1981 Winter Simulation Conference Proceedings
T.I. Ören, C.M. Delfosse, C.M. Shub (Eds.)

USE OF COMPUTER SIMULATION IN DESIGNING COMPLEX MATERIAL HANDLING SYSTEMS

Kailash M. Bafna, PhD, P.E.
Associate Professor
Dept. of Industrial Engineering
Western Michigan University
Kalamazoo, MI 49008

ABSTRACT

This paper discusses the application of computer simulation in the designing of complex material handling systems. It is divided into three parts. The first part discusses the need for using simulation. This is followed by guidelines helpful in the planning and development of the simulator. Finally, the use of proper input data for conducting the analysis is discussed.

1. INTRODUCTION

Solving material handling problems is no longer a one-shot approach where either an additional fork-lift truck is provided or a length of conveyor is added to move the material between two points or where a crane or hoist is added. The term "material handling systems" has been coined in the last decade and is here to stay. The complexities of these systems is increasing rapidly due to mechanization, automation and, above all, the microprocessors which are used for the overall control of such systems. These systems integrate various types of equipment and may cost anywhere from a million dollars to even as high as 15 to 20 million dollars.

The design and capacities of individual equipment used in large systems may be adequate but, when they are integrated and operated as a single system, they can produce bottleneck points during operation. This can result in extremely expensive hardware and controlling software modifications and/or replacements sometimes running into the hundreds of thousands of dollars. This expense, which may decide whether the prime contractor and designer of the system makes a profit or a loss on the system, can be minimized and even almost totally eliminated if the design of the system is verified by using computer simulation. This paper discusses the use of computer simulation in designing and verifying the designs of such complex material handling systems.

2. WHY USE SIMULATION?

By developing a simulator to represent a system, it is possible to experiment with this simulator to obtain the operating statistics for various parts of the material handling system. Flow rates at different points can be controlled to any desired criteria, operating and decision rules for the system can be modified as desired, and changes can be made to the planned configurations of the system hardware. Such flexibility permits the determination of flows and queue build-ups for the system when operated as a whole, and thereby identify the bottleneck points and maximum possible capacities for various sections of the system.

Will the system, as designed, perform at the desired levels? This question is raised not only by the purchaser of the system, but also by the designers. Shadows of doubt are cast even on the best of designs prepared by the most experienced designers because of the complexities introduced by the integration of various types of automated and computer controlled equipment. Some of the factors which increase the complexities are:

(a) Flow capacities of individual components are usually based on uniform flows. However, flows are seldom found to conform to the uniform distribution.
(b) Individual components may be capable of giving the desired flow rates. However, due to interactions of components at the merge points, flows at these points may be substantially lower.

(c) The flows at various points of the total system are not identical due to merging and splitting up. The distribution of these flows are usually very different from the original flows.
(d) Surges in the flow upstream change in their characteristics as they move downstream.

In addition to the application discussed above, the simulator can also be used to study the following:
(a) Interactions of the various components of the total system.
(b) Effects of changing speeds and rates of individual components on throughput of the system.
(c) Effects of breakdowns and repair times on throughput.
(d) Insight into which variables are most important.
(e) Effects of changing operating policies and decision rules of the working of the system.
(f) Effects on the operation by varying the load arrival/departure patterns.

The most important fact that should be remembered is that all of this analysis and evaluation of the system can be done before actually installing the system. This can result in tremendous savings, especially if changes are necessitated in the original design.

3. PLANNING AND DEVELOPING THE SIMULATOR

Having made the decision to go ahead with the simulation study of a complex material handling system, one cannot immediately begin the development work on the simulator. Several other decisions have to be made prior to commencing such work. These are discussed in the following sections.

3.1 How Much Money Should be Spent on the Study?

It is possible to conduct a simulation study with a fairly small investment ranging from $1,000 to $5,000. However, these same systems can be studied more precisely and thoroughly using larger investments from $10,000 to $30,000. Obviously, the cheaper programs need less time to develop and provide only a very cursory check of the design. On the other hand, the more expensive programs can take several weeks and even months to develop and study the actual system. Such simulation studies provide an in-depth look at each and every aspect of the design, are far more reliable, and have several uses.

The amount of investment to be made on the simulation study should depend on the reason for conducting it. If the analysis is being done to evaluate an existing system to check its performance, or to study the effects of minor changes to it, a small investment should suffice. However, if the study is being conducted to evaluate the design of a new system before it is installed, a detailed analysis should be made and the design thoroughly evaluated prior to its acceptance for construction and installation. If this be the case, a higher investment is dictated. As a rule of thumb, it would not be at all out of place to spend from 1/2 to 1 percent of the total system cost for the smaller systems to 1/4 to 1/2 percent on larger systems for the simulation study.

3.2 How Much of the System Should be Simulated?

This is a difficult question to be answered. However, certain guidelines, if followed, should aid in making this decision. The following parts of the system should be included in the simulation study.
(a) Sections of the system having a merge point thus bringing the final capacity of that part close to the overall system capacity.
(b) Sections having several merges within a short distance even if the resulting capacity is well below the system capacity.
(c) Sections having excessive flows from and to the conveyors such as those having inspection stations, pick stations, repair stations, etc.
(d) Sections involving elevators.
(e) Entry and exit conveyors taking material to and from the automated storage and retrieval (AS/R) system.
(f) The entire AS/R system, especially if it uses transfer cars to move the storage/retrieval (S/R) machines between aisles. Also, if the throughput of the AS/R system is close to the combined capacity of the S/R machines, it should be included in the study.

The above are guidelines to be used only if it is desired not to simulate the entire system due to monetary or time considerations. However, it should be remembered that there is nothing comparable to simulating the entire system for obtaining more precise and reliable results.

3.3 How to Plan for Easier Debugging?

Most of the simulation languages have their own debugging aids which can be built into the simulator when designed. In addition to using these, I have had better luck in debugging with considerable savings in debugging time by following a few simple procedures.
(a) Design the simulator so that it can be run in small segments representing definite sections of the system. For each of these segments there should be some way of putting in the loads following any desired distribution and also collecting statistics on the load outputs from that segment. Tracing of events for purposes of debugging is much simpler over smaller segments than through a complete large system.
(b) When debugging each segment, run the simulation with a very low activity level. Event printouts in this case are less cumbersome and provide for faster manual tracing.
(c) Combine two or more smaller debugged segments into larger segments and debug these as explained above. Continue till the entire system is debugged.
(d) When special input distributions for material are specified, sometimes it helps if the simulator is first debugged using uniform distributions prior to running it with the actual distributions.

Debugging of a simulator is a skill which is learned by actual practice. Besides, each new simulator representing a different system needs a slightly different approach for debugging. However, the guidelines presented above are very general in nature and, if followed, should be of assistance especially to the novice.

3.4 Which Language Should be Used?

Anyone contemplating simulation for the first time wants to know which language is the best. The more he asks around to find an answer to his question, the more he gets confused. The correct answer, of course, is the language that the person who is to develop the simulator is familiar with. Technically this may not be true; however, practically speaking, this is really what happens. It is difficult to find individuals who are well conversant with several simulation languages and are truly in a position to evaluate the problem and determine the best language for it.

There are three principal established languages which are used for event-oriented simulation--FORTRAN, GPSS, and SIMSCRIPT. GASP IV, SLAM, Q-GERTS, and GEMS are other simulation languages but, since all of these are FORTRAN-based, they can be considered as a subset of FORTRAN. The operational characteristics of these languages as shown by Phillips (1980) are presented in Table 1.

When selecting a language, the capabilities of that language should be carefully analyzed. If the language requires a special compiler, can this be used with the computer system available for performing the simulation? Is the language under consideration capable of providing all the desired reporting capabilities? Once the simulator has been developed, does the language provide ease of modifying the simulator to incorporate changes in the system design and operating policies? If the simulation study is being performed by an outside agency, do in-house capabilities exist in that language to verify the work? A language should be selected only after a proper evaluation of these questions.

4. USE OF PROPER INPUT DATA

A simulator is designed to study and analyze a system. Considerable time and money may have been spent on its development and it may represent the actual system configuration to the minutest detail. However, unless proper data is used in running the simulator, the results obtained are not worth much and cannot be completely relied upon. The data representing conveyor speeds, transfer times, processing times at inspection, times at picking and packing stations, times needed for communicating with the system controlling computer, identification time, etc., must be precise and similar to those in the actual system.

Distributions and probabilities should be used carefully in order to obtain reliable results. The following guidelines, if adhered to, will yield better results from the simulation.

1. If the probability of an event is given, spread this out randomly and not uniformly. For example, if 1 out of 10 (or 10%) loads are to be rejected, select the reject loads randomly with a 10% probability. Do not reject every tenth load.

SIMULATION LANGUAGE / CHARACTERISTIC	GPSS IV/V	SIMSCRIPT 2.5	GASP IV	SLAM	Q-GERTS	GEMS
Language Base	GPSS	SIMSCRIPT	FORTRAN	FORTRAN	FORTRAN	FORTRAN
Special Compiler	Yes	Yes	No	No	No	No
Structured Input	Yes	Yes	Yes	Yes	Yes	Yes
Flexible Reporting Capabilities	No	Yes	Yes	Yes	Yes	Yes
The Event Monitors	Discrete	Discrete	Continuous/ discrete/ combined	Continuous/ discrete/ combined	Discrete	Discrete
Auto. Treatment of Resource Requirements	No	No	No	Yes	Partially	Yes
Continuous* Event Capabilities	No	No	Yes	Yes	No	No

*Differential/difference equations

Table 1. Common Simulation Languages Operational Characteristics

2. If the average time for an activity to be completed is known, do not use this time for completing all loads. Use the appropriate distribution to generate the actual activity completion times. If the distribution of the times is not known, let the time be uniformly spread between the maximum and minimum possible times for that activity. This is especially important where the activity duration time is man-dependent (and not machine controlled).

3. The general tendency when analyzing material handling systems is to assume arrival of loads following an exponential or uniform distribution. However, when using the simulator as the tool for analysis, specific distributions developed from actual data collected on the shop floor can be used thereby yielding more representative results. As an example, let us assume we are simulating the arrival of loads by truck. There can be two distributions involved in this--distribution of the arrival of trucks, and the distribution of the number of loads arriving in each truck. For the first part, a histogram is developed using past data (projected to the future demands, if necessary) which gives the number of trucks arriving during each hour of the day. During simulation, depending on the time of the day in the simulator clock, the truck arrivals can be generated randomly using the mean arrival rate for that hour. When a truck arrival is generated, the number of loads on it can be determined using the distribution of the number of loads on a truck.

When deciding which data to use, one can be carried away into using average times. These are readily available (whereas obtaining actual distributions need considerable effort and data crunching) and are much easier to program for use by the simulator. If simplified data are used for the analysis, this fact should be kept in mind when evaluating the results since they would not be quite as reliable.

5. SUMMARY

Computer simulation is a very powerful and useful tool for analyzing complex material handling systems. It can be used to verify the design, analyze the performance if specific hardware or operational changes are made, or just obtain information about a system. It is desirable to simulate the entire system if the time and money availabilities permit it. Accurate data and distributions and probabilities of activities should be used carefully in order to obtain reliable results.

REFERENCES

Phillips, Don T. (1980), Simulation of Material Handling Systems: When and Which Methodology?, Industrial Engineering, Vol. 12, No. 9, pp. 65-77.