of commercial exploitation and maximum economic yield in biologically and technologically interdependent fisheries", Jour. Fisheries Research Board of Canada 32, 1825-1842.
10. Meuriot E. and Gates J.M., 1983, "Fishing allocations and optimal fees: a single and multilevel programming analysis", American Journal of Agricultural Economics, 65, 711-21.
11. Aguero M., 1983, A Bioeconomic conditional predictive trade model in fisheries: the hake fishery. Ph D Thesis, University of Rhode Island, Kingston, Rhode Island.
12. Logan P.N., 1984, Linear programming and bioeconomic modelling of an artisanal fishery. PhD Dissertation, University of Rhode Island, Kingston, Rhode Island.
13. Onal H., McCarl B.A., Griffin W.L., Matlock and Clark J., 1991, "A bioeconomic analysis of the Texas shrimp fishery and its optimal management", American Journal of Agricultural Economics, 73, 1161-70.
14. Ahmed, M, 1992, "Determination of fisheries benefits from floodplain riverine systems in Bangladesh: a mathematical programming approach", Aquaculture and Fisheries Management, 23, 599-622.
15. Smith, D. V, 1975, "New Seeds and Income Distribution in Bangladesh", The Journal of Development Studies, 11(2), 162-186.
16. Pruzan, P. M, 1978, "The Bangladesh grain model", European Jour. of Operational Research, 3, 110-121.
17. Berlage, L. J. J. B, 1973, "An Application of Dynamic Programming Models to Foodgrain Import and storage policy in Bangladesh", The Bangladesh Economic Review, 1, 4, 341-374.
18. Rahman, S and Smith, D, 1999, "Deployment of rural health facilities in a developing country", Journal of Operational Research Society,
19. Sagasti, F. R., 1972, "Management science in an underdeveloped country: the case of operations research in Peru", Management Science, 19, 121-131.