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SIMULATION: AN OVERVIEW

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1. INTRODUCTION

Simulation is one of the most powerful analytical tools available to managers of complex systems. John McCloud compared simulation to a scalpel. In the hands of a skilled practitioner, it is a fabulous instrument for correcting problems, but in the hands of the unskilled, it can do great harm. In every research study done on the utility and use of operation research techniques, simulation has always turned up either first or second. The reason, as I hope will become evident during this discussion, is its great versatility, flexibility and power.

I would like to begin by defining what simulation is and what it is not. First of all, it is not a language. A good simulation model can be programmed in any general or special purpose language. A survey by Naylor indicated that the majority of corporate simulations were programmed in FORTRAN. Knowing a particular simulation language may make it easier for you to code a model, but it will not teach you to design good simulation models nor make you a skilled simulationist. No one would argue that someone who had taken a one week short course in FORTRAN programming was now a mathematician. Likewise, learning a special purpose simulation language does not teach you how to do a good simulation.

In this paper, we will define simulation as the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system, or of evaluating various strategies for the operation of the system. Thus we understand the process of simulation to include both the construction of the model and the analytical use of the model for studying a problem. The types of systems that can be simulated are those that are either in existence or capable of being brought into existence. Therefore, systems in the preliminary or planning stage can be modeled as well as those already in existence.

2. WHAT CAN BE SIMULATED

When considering the question of what kinds of systems can be simulated, the answer is that almost any type has or can be studied. The broad range of applications of this methodology is almost impossible to classify. Rather than try to give an exhaustive list, we will simply try to point out some representative areas of application.

COMPUTER SYSTEMS-hardware components, software systems, networks of hardware, data base structure and management, information processing, reliability of hardware and software, etc.

MANUFACTURING-material handling systems, assembly lines, automated production facilities, storage facilities, inventory control systems, reliability and maintenance studies, plant layout, machine design, etc.

BUSINESS-stock and commodity analysis, pricing policy, marketing strategies, acquisition studies, cash flow, forecasting, transportation alternatives, manpower planning, etc.

GOVERNMENT-military weapons and their use, military tactics, population forecasting, land use, health care delivery, fire protection, police services, criminal justice, roadway design, traffic control, sanitation services, etc.

ECOLOGY AND ENVIROMENTAL-water pollution and purification, waste control, air pollution, pest control, weather prediction, earthquake and storm analysis, mineral exploration and extraction, solor energy systems, crop production, etc.

SOCIAL AND BEHAVIORAL-food/population analysis, educational policies, organizational structure, social systems analysis, welfare systems, university administration, etc.

BIOSCIENCES-sports performance analysis, disease control, biological life cycles, biomedical studies, etc.

The above list does not even begin to cover all of the areas that have been studied using simulation. It is safe to say that one would be hard pressed to find any arena of human endeavor that has not seen some simulation activity.

3. WHEN TO SIMULATE

All simulation models are so-called input-output models. That is, they yield the output of the system for a given input. Simulation models are therefore "run" rather than solved. They are incapable of generating a solution on their own in the sense of analyical models; they can only serve as a tool for the analysis of the behavior of a system under conditions specified by the experimentor. The exception to this statement is that a simulation model can be used to find the optimum values for a set of control variables under a given set of inputs.

We have defined simulation as experimentation with a model of a real system. An experimental problem becomes apparent when a need develops for specific information about a system that is not available from known sources.

Simulation has the following advantages:

It can be used to explore new policies, operating procedures, decision rules, organizational structures, information flows, etc. without disrupting the ongoing operations.

New hardware designs, physical layouts, software programs, transportation systems, etc. can be tested before committing resources to their implementation.

Hypothesis about how or why certain phenomena occur can be tested for feasibility.

Simulation allows us to control time. Time can easily be compressed, expanded, etc. allowing us to quickly look at long time horizons or to slow down a phenomena for study.

It can allow us to gain insight into which variables are most important to performance and how these variables interact.

Simulation allows us to identify bottlenecks in material, information and product flows.

The knowledge gained about a system while designing a simulation model, may prove to be invaluable to understanding how the system really operates as opposed to how everyone thinks it operates.

Through simulation we can experiment with new situations about which we have limited knowledge and experience so as to prepare for what may happen. Simulation's great strength is its ability to let us explore "what if" questions.

Another way to look at the question of when to use simulation, is to examine common goals or purposes which have motivated simulation studies in the past. Among these are:

EVALUATION: determining how good a proposed system design performs in an absolute sense when evaluated against specific criteria.

COMPARISON: comparing competitive systems designed to carry out a specific function, or comparing several proposed operating policies or procedures.

PREDICTION: estimating the performance of the system under some projected set of conditions.

SENSITIVITY ANALYSIS: determining which of many factors are the most significant in affecting overall system performance.

OPTIMIZATION: determining exactly which combination of variable settings will produce the best overall response of the system.

FUNCTIONAL RELATIONS: establishing the nature of the relationship among variables and the system's response.

This list of advantages and common goals or purposes is not exhaustive, but is merely intended to suggest the great utility of simulation in solving a broad range of significant problems.

4. HOW TO SIMULATE

Assuming that a simulation is to be used to investigate the properties of a real system, the following stages may be distinguished:

SYSTEMS DEFINITION-Determining the goals of the study as well as the boundaries, restrictions and measures of effectiveness to be used in defining the system.

MODEL FORMULATION-Reduction or abstraction of the real system to a logical flow diagram.

DATA PREPARATION-Identification of the data needed by the model, and their reduction to an appropriate form.

MODEL TRANSLATION-Description of the model in a language acceptable to the computer used.

VALIDATION-Increasing to an acceptable level the confidence that an inference drawn from the model about the real world system will be correct.

STRATEGIC PLANNING-Design of an experiment that will yield the desired information.

TACTICAL PLANNING-Determination of how each of the test runs specified in the experimental design is to be executed.

EXPERIMENTATION-Execution of the simulation to generate the desired data and to perform sensitivity analysis.

INTERPRETATION-Drawing inferences from the data generated by the simulation.

IMPLEMENTATION-Putting the model and/or results to use.

DOCUMENTATION-Recording the project activities and results as well as documenting the model and its use.

The process of designing, programming and running a simulation is not really as straight forward as the above implies. There are invariably many false starts and a recycling thru the steps several times. In addition, the whole process has in the past been more of an art than science. However, it is believed that due to the excellent research done during the last ten years, we are on the verge of a significant leap forward in the state-of-the-art in simulation.

5. WHAT OF THE FUTURE

During the past ten years, there has been an unprecedented surge in very excellent research on the methodologies of simulation. In addition, the breakthroughs in computer technology, both in terms of hardware and software, has been truly mind boggling. We can just barely perceive of the impact color graphics, antimation, interactive programming/debugging and the micro-computer will have on simulation in the future.

There has been a great deal of excitment about the truly revolutionary impact that Decision Support Systems (DSS) are beginning to have upon managers and the management process. Many are saying that there is nothing new in DSS, that it is simply Management Information Systems in a new disguise. I am not one of these. I believe that DSS (if properly defined) is indeed something new and that simulation will play a critical and vital part. DSS is not a particular set of commercially available software programs. Rather, it is the end result of a philosophy of how we can put the power of the computer at the disposal of the manager.

A DSS is an integrated set of interactive computer programs that 1.) allows a user access to a wide range of computer capabilities without requiring expertise in the system being used, and 2.) allows a user to run sophisticated models such as simulations, planning and scheduling algorithms, financial analysis programs, etc. by simplifying the user's interaction with them. Such programs will be more than simply financial spreadsheets. They will include the full range of operations research tools and particularly simulation models.

As stated earlier, simulation models are ideally suited to answering "what if" type of questions, which is one of the main goals of a DSS. I do not propose that we are, today, capable of designing fully automated simulation models that the average manager can sit down and interact with. But, we are getting close. We cannot yet fully automate the process of taking questions asked in English, and then select the appropriate model, obtain the required data from a data base, design the appropriate experiment, execute it so as to obtain the answer to the desired accuracy, and portray the answer in understandable color graphics. But we are getting closer with each new research result and each new or improved simulation language.

If you look closely, you will begin to see the emergence of the necessary bits and pieces: graphical input and output analysis, simulation languages that run on micro-computers, interactive model design, antimated displays as the model executes, etc. The next five years are going to be a very exciting time.

In order to help accelerate these advances in the state-of-the-art, the Texas Engineering Experiment Station of Texas A&M University formed (in early 1982) the Decision Support Laboratory. The goal of the Lab is to develop, in coalition with government and industry, the necessary mathematical and simulation models, tools, techniques and methodologies to accurately predict the behavioral, economic, and operational characteristics of complex systems. The purpose is to provide the computerized decision support that managers need in their strategic (long range), tactical (medium range) and operational planning. Inquiries are invited.