SIMULATION OF PLANT OPERATIONS: A CRITICAL EVALUATION

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Abstract

The shortcomings of simulation as applied to plant operations are attributed to a lack of understanding of operating problems by the analyst and to a lack of understanding by operating personnel of the limitations of simulation. It is asserted that exploring the untapped potential of simulation as a research tool as well as an analytic tool should lead to more effective analysis of plant operations.

I. INTRODUCTION

The rapid growth in the use of simulation as a tool for analysis of plant operations, and the proliferation of special purpose simulation languages [1] has led us to the point of overlooking some important problem areas. My critique of the current state of the art is based upon the following assertions:

(1) Many sophisticated proposals for applying simulation models to plant operations are so sophisticated, in the technical sense, that they fail to address the real problems faced by operating personnel.

(2) Simulation is often used as the analytic tool, whereas it should only be used where the complexities of the problem defy the use of tractable mathematical models.

(3) Documentation of the procedures of validating both the accuracy and the precision of simulation models is rare. Indeed, most papers on the subject, including some presented here, merely pay lip service to validation.

(4) The creators of workable, validated simulation models often fail to design the systems support and data requirements systems necessary to use such models on a recurring basis. A precise and accurate simulation tool is of little value to operating personnel if there are no systems designed to provide input and/or to make changes in the model.

(5) Rarely, if ever, do we see rigorous analysis of the output of a simulation model with an eye towards either distilling out tractable analytic models or simplifying the simulation model itself.

(6) Many simulation models are used for purposes other than those they were designed for. The misuse comes about in the stretching of the model logic, or in the addition of so many new subroutines, that inaccurate results are obtained at a cost in computer

time, far beyond reasonable limits.

Lest I leave the wrong impression, I am making extreme assertions only to raise discussion. Indeed, we all have committed one or more of these sins in varying degrees. I am reflecting here on potential dangers, in the main, and not on the many good applications of simulation to plant operations. I will amplify my remarks on these assertions.

II. APOCRYPHAL STORY A - "A SOPHISTICATED MODEL"

Apocryphal Story A concerns a study of the operations of a chemical plant. The plant produces m products in n kettles in a batch mode operation. The problem appears to be how to schedule the products on the kettles to meet demand at a minimum cost. The published papers on this subject are numerous, and they all are explicit in their analysis of product changeover costs as an objective function. Some of the analytic techniques that have been developed are usable if one makes simplifying assumptions. In practice, this implies that the "problem" is assumed away. If we are not willing to make such simplifying assumptions, we turn to simulation as a device for testing alternative scheduling rules. We have thus fallen into at least one trap, simulation is being used for a purpose in which it is inefficient--optimization. After using up the budget for this project, we pick the best scheduling rule and meekly suggest further work along these lines. Our report to operating personnel indicates a potential savings of 10-15 percent in changeover cost with the new rules, and we show the usual cost-benefit ratio for the project. Why be critical?

Let us go back to the beginning of the story. The problem appeared to be a scheduling problem. Maybe, in fact, the problem was an inventory control problem and scheduling was a second-order effect. A more thorough analysis of the inventory policies may have indicated a 25 percent saving in total operating cost. In our rush to do something sophisticated in scheduling, we have not addressed the basic problem; we failed to define the system adequately.

The trouble with this apocryphal story is that it too often occurs in practice.

III. APOCRYPHAL STORY B - "LET US SIMULATE IT"

This next story concerns the use of simulation in quality control. One of the products of a machine shop is a steel shaft combined with a steel sleeve. The two parts are machined to within certain tolerances. A quick data study indicates the following:

(1) Shaft diameter, has a Normal distribution with mean 1.320 inches and standard deviation 0.006 inches.

(2) Sleeve diameter has a Normal distribution with mean 1.321 inches and standard deviation 0.009 inches.

The quality control problem is as follows: What percent rejects of shafts and sleeves should we expect where we reject either because the shafts are too big (no fit) or too small (too much play in the sleeve)?

One can simulate the difference in the diameters and by taking a sufficient number of samples, the distribution of this difference can be obtained within the appropriate confidence limits.

Here is a classic misuse of simulation where an analytic result is not only easily obtainable, but is also exact. I will not insult your intelligence by claiming that anyone would have performed such a simulation.

But, this story is a paraphrase of an article published several years ago in an engineering journal.

To be sure, we do not see these travesties today in our sophisticated applications of simulation. Yet, how often do simulation models applied to inventory control rediscover the Wilson lot size model with safety stock corrections, or how often do they rediscover the M/G/1 queuing phenomena?

IV. DOCUMENTATION OF VALIDATION

Validation of simulation models is a sorely neglected detail; at least the papers published on simulation rarely mention the subject. The two major criteria for validity are accuracy and precision. Accuracy here is used in the sense of comparing a model of the present system, with the actual system itself. Studying the effects of new scheduling rules or new inventory policies can be a meaningless exercise if the model is inaccurate. Inaccuracies may be diagnosed by comparing average statistics. Is the inaccuracy caused by simplification of the model or is it caused by the fact that the simulation logic produces too high a frequency of occurrence of events which rarely occur in reality, or too low a frequency of occurrence of events which occur often in reality? Diagnosis of the causes of inaccuracies may be extremely critical.

The precision problem concerns itself with run lengths and experimental design. The proper run length for a given model often defies our intuitive judgment. A recent report by Fishman [2] gives an analytic handle on the run length problem. All too often, the run length is determined by the budgeted computer time and the number of experiments to be run.

The whole area of simulation validation lends itself to more extensive research by both theoreticians and practitioners.

V. APOCRYPHAL STORY C - "DON'T WORRY ABOUT DATA"

The XYZ Fabricated Steel Products Co. makes a thorough analysis of their problems in scheduling plant operations. Their OR Group designs a real-time job shop simulator for routine daily scheduling on the basis of past data on job routings, processing times, methods sheets, and so on. In order to run the scheduling routine, the following data must be input daily:

(1) New job orders
(2) Engineering or Technology changes on current jobs
(3) Job status reports - location of jobs and remaining processing time if in-process, rework requirements, material delays, etc.
(4) Machine status reports - operable, in maintenance, in repair, etc.
(5) Manpower status - labor availability for each machine group, overtime allowances, etc.
(6) Materials status - shortages for current requirements, remaining stocks unallocated to current work, etc.

Unfortunately, the OR Group did not concern itself with the trivial details of supplying data to the simulator or of maintaining such a data system. After all, this is all standard data which our "systems people surely collect regularly."

A careful check of the information systems reveals that Categories 1 and 2 are collected weekly, Category 3 is collected daily, and Categories 4 through 6 are stored on a sequential access device and are summarized into two-week totals. A complete redesign of the information system to collect data on a daily basis, to check the data for consistency, and to print out schedules and summary reports from the model is estimated to cost 10 times the cost of running the model.

Not only has there been no commitment by the plant operations department to spend that much money, but there has been no means provided to analyze the benefits obtained from such an expenditure.

But this is just a hypothetical story. It never happens in our sophisticated world.

VI. MISUSES OF SIMULATION - "THE STRETCHING OF LOGIC"

The stretching of the logic of a simulation to cover this new wrinkle or that new possibility is most prevalent where the "plant" operations are a logistics system operation. It occurs, often, when a special purpose simulation model is generalized to account for one or two more possibilities.

In practice, this means something like trying to simulate the movement of air traffic for the entire Western hemisphere with a simulator that describes aircraft congestion problems on routes between Reno, Nevada and Yreka, California.

The problem here seems to be two-fold. Time pressures on the part of operating personnel to make a quick analysis cause them to see similarities between the current problem and last year's "Simulation Analysis of Maintenance Schedules;" we as practitioners by the same token have failed to stress the limitations of particular models or systems.

Often, the misuses are based on a well-known management maxim--"We don't have time to do it right the first time, but we have the time to do it twice."

VII. SIMULATION AS A RESEARCH TOOL

Unfortunately, the gulf between management scientists who study real problems related to plant operations and theoreticians who abstract these problems for analysis seems to be widening. The growing power of computers facilitates the use of simulation models. Once we have studied a particular operating problem in enough detail to recommend a simulation, the book on further mathematical analysis is closed. On the other hand, when theoretical analysis becomes untractable if applied to an operating problem, the book on reality is also closed. It seems to me that one of the great untapped potentials of simulation lies in furthering theoretical investigations that may lead to valid, easy to use analytic models.

To illustrate this idea, consider the following problems:

(1) In planning the size and composition of a transport fleet for a short haul delivery system, a linear programming model can be used if time is aggregated to some reasonable level. The optimal fleet mix from this model may be unworkable from the point of view of day-to-day scheduling. A simulation model can test the operational feasibility of any fleet but it is quite inefficient in searching for an optimal mix. The use of simulation to alter the performance coefficients in the linear programming model, and the use of the linear programming model to find an optimal mix can be an improvement over using one technique or the other by itself.

(2) In planning the size and number of crude oil storage tanks at marine terminals, one is faced by a complex interaction of the stochastic processes--the arrival pattern of demand which varies the drawdown rate in the tanks, etc. A typical, although not unique, objective function is the minimization of tankage cost plus ship delay cost due to insufficient ullage. (Tank capacity minus inventory level.) A simulation model of this process reveals that tankage cost varies linearly with tankage size and that average ship delay costs are inversely proportional to tankage size. One might suspect that lurking in the background of the complex interaction of stochastic processes lies a tractable analytic model that may yield a good approximation to the simulated results.

Using simulation models as research tools requires some unbending on the part of both practitioners and theoreticians. The results can only serve to make simulation less of an epithet used by theoreticians, and to make practitioners less scornful of analytic models.

VIII. SUMMATION

I have made some assertions and have related some incidents of poor practice "that occur only in our competitor's shop." Let me suggest a few guidelines to your competitor then, that may prove useful in evaluating proposals for simulation studies of plant operations.

(1) Has there been a thorough diagnosis of the problem to go ahead with the study?

(2) Has there been sufficient analysis of the problem that defies mathematical analysis?

(3) What are the detailed complexities of the problem that make simulation the best tool for analysis?

(4) What are the procedures and guidelines for validation of the model?

(5) What are the data requirements for the model? Does the systems support for the model exist?

(6) If this is special purpose model, are we sure that the available general purpose simulators are not applicable to the problem?

(7) through (N) add your own list.

What we should be doing is making a simulation a sharper analytic tool and a valuable research tool. The rigor with which we carry out simulation studies should be no less in principal than that required of experiments in a laboratory. The potential rewards are great in contrast to the litter of unused and unusable reports.

I suspect that three years from now someone else will be making the same critique of simulation that you have just heard. I hope that our progress proves me wrong.

REFERENCES

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BIOGRAPHY

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