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9. ABSTRACT

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SECTOR ANALYSIS AND THE GENERAL SYSTEM SIMULATION APPROACH TO AGRICULTURAL DEVELOPMENT PLANNING

by

Michael H. Abkin and George E. Rossmiller[1/]

Planning is now recognized as a necessary and legitimate activity of governments throughout the world. Even in the United States where only a few short years ago "planning" was considered a dirty word (and in some quarters, still is), governments at all levels are finding it increasingly necessary to engage in planning activities. Thus, we are not here to argue the merits or faults of governmental planning. Rather, we will accept the fact that planning activities will continue and probably will become increasingly important functions of governments. Once governments recognize the need for and validity of the planning function, they should strive for excellence in carrying out that function. Once the commitment to planning is made, then necessary resources should be made available, the necessary institutional framework developed, and the necessary coordination provided to insure well conceived plans and successful results. The approach and planning tool we are suggesting here is presented in the context of agricultural development planning, but it is completely generalizable to other sectors of the economy and other aspects of the social system.

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In this paper, we first discuss briefly the decision-making process itself, the inherent uncertainty of the information it requires and its universal use of models. We then describe sector analysis and general system simulation as an approach to agricultural development planning, looking at the Korean project as a case study. Finally, we look at some of the advantages, costs, requirements and limitations of the approach.

Uncertainty and Modeling in the Decision-Making Process

The Decision-Making Process

Since a broad objective of governmental planning is to solve immediate problems, to avert contemplated future problems, and to confront issues which if left unattended may become problems, it will be instructive for us to take a look at the process by which decision makers go about solving problems or confronting issues. A schematic diagram of such a decision-making process is presented as Figure 1.

The first steps in any decision-making process is the recognition that a problem or issue exists and then the definition of the problem or issue in terms allowing for observation and analysis. The analysis applies collected data and information to determine the probable consequences of alternative courses of action toward solution of the problem or issue as defined. On the basis of such analysis, a decision is made upon the course of action which will be followed. Once action is undertaken, the decision maker must stand ready to accept the responsibility for the consequences brought about by the action. The process is continuous and iterative in that the results of the decisions and actions must be constantly evaluated, issues redefined, observations extended, analysis reappraised and decisions and actions

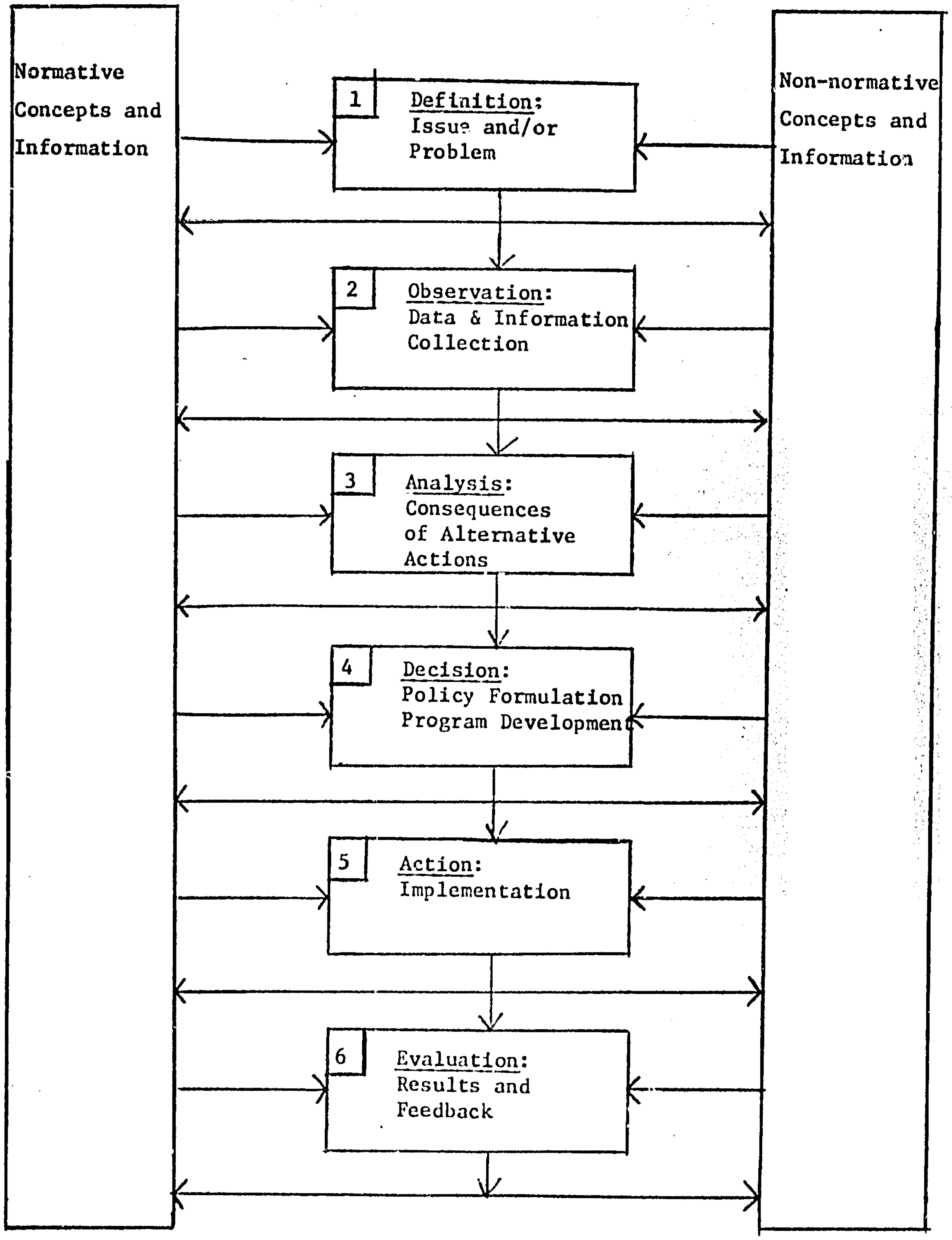

Figure 1. The decision-making process.

adjusted accordingly in the light of new experience, new knowledge, and changing conditions.

Knowledge and Uncertainty

Throughout the decision-making process, both normative and non-normative knowledge must be collected and used. Normative knowledge pertains to the goodness or badness of a condition, situation, or thing. Normative concepts are necessary to define a society's values--"what ought to be" or "what ought not to be"--and thus indicate what kinds of non-normative information is important and should be observed and analyzed. Non-normative knowledge is information about a condition, situation, or thing not pertaining to its goodness or badness; that is, knowledge about "what is," "what has been," or "what will be." It is important to note that our use of the term non-normative does not imply the positivistic notion that normative facts and experiences do not exist. Thus, non-normative knowledge can be acquired about normative concepts.

In the study of the Korean agricultural sector, for example, a considerable amount of time was spent in acquiring normative knowledge about Korean agriculture and its environment and a whole chapter of the project's report (Rossmiller, et al., 1972), entitled "Values and Public Choices for Korean Agriculture," was devoted to a discussion of these findings. (See also Johnson and Zerby, 1972.) This normative knowledge was acquired through continuous and substantive interaction with Republic of Korea (ROK) decision makers at various levels and in various agencies as well as through a thorough review of existing policies and programs, including how they were operationalized and administered.

The analysis of three alternative agricultural sector development strategies and the recommended development strategy found in the Korean sector study are based on a synthesis of the normative knowledge with the non-normative knowledge gained during the study. The non-normative knowledge pertains to the future demands on the sector--an inventory of resources available, institutional and physical constraints, and the economic and sociopolitical environment within which the agricultural sector functions. Thus, it is clear in our point of view that normative knowledge and non-normative knowledge are the two supports upon which the decision-making process rests, the absence of either of which causes the process to fail.

In general, planning for social and economic development, like any planning for the future, is a process fraught with uncertainty. Two kinds of knowledge are necessary in the development planning process: (1) knowledge about the current normative and non-normative state of the socioeconomic system, and (2) knowledge about how that system will respond normatively and non-normatively in the future to alternative government policy instruments (we might call them controls on the socioeconomic system) and other external stimuli. We may safely say that, necessary as they are to the planning process, we will never have perfect knowledge of either kind. Having to settle for less than perfect knowledge means we have to deal with uncertainty--state uncertainty relative to the first kind of knowledge and process uncertainty (how the socioeconomic system behaves as an evolving complex process) relative to the second.

Models Used in Decision Making

In spite of the uncertainty inherent in the process, policy makers responsible for social and economic development have to make decisions (even no decision is a decision to do nothing), and in making those decisions they need as much information (imperfect as it may be) as they can get concerning the possible future consequences of alternative courses of action.

In arriving at a decision for action (Steps 4 and 5 in Figure 1), the decision maker must put the relevant data and information he has collected (Step 2 in Figure 1) into a logic framework from which, through analysis, inferences can be drawn as to the important consequences of alternative courses of action (Step 3 in Figure 1). This logic framework--no matter how simple or complex, informal or formal--can be regarded as a model. In projecting consequences of alternative courses of action, models are used almost universally since experimentation directly on the system may be too costly, too dangerous or physically impossible. These models typically range from intuitive mental images of the system to written verbal descriptions to complex computerized mathematical models, and more than one type of model may be used to provide information for any one decision. For example, a computerized mathematical model may be used to make projections of economic variables, while projections of political variables may be made with a mental model.

Government decision makers have traditionally made decisions and solved problems based upon analysis using informal model conceptualizations, making projections with intuitive mental constructs or simple paper-and-pencil calculations. The governmental decision maker with such informal models uses data and information from a variety of sources including opinion and judgment of knowledgeable men and is usually concerned about the attainment of multiple desirable consequences and the avoidance of multiple undesirable consequences.

A model of whatever kind is an abstract representation of a system, socioeconomic or otherwise. It is abstract because it is not, and cannot be, the same as reality. Given the intended purpose for which the model will be used, only characteristics of the system relevant to that purpose will be modeled, and even these characteristics will only be modeled to the level of detail sufficient for that same purpose. Thus, assumptions and simplifications--what to put in the model, what to leave out, what to aggregate and how much to aggregate--are a necessary and inescapable part of modeling whether we are referring to a mental image or to a computer program. In some cases the validity of such assumptions may be checked empirically. Ultimately, however, it is the decision maker's own subjective evaluation of the assumptions', and hence the model's, validity which must be used in interpreting the information received from the model or models he is using. Using a model, i.e., an abstraction of reality, to project time paths of variables is called simulation, and models of any kind--mental, verbal or mathematical--designed and used to make such projections are simulation models.

As the need for more complex and sophisticated economic analysis became evident to governmental decision makers, professional economists began building more complex models of reality based upon economic theory and using mathematical and econometric representations of relationships to formalize the logic framework. Complex model building and mathematical representation became much more feasible as electronic computers arrived on the scene with the ability to perform extremely rapid calculations and to keep track of literally hundreds of variables and their interrelationships.

Mathematical models, where feasible, have many advantages over other kinds of models. The feasibility of mathematical models depends upon whether variables are quantifiable or can be qualitatively classified and whether structural relations among variables can be stated explicitly. Mathematical models of economic subsystems of socioeconomic systems are being used in research and planning in private industry and in government, while intuitive and verbal models are still pretty much the rule for analysis of social and political subsystems. Economic models are feasible because most economic variables are quantifiable and there is a sufficiently advanced body of theory and recorded data such that economic structural relations can be postulated in many cases. The qualifiers "most" and "in many cases" are necessary because there are still gaps in economic theory, particularly where it overlaps with social phenomena such as rural-urban migration and decisions of the farm unit as both producing firm and consuming household.

The advantages and disadvantages of using mathematical models, simulation or otherwise, depend somewhat on the particular kinds of models considered. Mathematical models in general, however, have some advantages over nonmathematical models. First, the language of mathematics is a precise language. That is, once known, there are no problems of semantics, i.e., no questions of connotations versus denotations, no euphemisms, no double entendres, no diplomacy. It is also a universal language; it can be understood by someone whose native tongue is English, Spanish, Yoruba, Urdu, or Korean. Another advantage is that in building a mathematical model all assumptions are automatically and necessarily made explicit. There is no question of hidden implicit assumptions or predispositions clouding the interpretation of information given by the model. Although the modeler himself may not always be aware of the assumptions he is making, nevertheless, once made, those assumptions are out in the open for all to see, evaluate and criticize. Furthermore, because assumptions are explicit--e.g., assumptions as to structure, aggregation, variables included and excluded, and data--the model may easily be modified to reflect different assumptions and to show their implications. Finally, whereas with mental or verbal models it is very difficult to project the consequences of a large number of assumptions about a complex system, mathematical models show all the logical implications, direct and indirect, flowing from the assumptions.

Specific kinds of mathematical models using specific techniques have their own relative advantages and disadvantages. For example, programming models are able to determine for the decision maker the choice of actions which will optimize the attainment of a given objective subject to constraints. The disadvantages of this technique are that it assumes there is only one objective or that all objectives (e.g., GNP growth rates, income, literacy, political stability, income distribution) can be reduced to a single interpersonally valid common denominator; the objective function and constraint equations are either linear or nonlinear in one of a few certain forms; and large-scale models of whole economies are generally too costly to use extensively, even on modern high-speed computers. On the micro level, e.g., a farmer or other decision-making unit, such models may have a place (Day and Singh, 1971; deHaen and Lee, 1972) since a single objective or combination of objectives may reasonably be assumed and interpersonal validity is not a problem. If a region is being modeled rather than a single farm, however, aggregation problems may become troublesome. On the macro level, on the other hand, e.g., a model of an economy to optimize development objectives over time, these problems preclude the use of programming techniques. The difficulties of finding an optimal policy with such a macro programming model mean planners and policy makers need, as an alternative, models which will project the consequences of alternative courses of action (i.e., simulation models) and which leave it up to the decision makers to subjectively and politically decide the "optimal" course.

Another specialized technique, one often used to perform policy simulations, employs econometric models, i.e., statistically estimated systems of simultaneous equilibrium equations (Naylor, 1970). The advantage of this kind of model is that it is derived directly from observed and recorded time series and cross section data on past performance of the system (economy, etc.). Therefore, it is said to be a good representation of the system by "explaining" observed system behavior. These advantages are also the technique's disadvantages. First, time series and cross section data, especially in developing countries, are either scarce, poor or non-existent. The question may be asked of a model based solely on such data, what real-world system does it represent? Secondly, statistical estimation procedures place strict requirements on the form of structural equations--specifically that they be linear in the parameters--even if theory or our own knowledge tells us another form would be more accurate. Finally, a model which may be a fair representation of a system in the past will not necessarily be so in the future, particularly in the case of developing economies where the system itself is changing.

There are other specialized techniques--e.g., input-output analysis, cost-benefit analysis, etc.--which we won't discuss here but which, like econometric models and programming models, are applicable only for particular purposes and only in special circumstances, e.g., where good data exists or where an objective function can be defined or where a particular structural form (linear, quadratic, etc.) is justified. In addition, while these models are mathematically rigorous and can be statistically verified and validated, they are very selective of the sources and types of data they will accept, whereas decision makers themselves may rely on a wide variety of data sources ranging from carefully controlled experiments to guesstimates. Furthermore, these models cannot provide decision makers with answers concerning the wide array of consequences to be expected from a specific course of action, nor can they easily be adapted to an assessment of the consequences of several alternative courses of action, particularly if simultaneous changes in several policies and programs are involved. Thus, a credibility gap has developed between many governmental decision makers and their professional economic analysts with respect to the usefulness of these kinds of models.

Sector Analysis and the General System Simulation Approach (GSSA)

Recently, agricultural planners and development economic analysts, in searching for new and better methods of attacking the problems of agricultural development, have turned toward what has become known as the sector analysis approach. This is attributable partially to the credibility gap discussed above and partially to the increasing recognition that the problem of agricultural sector development is comprised of literally thousands of separate, but interrelated problems. In the case of the Korean agricultural sector, for example, population and rising urban incomes are pressing against limited agricultural resources and the ability of traditional agriculture to increase and adapt food production to the demands. Food prices are high while farm incomes are low. Scarce foreign exchange is increasingly being used for the importation of food stuffs. More animal proteins are needed in the diet. Labor is rapidly moving out of agriculture as the rural-to-urban exodus quickens. Agricultural credit is in short supply and costly. Income distribution is a problem within agriculture, within the urban sector, between sectors, and among regions. Administrative and institutional problems in the agricultural establishment constrain the capacity of government to deal effectively with the problems of agricultural sector development. The list could go on and on, but it is already long enough to illustrate the point that the problems are complex and interrelated, and courses of action toward the solution of one is certain to create both desirable and undesirable consequences on many others.

In solving the problems of agricultural economic development, therefore, a broad perspective and a generalized analysis is required. A formal conceptualization (e.g., a mathematical model) which takes account of the problems and interrelationships of the total agricultural sector and its interactions with the rest of the economy is thus both a necessary and a fruitful undertaking for agricultural planners and their economic analysts.

Sector Studies

It is probably true that the terminology followed the deed in the case of many "sector studies." Conversely, since the term has come into vogue, it has in some instances been applied rather loosely to studies which must be considered, at best, poor representations of the sector analysis approach. Michigan State University has been involved in a number of studies which when viewed with hindsight can be classified as following the sector approach. Recent examples include a USDA contract project dealing with the projection of supply and demand responses of the grain-livestock economies and the trade prospects of the six countries comprising the European Economic Community under the Common Agricultural Policy (Epp, 1968; Mangum, 1968; Petit, 1968; Rossmiller, 1967; Sorenson and Hathaway, 1968); the USDA contract project analyzing the supply, demand, price, and trade consequences of entry of the EFTA countries into the EEC (Ferris, 1971); and the USAID sponsored project in Nigeria carried out by the Consortium for the Study of Nigerian Rural Development (CSNRD) (Johnson, et al., 1969).

While these studies clearly had different objectives and were focused on different kinds of issues, several common threads tie them together. First, they were all broad in their scope of analysis and general with respect to techniques and kinds of data and information used. Second, they traced the consequences of specific decisions and policies over time, thus following the simulation approach. Third, since each study viewed the subject matter with which it dealt as a system comprised of subsystems and itself as a subsystem of a larger system, each can also be viewed as employing the systems approach. Therefore, the logic framework used in all of these studies can be classified as a general systems simulation approach created for the specific analytical task at hand. They were all done with verbal and paper-and-pencil models, although computers were used as an aid in analyzing portions of the problems, and the end objective in terms of output was a published report detailing the analysis, findings, conclusions, and appropriate recommendations.

In all cases, the studies accomplished their objectives and were useful to varying degrees to decision makers in terms of the analysis they provided for input into the decision-making process. They all, however, had one major common limitation: they were most useful only at the time they were just completed. As the economic and social variables changed, as the environment changed, and as new knowledge became available, these studies--in report form and relying on informal verbal and paper-and-pencil models--quickly became dated and their usefulness diminished. As a result, reports of this kind, no matter how useful upon completion, have a relatively short shelf life.

With the development of high-speed electronic computers of large capacity and of software components adaptable to economic and social science research, it was a natural step to look toward this new technology as a more economic and efficient tool than those formerly employed in carrying out a general systems simulation type study. In particular, the use of a computer model enables the postulation of, and the projection of the consequences of, many more variables and complex relationships than are possible with informal paper-and-pencil or verbal models. Combining the computer with the methodology and orientation of the general systems simulation approach (GSSA) and with the conceptualization of problems within a sector framework, we come to the idea of a formal computerized general systems simulation model of an agricultural sector to address the many problems of economic development. Such a model can be a valuable analytical tool in helping decision makers in their planning, policy formulation and program development activities as they go about their business of solving problems. Furthermore, the shelf life of this type of work can be virtually indefinite since computerized models continue to exist to be updated, modified and used for policy analysis even after the initial effort and report have been completed.

Michigan State University has been involved in two projects applying this concept. After the CSNRD activities had been completed in Nigeria, MSU under contract with AID turned toward the question of the feasibility of building such a model of the Nigerian agricultural sector which would be capable of assessing the consequences of a multitude of policy alternatives and which could continually be updated with new data, information, and knowledge as they became available. Thus, the model could be used on a continuing basis as a valuable tool for analysis by decision makers (Manetsch, et al., 1971). Nigeria was chosen for this attempt primarily because of the wealth of data and information available from the CSNRD project. The charge was strictly developmental in terms of the methodology; operationalization of the model for actual use by decision makers would not be an objective until the developmental work had shown promise for the feasibility of so applying the methodology.

The second project, the Korean Agricultural Sector Study (KASS), built upon the Nigerian experiences and went beyond to actual policy application and implementation of the methodology. Before continuing with the general discussion of GSSA, let's look at the Korean experience as a case study.

The KASS Experience

Korea made a commitment to governmental planning in 1962 with the drafting of the First Five-Year Plan. The First and Second Five-Year Plans, covering the period 1962 through 1971, concentrated primarily upon the social infrastructure and basic and export industry. During this period, development in the agricultural sector was relatively slow because of the high priority assigned to the industrial sector by government decision makers. By the time it was necessary to begin drafting the Third Five-Year Plan, it had become evident that the decision to place the agricultural sector at a relatively low priority for development had created a lag relative to the rest of the economy which would require substantial attention during the plan period, 1972 to 1976.

As government planners and policy makers in the Ministry of Agriculture and Forestry, in the Economic Planning Board and on the Presidential staff wrestled with the problems of planning agricultural development in the relatively short five-year time frame of the plan, they found their planning judgments severely constrained by a lack of reliable data and inadequate economic analysis. Equally as disturbing, they had no comprehensive economic model or logic framework for projecting the consequences of their planning and policy decisions. The need for a comprehensive agricultural sector analysis was evident and several top governmental decision makers saw the need for developing a mechanism for continuing economic analysis as an aid in better and more comprehensive development planning, policy formulation, and program development in the long run.

Thus, in mid-1971 through the cooperation of the government of the Republic of Korea, the U. S. Agency for International Development and Michigan State University, the Korean Agricultural Sector Analysis and Simulation Project (KASS) was conceived. The objectives of this project were threefold. The first objective was to carry out a study of the Korean agricultural sector, including an inventory of available resources, demands on the sector, its physical and economic structure, and its social, political and institutional environment; and to analyze the consequences of following alternative development strategies, recommending one which would achieve agricultural sector development goals over a 15-year planning horizon and which would be consistent with national values. The second objective was to develop a computerized general systems simulation model of the agricultural sector which could be used as a continuing policy planning tool for the improvement and development of the capabilities of Korean decision makers in planning, policy formulation, and program development. Finally, KASS was to develop a Korean capacity for further development and use of such models for updating projections and for analyzing policy alternatives as conditions change and as new and improved data become available.

The short-term objective of producing a comprehensive agricultural sector study and the longer-term objective of developing the computerized agricultural sector model were viewed as complementary from the beginning. By first concentrating on those components of the simulation model which could best serve in the completion of the sector study, modeling time was saved and modelers were more clearly focused on their individual tasks in contributing to the total effort. Conversely, by counting on these model components to do the drudgery of computing projections, agricultural economic researchers could devote their energies to descriptive work in understanding how the agricultural sector functioned within its environment. This knowledge in turn could be used in conceptualizing the model components, while the model components themselves could help to identify the important data and information that were needed.

Approximately 20 joint Korean and American working teams were established to collect data and information on subjects determined of importance to producing the sector study. Subjects covered included crop and livestock production; land and water resource development; credit; agricultural supply response; price, income, and subsidy policies; research and technological advance; agricultural guidance system and rural education; rural infrastructure; administrative processes and institutions; population, migration, and employment; capital formation; and food demand and nutrition. Since the information and skills required to produce the data needed for the study were multidisciplinary in nature, the working parties included specialists from a variety of disciplines including sociology, public administration, extension and adult education, industrial psychology, research administration and technical agriculture, as well as agricultural economists and systems scientists accustomed to working with a wide range of information about technical, institutional and human change.

As the working parties were carrying out their tasks, four components of the computerized simulation model were built. Where possible, the software developed from the Nigerian experience was transferred to Korea and adpated to the Korean situation. The specific components developed to help prepare the projections for the sector analysis include an agricultural production component for 3 regions, 12 crops, and 6 livestock commodities which computes output, supply, farm consumption, income, costs, input requirements, and seasonal labor requirements; an urban demand component which computes nonfarm consumer demands for 19 agricultural commodities and 1 nonagricultural commodity as a function of price, income, and population; a population component which projects age- and sex-specific rural farm population and urban nonfarm population as a function of time-dependent birthrates, death rates and migration rates; and a dynamic national input/output model which projects urban nonfarm gross national product, income, and rate of consumer expenditure.

The Korean agricultural sector study was completed in the nine-month time limit only because the complementarities between the short- and long-term objectives of the project were exploited. Work is presently continuing in Korea on the second two objectives of the project--further development of new components for the model and refinement of existing ones, and building Korean capacity to continue the development, updating and operation of the model.

Mathematical Models and Data Sources

Mathematically, GSSA is general both in terms of modeling techniques and in terms of its data sources. Basically, mathematical modeling in GSSA begins with the view that socioeconomic systems are composed of both continuous and discrete time processes. For example, the aging of a population through time is continuous, while the macro decisions of policy makers and the micro decisions of production units (e.g., farmers) often occur at discrete points in time. Thus, differential, difference, and algebraic equations are all appropriately used to model these processes (Forrester, 1961; Abkin and Manetsch, 1973). A great deal of flexibility is allowed in that virtually and process,* or rather assumption about such a process, can be modeled in this way; i.e., it is a generalized modeling technique. While models of this kind are not limited to the use of (and hence not constrained by the restrictions of) any specialized technique such as discussed earlier, any such technique may be used where appropriate and justifiable. For example, a recursive linear programming resource allocation model (deHaen and Lee,

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*That is, any process whose variables can be quantified and whose structural relations can be explicitly stated. In addition, there are some mathematical restrictions (e.g., concerning boundedness and discontinuities) which probably don't apply to socioeconomic processes, anyway.

1972) has been proposed for use in conjunction with the Korean agricultural sector simulation model (Rossmiller, *et al.*, 1972); and both the Korean and the Nigerian simulation models (Manetsch, *et al.*, 1971) use input-output tables to represent the nonagricultural sector.

The greatest difficulty with using this approach, however, is that as the equations become more complex--i.e., as they increase in number, order and nonlinearity--*general analytical* solutions become impossible given the present state of the mathematical art. Therefore, taking advantage of the capabilities of large-scale digital computers, numerical techniques are used to generate *particular numerical* solutions, where the states of the system and the values of performance criteria are determined successively at discrete points in time for a particular set of inputs and initial conditions; i.e., the system is simulated (e.g., Holland, *et al.*, 1966; Manetsch, 1967; Forrester, 1969; Enos, 1970). Repeated simulations, then, will project the time paths of system performance criteria under alternative policy assumptions.

Conceptually, a simulation model of an economic system can be viewed in the following general mathematical form:

$$\psi(t+1) = F[\psi(t), \alpha(t), \beta(t), \gamma(t)]$$

$$\pi(t) = G[\psi(t), \alpha(t), \beta(t), \gamma(t)]$$

where:

$\psi(t)$ = a set of variables defining the state of the simulated system at any given time. State variables may include such quantities as production capacities, prices, population by subgroups, levels of technology, etc.

$\pi(t)$ = a set of output variables, including such performance measures as profit, income, growth rates, balance of trade, employment, etc.

$\alpha(t)$ = a set of parameters defining the structure of the system. These usually regulate rates of change of variables between levels and input-output coefficients, such as technical coefficients, behavioral response parameters, price elasticities, migration rates, birth and death rates, etc.

$\beta(t)$ = a set of environmental variables, such a world prices, weather, etc.

$\gamma(t)$ = a set of policy instruments, such as tax policies, production campaigns, investment alternatives, etc.

The state equation (ψ) is a general representation of the difference equation formulation of the system model which describes the state of the system at discrete points in time. The output equation generates the performance criteria π necessary in the model application stage to evaluate, in terms of the goals specified in the problem definition (see below), the performance of the system over time under various policy alternatives.

This general formulation of a simulation model is realized in the hundreds or even thousands of parameters and structural relationships (depending on the size of the model) actually incorporated in the model. Specification of the model, given the problem definition, requires: (1) precise description of the model components; (2) explicit algebraic and difference equations to represent the structures and mechanisms within components and the linkages between components; and (3) programming for computer implementation.

We have been discussing GSSA's generality with respect to mathematical modeling; the approach is also general with respect to its data sources. Whereas some specialized techniques (e.g., econometric models, input-output models) rely heavily if not wholly on recorded time series and cross section data, GSSA models, while using these sources where available and appropriate, are not limited to them. Initial conditions and system parameters may be estimated as well from surveys, censuses, experimental results, and knowledgeable intuition and educated guesstimates--that is, from the whole range of data sources decision makers have been using all along. Because of this flexibility, there is no constraint to remain "loyal" to the initial parameter estimates, and parameter estimation is thus an iterative process where estimates may be adjusted as part of the model testing and validation process (discussed below).

GSSA and the Decision-Making Process

The general system simulation approach (GSSA)--because of its generality with respect to data sources and modeling techniques and because of the ease with which GSSA models may be used to project the likely consequences of alternative policies--can be made an integral part of the decision-making process. That is, its generality approaches the generality decision makers have of necessity always used, thus facilitating the full participation of decision makers in all phases of GSSA and hence bridging the credibility gap often observed between policy makers and professional analysts.

Figure 2 depicts GSSA as having three phases: the problem definition phase (roughly analogous to Steps 1 and 2 of Figure 1), the system simulation phase, (roughly analogous to Steps 2, 3, and 4 of Figure 1), and the policy formulation and implementation phase (roughly analogous to Steps 4, 5, and 6 of Figure 1). Both normative (value) and non-normative information and knowledge are used throughout the process. When information is deficient, the consequences of such deficiency can be determined and new information can be sought if judged worthwhile. The whole process is highly iterative in nature; that is, stages are repeated as succeeding stages and new information bring out deficiencies in earlier stages. Finally, the making of decisions--decisions evaluating the results or the carrying out of any

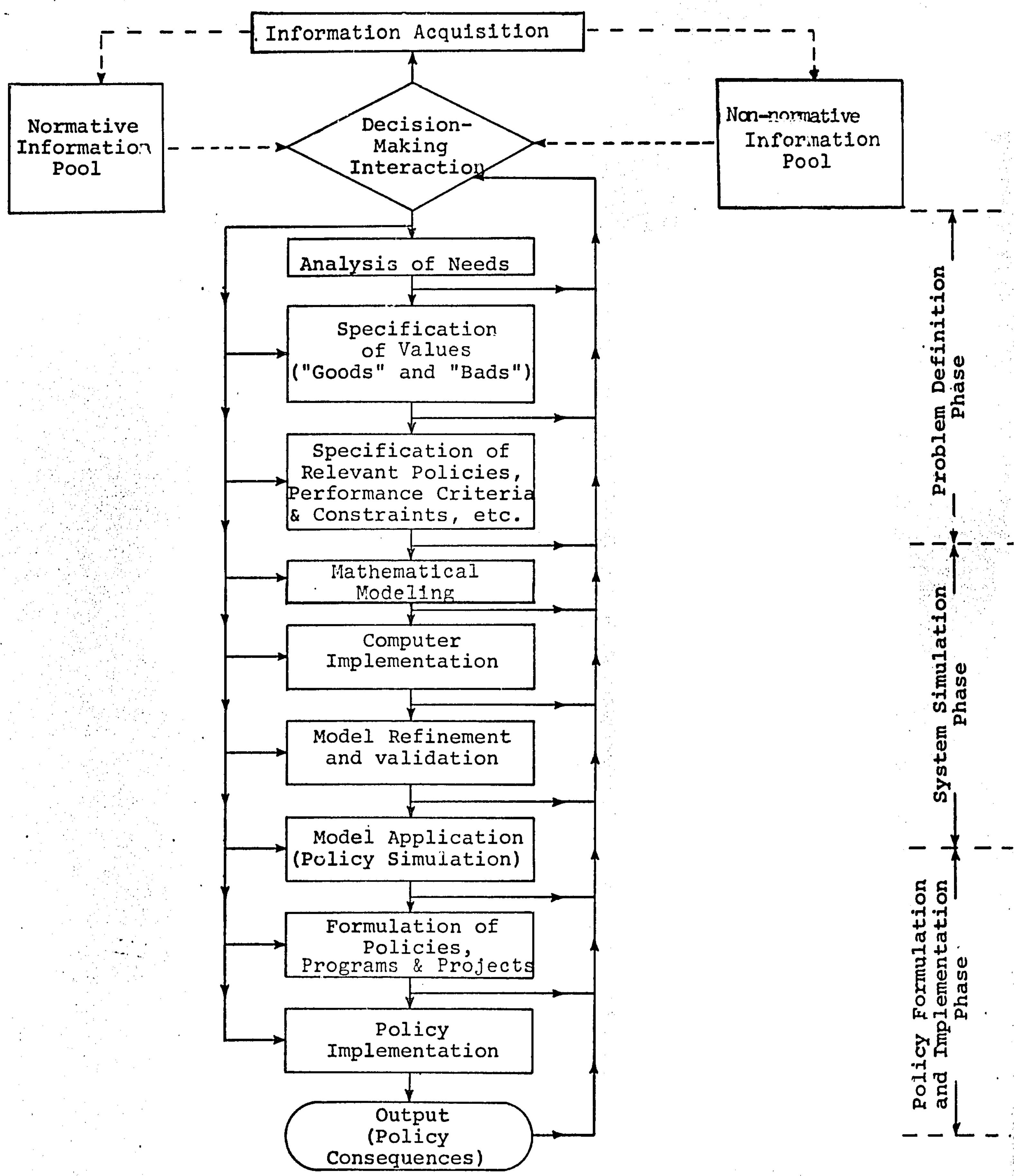

Figure 2. System simulation and the policy-making process.

stage of the process as well as about policy selection and implementation--is viewed as the result of interactions between information and active participants, including modelers, simulators and other consultants as well as the decision makers themselves.

The problem definition phase entails the explicit and precise identification of social needs, social values ("goods" and "bads"), relevant alternative policy instruments, system performance criteria and system and policy constraints. For example, an analysis of needs may indicate that society "needs," among other things, agriculture to feed itself and the rest of the nation and to support nonagricultural growth by supplying resources and demanding nonagricultural goods and services. In addition, social values may be specified such that increasing income is good but maldistribution of income between agriculture and nonagriculture and within each of them is bad; high daily per capita caloric consumption is good but, where food production competes with export production and/or where food must be imported, balance of trade deficits are bad; agriculture supplying labor to nonagriculture is good but urban unemployment is bad; etc. Given society's needs and values, alternative policies might be, among other things, to increase the productivity of agricultural resources, to improve the efficiency of the marketing and distribution system, and/or to promote import substitution and export production in both agriculture and nonagriculture, etc. Alternative instruments for carrying out such policies might include the use of tax rates as incentives and as sources of revenue to finance other programs and projects; production campaigns to increase the efficiency of agricultural resources; irrigation and mechanization programs; producer pricing policies;

setting foreign exchange rates and import quotas; etc. Relevant performance criteria will include levels and growth rates of GNP, per capita income, caloric and protein consumption, trade balances, unemployment, etc.

The above will be recognized as nothing new to development planning. Its formalization is necessary, however, to determine what sort of model is to be built, i.e., its subsystems and components and the level of aggregation desired of each, the policy instruments it is to include, the performance criteria it is to generate (π in the above equations), etc. The model is built as described earlier and then programmed for computer implementation.

Model testing, refinement and validation are closely linked processes. A simulation model is tested both to check its internal consistency and to assure that it is an adequate representation of the real economic system (adequate for the purposes at hand as stated in the problem definition). Tests may include such activities as tuning the model to track recorded time series, conducting sensitivity tests on model parameters (i.e., observing how the model responds to changes in parameter values) and subjecting the simulated system to exogenous shocks or disturbances and observing the consequent responses. Test results will suggest refinements and modifications to be made in system structures and parameter values and will indicate areas where better data are most needed.

For a decision maker to base policy decisions on the experimental results of a model--<u>any</u> model, verbal or mathematical, paper-and-pencil or computer--he must have some degree of confidence in the validity of that model, i.e., how well it simulates the relevant behavior of the real system or phenomenon it is supposed to represent. As long as the decision maker is aware of the model's validity, perfect validity is not necessary. Indeed, perfect validity--in the sense of perfect information on the future behavior of the real system under various assumed conditions--is not possible. Decisions must be taken and implemented with or without mathematical models; models can be used, however, to improve the information input to the decision-making process as long as cognizance is made of their validity and until they are replaced by better, more "valid" models.

Validation or verification of the projections produced by a GSSA model and the related problem of placing confidence limits on the information used in model construction is still a limitation requiring much further work. Present statistical techniques are not capable of adequately dealing with the task of establishing appropriate confidence intervals on data input or confidence limits on the output of such models. The more rigorous statistical methods of verification and validation involve application of the tests of: (1) consistency with observed and recorded experience, (2) logical internal consistency of the concepts, (3) interpersonal transmissibility of concepts (including estimates and forecasts), and (4) workability when used to solve problems. In carrying out validation or verification tests on GSSA models, the rigorous tests of statistics are used if available and applicable. If not, the four general tests are simply applied less rigorously. Further discussion of validation of simulation models, which space does not permit here, may be found in the literature (e.g., Van Horn, 1971; Johnson and Rausser, 1972).

The most important reason for developing a simulation model (in this context) is to provide a laboratory for exploring the consequences of a wide range of alternative plans or management strategies. This is an iterative process involving close interaction among decision makers and systems analysts. One simulation experiment can lead to the creative design of a new and better one which may involve reprogramming or even basic modifications of the model. The objective of such simulation experiments is to unfold a set of development strategies that are consistent, mutually reinforcing and show how resources could be effectively used to solve the basic problem (as defined).

Appendix A consists of some sample output from the Korean model as it was operating at the time the sector study was put together. It shows the consequences of the second of four policy strategy sets investigated. It illustrates one way of presenting results, namely, in tabular form; many other formats are possible, including graphical displays. In the table shown, any four years between 1971 and 1985 can be chosen for output display in comparison to the 1970-base year, depending on the requirements of the user. The 28 items in the consequences table and the 14 commodities in the supply-disappearance table are those deemed of most interest in Korea. The list could be expanded, contracted, or changed if different interests develop and as the model capabilities increase.

Policy simulation results may suggest further alternatives to be tested in an iterative process of policy formulation. Eventually, a decision is made to implement a particular set of policies. The real-world consequences of that decision will influence later policy formulations and may even lead to a redefinition of the problem, thus continuing the iterative decision-making process outlined in Figure 1 with the model integrated as a part of that process as indicated in Figure 2.

Advantages, Costs, Requirements, and Limitations of GSSA

The system simulation approach, as part of the decision-making process (Figure 2), can provide important contributions to three broad aspects of development planning and policy making: understanding the socioeconomic system, formulating development policies, and focusing research activities. These aspects are somewhat overlapping; for example, both research and an increased understanding of the problem certainly contribute to improved policy formulations.

Detailed analyses of the behavior of a system simulation model under a range of data, structural assumptions and policy conditions provide a comprehensive view of the complex and dynamic socioeconomic system under study. This, combined with the model-building process itself--particularly the identification of causal and structural relationships--can contribute substantially to an improved understanding of, and sharpened intuitions regarding, the development process in general as well as the particular socioeconomic system of concern. For example, sensitivity tests will pinpoint sensitive parameters, and the analyses carried out to explain the simulated consequences of parameter changes will highlight complex interactions of the simulated system. Insofar as the simulated system faithfully represents relevant behavioral patterns of the real system, the heightened understanding can be a valuable asset in reducing some of the uncertainty policy makers necessarily face.

A more direct input to the policy-making process is the capability of a general system simulation model to explore the consequences and implications of a wide range of development policy options by projecting time paths of relevant output variables under alternative combinations of policies. Using the same data as is available for other approaches and techniques, GSSA models take account of many more complex policies and interactions than can be done by hand or with models necessarily simplified by the constraints of the specialized techniques used. In this way, a good deal of uncertainty concerning the system's direct and indirect responses to various policies can be reduced. Another important application of such a model to policy formulation is in dealing with the uncertainty inherent in the quality of the available data. Sensitivity tests, where key parameters are varied in each of a number of alternative policy situations, can be used to evaluate the sensitivity of policies to data uncertainty. Alternatively, the model can be run in a Monte Carlo mode where uncertain parameters are assigned probability distributions, a number of runs are made with observations from those distributions, and output statistics are generated. This is information essential in the search for stable policies, that is, policies which will have the intended results even though projections are based on poor data.

A third contribution the system simulation approach can make to development planning is a focus for research activities. There are primarily three ways in which use of a simulation model can provide a central theme to coordinate and guide research. First, since this type of model uses data from many sources and since it requires tight internal logical consistencies, data inaccuracies can in many cases be brought to light. In addition, through sensitivity analysis it is possible to obtain an indication of the relative consequences of variations and errors in parameter estimates. This kind of information can be useful in determining where the greatest payoffs are to be found in allocating resources to the collection of further and more accurate data. Secondly, the model's application will motivate investigations into structural relationships among, and the behavior of, component elements of the socioeconomic system. These efforts will be necessary to provide theoretical models for the continual improvement and updating of the simulation model's assumptions and representations of the real system and to keep it relevant to the needs and concerns of policy makers in a changing world. Finally, technological research may be suggested by simulated policy experiments speculating on the likely consequences of the introduction of an innovation which may not actually be developed at the moment. Of course, the projected consequences would have to indicate that the expense of undertaking such research and development was warranted.

While an old popular song says "the best things in life are free," this is not true of the generalized system simulation approach to development planning and policy making--which is to say that GSSA is neither free nor one of the best things in life. First, its costs and requirements; then its limitations.

A fully developed computerized sector simulation model requires large capacity and sophisticated handware and software facilities not necessarily immediately available in developing countries. In order to handle large models and combinations of models, a large-scale computer (at least 32,000 words of core) with tape drives, a FORTRAN compiler and software which can manipulate and modify programs on tape are necessary and desirable. Since these computer facilities aren't needed full time for GSSA modeling and policy simulations, fixed costs can be shared with other research and data processing activities using the facilities. The Nigerian model currently uses the hardware capacity at MSU while the Korean model uses hardware capacity available in-country. For efficiency in model development, for timeliness in model operation, and for building of an indigenous capacity for handling the model, the hardware system upon which it is run must be located in the country of application.

More important than the computer costs, however, are manpower needs (Manetsch, 1972). The skills and training required for indigenous personnel are substantial and must be planned and programmed as a part of a model development project. Professionally, a multidisciplinary team is required to perform the three phases of the process. The kinds of disciplinary representation required depend on the field of application. While a systems scientist and a computer programmer may be necessary components of any team, agricultural development applications, for example, will also require the services of agricultural economists with consulting by agronomists, livestock specialists, sociologists, political scientists, statisticians, etc. If the approach is to be an integral part of the policy-making process, appropriate public administrators will also be an essential part of any team. Different stages of the process (Figure 2) will require different levels of expertise of each team member. Furthermore, since the individual members are to cooperate and work together as a team, each should have some familiarity with the other disciplines represented as well as a high level of competence in his own. This kind of manpower is relatively scarce, even in the developed countries, but is essential if GSSA is going to be applied on a large scale.

At an early stage in the development and operationalization of a sector simulation model within a country, attention must be given to how and where to institutionalize the effort to insure maximum long-run flexibility in institutional structure consistent with short-run development and operational objectives; access by users and responsiveness to user needs; participation by interested parties both within and outside government in development of the model and its operation; and assurance of a continuous flow of qualified personnel associated with the model through graduate and post-graduate training programs and participation in professional activities both in-country and abroad with an ultimate objective of generating an internal capacity for talent reproduction.

It is absolutely imperative that project personnel establish among themselves a cordial, frank, and honest working relationship as colleagues with common objectives and agreed-upon targets. No less important is the need for free access by project personnel to top level decision makers and their staffs, again on a frank and professional level, in order to provide project personnel with both the normative and the non-normative knowledge necessary for development of a useful and relevant model, and in order to keep decision makers informed of the progress and capabilities of model development and operationalization.

In general, the limitations of the general system simulation approach are the same as those of other approaches using other kinds of models and techniques. First, any model needs data, and large scale simulation models need more than most. This is not as limiting a factor for GSSA, however, as it is for other techniques which rely heavily on data for model validity, e.g., econometric models and input-output models. On the contrary, sensitivity tests on a simulation model can identify which data are most crucial (i.e., to which the model is most sensitive), and this information will help in interpreting simulation results as well as suggest data collection priorities. In addition, the data limitation is eased somewhat by the flexibility GSSA has in the data sources it can tap.

Secondly, a simulation model, like any model, must make assumptions as it abstracts from reality, and thus its realism is necessarily limited. A system simulation model also requires a body of social and economic theory upon which to base its structural assumptions. Thus, mathematical simulation models are limited to those areas for which theories exist as to the quantification of relevant variables and structural relationships.

Finally, a general shortcoming of GSSA is that its models are not easily explained. Unlike more specialized models, e.g., recursive linear programming models and sets of simultaneous equations, system simulation models cannot be written out in simple matrix notation; instead, large numbers of recursively linked differential equations have to be described equation by equation and component by component. While general diagrams can be drawn illustrating how the equations and components are linked together, they are neither mathematically elegant nor satisfying to the person who would like a simple total comprehension of the model from which he can deductively derive details concerning the model itself.

Conclusion

We may conclude by emphasizing that the general system simulation approach is neither a panacea nor black magic. Those who consider it a panacea run the very real risk of believing everything the computer "says" as if it were an oracle providing perfect information about the future. Others may feel it is something to be feared and shunned as if it were another step in the direction of computers taking over and making decisions for man. The truth, as usual, lies somewhere in between these extremes.

System simulation can be a very useful tool in the decision maker's toolbox, providing him with more information than he might otherwise get on the likely consequences of alternative actions. But that information will still not be perfect, for it will be but the logical implications of man's assumptions about reality and therefore will rest on the validity of those assumptions. Nevertheless, we might not have even that information without the use of large-scale computerized mathematical models to project the implications of a complex system of assumptions.

Furthermore, GSSA models can only provide this information in areas where mathematical models are feasible, for example certain areas of economics. Much political and social information must still come from informal mental or verbal models. As an approach, however, GSSA provides a formal process for considering these other kinds of models in conjunction with computerized mathematical models in trying to reduce the uncertainty inherent in the development planning and policy-making process.

Finally, and most importantly, decision makers in a country contemplating the installation of a computerized simulation model of the agricultural sector, for example, for use as an analytical aid in planning, policy formulation, and program development must be fully appraised of the resources required, human and otherwise, both for initial model development and sustained operation. They must know what such a model can and cannot do and be willing to live with its limitations.

If the requisite criteria and conditions are acceptable to agricultural planners, they can find a computerized sector simulation model a valuable analytical aid in helping them assess the consequences of alternative planning strategies and in making the decisions necessary to solve the many problems of agricultural sector development.

REFERENCES

Abkin, Michael H. and Manetsch, Thomas J. "A Generalized System Simulation Approach to Agricultural Development Planning and Policy Making." Paper to be presented at the IFAC-IFORS Conference on Systems Approaches to Developing Countries. Algiers. 1973.

Day, Richard H. and Singh, Inderjit. "A Micro-econometric Study of Agricultural Development." Workshop Series 7120, Social Systems Research Institute. Madison, Wisconsin. 1971.

deHaen, Hartwig and Lee, Jeung Han. "Dynamic Models of Farm Resource Allocation for Agricultural Planning in Korea: Application of Recursive Programming Within a General Systems Simulation Approach." Agricultural Sector Simulation Project Working Paper. Michigan State University, East Lansing. October, 1972.

Enos, J. Modeling the Economic Development of a Poorly Endowed Region: The Northeast of Thailand. RM-6135-ARPA (Santa Monica: The Rand Corporation. 1970.)

Epp, Donald J. Changes in Regional Grain and Livestock Prices Under the European Economic Community Policies. Research Report No. 4. Institute of International Agriculture, Food, Nutrition, Rural Development, Michigan State University, East Lansing, Michigan. 1968.

Ferris, John, et al. The Impact on United States Agricultural Trade of the Accession of the United Kingdom, Ireland, Denmark and Norway to the European Economic Community. Research Report No. 11. Institute of International Agriculture, Food, Nutrition, Rural Development, Michigan State University, East Lansing, Michigan. 1971.

Forrester, Jay W. Industrial Dynamics. (Cambridge: M.I.T. Press. 1961.)

Forrester, Jay W. Urban Dynamics. (Cambrdige: M.I.T. Press. 1969.)

Holland, Edward P., et al. "Dynamic Models for Simulating the Venezuelan Economy." The Simulmatics Corporation, New York. 1966.

Johnson, G. L., et al. Strategies and Recommendations for Nigerian Rural Development, 1969/1985. CSNRD 33. Consortium for the Study of Nigerian Rural Development, Michigan State University. July, 1969.

Johnson, Glenn L. and Lewis K. Zerby. What Economists Do About Values: Case Studies of Their Answers to Questions They Don't Dare Ask. Michigan State Agricultural Experiment Station, East Lansing. 1972.

Johnson, S. R. and Rausser, G. C. "Some Issues Regarding Verification and Policy Experimentation for Sectoral Models for Agriculture in L.D.C.'s." Working Paper for A.D.C. Workshop at Purdue University. February, 1972.

Manetsch, Thomas J., et al. A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria. Michigan State University, East Lansing, Michigan. November, 1971.

Manetsch, Thomas J. "Computer Simulation Analysis of a Program for Modernizing Cotton Production in Northeast Brazil." Division of Engineering Research, Michigan State University, East Lansing. 1967.

Manetsch, Thomas J. "Some Thoughts on the Development of Human Resources Required to Institutionalize Agricultural Sector Simulation Models in Developing Countries." Draft Ideas, Michigan State University, East Lansing, Michigan. 1972.

Mangum, Fred A., Jr. The Grain-Livestock Economy of Italy with Projections to 1970 and 1975. Research Report No. 2. Institute of International Agriculture, Food, Nutrition, Rural Development, Michigan State University, East Lansing, Michigan. 1968.

Naylor, Thomas H. "Policy Simulation Experiments with Macroeconometric Models: The State of the Art." American Journal of Agricultural Economics. 52:263-271. May, 1970.

Petit, Michel J. and Viallon, Jean-Baptiste. The Grain-Livestock Economy of France with Projections to 1970 and 1975. Research Report No. 3. Institute of International Agriculture, Food, Nutrition, Rural Development, Michigan State University, East Lansing, Michigan. 1968.

Rossmiller, George E. The Grain-Livestock Economy of West Germany with Projections to 1970 and 1975. Research Report No. 1. Institute of International Agriculture, Food, Nutrition, Rural Development, Michigan State University, East Lansing, Michigan. 1967.

Rossmiller, George E., et al. Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985. Agricultural Economic Research Institute, MAF, Seoul, Korea and Department of Agricultural Economics, Michigan State University, East Lansing, Michigan. 1972.

Sorenson, Vernon L. and Hathaway, Dale E. The Grain-Livestock Economy and Trade Patterns of the European Economic Community with Projections to 1970 and 1975. Research Report No. 5. Institute of International Agriculture, Food, Nutrition, Rural Development, Michigan State [illegible]

Van Horn, Richard L. "Validation of Simulation Results." Management Science. 17:247-258. January, 1971.