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ABSTRACT

Although the techniques of simulations and systems analysis are often abused, they can provide a useful framework for rural development research. However since system simulation models can generate what appears to be precise data, it is well to remember that results are merely projections of what would be expected to occur if all the conditions of the model were met. Often the usefulness of a simulation model can be enhanced by interdisciplinary cooperation. Although this can cause communication problems, it frequently results in valuable insights. Three kinds of simulation models have been used in rural research; dynamic feedback commodity models, area models, and resource use models. Some of the variables that interact in simulation models are economic, physical, cultural/sociological, and biological. Using an interdisciplinary system simulation model we should be able to anticipate the effects of a change in a rural development program on a community's population, income, environment, service facilities, and tax structure. (MG)

SYSTEM SIMULATION AS AN INTERDISCIPLINARY INTERFACE IN RURAL DEVELOPMENT RESEARCH

Ray V. Billingsley

INTRODUCTION

There are many definitions of simulation. Broadly defined, practically any computational technique can be incorporated in simulation and in this context, simulation should be considered a procedure or process rather than a method or technique. In practice, the methods and techniques commonly used in Agricultural Economics research can all be incorporated in simulation models. However, rerunning a linear programming or multiple regression model a number of times testing a number of alternative assumptions is not system simulation.

Simulation and system analysis have become buz words. By reviewing titles and abstracts of research publications, one can easily obtain the impression that a great deal of work is being done in this area. However, an investigation of the publications is often disappointing in that these terms are being indiscriminately used. Perhaps it is a general tendency to overuse fad words and to incorporate them into our current research jargon. There may even be a

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tendency to use a more sophisticated technique than necessary which may obscure the relevance of the results. An example would be developing a simulation model when linear programming or even simple budgeting would be appropriate.

These dangers of fads in research are emphasized because this paper deals with the currently popular technique termed simulation and the fashionable rural development area of research. Rural areas are systems, and rural development includes many objectives related to such things as distribution of income, environmental considerations, employment, population, education, total income, industrialization, and community services.

Jay Forrester contends that the human mind is not adapted to interpreting how social systems behave and that it is thus necessary to employ an analytical tool such as simulation to identify and quantify the many interrelationships of variables in these systems. Due to the complexity and interdependence of these relationships, the human mind cannot adequately interpret how the system will behave. Perhaps it is for this reason that Forrester is able to observe that "history teaches that, in complicated social systems, efforts to improve things often tend to make them worse, sometimes much worse, and on occasions calamitous," [5]. We need only mention the failure of our welfare and agricultural programs in eliminating rural poverty. Further, to show that things do not necessarily improve after an extensive time lapse, one need only look at the failures involved in assimilating the cultures of the American Indian after the intrusion of European immigrants.

Spending huge quantities of money does not necessarily help either, as evidenced by the fact that building more low-cost housing in the city slum areas does not reduce the social problems associated with these areas.

System simulation techniques, developed originally for physical systems, are well adapted to social systems. The feedback loops and nonlinearity is descriptive of the interrelationships of variables, provided a realistic mathematical model is developed. Forrester calls this method "system dynamics," having patterned it after the earlier design of physical systems primarily in engineering called "industrial dynamics" [6]. Under this framework, system simulation provides an appropriate tool of analysis for rural development research since multiloop feedback systems can be modeled.

A word of caution is perhaps called for at this point. Most simulation models, by their very nature, generate a sizable amount of what appears to be very precise data. Many people who use research results consider them as estimates of what has occurred or predictions of what is expected to occur with some implied or explicitly stated level of significance. Simulation results are not to be interpreted as "predictions" but only as "projections" of what would be expected to occur if certain assumptions are made with respect to changes in one or more policy variables in the model.

This is a very important point and one that should not be overlooked by simulation model builders and users. It basically means that the simulation model (computer program) becomes the primary product, not the research results as most researchers are prone to think. If one thinks about this a bit, the reasons become obvious but it is a point that seems to have been missed by a number of people.

CHARACTERISTICS OF SIMULATION

Basically, simulation is an abstract representation of a "real life" situation by a model. Typically, this involves the building of an operating model which is largely mathematical in nature. Simulation provides a means of dividing the model-building job into smaller component parts and then combining these parts in their natural order and allowing a computer to present the effect of their interaction on each other. Such a model may be deterministic or stochastic and may have optimizing or maximizing features with respect to specific performance criteria, but these are not necessary requirements for a simulation model. Rather, a simulation model is used to describe the operation of a system in terms of time-related events in each of the individual components and among the components of the system over a wide range for each of the parameter values. This is the reason simulation results are to be interpreted as "projections" of what would be expected to occur given certain assumptions. In this manner many different sets of projections can be run as one or more policy variables in the model are changed. This provides an opportunity for evaluating alternative policies rather than predicting future events.

Until recently, the principal way to estimate the behavior of social systems was by guess or intuition. In business and management, fairly good techniques have been developed to measure the results based on the decisions made from guesswork. However, in other more complex social systems, the results do not become as immediately obvious, and many times are completely overshadowed by events occurring in other parts of the system. Socially oriented programs may be continued for years before anyone notices that conditions are not really improving and may, in fact, have deteriorated.

Fortunately, the development of system simulation techniques which handle the feedback loops so well in simulating physical systems also have application in social systems. It is these feedback loops and the nonlinear, interactive responses that the human mind does poorly but the computer does well, provided a realistic mathematical model is developed.

INTERDISCIPLINARY INTERFACE

Because of the many disciplines involved in modeling any system, the work on most models has been interdisciplinary oriented. One of the first problems encountered by an interdisciplinary team is that of communication. Basic to this problem of communication is the fact that many terms common to several disciplines have important and critically different definitions. This is perhaps the main reason for flow charts becoming the basic language used in system model building. It is easy to learn, since it involves no more than 5 or 6 different symbols and is extremely powerful because interactions and directional functional flows are explicitly indicated, (see Figure 1) [1]. As the arrows indicate, the general movement of the process is from problem definition to model application but the reverse arrows indicate that

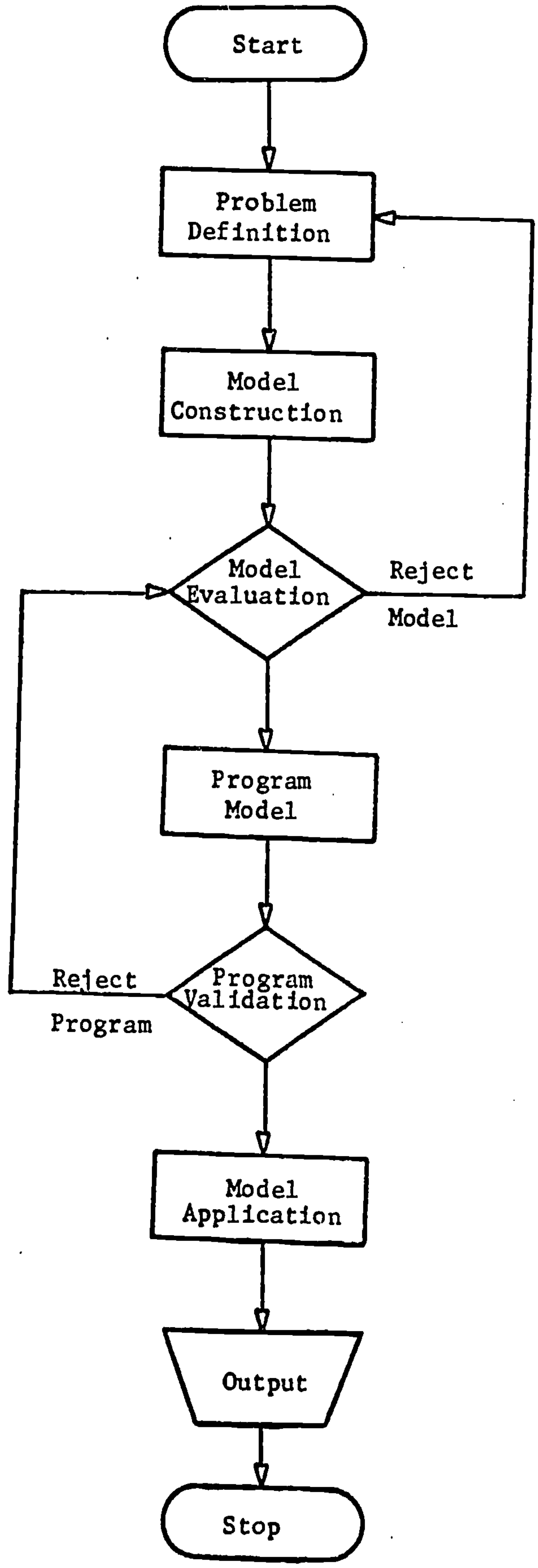

Figure 1. Computer Simulation as an Iterative Problem Solving Process.

the process is iterative or learning in nature. A prior stage may have to be revised on the basis of information acquired during a subsequent stage. It is in this manner that interdisciplinary teams work together in changing the model's structure which leads to a realistic simulation of the system. The output of the model consists of a set of performance variables associated with various policies or strategies. The decision maker may then choose among a range of alternatives using his own criteria.

Individuals who work with an interdisciplinary research group are, however, faced with a dilemma. The dilemma is one of specialization versus diversification. Good communication usually results between specialists within a given discipline because they use the same technical terms and attach generally the same meaning to them. But if the technical terms familar to a specific discipline are used with a multidisciplinary group, effective communication becomes difficult. Not only are the individuals in the other disciplines not familar with many technical terms, but also many common terms have specialized and/or different meanings according to the discipline using them. When a member of one discipline uses a term, the meaning intended may not be fully comprehended. In order to avoid these difficulties, specialists when communicating with a multi-disciplinary group will usually resort to using layman terms. But such terms are not able to communicate the concepts of a technical field. They lack the precise definitions, finely drawn distinctions and subtle nuances of technical terminology. This results in the illusion of improving communication but actually may result in incomplete information being conveyed concerning relevant variables so that sometimes an all or nothing conclusion is made on the basis of rather nebulous criteria. The difficulty can go undetected because no one recognizes the incompleteness of the information being conveyed. Therefore, it is just as important for a multi-disciplinary group working on a problem to use precise terms in communicating with each other as for individuals from the same discipline.

One of the advantages of using a simulation model is that it includes a mechanism for a common, very precise language. Any simulation model that is run on a computer requires a rigorous framework interconnecting quantifiable variables. Building simulation models also results in valuable feedback which would not occur if the group working together consisted of specialists in one field. Specialists continue to work together in building specific parts of a simualtion model and will, of course, use verbally the very precise technical terminology familar in their discipline. In order to communicate with specialists in other disciplines and in fact to put their part of the model onto the computer program, the technical terms and relationships must be re-expressed in a language understandable by the computer. If these relationships are correctly expressed, then all individuals from the various disciplines will use the relationships in exactly the same way.

Before the completed simulation model can run, however, much desirable interaction will occur between the different disciplines. This interaction is not only beneficial to the research project as a whole, but frequently results in much valuable insight on the part of the individual disciplines because they see precisely how their discipline reacts and interreacts with the other disciplines. When a member of one discipline communicates successfully with members of other disciplines, he gains exposure to and an understanding of the principles, techniques and insights of these other disciplines. It is natural for him to apply these to his own subject area and when he does innovation results.

There are several characteristics that can be identified as contributors to a good simulation model. For example, to facilitate model use by other researchers, it needs to have flexibility in manipulation of variables and parameters, few data requirements, output which is easy to read, ease in modification and an adequate user and programmer documentation [3].

Simulation models, carefully constructed and tested, offer an effective method of analysis and provide new opportunities in rural development research. This common ground of analysis for research provides new insight into actions and interactions of the system being studied. With this common framework established, there is a vehicle for communication. The simulation model allows each discipline the opportunity to interact in a precise way with each other. In this way, there is useful feedback to each discipline. Several examples of the simulation approach could be discussed at this point but this has been adequately discussed at this conference by others. In a previous paper [1], the author has discussed a number of simulation models which were broadly classified as follows: (1) Dynamic feedback commodity models [14, 16], (2) Area models [4, 11, 13, 15, 17], (3) Resource use models [2, 7]. Detailed discussion of these models will not be repeated here.

Dynamic Feedback Commodity Models

Dynamic commodity models [14, 16] are included in this discussion because generally they have been regionally or nationally oriented. A commodity model, at best, could only be considered a submodel for a regional system. Most regional or area models will incorporate several commodity submodels and economic variable levels.

Area Models

Perhaps the most promising simulation models for research in rural development are area models [4, 11, 13, 15, 17]. Most of these models were constructed by an interdisciplinary effort and illustrate the kind of interchange required in developing system simulation models. Some of these models are multipurpose in nature and serve as a data bank as well as a system simulation model.

A significant feature of some of these models is the zoom feature. This allows the user to deal with areas of different size. The characteristic features of the region are specified in the model on the basis of grid coordinates and maybe summarized by different levels of aggregation. This type of feature makes a model extremely valuable for all types of community development planning, including rural development, as well as environmental evaluation of proposed plants or changes in land use.

The analytical scheme used to build this type of model is called "cross-impact method" [4]. This procedure provides a much more compact presentation of the interrelationships between the variables in the system. The procedure is one of arranging all the elements of the system in the form of a matrix and in each row in the matrix indicate the effect each feature has on all other features. This procedure illustrates very well the interactive, multiple feedback loop relationships involved in system simulation.

Resource Use Models

Resource use oriented simulation models are also important in rural agricultural development research but will not be discussed in detail. It is sufficient at this time to mention that linear programming is a convenient framework for developing resource use models. Although running a linear programming model a number of times using certain variables as policy variables does not really meet the criteria of system simulation, it can in many respects provide much useful planning information.

Key Submodels for Rural Development Research

Since rural development research has multiple objectives, single objective function maximization models are difficult to apply. This makes simulation one of the most promising techniques since several variables can be monitored under different conditions and the expected effect on each observed.

The relationship among important variables can be established in several submodels which might include (1) economic, (2) physical, (3) cultural/sociological and (4) biological. Each of these submodels would include quality of life performance variables which would be such things as income, employment, community services, pollution, resource use, tax base and so on. This is not an all inclusive list but an example of important considerations necessary to a multiple discipline and effective rural development program approach. The submodels would be linked together by an executive program using relationships among the submodels. All policy variable changes are activated through the executive program.

Disciplines Involved

With a broad scope program of research aimed at rural development, there are several disciplines that are needed to identify and quantify the many interrelated operations. Sociologists provide inputs to areas such as demography, social conditions and education. The environmentalist's concern for externalities or effect on the ecosystem of alternative actions provides balance to the simulation model. Technical agriculturalists provide technical coefficients, probability distributions and physical relationships.

An agricultural economist's responsibility could include defining the economic relationships and incorporating institutional parameters into a model. The economist can also work with local, regional and national governmental officials to develop alternative feasible policies for evaluation. The responsibilities outlined in the above discussion includes some overlapping and some gaps both in needs and disciplines involved but provides a point from which to initiate action.

In the case where a model is to be developed, each discipline would be responsible for a submodel that explains the section for which it has responsibility. These would be the submodels discussed above. The different submodels are incorporated into a single model of the region through an executive program.

Types of Research

With a rural development simulation model that includes the interaction of the cultural-sociological, physical, biological and economic systems, the expected influence of alternative policy variable strategies can be simulated. With a strategy or policy change imposed on a rural development simulation model, the anticipated effects on a community's population characteristics, income distribution, environment, service facilities and tax structure can be observed. With such a model, there is an opportunity to manipulate many policy variables and observe their effects in a very short time.

Figure 2 is a generalized synoptic of a rural development system simulation model. The four submodels are linked together through an executive program. Alternative policies are specified and activated in the executive program and include changes in both variable levels and parameter rates. Some examples of policy variables or rural development strategies that can be tested include changes in community and health services, expanding local industry, tax changes, enacting zoning or waste disposal standards, etc. The two directional arrows

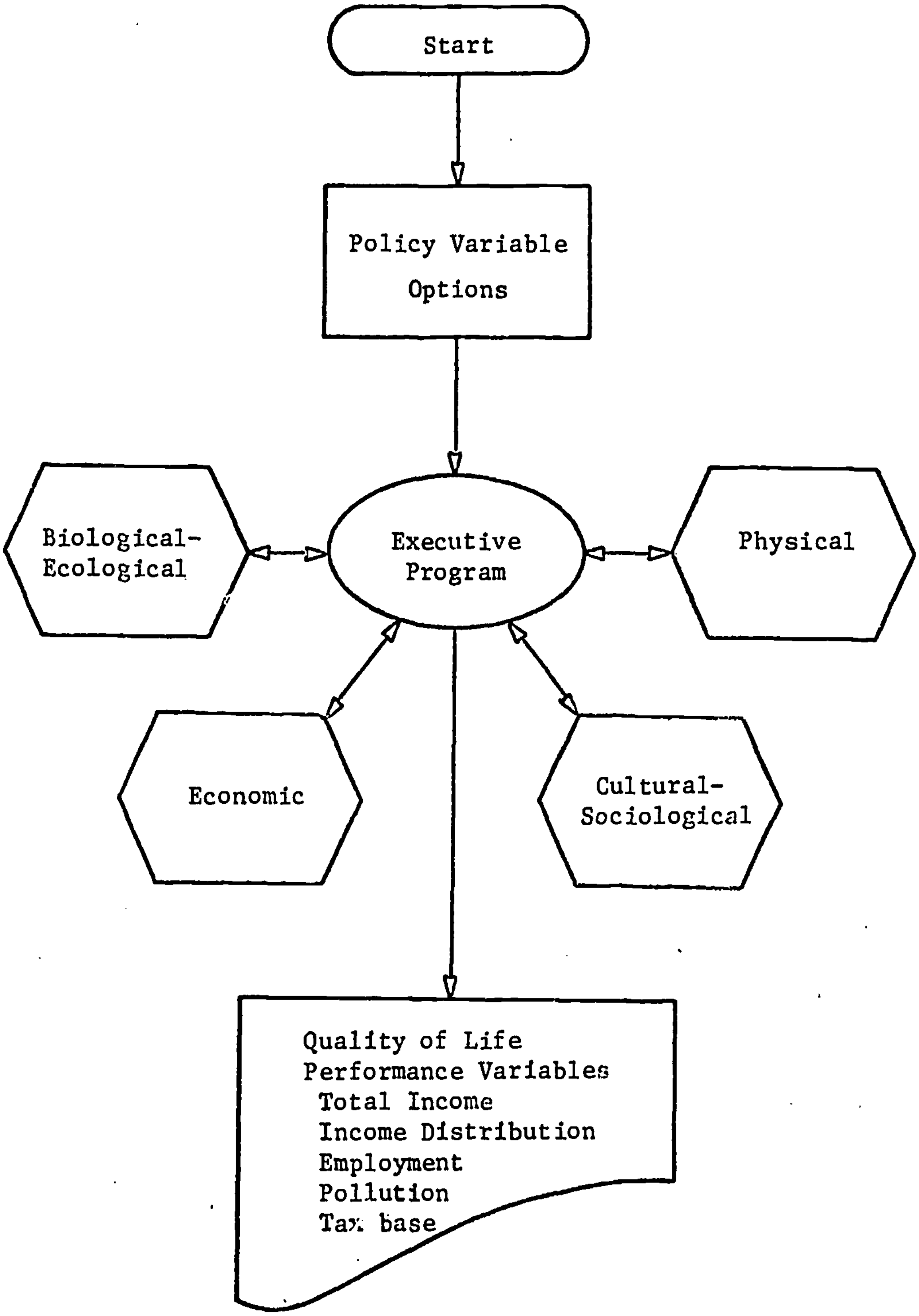

Figure 2. A Generalized Synoptic of a Rural Development Systems Simulation Model.

in Figure 2 represent the multiloop feedback interactions between the different submodels.

Researchers can interject various changes or stimuli and simulate the effects. With the various strategies, the tradeoffs that may be necessary for rural development become apparent. Decisions regarding development objectives lie with the community leaders. The model simply indicates the outcome of different actions. This can be helpful in identifying specific types of industry a community may find desirable to avoid and quantifying conflicts among objectives that exist in attempts to bring about rural development.

CONCLUSIONS AND LIMITATIONS

Simulation provides a powerful tool for rural development research and can consider many alternatives and many actions. It facilitates interdisciplinary research, permits simultaneous consideration of multiple objective functions and allows for a large degree of flexibility in modeling rural development systems.

However, it is useful to acknowledge some of the shortcomings or limitations associated with simulation. When simulation is to be applied through an interdisciplinary effort, there is the danger common to interdisciplinary research of becoming so entangled that little or no progress results. This is generally due to a lack of communication between researchers in different disciplines.

Even more basic is occurrence of communication problems between the model builders, the model users and the policy decision makers.

As this suggests, communication is a most important part of rural development research and a vulnerable part of simulation. The effectiveness of this type research is greatly reduced if not nullified by a communication barrier at any of the above points, i.e., disciplines, model builders, model users and policy decision makers.

Even with communication problems solved, there are problems or disadvantages that can be associated with the simulation model. These models tend to be more complex and can (1) become too complicated and intricate for meaningful application and (2) make it difficult, if not impossible, to uncover bias of researchers. There can also be a misspecification of a model and, hence, misleading results are derived. Misspecification can arise from making a model too abstract, including the wrong variables and including incorrect relationships.

One general problem of simulation modeling is concerned with the lack of proper data, theories and hypotheses. In addition to these problems, simulation models are too often characterized by huge quantities of output. This makes interpretation and analysis difficult and evasive. Lastly, the cost of data and computing time may seem to be high, but nevertheless simulation is potentially one of the most effective alternatives available for interdisciplinary rural development research.

REFERENCES

[1] Billingsley, Ray V., and Ronald D. Lacewell, "Systems Simulation and Rural Development Research," Quantitative Techniques with Application to Rural Development Research, Southern Farm Management Research Committee, The Farm Foundation, March 1972.

[2] Billingsley, Ray V., and Douglass Norvell, A Macro Economic-Demographic Simulation Model of the Dominican Republic, International Programs Information Report No. 71-1, Texas A&M University, 1971.

[3] Billingsley, Ray V., and Stanley E. Wilson, Program and Model Documentation Standards, Departmental Program and Model Documentation Series No. 70-1, Department of Agricultural Economics, Texas A&M University, February 1971.

[4] Cain, V. R., The Regional Modeling Program at Oak Ridge National Laboratory, Meeting of Rural Sociology Section of the Association of Southern Agricultural Workers, Jacksonville, Florida, February 1-3, 1971.

[5] Forrester, Jay W., Conterintuitive Behavior of Social Systems, Testimony for the Subcommittee on Urban Growth of the Committee on Banking and Currency, House of Representatives, Washington, D.C., October 1970.

[6] Forrester, Jay W., Principles of Systems, Cambridge: Wright-Allen Press, 1968.

[7] Halter, A. N., and G. W. Dean, Simulation of a California Range-Feedlot Operation, California Agricultural Experiment Station, Giannini Foundation of Agricultural Economics, Giannini Foundation Research Report No. 282, University of California, May 1965.

[8] Hartman, John J., Annotated Bibliography on Simulation in the Social Sciences, Iowa Agricultural and Home Economics Experiment Station, Iowa State University, Ames, Iowa, 1966.

[9] Hillier, Frederick S., and Gerald J. Lieberman, Introduction to Operation Research, San Francisco, Holdenday, Inc., 1968.

[10] Holland, Edward P., et al., Simulmatics Corporation, Dynamic Models for Simulating the Venezuelan Economy, Cambridge: The Simulmatics Corporation, September 1966.

[11] Johnson, Glenn L., et al., A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria, Michigan State University, East Lansing, Michigan, June 30, 1971.

[12] Kresge, David T., and Paul O. Roberts, Systems Analysis and Simulation Models, The Brookings Institution, Washington, D.C., 1971.

[13] Maki, Wilbur R., Richard E. Suttor, and Gerald R. Barnard, Simulation of Regional Product and Income with Emphasis on Iowa, 1954-1974, Department of Economics, Iowa State University, Research Bulletin 548, Ames, Iowa, September 1966.

[14] Mathis, William K., A Simulation Model of the Cacao Industry of the Dominican Republic, International Programs Office Working Paper 69-2 Progress Report, Texas A&M University, March 1966.

[15] Mittra, Sid, Development Planning with a Simulation Model: The Case of Venezuela, a paper presented at the Southern Economic Association Meetings in New Orleans, Louisiana, November 1968.

[16] Raulerson, Richard C., Grower-Oriented Supply and Marketing Policies for Frozen Concentrated Orange Juice, Ag. Econ. Report 1, University of Florida, Gainesville, Florida, November 1969.

[17] Schreiner, Dean, and George Muncrief, Estimating Regional Information Systems with Application to Community Service Planning, prepared for presentation at the Mid-Continent Regional Science Association meetings in Winnipeg, Canada, June 14-16, Oklahoma Agricultural Experiment Station Journal Article 2313, Oklahoma State University, Stillwater, Oklahoma.

[18] Texas Water Development Board, Systems Simulation for Management of a Total Water Resource, Vol. I, Report No. 118, 1970.

[19] Tweeten, Luther, Systems Planning for Rural Development, Journal Article 2253 of the Agricultural Experiment Station, Oklahoma State University, Stillwater, Oklahoma, 1971.

[20] Watt, Kenneth, and Staff, "A Model of Society," Simulation, Vol. 14, No. 4, pp. 153-164, April 1970, LaJolla, California.

[21] Werner, Roland, and Joan T. Werner, Bibliography of Simulations: Social Systems and Education, Western Behavioral Sciences Institute, LaJolla, California, January 1969.