SOLVING HEALTH CARE PROBLEMS WITH THE SIMULATION APPROACH

by

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Simulation research is a promising approach for studying the problems of the health care industries whether the problems occur at project, program or policy levels. As simulation permits researchers and decision makers, both public and private, to ascertain better the consequences of alternative courses of action which might be taken to solve problems, it is useful in designing and selecting solutions. This paper will explain what is meant by simulation and then trace out briefly some of the experiences agricultural economists have had with the approach. It will then consider the selection of systems for simulation modeling and the steps involved in building and using simulation models. The discussion will then be made a little more concrete by considering the simulation model which might be developed to solve the health care problems of aged, commercial farmers in the Grand Traverse area of Michigan. After this, criticisms and shortcomings of the simulation approach to solving practical problems will be discussed before concluding with a brief summary of the place of simulation in solving health care problems.

What Is Simulation

One of the first things to do in addressing people interested in applying the simulation approach to help solve health care problems is to answer the question, "What is simulation?" Even if this were a report for simulators,

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it would be necessary to indicate the meaning which one wants to attach to the word because there are many, many different types of simulators, each type calling a somewhat different thing simulation.

I am going to talk about "generalized, computerized, systems-science" simulation. Such simulations are not specialized with respect to type or source of data, technique, discipline, or philosophy. They are adapted to utilize modern, high-speed, electronic computers and, hence, can be referred to as computerized. They also deal with the structure of systems and the activities which go on within such systems; hence, the approach of systems scientists is advantageous and simulations involving their work can be referred to as systems science simulations. Though systems scientists made their name in the aerospace industry originally, the systems science approach is applicable to any system including environmental or ecological systems; economic, social and political systems; and, of course, medical and health care delivery systems.

Having discussed briefly the meaning of the adjectives "generalized," "computerized" and "systems science," it remains to discuss the meaning of simulation as a noun. The word is used here to stand for a representation of a real world system which is capable of tracing the evolution of the system and activities generated within that system through <u>time</u>. The two essentials are that the system represent or be thought to represent at least some aspects of a real world system and that it be capable of operating through time. Examples include ship testing basins and pilot plants as well as mathematical representations of such operating systems as universities, hospitals and agricultural sectors. Models can also be expressed in English rather than in mathematics and, as such, can be still representative of real world systems at points of time and through time. The simulation

models that are to be discussed herein represent systems from the real world in terms of equations capable of being put on computers.

Why Simulate?

When one is asked the question, "Why simulate?" the experienced simulator is likely to answer, "because decisions concerning practical problems are almost always based upon knowledge concerning: (1) the structural nature of an existing or newly designed system about which a decision is being made and (2) how it would operate through time." To the simulator, this answer is as true historically as currently and will continue to be true for the indefinite future. Such an answer indicates that simulation is not a new thing dependent upon recent advances in mathematics, various subject-matter disciplines, and computer technology. It recognizes that down through the ages it has been important for decision makers to understand the structure of the systems they are trying to modify and to envision how the system's behavior would be affected by their decisions. Even before the advent of the written word, it is likely that the family, governmental, and military decision-makers who attained the greatest successes were those who did a superior job of envisioning the system in which they existed including how it would operate through time if various modifications were made in it.

My own early experiences as an agricultural economist include a period of pre-computer research in the Statistical Service Section of the Division of Historical and Statistical Research of the old Bureau of Agricultural Economics of the U. S. Department of Agriculture. The section served administrators from the executive branch and senators and congressmen from the legislative branch of the U. S. Government. It was continually engaged in developing statistical pictures of the structure and nature of the

U. S. agricultural economy or of some part thereof which was particularly relevant to then current problems and issues before administrative and legislative decision makers. As a young, grade one, junior professional assistant, I was asked repeatedly to make projections concerning the consequences through time of alternative legislative and administrative actions. Econometricians at the Cowles Commission at the University of Chicago had not yet developed the simultaneous equations technique of estimating the parameters of sets of simultaneous equations; hence, the specialized simultaneous econometric equations of the Cowles Commission variety were not used. Also, as linear programming had not yet been developed, specialized single period, static and multi-period dynamic and recursive linear programming were not employed. However, both mathematical and graphic correlation techniques were employed on occasion while a great variety of economic, political, technological, sociological and administrative concepts and theories were used. A great diversity of information was mobilized from "situation report writers" who had responsibility for accumulating various kinds of information from many sources concerning various commodity and subject matter areas. Supplemental information was obtained from lawyers, farmers, old Sears Roebuck catalogues, agronomists, animal husbandrymen, business men, sociologists, demographers, government administrators, congressmen, etc. This information was assembled on an ad hoc, flexible, seat-of-the-pants basis into a picture of "the situation" relevant to the problem at hand. Projections were also developed for alternative policy, program and project designs. These projections were developed laboriously but flexibly with paper, pencil, desk calculator and hunch until a reasonable picture was obtained of how

the existing system looked, operated and would be modified by the legislative and administrative proposals under consideration. Also, there was a great deal of interaction between the people making the projections and the decision makers. For a person as junior as I was at that time, the interaction with senators, congressmen, and government administrators was often with my supervisors rather than directly with me though it was not too long before it was clear that administrative and legislative decision makers wanted to talk directly to the person making the projections. Oftentimes the decision makers did not like the projected consequences of their own proposals and wanted to develop still other alternatives. In doing this, they wanted to talk to persons more capable than they were of describing the existing situation and of envisioning the consequences of their alternatives through time; hence, they sought direct contact. And, the person of making the projections found such interaction an important source of information.

The interactive process which was just described is far from unique; instead, it is characteristic of real world decision making, both public and private. Essentially, it is a staff/decision-maker relationship usually found between staff and decision makers in the military as well as in other administrative branches of the government and between legislative staff members and legislators. It is also the sort of working relationship which exists in businesses between decision makers and their staffs. My own studies of the managerial activities of individualistic farm entrepreneurs indicate that this relationship exists even for the single entrepreneur who serves simultaneously as decision maker and investigative staff.[1/]

[1/] Glenn L. Johnson, et. al., A Study of Managerial Processes of Midwestern Farmers, Iowa State University Press, Ames, Iowa, 1961.

The same is undoubtedly true of the M. D. operating as an individual entrepreneur. In the case of the single entrepreneur, interaction between investigators and decision makers is more complete and easier attained than in the case of multiple-person decision making units; however, the interaction is no less important for the single entrepreneur than for the multiple person entrepreneurial unit.

One of the disadvantages of paper and pencil, seat-of-the-pants, ad hoc projections is their high cost. They require large inputs of expensive professional time and the slowness with which computations can be made, make it difficult to make projections for more than a few at a few points in time for a small number of alternatives.

In the 40's and 50's, there was a period of time in which considerable mathematical and statistical progress was made with respect to very specialized techniques. One "leap forward" came at the Cowles Commission at the University of Chicago where the technique of making probability estimates of parameters of systems of simultaneous equations was developed. At the time this development was taking place, there was a great deal of hope that it would make the informal kinds of projections described above much more accurate and hence more effective; however, the technique did not live up to its promise. Retrospectively, the difficulty seems to be that the technique of making probabilistic estimates of the parameters of simultaneous equations was: (1) unduly specialized on sources and kinds of data; (2) dealt only with linear relationships when non-linear ones should be used; and (3) often assumed maximizing behavior on the part of producers and consumers who have not yet "sorted things out" well enough to maximize. Primarily time series and, in some instances, cross-sectional data were used. It was difficult to incorporate experimental data and prior information to which probabilities

could not be assigned and the information contained in the judgments of administrators and experienced personnel. To some extent, this difficulty has been overcome by recent developments of the so-called Bayesian approach to statistics.

Another development had to do with the development of linear programming which has also been computerized. Linear programming computations are maximizing computations and require the selection of a variable to be maximized. After its initial development, linear programming was extended so that programs could be run recursively and, hence, used as specialized simulation models. As linear programming models must maximize something, they, like the systems of simultaneous equations developed by econometricians, are of limited usefulness in exploring the structure of systems and the behavior of persons organizations not yet able to determine what to maximize. Simultaneous equations and linear programming projections have not achieved the wide acceptability of seat-of-the-pants projections among decision makers and important credibility gaps have developed for these techniques. These gaps have not been easily bridged by interactions between investigators and decision makers for a number of reasons. Included in these reasons are the complexity of the estimation technique, the narrow range of information used by investigators which often ignores information readily available to decision makers, the obvious premature or inappropriate uses of maximization, and the exclusion of creative, inventive ideas of decision makers. The unfavorable experiences of decision makers and administrators with projections produced by such highly specialized techniques have produced a suspicion of all computerized sophisticated estimates and a tendency to prefer common sense, more understandable, broader based, less specialized projections.

As more specialized approaches such as simultaneous equations and the linear programming techniques have less flexibility than the old paper and pencil, seat-of-the-pants projections, there is a need to maintain flexibility in modeling the structures and operations of real world systems. Generalized, computerized, systems-science simulation models have been successful in maintaining the flexibility of the seat-of-the-pants projections while exploiting the computation efficiency of the modern electronic computer and utilizing such specialized techniques as linear programming and econometric estimation of parameters of simultaneous equations; thus, part of the answer to the question of "Why simulate?" is that simulation can maintain the flexibility of the more creditable traditional seat-of-the-pants projections with respect to sources of data, kinds of information, disciplines, specific techniques without being constrained to specific types and sources of information, specialized techniques or single philosophic point of view. Furthermore, simulation can deal with criterion variables which are normative as well as with positive variables without necessarily maximizing or assuming maximization. Like the old seat-of-the-pants projections, simulation can permit creative, inventive, and original interactions with decision makers.

At this point, it is worthwhile to illustrate the decrease in costs which has been made possible by the use of systems science techniques and electronic computers in making projections. Neither systems science techniques nor the computer reduce the flexibility of the old seat-of-the-pants approach yet, together, they greatly reduce costs for a given system of any important degree of complexity. This can be illustrated from experiences in carrying out agricultural sector analyses of the development problems of two countries--Nigeria and Korea. Using seat-of-the-pants traditional projections for Nigeria,

an inter-university team expended 30 professional man-years of time constructing projections for three main policy alternatives at three points in time for Nigerian agriculture.[1/] In this connection, it was necessary to amass a great deal of information about the Nigerian agricultural situation. The project took three years. It was expensive. It did attain acceptability. The Nigerians used the final report along with an earlier report from FAO on Nigerian agriculture as the two basic resource documents for a six month agricultural development planning exercise and seminar. This planning exercise and seminar became the basis for the "perspective" agricultural development plan which is the basic input concerning agriculture into the development of Nigeria's next five-year plan. The high cost of making these seat-of-the-pants projections was impressive; as a result of these high costs, steps were taken to investigate the possiblity of using the generalized computerized systems-science, simulation approach. At a national conference of persons informed concerning this approach, it was concluded that the necessary software had not yet been developed. Fortunately, the Agency for International Development contracted with Michigan State University to proceed to develop such software with the hope that the cost of doing subsequent sector analyses could be greatly reduced. Subsequently, it costs about one-fifth of what the Nigerian study cost to develop the necessary software to model the Nigerian economy. [2/] This software was developed by the time the Nigerian Agricultural Development Seminar was held. In connection with that seminar, simulations were run for 17 policy alternatives by years for twenty years into the future at a cost of less than 2 percent of what the original seat-of-the-pants projections cost for these alternatives at three points in time.

[1/] Johnson, Glenn L., et al., "Strategies and Recommendations for Nigerian Rural Development 1969/1985," Consortium for the Study of Nigerian Rural Development, July, 1969.

[2/] Manetsch, Thomas J., et al., A Generalized Simulation Approach to Agricultural Sector Analysis, Consortium for the Study of Nigerian Rural Development, November, 1971.

Shortly after this, an agricultural sector study was done for Korea. Many of the software components developed for Nigeria were directly transferable to Korea. The main problem was to quickly amass a description of the current Korean situation. This was done utilizing the services of about 20 persons who were not particularly oriented to systems-science simulation modeling. However, the systems scientists and agricultural economists involved who were oriented towards such simulation modeling used their knowledge of such models and modeling techniques to guide the activity of the 20 or so non-simulators who participated in the Korean study. This greatly increased the efficiency with which observations were made on the existing economy. Further, the simulators were able to build that information quickly into mathematical equations which could be placed on the computer. This meant that the Korean group, unlike the Nigerian group, did not have to spend large amounts of very expensive professional time carrying out paper and pencil and desk calculator computations. The upshot of it was that the Korean's agricultural sector study document reached first draft stage within 7 months rather than 36 months at a cost of approximately one-fourth the cost of the Nigerian study.[1/] Still further, the Korean model was much more comprehensive and dealt with many more policy alternatives in much more detail than the original seat-of-the-pants projections for Nigeria. Clearly, there has been a substantial reduction in costs of making projections without losing the flexibility of the old seat-of-the-pants traditional projections.

Incidentally, it must be streesed that the generalized, systems-science simulation approach is not to be compared with such specialized techniques as linear programming, simultaneous econometric equations, cost/benefit analysis,

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[1/] Rossmiller, G. E., et al., Korean Agricultural Sector Analysis and Recommended Development Strategies 1971-1985, Korean Agricultural Sector Study Team, 1972.

input-output analysis, etc. It is not a specialized technique; instead, it is an approach. As an approach, it utilizes any one of such specialized techniques if it is appropriate to use them. In utilizing such a technique, the approach could concentrate entirely upon the technique or merely use it to model some small component of the system being modeled. In many instances, the investigation reveals that it is not advantageous to utilize certain specialized techniques such as linear programming, simultaneous econometric equations or cost benefit computations.

What System Should be Simulated

The building of a simulation model is like the building of, say, a working model of a ship or airplane. One does not set out to model the abstract; instead, one models some thing. The system involved in the solution of the practical problem of concern is modeled in practical, problem-solving work.

In this manuscript we are concerned with problems in the medical and health care industries. Thus, the systems which we are interested in modeling and simulating are medical and health care systems and which sub-system within a medical and health care industry we should be concerned with is determined by the practical problem we wish to work on. In some instances, we may be concerned with simple models of, say, the process of admitting persons to hospitals because problems are occurring at that point. In other instances, the problems may involve a community health care project and a larger sub-system would have to be modeled. In still other instances, the problem may involve medical or health care programs involving substantial numbers of projects in which case still larger sub-systems have to be modeled. In still other cases, the focus may be upon medical and health care policy problems. Generally speaking, policy problems involve the operation of very

large sub-systems of the health care industry involving numerous programs and projects. At this point it is sufficient to make the point that the particular part of reality to be modeled and simulated depends upon the practical problem which we face. Practical problems are defined in terms of the value of conditions, situations and things being sought and avoided in real world situations. Information about values is normative. Normative information accumulates throughout the problem-solving process. At the beginning of a simulation project, it is not usually clear what all the relevant values are. As the project progresses and as the model develops, normative information is accumulated as to what is more and what is less important than originally thought; thus, the problem and the system to be modeled and simulated changes as a simulation study of a problem progresses from its beginning to its conclusion.

Simulation and the Process of Solving Practical Problems

The above discussion has indicated that the system to be simulated is determined by the problem to be investigated. Simulation can be viewed here as an iterative problem-solving process which involves problem formulation, mathematical modeling, refinement and testing of the resulting model, and creative design and executive of simulation experiments intended to provide answers to the questions posed. We conceptualize the process as shown in Figure 1. As the arrows indicate, the general movement of the process is from definition of the problem toward model application, but the reverse arrows indicate that the process is iterative or "learning" in nature. Prior stages often have to be repeated on the basis of feedback information acquired during a subsequent stage. In this manner, changes in model structure, parameters, etc., are introduced which lead to a better model. The "output"

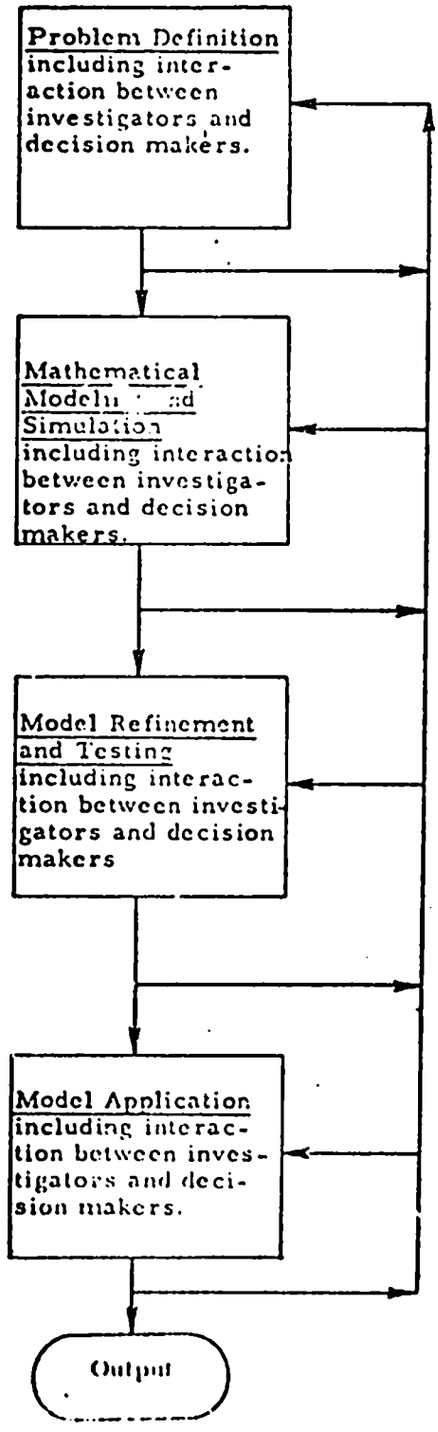

Figure 1. Model formulation as an iterative problem investigating process.

of a simulation is a set of system performance variables associated with each set of policies and/or strategies.

The first step in solving a practical problem is problem definition. Problems involve failures to attain as much as possible of the conditions, situations and things which are valued positively and/or the encountering of more conditions, situations and things which are valued negatively than is necessary in the existing situation. A problematic situation cannot be fully understood until it is described in a nonnormative terms as well as in normative terms of what conditions, situations and things are valued positively and negatively. The situation for which the problem exists must be known before a decision-maker can identify the problem as one for which solutions may be attainable.

The relevant values are both pecuniary and non-pecuniary, the latter involving the values studied in consumption and welfare economics while sociology, psychology, medicine study both pecuniary and non-pecuniary values. Eventually, selection of the "best" among alternative courses of action as the solution of a problem, requires a single normative common denominator among the "goods" and "bads" involved. Interactions between investigators and decision-makers is important in learning about these trade-offs. The long laborious process of learning normatively about these trade-offs cannot be short-cut by immediate premature recourse to the maximization computations of economists without paying the costs of irrelevant maximization. Those costs include just rejection of results by decision-makers.

Also, it seems inappropriate to regard the simulators as dealing only with the positive or non-normative while leaving answers to normative questions wholly up to the decision makers because: (1) decision makers help in making normative observations and analyses, and (2) the staff members must know what "is important" before they can tell what kind of nonnormative information they should use in constructing the simulation model.

When the simulator is given responsibility for helping solve a problem one of his first activities is to develop a mathematical model capable of simulating the performance of the system through time in response to decisions which may be made concerning projects, programs and policies.

The third step for the simulator attempting to assist decision makers is to refine and test his model. In building, refining and testing the model, it is extremely important for the simulator to have contact with decision makers. Contact with the decision makers often permits them to see how the model operates and to point out the shortcomings of the model for the purposes of reaching decisions on the problem at hand. Oftentimes initial simulations of the future consequences of proposed solutions will result in a redefinition of the problem. Such redefinitions of the problem often make it necessary to simulate a different system which, in turn, makes it necessary to change the mathematical models which were developed in the second step. Model testing involves application of the usual statistical tests of significance and choices among hypotheses where such tests and choices are appropriate. However, as the simulation approach is a very flexible one using information from a wide variety of sources, the rather specialized, positivistic tests of statisticians are not adequate to handle the subtle questions of validation and verification involved in testing models dealing with the normative as well as the positive and leading eventually to prescriptions to solve problems at hand. Our verification and

validation techniques are highly specialized on the positivistic content of our work with little attention to problems of verifying and validating the normative information and prescriptive conclusions. Unfortunately, the credibility which a simulation attains depends importantly upon the validity and veracity of its normative and prescriptive contents. Before decision makers will actually use the results of a simulation model in making decisions concerning alternative courses of action they must have faith in the model. Faith in a simulation model is increased, of course, by seeing the model modified to meet objections raised by decision makers to the model itself. Thus, the interaction between simulators and decision makers is extremely important. Each application of the model becomes a test of the validity and veracity of the model.

In most cases the construction of a simulation model is a multidisciplinary task. Problems define the system to be modeled and problems are no respecters of the disciplinary boundaries of university organization charts. Ernest Nesuis observed, as Director of the University of Kentucky's Agricultural Extension service, that--"Universities have departments; farmers have problems." Attempts to develop simulation models of medical and health care delivery systems are bound to involve far more than economics. In fact, economics is likely to be unable to furnish more than a fraction, say, less than one-tenth of the concepts and descriptive information required to simulate that part of a medical and health care delivery system involved in any particular practical problem. The medical discipline itself will be required to furnish substantial amounts of information and concepts concerning the production, utilization and values of medical and health care services. In addition, engineers and architects may be involved in developing physical facilities important in many health care delivery systems. Sociologists

may have important contributions as will the administrators of hospitals, projects and programs. Nurses and technicians, too, may have information, concepts and ideas to contribute depending upon the problem and, hence, the particular subsystem under investigation. It is important to note that typically the information required from many disciplines to model a system cannot be supplied by "interdisciplinarians," i.e., investigators who purport to know enough about a large number of disciplines to study any particular subsystem found to be relevant as to the solution of a particular practical problem. This is because more than superficial knowledge of many different disciplines and areas is typically required; instead, in-depth knowledge of such subjects as the different phases of medicine, pharmacy, economics, civil engineering, hospital architecture, statistics, nursing, bio-chemistry, etc., are required. When a simulation model of a system is being developed, detailed in-depth knowledge from highly competent people is required. The "jack-of-all-trades" interdisciplinarian seldom has this kind of detailed knowledge in a sufficient number of areas. Thus, simulation work typically becomes a multidisciplinary team effort involving substantial, if not always lengthy, contributions from a large number of people with very great competence in their different respective disciplines and fields.

My own experiences with simulation has involved mainly the modeling of agricultural systems. In this experience I have found when the contributions of an animal husbandry man are needed in solving a beef production problem that we need the best beef specialist to be found. Similarly when working with problems involving crop research, highly competent plant breeders, soil chemists, and soil physicists. A characteristic required of the disciplinary members of a multidisciplinary problem solving team is an interest in working on practical problems. Another required characteristic is a

willingness to join others in cooperative team efforts to bring their highly specialized, in-depth knowledge of a particular area to bear on the problem in concert with similar knowledge from equally competent people from other disciplines.

A Possible Simulation Model for a Medical and Health Care System

While I have not done a great deal of work on health care delivery systems, I have studied two rural health care industries in considerable detail, one in the Copper counties of the upper peninsula of Northern Michigan and the other in the Grand Traverse Area of the northern part of Michigan's lower peninsula.[1/] My knowledge of these two health care industries indicates that simulating the subsystems involving the medical and health care problems of these areas would be very similar to modeling the subsystems relevant to agricultural development problems in countries such as Nigeria, Korea, Colombia, and Venezuela, where I have had experience, or in modeling agricultural systems in Michigan, Kentucky and in the United States where I have also had experience.

As indicated above, simulation models are not built in the abstract; instead, some thing is modeled. In the case of medical and health care delivery problems, the thing to be modeled is the system in which the problem under investigation is located. It would be nice if we had a model of a medical and health care delivery system to present at this point to illustrate how the model reflects the structure of the system and its operating characteristics

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[1/] Doherty, Neville J. G., "The Economic Structure and Performance of the Medical Industry in Michigan's Grand Traverse Region," Ph.D. Thesis, Michigan State University, 1970.
Doherty, Neville et al., "Health Care Industries in the Michigan Grand Traverse and Copper Country Regions: Case Studies in Community Resource Development," Michigan State University Agricultural Experiment Station Research Report 177, November, 1972.
Sarkar, Shyamalendu, "The Copper Country Medical Industry of Michigan as it Serves Rural People," Ph.D. Thesis, Michigan State University, 1969.

through time when alternative solutions to the problem are introduced into the system. Unfortunately, we do not have such a model at our disposal.[1/]

In lieu of discussing an existing simulation study of a health care problem, I am going to discuss the construction of a model for a sub-part of the Grand Traverse area medical system which I believe should be developed. As indicated above, the medical industry of the Grand Traverse area has been studied in considerable detail but not in enough detail to develop detailed models of the different subsystems of the Grand Traverse areas medical industry which would be relevant for various problems. I will discuss in a very tentative way what would be involved in studying that subsystem of the Grand Traverse area's medical industry which would be relevant for solving a particular problem.

The problem with which I will deal is that of an inadequate health care delivery system for aged commercial farmers of the Grand Traverse area. While the residents of the area are not extremely wealthy they have about average incomes for a northern state. The farming of the area is mixed but includes a substantial number of fruit farmers who are well-to-do. The problem of health care for the aged, well-to-do, commercial farmers in the Grand Traverse area is mainly one of organizing facilities to serve them and not one of inadequate private resources with which to provide health care during retirement. There are other rural residents, however,

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[1/] However, readers interested in the details of simulation model construction are referred to simulation models which have been developed for the agricultural economics of Nigeria and Korea both of which are published in book form and are readily available from the Department of Agricultural Economics, Michigan State University (Manetsch, Thomas J. et al., "A Generalized Simulation Approach to Agricultural Sector Analysis," Department of Agricultural Economics, Michigan State University, November, 1971, and Rossmiller, G. E. et al., "Korean Agricultural Sector Analysis and Recommended Development Strategies 1971-1985," Korean Agricultural Sector Study Team, 1972.

who are farmers in the poverty class with inadequate resources to provide health care in their old age regardless of how well the health care delivery system is organized to serve the needs of elderly people. The problem then is a twofold one involving the development of a superior organization for delivering health care to the rural aged, both those who have adequate resources and those who do not. Thus, a rather large subsystem involving both the well-to-do and the poor is involved.

Solving this problem requires organized knowledge of the present as well as knowledge as to how the system would operate over time if modified in various ways to solve the problem. A simulation model for such a system needs to be flexible enough to permit modification to account for and estimate the consequences through time of modifying the system in accordance with possible project, program and policy decisions resulting from the creative and imaginative efforts to build a better system to care for the area's rural aged.

Undoubtedly, a careful investigation will indicate the existence of a wide variety of arrangements to care for the aged. A large number of the aged provide their own housing, transportation services and have incomes and resources with which to buy assistance from the area's hospitals, public service agencies, doctors, dentists and osteopaths. Those well-to-do persons with less personal physical capacity are in the area's nursing homes and hospital facilities. Also substantial numbers are living with their children. The existing situation includes a relatively high proportion of retired people with the physical capacity to deliver health care services to still older people. Few of the retired, however, provide health care services to others except on an informal, private basis within families

where retired couples look after each othe and occasionally a brother or sister looks after his or her brother or sister.

To know the existing situation requires knowledge of the financial reserves of the aged. These reserves take the form of savings accounts, income, paid up insurance policies, social security claims, medicare arrangements, real estate, other real property, various savings accounts, and other forms of personal property.

The relevant subsystem also includes the existing public and private agencies which provide medical and health care services to the aged. Generally speaking, the Grand Traverse area is well endowed with hospitals, clinics and medical practitioners.

In addition to the rural aged, the Grand Traverse area has a large number of urban aged. These also include people with both adequate and inadequate financial reserves. As a group, the urban aged have a different mixture of personal capacities and skills which might be used to provide medical and health care services to their fellow aged citizens. They, too, provide health care services to each other on a private but not on a public basis.

The area has no existing public facilities for facilitating the production of health care services by the aged for the use of the aged, rural or urban and well-to-do or poor. Generally speaking, the Grand Traverse area is a high wage rate area with expensive common labor and skills for looking after the aged. Thus, it is important to develop public as well as private organizations to facilitate the production of health care serivces by the aged for the aged. Such organizations should involve both rural and urban aged in order to include a better mix of skills and capacities.

It is also important that such organizations offer the aged poor, both rural and urban, the opportunity to earn their way. These considerations require a model capable of simulating a subsystem of the Grand Traverse medical industry including both rich and poor, rural and urban aged and involving both present and non-existent institutional arrangements.

The area is in a rather heavy snow belt in the northern part of Michigan's lower peninsula. In some parts of the region the expected snowfall is over 100 inches per year. This means substantial transportation problems for isolated, aged, rural residents. Despite this many persons retire into the area because of the beautiful scenery and the pleasant four seasons which characterize the region. Thus, the proportion of aged persons in the region is higher than normal and the problem of providing health care services for them in the winter is greater than in many other regions of the United States. This means that the simulation model will have to be spatially as well as time oriented and that it will have transportation components involving, possibly, the minimization of transportation costs.

Presently, there are a substantial number of rest homes and the hospitals of the area have a rather high proportion of their facilities devoted to geriatrics. To my knowledge there are no "retirement communities" designed to provide a changing pattern of services to persons passing from retirement at age 65 through the remaining years of their life.

A simulation model of that part of the Grand Traverse medical industry which serves the rural aged would have to model the existing resources, facilities, populations of the aged, the destination of their health care expenditures, the production of health care services, the provision of medicines, and the provision of equipment and building services. Once a model is constructed of

the existing situation, it would have to be examined to ascertain if the model had sufficient flexibility to project the consequences of changing the system institutionally, technically and humanistically to better serve the aged. As the rural aged are not adequately cared for, whether rich or poor, a considerable amount of flexibility will be required to estimate the consequences through time of the varous proposals which may be advanced for improving the system. Though not much work has been done systematically on how the present system could be modified, a research effort devoted to modeling and improving the present system would probably lead to a wide range of proposals on the part of creative, imaginative people. These proposals will have to take into account the high wage rates of the area, the area's climate, and the skills and capability of the aged themselves as well as their medical age. As the skills of the aged are considerable at age 65, creative, imaginative problem solvers are likely to seek ways of utilizing some of these skills, particularly if they are held by the aged poor. Some 65 year old persons would desire to work for a few years within a few years within a system to provide health care services to the aged in order to pile up credits in the system for the years in which he or she will be unable to work. However, the mixture of skills held by retured commercial farmers and their wives is not adequate to care for the aged. Thus, proposals to solve the health care problem for the rural aged of the Traverse area should not be confined to rural residence alone; instead, larger groupings of people are needed with wider ranges of skills. In addition to the cooking, nursing and handyman skills likely to be prevalent among rural residents, urban skills are also needed to look after the aged. These needed urban skills include those of nurses, lawyers, carpenters, plumbers, electricians, M.D.s, dentists, eye specialists and a wide variety of other skills which can be used to provide facilities, medical and health care services to the aged.

Imaginative, creative, problem-solvers studying the problems of the aged in the Grand Traverse area are likely to see the need for new institutional arrangements in which to account for the contributions of the aged to the care of other aged people. They are also likely to see the need for physical facilities in which it is possible for some of the aged to look after others of the aged.

The Grand Traverse area includes many villages and small communities on excellent all-season roads and highways. Many of these communities need additional industry. Some of them would make excellent locations for new facilities for the aged. Again, imaginative, creative problem-solvers are likely to conceive of facilities in addition to but not excluding nursing homes. Some of these small Grand Traverse villages and communities have churches, grocery stores, nursing homes and other facilities providing the services which the aged need in a general environment far superior to the urban areas in which many nursing homes are located. One wonders about the possibility of establishing facilities in such communities including separate houses and apartments for the aged as well as clinics and nursing homes for persons requiring supervision, bed care and, eventually, complete hospitilization. Such villages and communities could be utilized as retirement communities without being devoted entirely to the aged.
Such arrangements would provide a more desirable mix of ages than commonly found in rest homes and could provide a capable older person with creative productive employment for additional years of their life in providing services not now produced and distributed to the aged. The institutional arrangements would have to involve some sort of central organization or association with (1) a central accounting system, and (2) a control system for controlling the utilization of the aged in order to avoid exploitation of some of the aged by the aged and to eliminate the incompetent from the service group.

The model would involve a demographic component for persons from say 40 years of age to 95. Such a distribution of ages would permit the demographic components of the model to make projections 25 years ahead without running out of people below 65 years of age. The demographic components would have to be specific with respect to wealth, incomes, and physical capacities as well as with respect to age. The model would also have to have components which would deal with the utilization of resources to produce and distribute medical and health care facilities for the aged. These components would have to be built in a flexible, detailed way so that they could be modified on the basis of projects, programs and policies which might be considered to solve the problems of health care for the rural aged of the Grand Traverse area. The model would also have to keep track of monetary flows <u>from</u> the people being cared for, from governmental agencies, and from voluntary agencies <u>to</u> the suppliers (including some of the aged) of health care services.

Questions About the General Systems Science Simulation Approach to Problem Solving

This paper has stressed the advantages of using the generalized, systems-science simulation approach to study existing systems and the operation of existing and modified systems through time. It is now time to consider criticism which has been directed at shortcomings of the approach.

One of the first criticisms to be leveled at the approach involves the GIGO principle--[Garbage In, Garbage Out (data)]. It is pointed out that modeling

such systems requires a large amount of data and information about the existing structure and how the structure would perform in the future. This is true. And it is true that poor information produces poor models of existing situations and systems. However, the data and information required to solve a problem do not change as a result of computerizing the computations or of expressing the model systematically in mathematical form. Essentially the same data and information are required for paper and pencil, desk calculator projections as are needed to make those projections on the computer provided the same problem and, hence, the same system is under consideration. The advantage gained from describing the situation mathematically and running the computations on the computer is the greater computational efficiency of the electronic computer. However, that efficiency leads to a significant advantage; when data are of questionable reliability, the computational efficiency of the electronic computer makes it economic to operate the model with various assumptions about the data. If the model is operated with certain variables or parameters at their highest possible value and at their lowest possible value without significantly affecting the results then we can be relatively confident our information about the variable or parameter has sufficient accuracy. On the other hand, variables thought to be reliably known may prove unreliable when the model is operated with these variables inserted at its highest possible and lowest possible values. This process of investigating the consequences of inaccuracies in data is referred to as "sensitivity analysis." Sensitivity analysis tells us a great deal about the adequacy of our knowledge and where we need to improve our data. With paper and pencil projections, it is simply not practical to carry out sensitivity analysis because of the high costs of computations.

Another question often raised about the simulation approach arises when simulation models are used to project the consequences of institutional

technological and humanistic innovations which have never been used in the past and, hence, for which there is no relevant history to use in validating and verifying the model and its projections. The tests for the validity of such models are their: (1) logical consistency, (2) consistency with such related experiences as we have had in the past with similar components of the model and (3) clarity as models must be definite and clearly enough stated to be understandable for decision makers using them before they will be regarded as valid. The first real empirical test of any newly designed system occurs, of course, when used to solve the problem it was designed to help solve. At that time the model and its projections pass or flunk the pragmatic test of workability.

The more general question of validation and verification is further complicated by differences in the philosophical underpinnings of various builders and users. For instance a positivistic modeler or user believes that only the non-normative content of the model can be validated or verified; thus he believes, metaphysically, that it is impossible to verify the normative content of the model and the prescriptions to which the model may lead, prescriptions being based upon the normative as well as the non-normative or positivistic content of the model. By contrast, pragmatists (of which there are many in colleges of education and in institutional economics) hold metaphysically that normative or positive knowledge do not exist independently of each other; thus, pragmatists reject the possibility of independent validation or verification of either the normative or positive content of the model and concentrate almost entirely upon validating or verifying the prescriptive content. To the pragmatist the most important test for validating or verifying a prescription is the test of workability. It is when the model is used to produce a prescription which is then applied that the model is or is not validated. Validation by the test

of workability occurs problem by problem because both the normative and positive concepts which go into the model are dependent on each other within the context of the problem under investigation. It suffices to point out at this point that simulation models used in a problem-solving context should not be constrained by the metaphysical presuppositions of different philosophies.

Because general, computerized, systems-science, simulation models are quantitative, questions are often raised about how nonquantifiable information can be used in them. This question is not as serious as it appears to be at first sight. Not all quantification must be cardinal--some of it can be ordinal. Still other forms of quantification do not involve more than counting the occurrences of certain events which may or may not be quantitative. A situation which often arises occurs when someone such as a sociologist, psychologist or political scientist says that there is "something" in the environment which defies quantitative simulation in the sense of being measurable cardinally or ordinally, or even countable. My own experience in such situations leads me to conclude that <u>if</u> the person raising the objection <u>really knows something about something</u> it can be incorporated in a quantified simulation model; however, it must be admitted that a quantified model cannot handle that which the psychologist, political scientist or sociologist <u>does not know</u> but only asserts <u>may</u> exist. If persons talking about these "undefinable somethings" know something about them, it is relatively easy to model that which they know. It is, of course, impossible to model that which the critic cannot describe but only asserts exists.

The simulation models which I have been discussing are flexible with respect to sources of information and specific techniques. One component

of the model may employ a specialized technique such as recursive linear programming, while another may be an input/output analysis, a third a complicated factorial analysis, a fourth a cost/benefit analysis and a fifth spectral analysis. However, many of the components will be simple consisting of strings of differential equations collapsible into single equations linked to other equations through various "accounting" identities. Because such flexible, overall simulation models containing such a wide variety of components become large and complex, they are not easy to describe in the tidy, elegant ways usable for specialized components involving, say, recursive linear programming or systems of simultaneous equations with probabilistic parameters estimated by well-known econometric techniques from time series data. Users of such general simulation models simply have to recognize that the advantages of being flexible with respect to types of information and research techniques involves the cost of greater complexity.

General, computerized, systems-science, simulation suffers from and is often "tarred" with the brush of the credibility gap which has developed among decision makers and administrators as a result of their contact with inappropriately used, more specialized models. Among the specialized models which have been inappropriately used by researchers and decision makers are models involving systems of simultaneous equations with parameters, probabilistically estimated from time series data. Other types of specialized models which have developed credibility gaps with decision makers and administrators are: (1) linear programming models which maximize prematurely, (2) input/output analyses which ignore relevant details within subsectors of the economy, (3) cost/benefit ratios which assume common

denominators among goods being sought and bads being avoided when such common denominators do not exist, and (4) oversimplified models of agricultural development concentrating upon such single factors as land tenure, education and the creation of human capital, technological advance, under-employment, and the distribution of resource ownership. Much of the over-specialization on research techniques results from attempts of disciplinarians to handle practical problems with the concepts and techniques of a single discipline rather than recognizing that practical problems are multidisciplinary and require information and techniques from many different disciplines for their solutions. Simulators have to avoid specialization by discipline, technique and philosophy if they are to escape the justifiable complaints leveled at specialized studies.

Some General Conclusions About the Place of Simulation Modeling in Studying the Problems of the Medical and Health Care Industry

1. Generalized, computerized systems-science simulations preserve much of the flexibility which traditional, seat-of-the-pants projections have had and which have maintained their credibility with decision makers, both public and private. This flexibility has been with respect to types and sources of information and hence disciplines, techniques, philosophic orientation, and with respect to the use or non-use of maximization.
2. There has been a dramatic decrease in a cost of making projections of any given degree of complexity as a result of shifting from paper and pencil and desk calculator to modern electronic computers.
3. A side benefit of computerized, generalized systems-science simulation investigations is to be found in the "capital value" of the

mathematical components of different simulation models. These mathematical components are used repeatedly; hence, once produced they are available for use in one appliation after another. This is particularly true of demographic and marketing components of models.

4. There are a sufficient number of components developed in connection with the modeling of systems outside of the medical and health care industry to guarantee that modeling work could go forward rather rapidly with respect to the medical and health care industries.

5. It is now time to move forward in using the generalized, computerized systems-science simulation approach to medical and health care delivery problems.

6. Such applications will have to be carried out on a multidisciplinary basis dominated by an interest in the practical problem under consideration with disciplinary consideration subordinated to that interest.