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9. ABSTRACT

First, the author discusses the history of simulation work with particular emphasis upon his own experiences over the past 30 years or so. As part of this historical presentation he discusses the meaning of the general, systems-science, simulation analysis approach as he perceives it. This discussion of the meaning of general systems-science simulation analysis permits him to relate the general, systems-science, simulation approach to more specific techniques. As his colleagues deal with the specific applications which they have made, he is not very specific with respect to case studies; instead, he discusses validation and verification of general, systems-science simulation models. The manuscript is completed with a discussion of the developments still needed in the general, systems-science, simulation, analysis approach to policy, program and project analysis at both macro and micro levels.

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GENERAL, SYSTEMS-SCIENCE, SIMULATION ANALYSIS

--AN INTRODUCTION

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January 27, 1973

It is a little difficult for me to know how to be most helpful in introducing a session on general systems analysis which is in a part of a Colloquium on Advanced Methodologies for Agricultural Investment and Policy Analysis, that part being entitled, "Sector and Other Macro Models," while still other parts are entitled, "Project Evaluation Models," "Simulation for Project Evaluation," and "Commodity Models." The difficulty is that general, system-science, simulation analysis is useful in project evaluation, commodity analysis, and in sector and other macro models. Still further, another difficulty arises in distinguishing between the general systems approach and models based on less general techniques. As it is our responsibility to discuss the general, systems-science, simulation analysis approach, we have to deal with the specific techniques covered by Eric Thorbecke and Dick Day as well as with the presentations of Hussain, Al Egbert and Tony Rojko. All such techniques are, can be or should be, part of the general approach we are following. We would not want to have to get along without any one of them.

On the basis of experiences at a number of symposia and conferences dealing with simulation and sector analysis, it appears to me that I can be of most help by following an outline somewhat as follows: First, I will discuss the history of simulation work with particular emphasis upon my own experiences over the past 30 years or so. As part of this historical presentation, I will discuss the meaning of the general, systems-science, simulation analysis approach as we perceive it. This discussion of the meaning of general systems-science simulation analysis will permit me to relate the general, systems-science, simulation approach to more specific techniques. As my colleagues are going to deal with the specific applications which we have made, I will not try to be very specific with respect to case studies; instead, I will also discuss validation and verification of general,

systems-science simulation models. The manuscript will be completed with a discussion of the developments still needed in the general, systems-science, simulation, analysis approach to policy, program and project analysis at both macro and micro levels. An examination of the program for our colloquium will indicate that this paper cover the presentations I am responsible for on both January 29 and 30, 1973.

Historical Perspective

In order to gain perspective on simulation I propose to examine some relevant history. In part, this history is personal. I hope to be forgiven for references to personal experiences which are the source of my own sense of relevance and, hence, important for what I have to say.

If one were able to go back into history before the advent of the written word, I suppose he would find, military, family and governing decision makers involved in problem solving. I suppose further that the most successful of these family, military and governmental decision makers would be those able to acquire superior "pictures" or "images" of the situation in which their problems occur. Still further, I would conjecture that the most successful decision makers were those who could extend the picture of the current situation in which they existed into the future to envision the consequences of alternative family, military and governmental decisions.

As governments, businesses and military organizations have developed better decision-making capacity, increasing emphasis has been placed upon what we now refer to as situation reports, briefs and position papers. Investigative staffs, practical research organizations, etc., engage in the production of these reports and papers for various decision-making individuals and groups. Oftentimes, the interaction between decision makers and investigative organizations is very close. These briefs, situation

reports and position papers commonly involve the development of a picture of the current situation and "projections" as to the consequences of alternative courses of action and include, in some instances, justification for favoring one course of action over the other alternatives.

My own experiences with such work involves: (1) pre- and post-World War II experience in the Bureau of Agricultural Economics doing such work for members of Congress and administrators from the USDA, the Bureau of the Budget and other governmental administrators; (2) a period of time in the Navy in which I served as the staff supply officer for the commander of all the destroyers in the U. S. Atlantic Fleet; (3) service as a consultant and practical applied research to help decision makers reach decisions as to what actions should be taken to solve various problems these consultantive experiences including sessions with the Norwegian Institute of Agricultural Economics, TVA, Rockefeller and Ford Foundations, and membership in a State Department/Foreign Assistance/Military evaluation project in Thailand; (4) a directorship of the Economic Development Institute of the University of Nigeria; and (5) the directorship of the Consortium for the Study of Nigerian Rural Development and the Korean Agricultural Sector Study. Those more direct problem solving assignments are in addition to "arms length" studies of the burley tobacco industry, many micro farm management studies, study of the United States dairy adjustment problems of the late 50's, the feed-grain livestock adjustment problems and the 60's, and a study of the resource allocation problems of U. S. Agriculture in 1917 to the late 60's for Resources for the Future. These experiences contain a thread which leads to my current interest in general, computerized, systems-science, simulation as expressed in our agricultural sector analyses for Nigeria and Korea. I will trace out this thread in the paragraphs ahead in the hope that it will help some of you see more clearly the value of our approach.

Prior to World War II, when the USDA was involved in developing the national agricultural accounts and its capacity to produce situation reports for major commodities, agricultural income, marketing and transportation, and prices, the approach was an extremely flexible one. Regression and correlation analysis were the most complex techniques employed, but as O. C. Stine once said, "most of the important time-series data were developed using addition, subtraction and occasionally multiplication and division." At the technique level, the subjects discussed were whether or not graphic correlation was conceptually identical to mathematical correlation. Slanderous things were said about the nonlinear regression lines used by such seat-of-the-pants analysts as Louie Bean while Meyer Girschick worked with people like Dick Foote and Russell Ives in the USDA to improve economic analyses with the introduction of theory and what was then regarded as modern statistical techniques. Crude but flexible statistical techniques were employed. Information was gathered from a wide variety of sources including Sears Roebuck catalogs, the trade journals, historical accounts and the judgment of informed, experienced people. In addition to developing the National Agricultural Accounts, situation and outlook reports, and projections were developed, the latter with respect to program and project as well as policy problems.

In developing the outlook reports and in making projections, straightforward, nonstructural predictive equations were often used. In some instances, regression lines were interpreted as supply functions and in other instances they were referred to as demand functions. In connection with this work, Elmer Working wrote his important article entitled, "What do Statistical Demand Curves Show." It is probably important to note that it was only on rare occasions that statistically estimated supply and demand

curves were used to simultaneously determine an equilibrium price which was projected as the price which would actually materialize. Generally speaking, the situation and outlook reports and projections developed for problematic situations attained a high degree of credibility among legislative and administrative decision-makers.

Despite the high credibility which these situation reports and projections attained, there was a great deal of critical soul-searching done by the persons doing this work. They felt uneasy with their informal, apparently unscientific methods of bringing together a great melange of data using ad hoc seat-of-the-pants techniques to extract their meanings and to make projections as to the consequences of alternative courses of action. Economic theorists and statisticians were critical of the situation, outlook and projection workers who were, perhaps, oversensitive to these critics while appreciating inadequately the credibility which their work had attained with decision-makers.

By the end of World War II, significant advances had been made by members of the Cowles Commission at the University of Chicago in techniques for making probabilistic estimates of the parameters of systems of simultaneous linear equations. These techniques tended to be specialized on time series data, linear equations and behavioral assumptions involving maximization. When I left the USDA to go to the University of Chicago, it was with high hopes that the simultaneous equations approach of the Cowles Commission would permit me to overcome the imprecision, the sloppiness, and the unscientific aspects of the situations, outlook and projections work I had been doing at the USDA.

Persons using the simultaneous equations techniques developed at the Cowles Commission have been successful in winning a considerable number of

awards from the American Agricultural Economics Association, formerly called the American Farm Economics Association. However, in all candor, it must be admitted that applications of the simultaneous equations technique have not attained the credibility among decision makers which the old seat-of-the-pants projections attained and still maintain. Recently, an Australian graduate student of mine examined two simultaneous equation studies, both award winners in the American Agricultural Economics Association. I authored one of them. Both studies failed to maintain validity for more than a short period of time after being constructed. Among governmental decision makers there has been a "credibility gap" with respect to applications of simultaneous equations (Cowles Commission variety) done in the Department of Agriculture. Similar skepticism was encountered by analysts from the National Bureau of Economic Research and by Kline and Goldberger with their national econometric model of the United States, the agricultural sector of which was developed by one of my graduate students, William Cromarty. The failure of systems of simultaneous equations (with probabilistically estimated parameters) to attain the credibility of seat-of-the-pants projections is one of the problems encountered by persons doing generalized, computerized, systems-science simulations these days. More will be said about this later.

Also, the development of linear programming was well underway while I was at the University of Chicago. Tjallings Koopmans worked on optimum systems for utilizing available ships to ship war materials in the Pacific area during World War II. Again, there was much hope that linear programming would overcome the imprecision and the ad hoc nature of many seat-of-the-pants projections. This hope was shared by farm management men who had been

budgeting and planning farms on the basis of a wide range of technical, institutional and people-oriented data. There was also the hope that the soil conservation plans being made by the ecologists of that day could be better handled with linear programming, while, at governmental levels, there was hope that irrigation, flood control and other problems could be more effectively handled with LP as well as problems involving the geographic distribution of production, etc. As Koopmans was explaining the theory of linear programming in the late '40s, there was the hope that improved computers would make it possible to carry out the large scale matrix inversions involved in such work. Forerunners of present day solid state computers were beginning to come into existence.

As in the case of simultaneous equations with probabilistically estimated parameters, linear programming has not fulfilled the hopes which we had for it. Even more work has been done with linear programming than with simultaneous equations. In my experiences, studies involving this technique include the Lake States Dairy Adjustment Study, the Feed-Grain Livestock Study, plus a large number of my own studies. One reason for LPing these studies was the ill repute into which simultaneous equation analysis of supply responses had fallen. However, the results obtained from the LP studies were no better and in many cases were worse than those obtained from simultaneous equation analysis. Thus, it must be admitted that a very substantial "credibility gap" now exists with respect to the results of linear programming computations. This is despite the fact that the original single period LP's have been expanded to complex recursive LP's, integer programming, multi-period LP's, etc. Somehow or another, the flexibility of the old farm management and soil conservation budgeters

and of the industrial and governmental seat-of-the-pants projectionists has not been maintained by the LP analysts. The budgeters and projectionists have been in position to do important premaximization work as well as to carry out maximization computations, however less efficient their computations are for purposes of locating economic optima and equilibria. Their strengths are to be found in this premaximization work which helped attack the sequence problems which must be handled before maximization computations can locate economic optima and points of equilibria, in the use of such premaximization computations to find common denominators among the non-monetary values being sought and avoided in planning processes, and in investigating (under risk and uncertainty) the consequences of using alternative decision making rules.

Another group of specialized techniques which has come into considerable prominence in recent years includes benefit/cost ratios and internal rates of return. These have been used more for project analysis than for analyzing alternative policies and programs. Probably because they have not been as oversold as simultaneous equations and linear programming, there has been less disillusionment with these techniques than with the other two; however, they have not developed high degrees of credibility. Basically, they suffer from one of linear programmings difficulties, that difficulty being the necessity of having a common denominator among the goods being sought and the bads being avoided. Until such a common denominator is available, benefit/cost ratios and internal rates of return cannot be computed. When non-monetary values are being sought and avoided, the benefit/cost analyst or the internal rate of return analyst generally tries to convert non-monetary values into monetary values or omits them. To the extent that the conversion is questionable or important non-monetary values are omitted, the work fails to gain credibility among decision makers.

The failures of specialized techniques should not be overemphasized--it's not that the techniques themselves are particularly deficient; instead, the difficulty in my judgment is found in inappropriate, inflexible uses of specialized techniques which are easy to misuse precisely because they are specialized.

The above experiences preceeded about two years service as director of the Economic Development Institute of the University of Nigeria where we worked on a wide variety of economic development problems. On completing this assignment, I returned to Michigan and was asked to head up the Consortium for the Study of Nigerian Rural Development (CSNRD). That consortium included the University of Wisconsin, Kansas State University, Colorado State University and Michigan State University on this side of the Atlantic and the Universities of Nigeria and Ibadan in Nigeria. In addition, the U. S. Department of Agriculture, the Research Triangle Institute, the U. S. Department of the Interior and, of course, AID were involved on the U. S. side while on the Nigerian side the Federal Research Department, the National Universities Commission and the Ministry of Economic Development were involved as well as the Ministries of Agriculture and Economic Planning of the four regions existing before the secessionist (Biafran) difficulties. Both at the University of Nigeria and as Director of CSNRD, I was unwilling to specialize development research inflexibly on simultaneous equations, linear programming in its various forms, benefit/cost ratios, or any one such specialized techniques. At the Economic Development Institute, we had used a wide range of data and techniques. When I became director of CSNRD, I resolved to be equally flexible with respect to both specialized techniques and sources of data; hence, the CSNRD effort cannot be characterized as focused on any particular technique. Actually, we did make rather extensive use of linear programming for one sub-project and did use benefit/cost ratios to a limited extent. Because of the lack of

time series data, we did not use the Cowles Commission variety of simultaneous equations extensively. We operated flexibly using data available from any source including the opinions of experienced, reputedly wise personnel. The final report of the consortium is a result of using about every source of information at hand and about every technique which was possible to apply, given the data available in Nigeria at that time.

Just before I started the CSNRD project, I also accepted a grant from Resources for the Future to study U. S. agricultural policies 1917 through the late 1960's. The grant for doing this work was based upon a work plan which did not specify that any particular technique such as linear programming, simultaneous equations, cost/benefit ratios, input/output analysis, etc. be employed but provided, instead, that the techniques to be used would be those found appropriate in view of the data available and situations and problems to be studied.

While administering the CSNRD project, I became very impressed with the large amounts of money and manpower used up by our flexible, seat-of-the-pants approach. At about this time, I heard Albert Halter deliver a presentation at the North Central Farm Management Research Committee on computerized, systems-science simulations. He spoke about an analysis which they had carried out of a watershed development project in Oregon. The project involved water storage, recreational, drainage and irrigation values. A common denominator was not readily available to translate the water storage values into terms comparable with the values of attaining recreational irrigation, and drainage objectives. Hence, neither LP or cost/benefit analysis were applicable. Further, a great range of data was required and only some of the data were available and, that, from a great variety of sources.

As Halter explained the generalized, systems-science, simulation approach they were following, I was struck with (1) the efficiency with which computations were being made, and (2) the similarity between it and the earlier seat-of-the-pants projections of the USDA and the work of practical farm management analysts and soil conservationists all of which had maintained a level of credibility not attained by more modern, specialized techniques. The approach which Halter was describing was flexible with respect to types and sources of information. It did not require maximization; instead, it often produced "print-outs" of the results of following alternative policies and programs through time in terms of the attainment of a number of different goods and the incurrence of a number of different bads. The print-outs looked more like the menus which one inspects when he goes to a restaurant than the solution to a linear programming problem. When one goes to the restaurant, he knows the situation he is in. Similarly, the decision makers for the Oregon watershed had a pretty good idea of the situation which they were in both as a result of their own work and as a result of the work which Halter had done. What was needed, so to speak, was a menu showing the consequences through time of alternative courses of action in terms of several different kinds of goods being sought and bads being avoided. To have provided the Oregon decision makers with maximizing computations would be like presenting a person in a restaurant with a menu describing five meals as follows: - meal one--400 net utils, meal two--425 net utils, meal three--426 net utils, meal four--428, and meal five--435 utils. Decision makers with respect to the Oregon watershed were interested in what kinds of goods would be attained, when and by whom. They were also interested in what kinds of bads would be imposed upon them and when. A person selecting a meal is interested in whether or not he will have soup

or cocktail and, if the latter, whether or not it will be alcoholic, whether he will have access to a gourmet table, what the entree will be, what kind of salad dressing he will have on what kind of salad and whether or not the main course will be followed by desert, coffee and, perhaps, an after dinner liquor. After he has such information, he may be able to find the "trade-offs" (common denominators) among the goods and bads involved and be able to select the best among the alternatives before him. I believe that the Oregon decision makers were in essentially this situation.

As a result of hearing Halter's presentation, I investigated the possibility of applying the generalized, computerized, systems-science, simulation approach to the work of the Consortium for the Study of Nigerian Rural Development. There appeared to be tremendous advantages in computerizing the computations while maintaining great flexibility with respect to techniques and sources of information permitted by the approach. Hence, I prevailed upon Michigan State administrators to provide resources to hold a simulation conference. A number of notable persons attended that conference including Wolf Stolper who helped develop the first Nigerian development plan, Irma Adelman, a number of systems scientists from the space industry, and a number of persons concerned with agricultural development. The conclusion at the conference was that the approach was not yet well enough developed for the Consortium for the Study of Nigerian Rural Development to apply it in connection with its Nigerian work. While software components were available with respect to simultaneous equations, linear programs, etc. it was apparent that these components were not a sufficient basis upon which to develop such generalized models. Many of the other components simply had not been developed. Still further, the general system into which such components could be embedded had not yet been developed. Hence,

CSNRD investigators went back to work following the costly but flexible seat-of-the-pants approach which had credibility among decision makers.

As a result of the conference held at MSU, AID contracted with Michigan State University (contract AID/csd-1557) to develop the simulation approach for the purpose of doing agricultural sector analyses of the general type we had undertaken in Nigeria. There was considerable skepticism in the Research Advisory Committee of the AID and in AID itself. This skepticism grew more out of the credibility gaps for simultaneous equations, linear programs, etc., with which people had had experience than out of the general, computerized, systems-science, simulation approach with which they had not yet had experience and which was not yet recognized as basically similar to the old, seat-of-the-pants projections. There was and still is a general distrust of any systematic, computerized analysis. As a result, the contract was let sequentially to model only a subsector the first year with subsequent funding dependent on success the first year. Because simulation requires that something from the real world be modeled and inasmuch as we knew a great deal about Nigeria as a result of the CSNRD study, we elected to model the beef sector of northern Nigeria. Another reason for modeling the beef sector of Nigeria was the fact that a beef subproject of the earlier CSNRD project had been cancelled as a result of the earlier secessionist difficulty in eastern Nigeria. Copies of the Nigerian simulation study have been made available to persons attending this conference and considerable attention will be given to various aspects of the Nigerian model and its components developed in the next few meetings of this colloquium.

Our next experience at Michigan State University was with a project conducted under contract AID/csd-2975. That project committed Michigan State

University to apply the simulation components and models developed under the earlier contract in actual situations. Under this contract, an exploratory team went to Korea in June of 1971 under AID/cad-184. By September of 1971, a simulation team was in Korea under the field project directorship of Ed Rossmiller with Tom Manetsch providing the systems science skills.

Under this project, approximately 40 man-months were used and the draft report for the Korean project was delivered at the end of seven months. Costs ran at approximately 20 percent of the seat-of-the-pants Nigerian study which took three years and over 30 man-years. Eight special reports based on a larger number of working papers were prepared for Korea. Probably a higher proportion of the professional man-months was devoted to collecting descriptive information about the organization, structure and administration of the agricultural sector of Korea than was true in the case of the Nigerian seat-of-the-pants study. Had computers not been available in Korea, the project would have taken longer but the use of computers in Japan or in the United States would have resulted in great economies vis-a-vis the Nigerian project. It is sometimes stated that poor countries cannot afford to computerize agricultural sector studies. On the basis of my experience in administering three different, major research projects, I would reverse the statement and assert that poor countries cannot afford a non-computerized agricultural sector study unless, of course, the study is being subsidized by some rich donor country or international agency.

As in the case of the Nigerian study, the Korean simulation model and results have been distributed to members of this symposium and will be discussed in considerable detail by my colleagues; hence, I will not discuss that model in detail.

The next portions of this section will (1) describe the general, computerized, systems-science simulation approach, (2) discuss backgrounds of teams required to do multidisciplinary work involved in sector analysis and finally the role of simulation in sector analysis, and (3) discuss aspects of problems encountered in sector analysis that create need for the systems-science approach to simulation.

The Meaning of the General, Computerized, Systems-Science, Simulation Approach

The approach is describable with four adjectives: (1) general, (2) simulated, (3) systems-science, and (4) computerized.

The approach is general with respect to (a) techniques, (b) kinds of data and information used in building and usable in operating it, (c) subject matter, and (d) philosophic orientation. It is our observation that there is a credibility gap among both public and private decision makers concerning highly specialized models and analyses. The approach attempts to avoid this gap by building a general model to trace the consequences through time of following alternative courses of action based on at least as wide a range of kinds and sources of data and information as decision makers use without specializing in any one technique to the exclusion of techniques frequently used effectively by relevant decision makers. In addition, the approach carefully avoids premature application of maximization techniques in situations where decision makers realize that the multiplicity of goods sought and bads avoided has not yet been reduced to a common denominator to be maximized.

As decision makers seek so many different goods and avoid so many different bads in developing agriculture, it is very difficult for them or anyone to find a common denominator for a maximizing model. Consider, for instance, the goods of (1) adequate food, (2) political stability, (3) off-farm migrants to develop industry, and (4) education. Also consider the bads of (1) unequal incomes between farm and urban people, (2) dependence on food imports, (3) water and air pollution, (4) urban slums, (5) destructive revolution, (6) malnutrition, (7) illiteracy, etc. Who can determine, before analysis, a common denominator among such divergent goods and bads?

And how can one be sure that the damages imposed on some by unequal agricultural growth are greater or lesser than benefits conferred on others? Who can know ahead of time the best order in which to execute the projects within a program, and the programs within a policy? And, if knowledge is uncertain, how can one know whether decision making should be cautious or chance taking?

Because of such complex questions, the approach uses, initially at least, general models to project the consequences of following alternative courses of action--in terms of several goods attained and bads incurred. These variables are termed performance variables or criteria. In this approach investigators view themselves as assisting public decision makers by (1) making projections of performance or criterion variables available, and (2) helping to reach prescriptive decisions as to the right action to take concerning policies and programs. Thus, the approach is general with respect to the use or nonuse of maximizing models.

It is also general with respect to sources of data and techniques, as it accepts data and information from many sources, that is, time series, carefully controlled experiments, the normative and non-normative judgments of informed men, survey data, and opinions, etc.

The approach is designed to trace the consequences of alternative courses of action through time. Therefore, it can be viewed as capable of simulating the performance of an agriculture sector under alternative policies. It is this ability to trace consequences through time which makes it a simulation approach. Simple planning and budgeting models employed long before the existence of even simple mechanical desk calculators were simulation approaches. Historically, such approaches attained and maintained high credibility among both public and private decision makers. It is a mistake to assume that only a computerized approach can be a simulation approach and that all simulation models are computerized. To do so is to

ignore some of the most effective simulation work done and most of the actual basis for private and public decision making. However, our models are constructed so they can be computerized.

The approach is also a systems science approach in which an agricultural sector is viewed as a system made up of sub-systems, and which is, itself, a sub-system of a still larger system, the national and world economies. When and if a general systems simulation model of the nonagricultural sector of a country is developed in the detail being created for agriculture, it will be easier to study more fully the farm/nonfarm interactions for the entire economy.

Required backgrounds for members of general, systems-science simulation teams:--Building simulation models is like the building of, say, a working model of a ship or an airplane. We do not model in the abstract; instead, we model some thing. The thing which is modeled in agricultural sector simulation exercises is the system involved in solving a specific practical problem of concern to some decision making unit such as a Ministry of Economic Planning or a Ministry of Agriculture. We have already seen the advantages of an approach which is general with respect to techniques and sources of information but have not stressed the number of disciplines typically required to model the system within which most practical problems exist. Practical problems are no respectors of the disciplinary organizations of universities. Ernest Nesslus, then director of the Extension Service at the University of Kentucky and now an agricultural economist working in South Vietnam, once observed that farmers have problems while universities have departments and that that difference is at the core of the problem of organizing universities to assist farmers.

Development problems have a way of involving combinations of the technological, institutional and humanistic disciplines which vary depending

upon which problem is being dealt with and, hence, which system is being modeled. This means that the teams which are set up to do simulation modeling work have to be multi-disciplinary in character and that the administrators of simulation projects must be capable of mobilizing assistance from different technical agricultural disciplines, the different rural social sciences and from the humanities, mathematics and statistics.

In the Nigerian simulation work, we drew repeatedly upon the skills, knowledge and concepts of animal husbandrymen, soil scientists and plant breeders. We also drew upon skills, concepts and descriptive information of economists, sociologists, educators, anthropologists, mathematicians, administrators and statisticians. The same was true in connection with the Korean simulation model. As economists, we must recognize that economics is not the dominant discipline in the general, systems-science simulation approach and that, for that matter, economists have no unique claim on or capacity for being project leaders to apply the approach.

In the Korean simulation work over 20 working parties were established. Each party produced a working paper. The working parties consisted of both Korean and MSU specialists in each particular subject. The working papers dealt with such subjects as crop and livestock production, credit, the National Agricultural Cooperatives Federation, water resources, price income and subsidies policies, technical agricultural research and advance, extension, rural institutions and infrastructure, administrative processes, population, capital formation, employment and migration, and nutrition. The working papers were later consolidated into eight special reports. You are urged to check the appendices of the Korean report for a listing of the working papers and special reports.

In several instances the working parties developed informal projections based upon a wide variety of data, information sources, techniques, and

judgments. Later some of these projections were used as inputs in the formal, computerized simulation model. Recognizing that information and skills from many disciplines were required, the persons assigned to produce various working papers included a sociologist, a person trained in public administration, an extension personnel specialist, an industrial psychologist, an animal husbandryman and an experiment station director as well as agricultural economists.

The importance of these working parties and papers in the Korean study cannot be over-emphasized. Had the simulation model not been used in computerized form, the budget simply would not have permitted such a large personnel input into the working parties and into the fundamental, basic working papers which proved to be so important in developing the formal simulation models and simulation projections; instead, a much higher proportion of the project's expensive professional time would have been consumed making paper-and-pencil and desk-calculator computations.

Aspects of generalized, systems-science, simulation models of importance in sectoral analysis:--We need to discuss more specifically the unique role which generalized, systems-science, simulation models have to play in finding solutions to agricultural development problems, particularly those problems occurring with respect to programs and policies at the sectoral level. At such levels the problems encountered are complex ones involving the attainment of a large number of values, some monetary and some non-monetary, and the avoidance of a large number of bads, some of which are measureable in monetary terms and some of which are not. We have already stressed the advantages of the flexibility which general systems science simulation models have with respect to sources of information and techniques of analysis. If in addition to maintaining these kinds of

flexibility, the systems analyst can maintain a philosophic orientation sufficiently flexible to permit analysis of questions involving both monetary and non-monetary values, much greater progress can be made in reaching solutions to these problems.

We have stressed the advantage of considering techniques which do not require immediate maximization; however, solving practical problems eventually involves attaining prescriptive information as to the right course of action. The ultimate use of the generalized, systems-science, simulation approach is to maximize in the sense that the purpose is to assist in determining the best course of action to be taken. If the modeling is done in a flexible way with respect to philosophic positions, much progress can be made in showing decision makers the consequences of alternative courses of action in terms of what goods will be received by which groups of people, when, and in what quantities. Similarly, much progress can be made in showing decision makers which bads will be imposed upon who, in what quantities, and when. After such projections are available, interaction between investigative staffs and decision makers becomes extremely important. During such interactions, much can be learned concerning the trade-offs among the numerous goods and bads involved in the solution of the problem. Learning about the trade-offs is tantamount to, or the same as, finding a common denominator among the various goods and bads. To the extent investigators and decision makers can work interactively to find trade-offs, they can develop a basis for choosing the best among the alternative courses of action they are considering.

In connection with the above discussion, I would like to call your attention particularly to Chapter IV of the Korean Agricultural Sector Analysis report. That chapter discusses the KASS approach and related methodological issues with particular emphasis upon the problem of working

with the normative. Of special importance is a glossary of terms. Once this glossary of terms is mastered, much more meaningful discussions can be carried out concerning the methodological issues involved in working with normative information to reach prescriptive conclusions. I would also like to call attention to Chapter V where Ed Rossmiller, the field project leader for the Korean Agricultural Sector Study, has used the glossary of terms from Chapter IV to discuss the values important for the development of Korean agriculture. Following and during interactions concerning the projections reported in Chapter VI, the recommendations were developed which are presented in Chapter VII. I hope you will relate Chapters IV, V, VI and VII to each other.

Because we are at the World Bank Colloquium, it seems particularly important to point out the relevance of the above discussion for the activities of the World Bank. In the December 15 issue of the Christian Science Monitor, Harry B. Ellis reported an interview with Vice-President Kenneth Thompson of the Rockefeller Foundation who, according to the interview "was echoing" what Robert S. McNamara, President of the World Bank, had long been stressing when he stated, "that foreign aid problems by in large fail to reach down to the poorest people of the poorest land." The article continues, "Asian, African and Latin American populations continue to burgeon. The elite classes of developing countries--those who hold land, wealth and political power--benefit from crop explosions and other foreign aid offshoots, but often fail to spread these gains among their poor." The article places great stress on the attainment of non-monetary values having to do with the distribution of income and the elimination of poverty. Eliminating poverty involves paying attention to the value of more equal access to employment opportunities, nutrition, education, etc.

The Korean Agricultural Sector Study analysts followed the line of reasoning advocated by Mr. McNamara of the World Bank and paid considerable attention to the distribution of income between the farm and non-farm sector and within the farm sector. They also devoted considerable attention to the rate at which employment opportunities could be developed in the two sectors. Non-monetary values taken into consideration included the advantages of fairly high degrees of food self-sufficiency in a country on the edge of troubled Asia, the value of more equally distributed employment opportunities and the value of more equal incomes for farmers. As a result of taking such non-monetary values into account, KASS investigators in interaction with Korean decision makers concluded that relatively high internal grain prices should be maintained in Korea along with an expansion of research efforts to improve grain production possibilities in Korea in order to create more rural employment opportunities and higher incomes for rural people as a way of stemming the rapid out-migration of untrained disadvantaged people from the countryside to unemployment in the slums of cities such as Seoul and Pusan. However, it is interesting to note that the Korea study effort was followed by the efforts of an IBRD mission to study Korea's agricultural sector which focused much more narrowly on monetary values than did the KASS group in an apparent unawareness of President McNamara's interest in non-monetary values.

Validation and Verification

Persons using LP components and those following the general, systems-science, simulation approach are often queried concerning the reliability of their estimates of parameters, criterion variables, and prescriptions by users of their analysis. Further, as noted above, econometricians using simultaneous equations systems with parameters probabilistically estimated from time series data have repeatedly encountered credibility gaps with respect to their results.

A significant conference on the problem of validating and verifying components of simulation models was held at Purdue University under the sponsorship of the Agricultural Development Council. At that conference, there were intense discussions between, on one hand, statistically-oriented persons intent upon validating estimates of parameters and variables according to techniques developed by statisticians and, on the other hand, linear programmers accustomed to obtaining estimates of unit requirements by "hook or crook." The linear programmers were not particularly sympathetic to the more "purist" attitudes of the statisticians. And, the statistionally-oriented were not sympathetic to the ad hoc approach of the programmers. Fortunately, there were at the Purdue conference some Bayesian statisticians who were more tolerant of the introduction of "prior" information to which "subjective" probabilities could or could not be attached. In general, the general, systems-science, simulation analysts felt more comfortable with the arguments of the linear programmers and the Bayesian statisticians because the general, systems-science, simulation analysts were also inclined to obtain information and data of any type needed from any available source including the judgments of wise, experienced persons to which only highly subjective probabilities can be attached.

It seems worthwhile making a few general statements about validation and verification. What validation and verification means to a particular investigator depends in part upon "the philosophy of truth" which guides his thinking. The positivist, for instance, feels that estimates of parameters and variables can only be validated or verified if they are free of normative content. His metaphysical predilections indicate to him that it is impossible to validate or verify the empirical meaning of any concept having to do with good and bad or right and wrong. The pragmatist, on the other hand, has metaphysical predilections which indicate to him that the truths of normative and positive statements are interdependent and that it is really nonsense to talk about the truth of one kind of statement without talking about the truth of the other within the particular problem-solving context in which the question of truth arises. By contrast with positivists and pragmatists, some purely normative investigators admit the possibility of verifying or validating the empirical truth of normative statements. We should observe that all of these different philosophies are "respectable" among philosophers and that positivism is by no means as dominant in philosophy as in the physical sciences and statistics.

In discussing validation and verification, it is worthwhile distinguishing among three kinds of estimates or information: the positive, normative and prescriptive. Normative information deals with the goodness and badness, per se, of conditions, situations and things. The positive deals with characteristics of conditions, situations and things which do not deal with their goodness and badness; hence, the positive is synonymous with the non-normative and can be so described. So defined the positive and normative are dichotomous. However, the positive and normative overlap in the sense portrayed as in Figure 1. The lune which is both positive and normative can be labelled prescriptive. Prescriptive information and

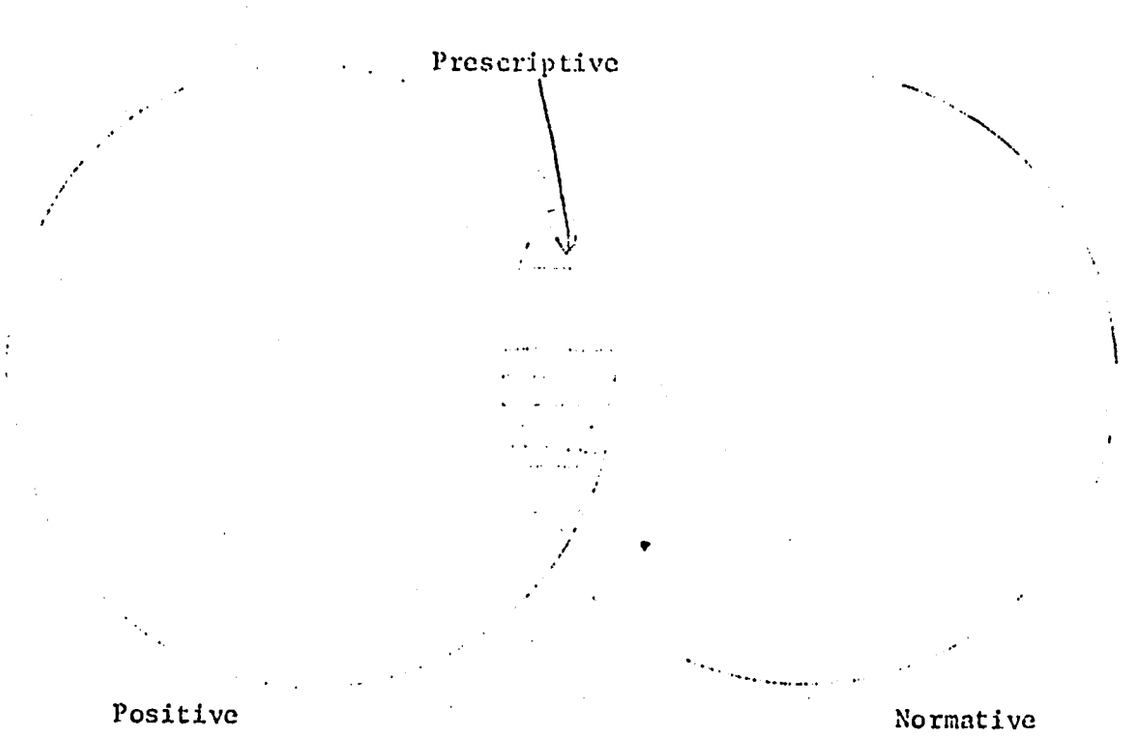

Figure 1

estimates indicate what it is "right" or "wrong" to do or to try to do and is based on both positive and normative information. Obviously, normative information is not enough to indicate by itself what it is right or wrong to do. It is sometimes wrong, for instance, to do that which is good because something better can be done. Conversely, it is often right to do that which is bad because nothing less bad can be done. Estimates and information about what is right or wrong to do are prescriptive and depend upon both positive and normative concepts.

In agricultural sector analysis we are often seeking to determine which policy is right and which policies are wrong. Similarly, at the program level we seek to prescribe for right programs and against wrong programs. The same is true for projects. In reaching such prescriptions about policies, programs, and projects, we need both normative and positive information and questions arise concerning the validity and truth or veracity of all three kinds of information.

In the modern world of the 20th century, validation and verification techniques and procedures are probably more highly developed and certainly more widely known and appreciated with respect to positive information than with respect to normative and prescriptive information. Procedures for validating and verifying positive information tend to be those developed by people following the positivistic philosophy which has dominated modern science. A relatively high proportion of statisticians are positivists.

Briefly, we accept and reject estimates and information according to whether it passes the four different tests. One of the tests is that of logical consistency with previously accepted concepts. If a bit of information is inconsistent with previously accepted concepts, either it must be abandoned or the previously accepted concepts must be modified until logical consistency is re-established. The consistency test occurs in a

second form. An investigator forms a new concept on the basis of new data from either a controlled experiment or observations on an operating system. This is the empirical test of experience. If the concept based upon the new information is inconsistent with other previously accepted concepts, either it has to be rejected or the previously accepted concepts have to be revised. A third test is that of clarity or intercommunicatability. This test insists that two persons in possession of the same set of previously accepted concepts and in possession of the same new data and information will reach essentially the same conclusion about its truth or falsity. If they do not, the concept has not obtained interpersonal communicatability and its validity is questionable. When a concept or estimate is regarded as true and attains this kind of communicatability, it is acceptable insofar as this test is concerned. The fourth test is the test of workability. If a new bit of information such as an estimate or a concept is used to solve a problem, a solution must be reached if the new information or concept is to remain acceptable. As a moments reflection will indicate, the test of workability is a special case of the second test which is the test of experience; however, it is not positivistic because valid normative information is required in order to verify whether or not a solution to a problem is obtained.

Whether or not all of the above four tests are applicable to normative and prescriptive as well as to positive information depends upon whether persons actually experience goodness and badness in the same way that they experience the positive or non-normative aspects of reality. In agricultural sector analyses we are concerned with the goodness and badness of unemployment, more or less equally distributed incomes, more or less adequate diets, polluted and non-polluted environments, justice and injustice, etc. If we

actually experience the goodness and badness of such conditions, situations and things, then the second of the four tests pointed out above is applicable and we can consider the possibility of empirically validating and verifying the normative concepts involved in our simulation models. Personally, I believe that we do experience the reality of the goodness and badness of such conditions, situations and things and that normative concepts are refutable and verifiable on the basis of experience.

Whether or not you agree personally with me, I believe that you have found that, in practice, normative and prescriptive information are treated as verifiable by decision makers. Thus, when general, systems-science, simulation models are used to help reach prescriptions as to what ought to be done, questions also arise as to whether such prescriptions are validatable or verifiable. If normative concepts are verifiable or validatable in the above sense, then prescriptions can be validated or verified. In fact, the fourth test listed above, the pragmatic test of workability, presumes that a solution to a problem can be recognized as having obtained the goodnesses being sought and as having avoided the badnesses being avoided.

Needed Further Developments in the General, Systems-Science Simulation Approach

The Michigan State experience with general, systems-science, simulation analyses of agricultural sectors has revealed a number of areas in need of much further development before the approach will reach its full potential. One area in need of further development involves ways and means of embedding in general systems-science simulation models, components based upon such specialized techniques as recursive linear programs, input/output analyses, the various benefit/cost ratio analyses, internal rates of return analyses, program evaluation and review techniques (PERT), and critical path analyses not to mention the systems of simultaneous equations of the Cowles Commission variety mentioned earlier in this paper. Another set of difficulties which need to be remedied by further development has to do with the inadequacies of economic theory as a basis for modeling such activities as the creation, saving, and use of farm generated capital; the process of investing in various forms of durable capital and the process of disinvesting in various forms of capital and labor viewed from the standpoints of both the individual firms in the economy and the agricultural sector as a whole; and the user cost problem which is closely related to deficiencies in investment and disinvestment theory. A third area in need of much further development has to do with the theory and concepts required to model changes in technology, institutions and in people. By and large, the disciplines concerned with such kinds of changes in society have not been particularly productive of theoretical systems useful in guiding the systems-science, simulation model builder. There are also serious problems encountered in building such models as a result of deficiencies in statistics and in the philosophies having to do with validation and verification, particularly

with the validation and verification of normative and prescriptive information. My colleague, Tom Manetsch will discuss needed developments in the "science of systems."

Ways and means of incorporating components involving specialized techniques into general systems-science simulation models:--One of the more important needs has to do with ways and means of embedding recursive linear programs into general systems-science analyses. The first recognition of a need to do this was stated publicly by Richard Day, who addressed this colloquium last week, at a conference at Iowa State University over two years ago where he pointed out that recursive linear programming should not be contrasted with general systems-science, simulation analyses and that he looked forward to the day when more general models would be available into which he could embed some of the recursive linear programming components he and his colleagues have been developing at the University of Wisconsin and in cooperation with Indian personnel at Ohio State University. It is the constructive attitude and work of people like Richard Day which will lead to ways and means of incorporating specialized linear programming components into more general, systems-science, simulation models.

The Korean model is seriously deficient with respect to a component for allocating land to different uses and for determining yields in different crops. Presently, land allocation in the Korean model is by a committee in a model including both man and computer operated components. As reported elsewhere at the colloquia, Lee, Jeung Han and Hartwig dellaen are working on incorporating a recursive linear programming component into the general model to replace the land allocating committee.

At the University of Missouri, there are one or two persons who are interested in incorporating PERT components in general systems-science analyses. I feel that such techniques and components hold considerable promise for investigating questions concerning the sequences in which projects should be performed within programs and in which programs should be inaugurated in executing alternative policy decisions and look forward to the day when ways and means will have been developed to incorporate components based on PERT techniques into general systems-science simulation analyses.

Similarly, I look forward to further development of ways and means of embedding components made up of sets of simultaneous equations with probabilistically estimated parameters into general, systems-science simulation models. I refer here to analyses of the type done by Eric Thorbecke, Lee Fletcher and many others and discussed at this colloquia. Such components have great value and should not be precluded from a system. Further, their advocates should not be permitted to preclude components based on other special techniques.

Among the other kinds of components which we need to learn to build into general simulation models, are components based upon cost/benefit and internal rates of return analyses.

Of particular importance are input/output (I/O) components which permit agricultural sector analysts to get from parts of the agricultural sector to other parts of the agricultural sector and particularly from the agricultural sector to parts of the non-agricultural sector and back again. The I/O components for our Nigerian model are crude while the I/O component for the Korean model is even cruder. Sam Daines of the Latin American

Bureau of AID is doing a great deal of agricultural sector analysis work with systems consisting primarily of LP and I/O components. He feels that input/output components as small as we have used in Nigeria are almost completely meaningless. I look forward to and will greatly welcome the development of ways and means of incorporating much larger I/O components than we have used for Nigeria and Korea into general systems-science simulation models and feel that Daines may have much to offer in the way of help in incorporating both LP and I/O components into more general modes. However, I/O components should be capable of accepting inputs from a great variety of other components rather than from just linear programming components. Day's recursive linear programming (RLP) components are important and it shouldn't be too hard to expand Daines I/O work to receive inputs from RLP components. We also know that it is not too difficult to develop ways and means of feeding inputs into national I/O tables from non-maximizing components of types commonly used in our own work. To my knowledge, no one has explored how to feed input/output tables with the output of cost/benefit, PERT and inte l rate of return components though, of course, such components may very well find important uses in the future.

It seems to me that this very brief sketch of work which needs to be done in order to incorporate various specialized techniques into more general models should indicate to us that we are wasting a great deal of time at colloquia such as this one comparing of so to speak, trees with forests; instead, we should be concentrating upon the best way to plant different varieties of trees in our forest.

Developments needed in economic theory to provide a better basis for modeling agricultural sectors:--Though economic theory is one of the better developed theoretical systems found in the academic world, it still has serious deficiencies which are revealed repeatedly when we use it to model the complex processes of agricultural growth, change, and/or deterioration. I will just mention a few of the areas which it is difficult to model and for which our components are particularly deficient.

In the agricultural economies of both the developed and the underdeveloped world, farm produced capital is important. Much of this capital is produced on the farm which is going to employ it. When this capital is produced, there is an increment in the real income of the farmer. This increment is automatically saved and invested. The ratios between the increments of income, savings and investments are all one and much of our theory about differential rates of income generation, savings and investment is irrelevant. In addition, it must be noted that much of the farm generated capital is produced by fixed underemployed labor, traditional capital and land used on an opportunity cost basis. The extra real income represented by such capital is not priced in the market. The marginal value productivity of such capital is, however, determined by the prices of the products which it will produce if such products are sold; if, however, the products are consumed, the marginal value product is not determined by a market price, but rather by an internal shadow price within a firm-household complex. Our models for studying the generation, saving and investment of capital produced on an opportunity cost basis from fixed resources are not at all adequate.

Closely related to the above difficulty is the user cost problem. The user cost problem is a disciplinary problem which must be solved in —

order to develop better models of the investment and disinvestment processes. Inasmuch as off-farm migration can be viewed as disinvestment of the agricultural sector in labor, the user cost problem remains a deterrent to the development of improved off-farm migration components.

We are all aware that the most durable goods, including people, are capable of generating various rates of service flows. Varying the rate at which a durable generates services generally involves an additional cost. This cost is referred to as a user cost. Before optimal decisions can be made to disinvest in a fixed durable, the optimum rate at which services should be extracted from the durable needs to be known. Similarly, before optimal decisions can be made about investments in durables, the optimum rate at which it is advantageous to extract services from the durable needs to be known. Thus, until the fundamental problem of user cost is solved, our models with respect to investment and disinvestment (including off-farm migration) will remain deficient. It is perhaps worthwhile noting that our attention was drawn to user cost by John Maynard Keynes who was impressed with the influence of varying the rates at which services are extracted from durables at different points in the business cycle. Subsequently, Arthur Lewis investigated the user cost problem in some detail. He came up with three formulations of user cost, but was unable to provide a rationale for accepting any one of them. Recently, Francis Idachaba, now at the University of Ibadan in Nigeria, has made some progress in deriving marginal and average variable user cost concepts. I look forward to the possibility that Idachaba may solve this problem. If he does, it will then become possible to develop better investment and disinvestment components for general simulation models. Incidentally, none of the

linear programs (recursive or nonrecursive) model investments and disinvestments with proper attention to the role which user costs play. Similarly, all models I have inspected with respect to off-farm migration are deficient in this respect as most off-farm migration models are not complete until accompanied by an investment model to provide a capital substitute to more than replace the labor migrating off farms.

Needed developments with respect to technological advance, institutional changes and changes in the human agent:--Much of economics is concerned with the definition of equilibria assuming the absence of changes in technology, institutions and in the human agent. By contrast, many of the policies, programs and projects which we are concerned with in agricultural sector analysis involve the processes of changing technology, institutions and people. Economic theory (even including that part referred to as the theory of economic development) offers little help in explaining technical, institutional and human change. The theories of induced technological, advanced and institutional change seem much too limited and appear to be the work of academic imperialists from the discipline of economics rather than full blown attempts to explain the origin of technical advance and institutional change. To understand these changes, we need to understand the technical sciences, political science and the processes of creating technical change through the administration of research agencies as well as the process of administering other institutions. Generally speaking, political science has done little to develop a theory of institutional change. Marxian economics provides what I regard as an inadequate naive model of changes in institutions which produces conclusions inconsistent with my observations of institutional changes in both the communist and capitalist communist worlds. With such glaring theoretical and conceptual deficiencies

about all one can do in a paper such as this is note them and express the hope that we will develop a better conceptual understanding of how technical, institutional and human change occurs so that we may better model the processes in the future.