MODELLING AND OPTIMIZATION TECHNIQUES IN ACCORDANCE WITH THE INFORMATION REQUIREMENTS FOR SOCIO-ECONOMIC DEVELOPMENT

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ABSTRACT

The main objective of this paper is to attempt to indicate in what way concepts such as modelling, simulation, optimization, etc. can be applied as a tool in the design of policies for socio-economic development.

A model as a basis for the design of policies should be in accordance with the existing administrative, statistical, political and sociological infrastructures.
The objectives of the development should be reflected by the model.

Both the frequent unavailability of data of good quality, as well as the fact that policy and decision makers should have some insight in the structure of the model, ask for the application of simple methods.

As an illustration of the considerations as laid down in this paper, two case studies are presented.

INTEGRATED SURVEYS

In general, the stagnation of development in a particular area is caused by an intricate complex of problems. The identification and analysis of these problems need to be carried out in a coordinated and integrated way. The importance of integration in the study of natural resources for development purposes was emphasised during the Unesco Conference on "Principles and Methods of Integrating Aerial Survey Studies of Natural Resources for Potential Development" in Toulouse, France in 1964. In this conference it was recommended that survey team leaders and other experts should be trained in the concepts, methods, techniques and practical operation of integrated surveys of natural resources, together with economic and sociological aspects of the intended development.

In order to provide such training facilities, and to ensure the further development of efficient, comprehensive survey procedures, Unesco and the International Institute for Aerial Survey and Earth Sciences (ITC) in The Netherlands, decided to establish the ITC-Unesco Centre for Integrated Surveys. This Centre commenced its activities in 1965.

Although many different definitions of the term "integrated surveys" do exist, within the scope of this paper "integrated surveys" include:

(1) all activities related to the formulation of the survey objectives, survey tasks, and survey activities, and

(2) the subsequent collection, analysis, and interpretation of all kinds of relevant information needed for the (re)formulation of concrete action programmes (or their alternatives) for development purposes.

The objective of integrated surveys is to ensure that the interrelated (often monodisciplinary) survey activities are in accordance with the common survey goals.

A detailed examination of the concept of integrated surveys, as well as its relation to concepts like modelling, simulation, etc. is presented elsewhere (for example, see 1/, 2/, 3/).

FOR WHOM IS THE MODELLING AND OPTIMIZATION EXERCISE SET UP?

Within the context of this paper, applications of modelling and optimization are viewed in their relation to socio-economic development. Modelling and optimization techniques may be applied to the domain of socio-economic development as powerful tools in demonstrating the consequences of specific policy measures. One should keep in mind that these policy measures have to be proposed by policy and decision makers, and that they are, after all, responsible for the decision. Using the words of HALTER and MILLER 4/: "Our conclusion (...) was that computer simulation is a powerful tool to be used in the decision-making process, but that it is not a replacement for the decision maker".

Policy and decision makers are responsible for the implementation of certain policies for development. The environment in which they act is characterized by a set of political and administrative conditions, typical for developing countries. Although it is rather difficult to give one single definition of "a developing country", one may observe that most developing countries are characterized by mass poverty, malnutrition, diseases, illiteracy, bad housing, great unemployment, rural-urban migration, a mainly agricultural based economy, unbalanced income distribution, poor management in both the public and private sectors.

Within this scope, the objectives for development may be formulated, as Zambia's President Kaunda does 5/: "National development is meaningless if it does not develop each one of our four million people in the country". He summarizes the Zambian objectives as follows:

(a) Every individual should receive sufficient food both in quantity (no starvation) and in quality (no malnutrition).

(b) Every individual should have a decent two or three-room brick house.

(c) Every individual should have adequate clothing and footwear.

The President of the World Bank, McNAMARA, speaking about rural development, expressed his view as follows 6/: "Essential elements of any comprehensive programme are:
- acceleration in the rate of land and tenancy reform
- better access to credit
- assured availability of water
- expanded extension facilities backed by intensified agricultural research
- greater access to public services
- and most critical of all, new forms of rural institutions and organizations that will give as much attention to promoting the inherent potential and productivity of the poor as is generally given to protecting the power of the privileged".

He also said: "We intend to continue to invest in large projects but we will emphasize on-farm development incorporating a maximum of self-financing so that the benefits of irrigation can reach small farmers more quickly".

These quotations may serve as an illustration of the type of development objectives that are relevant to developing countries.

It is obvious that the performance (and the control) of the various development activities have to be made explicit in accordance with the foregoing-mentioned development objectives. HALTER and MILLER made use of the following performance measures in their study of the Venezuelan cattle industry 7/: discounted net cash flows on farm level, foreign exchange balances, farm income, net beef imports, and domestically produced nutrient outputs. ROSSMILLER, et al. used as performance measures for the Korean Agricultural Sector Analysis 8/: agriculture gross product, value added, per-capita incomes, per-capita calories and proteins, profit per hectare (by crop), profit per man/year (by crop), seasonal labour demand profits (by crop and total), exports and imports, agricultural production (by commodity and region), etc.

Moreover, it is extremely important to have some idea about the capital investment requirements (and its availability).

Furthermore, the performance measures should be in accordance, to some extent, with the statistical concepts as used by the policy and decision makers. Otherwise these measures become isolated variables.

In every society, regional or national, there exist specific administrative, political, and social infrastructures. Although these structures may be weak, it is very important that they are considered carefully when studying development possibilities.

APPLICATION OF MODELLING AND SIMULATION TO SOCIO-ECONOMIC DEVELOPMENT

From the foregoing, it is clear that modelling and simulation methods can be applied fruitfully to socio-economic development only if this application is made in close cooperation with the responsible policy and decision makers, and if it fits within the existing infrastructures. In addition, many methods of modelling, simulation, optimization, etc. make use of sophisticated procedures which can hardly be applied in situations where sufficient and reliable quantitative data are missing. It should be noted that in developing countries in particular, sufficient and reliable statistical data are often lacking. For example, time series, if available, are incomplete; different statistical concepts are used when describing the same phenomena.

The lack of data, however, should not lead to a "data hunger" for masses of unrelated data. SHAH suggests: before any data collection programme is started, it is very important to consider questions such as what the data are required for, and how they will be processed and used. What is the necessary format and to what accuracy are the data to be collected. 9/

Note that the application of systems analysis facilitates in first defining the important elements to be investigated and subsequently in evaluating the accuracy to which the data have to be collected. In addition to the problem of unavailability of data, experience shows that it is necessary to have local professional talent with the capability of applying modelling and simulation methods. Too often these studies are conducted by foreign experts and take place completely isolated from local professionals in the fields of modelling, simulation and optimization. Such studies easily stop if the experts leave. If an expert recommends the application of (sophisticated) methods and procedures, the training of local professionals, in order to enable them to use these procedures by themselves, should be kept in mind. Quoting MAJOR, when he speaks about the MIT-Argentina Project 10/: "The group of Argentine professionals is now fully capable of further developing and utilizing the system of models constructed for the case study, and of developing other sets of models for water resources planning programmes in Argentina. The effort of this aspect of the programme was to present the Argentine Government with a "living report". To facilitate the work of these men after their return to Argentina, all of the models developed for the case study were designed so that they can be run on computation equipment currently available in Buenos Aires."

DIFFERENT TYPES OF MODELS

Models can be classified in various ways. A specific classification depends on the purpose this classification has to serve. Some examples of classification are:

- according to the model "language"
  - verbal model
  - analogue model
  - mathematical model
  - scale model
  - graphical (visual) model
- according to the change of the object (system) with respect to time
  - static model
  - dynamic model.

CLARK suggests the classification of many models presented in the hydrological literature as follows 11/:

- four main classes
  1) stochastic-conceptual
  2) stochastic-empirical
  3) deterministic-conceptual
  4) deterministic-empirical
- any of these main classes may be sub-classified in several ways
  a) linear or non-linear in the systems-theory sense
  b) linear or non-linear in the statistical regression sense
  c) lumped or probability-distributed or geometrically distributed.

The distinction stochastic/deterministic is according to CHOW 12/: "When the probability of hydrologic data is ignored, the mathematical model is known as a deterministic model. When the hydrologic uncertainty is considered, the model is called a stochastic model." The distinction conceptual/empirical is according to whether the model is or is not suggested by consideration of the physical process acting upon the input variable(s) to produce the output variable(s). (The term "black-box" corresponds to "empirical").

THORBECKE 13/ presented a classification of agricultural sector-models. He recognizes five distinctive classes.

(1) Non-formal, general equilibrium-consistency models. This type of approach relies on a general equilibrium-consistency framework rather than on formal quantitative models. This approach is used, among others, by FAO for the Country Perspective Studies.

(2) Linear programming models. Examples are the "Colombia Agricultural Sector Analysis" by a USAID team and the "Agricultural Sector Analysis in Thailand" by Iowa State University.

(3) Micro dynamic recursive programming models. The term "micro" refers to the fact that this type of model is built from "the bottom up": the maximization procedure is at farm level. The dynamic elements are introduced through recursive programming. An example is the Punjab Region Analysis.

(4) Multilevel planning models. The main characteristic of these models is the formal linkage of the agricultural sector model upwards with an economy-wide model and downwards with agricultural district sub-models. An example is the Mexican CHAC model.

(5) Systems-science, simulation models. These models are basically simulation-type models. The results of changes in exogenous variables, policy instruments and technology can be simulated within the model. In that way a number of "development plans" can be generated. An example is the Korean Agricultural Sector Analysis by Michigan State University (ROSSMILLER et al.).

The main advantage of classifying examples of available models like THORBECKE does, is obviously the possibility to catalogue these examples in a systematic way. This enables development study teams to find easily examples applied on similar situations that they are themselves confronted with. In this respect, HEADY made a plea in the Bucharest Planning Seminar 1971 to develop a handbook on overall and sub-system models. 14/

In the same way, SHAH and the author put forward a recommendation to report case studies and examples of cases where the methodology and concepts of systems analysis, modelling and model validation, simulation, etc., were developed and adopted for situations where sufficient and reliable data are not available. 15/

The author wishes to add one type of model to this list. A variation of the non-formal, general equilibrium-consistency model is formed by the "model" of "back-of-the-envelope calculations". In fact, one could often feel satisfaction already if one is able to find just some orders of magnitude of the phenomena under investigation.

TO WHAT EXTENT CAN THE APPLICATION OF MODELLING AND OPTIMIZATION SERVE AS AN AID TO POLICY AND DECISION MAKERS,

In the previous sections the environment in which modelling and optimization techniques may be applied to socio-economic development has been described. Here, the application of modelling and optimization techniques as an aid to policy and decision makers is considered. Broadly speaking, there are two important aspects: a) the purpose it has to serve (viz. being an aid to specific users) and b) the availability of quantitative data of good quality. In particular with respect to developing countries, both aspects ask for the application of simple methods. It should be clear to the users of the results of this application how these results are obtained. They should have confidence in the results. This is the only way to understand what these results really mean. Insight into the structure of a model is very often directly useful for solving the problem.

Besides this, the model has to reflect the relevant policy instruments and political constraints. In this respect AHLUWALIA distinguishes six different "areas of intervention" open to governments in the implementation of development plans. 16/

1) Factor markets determine prices, utilization levels, and income of labour and capital.

2) Ownership and control of assets determine the distribution of personal income. Human capital in the form of skills is influenced by education.

3) Taxation of personal income and wealth operates on personal income as a fiscal corrective on market-determined income.

4) Provision of public consumption goods, or direct income transfers by the state, complement post-tax income distribution patterns and, jointly with taxation of personal income and wealth, determine the net fiscal impact on the distribution of personal income.

5) Commodity markets are closely linked to the equilibrium in the factor markets. The commodity composition of final demand obviously affects the pattern of demand for factors and therefore factor incomes. Conversely, the income distribution directly determines commodity demand through consumption patterns.

6) Less subject to government influence is the state of technology. This determines the level of total output and the degree of substitutability between factors.

The choice of intervention depends to a large extent on the choice of strategy. The choice of strategy, in turn, depends on the chosen aims of development. Obviously, the applied model should reflect goals, strategies and policy instruments, as are relevant to the specific case.

Often it is difficult, or even impossible, to make the goals (or targets), strategies and instrumental variables explicit in quantified terms. One should remember that in the process of socio-economic development, many non-rational phenomena (such as human and social behaviour) take place and change in relation to an accelerating world. If this is the case, it is rather dangerous to build one mathematical model describing the entire system, or to apply sophisticated optimization methods. One could far better try to split up the entire complex system into smaller (and simpler) sub-systems. And, instead of applying mathematically oriented optimization techniques in such cases, one could study the physical consequences of the system under pre-set assumptions and conditions. By changing these assumptions and conditions, different alternative consequences can be obtained and compared by the policy and decision makers.

In this respect it is relevant to mention a study undertaken by DE FIGUEIREDO and GABUS of the Batelle Institute, Geneva. 17/ They represent future developments as the result of two types of factors: trends and events. Trends are used in the normal sense, events include all phenomena (economic, social, political, technological, etc.) which do not fit a general trend, and whose occurence may be outside but have an effect on the system. These two components constitute an "integrated" model (as they call it). This integrated model uses two types of complementary information: (a) statistical information as used in a traditional econometric model in order to explain relations between trends, and (b) intuitive information based on experts' evaluation of the probability of important events for a given economic development.

By using this integrated model, simulations can be carried out which take into account the interrelation between events and trends.

TWO CASE STUDIES

In this section the foregoing considerations are illustrated by two case studies.

In April, 1974 a team of the ITC-Unesco Centre for Integrated Surveys undertook field investigations in one of the Gouvernorats of Northern Tunisia. In April, 1975 another team of the Centre undertook field investigations in one of the Gouvernorats of the Sahel region of Tunisia. In both cases the team consisted of staffmembers of the Centre, as well as participants of the Standard Course.

The 1974 Survey 18/

The region under investigation is one of the most important agricultural areas of the country. Tourism has developed rapidly over the past five years and continues to expand. The demand for water is anticipated to exceed the locally available water resources representing eventually a major constraint upon development.

The purpose of this reconnaissance survey was to collect basic quanitative and quantitative data for the formulation of development alternatives with emphasis on the optimization of water utilization in the context of a regional development plan.

The survey included:

1) Evaluation of the present agricultural practices and scope for future development of rainfed and irrigated agriculture, livestock, forestry, and fisheries, in view of physical, technical and socio-economic constraints.
2) Evaluation of the present situation and scope for further development of tourism in view of physical, technical and socio-economic constraints and its impact on urbanization.
3) Evaluation of present and future surface and ground water resources, and the possibility of maintaining the present level of development and the scope of further development, eventually in conjunction with other sources of water supply.

From the beginning, it was clear that no sophisticated mathematical procedure could be applied in order to define the optimal water use within the gouvernorat. At least at that phase of the survey, no objective function could be expressed in mathematical terms and essential data were missing. However, several policy measures open to the decision makers for implementation could be fairly accurately described in a quantitative way. For instance, the area of certain types of soils under cultivation of specific crops. The consequences of such policies were described in terms of employment opportunities.

According to the classification set up by THORBECKE, the type of model that was applied could be called a "non-formal, general equilibrium-consistency model" (modified to the "back-of-the-envelope" method).

Through a comparison with the projected development of the labour supply and taking into account the labour requirements in tourism and services, indications could be obtained about the relevance of certain alternative policies of agricultural development. As the limit of the time horizon, the year 1986 was agreed upon. For the analysis and interpretation of the collected data, the gouvernorat was subdivided into four regions.

With respect to agriculture, three different types of resources were relevant in that phase of the survey: land, water, and human resources.

a) Land resources. The soils of the area were subdivided into a number (6) of classes according to their agricultural capabilities. The total acreage per soil capability class was measured.

b) Water resources. The amount of available surface and ground water was obtained with a high and a low estimate. The domestic water use for 1986 was anticipated. Subsequently the available water resources for agriculture could be estimated.

c) Human resources. For the year 1986 the total labour force was estimated. For the same year the employment in tourism was estimated with a high and a low estimate. Subsequently estimations for the residual to be employed in agriculture, services, transport and communications, industry and mines could be obtained.

Besides the information on the available resources, some characteristics of cultivated crops were known. For example, the required labour and irrigation water inputs per hectare, per year, and to what soil capability class the crop is restricted.

Based on the above-mentioned data, the consequences of some policy measures were calculated. In this specific case, some extreme policy goals were selected: maximum employment in agriculture, maximum citrus cultivation, minimum water use with maximum employment in rainfed agriculture, and minimum water use with maximum vineyards. For each of these policy goals the employment consequences were calculated.

The 1975 Survey 19/

The area of the 1975 survey is one of the most developed regions of Tunisia. Agriculture, tourism, industry, and services are the main economic activities.

The purpose of the survey was to identify, based on the investigation of land, water and human resources, various development alternatives and to determine their consequences, with emphasis on the employment situation to be expected by 1986.

The survey included:

1) Evaluation of available data of land and water resources in the survey area, which are relevant to development.

2) Analysis of the present state of agriculture and scope for agricultural development based on the present and possible future land and water resources.

3) Analysis of the actual situation of some second and third order "(sub)urban centres", and the identification of possibilities for promoting these centres in relation to agricultural and regional development potential.

4) Analysis of the present and projected social and economic situation in the principal sectors of economic activity with emphasis on the employment situation.

5) Analysis of alternative use of resources, in particular land and water, within the principal sectors of economic activity and the impact of employment.

As relevant to the scope of this paper, the format of the collected data was almost the same as in the case of the 1974 survey. The model that was applied in this case was, according to the classification set up by THORBECKE, a combination of the "non-formal, general equilibrium-consistency model" (modified to the "back-of-the-envelope" method) and the "linear programming model". The latter approach was selected because it was to be expected that the relevant policy goals were of the maximization type.

The linear programming problem may be represented in the following manner.

The objective function

$$\text{maximize} \qquad Z = C_1X_1 + C_2X_2 + \dots + C_nX_n$$

is subject to a set of constraints.

$$A_{i1}X_1 + A_{i2}X_2 + \dots + A_{in}X_n \leqslant B_i \qquad (i = 1, 2, \dots k)$$

$$A_{p1}X_1 + A_{p2}X_2 + \dots A_{pn}X_n = B_p \qquad (p = k + 1, K + 2, \dots, m)$$

$$X_j \geqslant o \qquad (j = 1, 2, \dots, n)$$

In this particular case, two different policy objectives were considered: maximum employment and maximum total gross value added. Therefore, Z can represent either the total employment or the total gross value added.

X_j $(j = 1, 2, \dots, n)$ are the activities. Both the (8) industrial activities as the touristic activity are defined in terms of creating gross value added in addition to the present situation. The agricultural activities are defined in terms of the amount of hectares under a specific number (8) of crops.

C_j ($j = 1, 2, \ldots, n$) are the value coefficients. In fact, there is a specific set of value coefficients in case of employment maximization and another one in case of gross value added maximization.

B_i ($i = 1, 2, \ldots, k$) are the constraints referring to the water, recycled water, and land resources.

B_p ($p = k + 1, k + 2, \ldots, m$) are constraints in the sense that the present levels of certain activities have to be maintained.

A_{ij} ($i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$) are coefficients relating to the activities and the constraints.

Some Comments on the 1974 Survey and the 1975 Survey

In both cases, before any attempt could be made at optimization, the reliability of the collected data was checked by a non-formal, general equilibrium-consistency approach. The data base as obtained in this way forms a tool in showing policy and decision makers easily some consequences of policy measures proposed by them.

In the 1975 survey an attempt was made to consider also the spatial consequences of proposed policy measures. It is felt at the ITC-Unesco Centre that much more research has to be devoted to this aspect.

Furthermore, it is felt with respect to both surveys, that information about the capital investment requirements and the possibilities to meet these requirements was almost lacking. (Likely this is mainly due to the short time the team was really on the spot).

CONCLUSION

The application of modelling and optimization techniques can serve as an aid to policy and decision makers, both in understanding better the existing situation as well as in selecting policies for development.

In the process of modelling and optimization, the policy and decision makers should play an active role. They are, after all, responsible for the ultimate policies for development. Technical specialists should avoid smuggling in their own subjective values under the slogan of scientific knowledge.

The model should reflect the existing relevant policy instruments and political conditions in which the policy and decision makers act. The model and optimization procedures should also be in agreement with the quality (reliability) of the available statistical data.

These considerations often may lead to the application of simple methods. Simple methods does not have a great scientific appeal. However, these simple methods may contribute to the solution of the urgent problems much more than the bulk of cases do where highly sophisticated methods and procedures are applied.

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REFERENCES

1/ BAKKER A.J. — Trends and Developments in Integrated Surveys, Proceedings of the 5th International Seminar, March, 1971 Publication of the ITC-Unesco Centre for Integrated Surveys.

2/ SCHULZE F.E. — Integrated Surveys and Development Planning. ITC Journal 1973, No.2 (Special Issue)

3/ de MAN W.H. — Integrated Surveys of Land and Water Resources for Development Purposes, Proceedings of the First IFIP Working Conference on Computer Simulation of Water Resources, Ghent, 1974. North Holland Publishing Company, 1975.

4/ HALTER A.N. & MILLER S.F. — Simulation in a Practical Policy-Making Setting: The Venezuelan Cattle Industry, Systems Approaches to Developing Countries, IFAC-IFORS Conference, Algiers, 1973.

5/ de GAAY FORTMAN B. — Rural Development in an Age of Survival, Occasional Paper No.21, Institute of Social Studies, The Hague, 1972.

6/ McNAMARA R. — President of the World Bank's Address to the Board of Governors 1973 Meeting, Nairobi.

7/ HALTER A.N. & MILLER S.F. — ibid

8/ ROSSMILLER G.E. et al. — Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985. Seoul and East Lansing, 1972.

9/ SHAH M.M. — Systems Engineering Approach to Agricultural and Rural Development Systems, Proceedings of the First IFIP Working Conference on Computer Simulation of Water Resources Systems, Ghent 1974. North Holland Publishing Company, 1975.

10/ MAJOR D.C. Investment Criteria and Mathematical Modelling Techniques for Water Resources Planning in Argentina: The MIT-Argentina Project, Systems Approaches to Developing Countries, IFAC-IFORS Conference, Algiers, 1973.

11/ CLARKE R.T. Mathematical Models in Hydrology. Irrigation and Drainage Paper No.19, F.A.O. Rome, 1973.

12/ CHOW V.T. ed. Handbook of Applied Hydrology. McGraw-Hill Book Company, 1964.

13/ THORBECKE E. Sector Analysis and Models for Agriculture in Developing Countries. Food Research Institute Studies in Agricultural Economic, Trade and Development, Vol. XII No.1, 1973.

14/ Planning Methodology Seminar, Bucharest, 1971. Irrigation and Drainage Paper No.11, F.A.O. Rome, 1972.

15/ SHAH M.M. & de Man W.H. Proceedings of the First IFIP Working Conference on Computer Simulation of Water Resources Systems, Ghent, 1974. North Holland Publishing Company, 1975.

16/ AHLUWALIA M.S. et al. Redistribution with Growth, A Joint Study by the World Bank Development Research Centre and the Institute of Development Studies at the University of Sussex. Oxford University Press, 1974.

17/ de FIGUEIREDO J.B. & GABUS A. Why and How to Introduce the Event Dimension into the Simulation of Development Policies Systems Approaches to Developing Countries, IFAC-IFORS Conference, Algiers, 1973.

18/, 19/ The Fieldwork Reports are unpublished internal documents of the ITC-Unesco Centre for Integrated Surveys.