SIMULATION FOR THE COMPUTER NOVICE

Janis Church

ABSTRACT

Simulation is a powerful tool for production and facility planning. Unfortunately, many of the manufacturing engineers who could use simulation to their advantage have not had training in using a computer. Even the simplest languages can be quite formidable to someone without any computer experience. If the engineer turns to a programming group for support, the time required to get a working simulation model can be increased substantially. Often time constraints prohibit this approach. Another problem with this approach is the communications gap which can exist between the computer staff and the manufacturing engineer. If the programmer does not understand the manufacturing system and the engineer does not understand the computer terminology, mistakes can be made in defining the simulation model and in interpreting the simulation results.

To overcome these problems, two simulation programs have been written for the manufacturing engineer who has had no training in programming. One is the Generalized Assembly Line Simulator. It was initially distributed in 1970 and is used to simulate progressive manufacturing systems. The second is the Manufacturing Simulator which was introduced in 1978. The Manufacturing Simulator is used to simulate systems with shared resources.

INTRODUCTION

Simulation can be a valuable tool in designing new manufacturing systems and in modifying existing systems. With simulation several alternatives can be evaluated and costly mistakes can be avoided. The types of mistakes which simulation can identify include excess capacity which does not contribute to production and inadequate capacity which limits production below requirements.

Despite the benefits of simulation, its use is not widespread. Most manufacturing systems are designed, installed and put into production without being simulated. There are several reasons for this omission. One reason is that the manufacturing engineers who are responsible for the design and installation of the system do not know about simulation. This is perhaps the most common reason, but it is becoming less prevalent. New engineers have been introduced to simulation in college and other engineers are becoming aware of simulation through trade/technical publications and conferences.

Another reason for bypassing simulation can be hard to justify. Cost avoidance can be difficult to document. If simulation uncovers some weaknesses in a proposed system, some will argue that the problems would have been spotted before installation anyway. If simulation verifies that the proposed system will meet production requirements without excess capacity, some will say that simulation didn't do any good. The best approach to eliminating this problem is to reduce the time and expense of simulating proposed systems.

Certainly the time and cost of simulation can be another reason why simulation is not used. The manufacturing engineer may be aware of simulation and feel that it can be justified but is unable to use simulation without assistance. If he goes to the data processing group for assistance, he may have to wait until a programmer is available. Then there is the time required to develop and test the simulation model. Frequently the planning schedule does not allow for such delays. Another problem with this approach is that the manufacturing engineer and the programmer don't always speak the same language. It isn't just "computerese". Manufacturing has its jargon too. As a result the model may not represent the proposed system and the output may be misinterpreted.

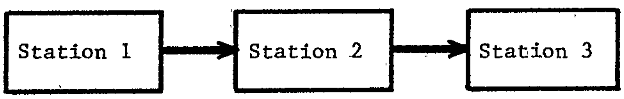
The companies sponsoring Advanced Manufacturing Methods, a research and development project which has been in existence since 1963, recognized these problems (2).

Representatives from these companies felt that it would be possible to develop simulation programs which could simulate some of the common manufacturing systems. The programs would have to be easy for the manufacturing engineer to understand and use. The time required to define the model would have to be short and the computer costs for running the program would have to be low. Two such programs have been written. One is used to simulate progressive manufacturing. The other simulates shared resources.

PROGRESSIVE MANUFACTURING

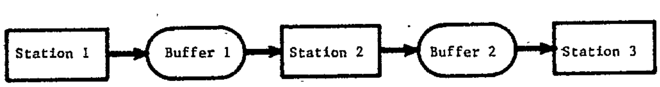
Progressive manufacturing is perhaps the most common characteristic of discrete product manufacture. A unit goes to a station where one or more operations are performed and then is transferred to the next station where additional operations are performed. The process continues until the manufacturing is complete or the product is removed from the system.

For example in a three station line as shown below, a unit would be worked on at station 1. When the work is finished the unit would be transferred to station 2 if station 2 does not have a unit. If station 2 has a unit, station 1 is blocked until station 2 can transfer its unit.



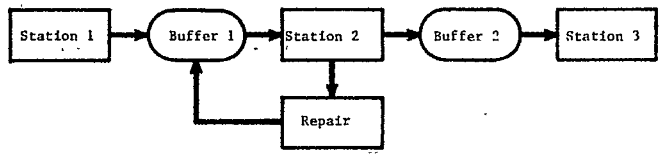
There are three reasons why station 2 may have a unit when station 1 tries to transfer its unit. Station 2 may take longer to perform its operations. The work time may be variable as it normally would be with manual operations. If station 2 is a mechanical station, it may be unoperative or jammed. Station 2 may also have a unit because it was unable to transfer the unit to station 3. Similarly station 2 may complete its work on a unit, transfer the unit to station 3 and find that station 1 cannot transfer a unit. Station 2 is then blocked until it can get a unit from station 1.

Production lost due to blocking can often be reduced by placing buffers or banks between the stations as shown below.

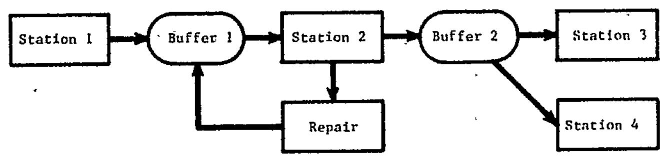


Even if station 2 cannot accept a unit, station 1 can continue to transfer units until buffer 1 is full. When the buffer is full station 2 is blocked until station 2 removes a unit from the buffer. Similarly station 2 can take units from the buffer until the buffer is empty. Then station 2 is blocked until station 1 puts a unit in the buffer.

Obviously many manufacturing lines would be more complex than this illustration. Not only would there be more stations, there may be additional paths. For example, station 2 may be an inspection station and rejected units may go to a repair station before being returned to the line.



There may also be alternative paths. For example station 2 may transfer units through buffer 2 to station 3 or station 4.



Given reasonably accurate performance characteristics it is not difficult to predict the behavior of the individual stations with simple arithmetic. However, without simulation, the interaction between stations is difficult to predict particularly as the network becomes more complex.

GENERALIZED ASSEMBLY LINE SIMULATOR

In 1970 the Generalized Assembly Line Simulator (GALS) was developed to simulate such lines (1). The name is a misnomer because it has probably been used to simulate machining lines more than it has been used to simulate assembly lines. The user describes each station and each buffer on the line.

A station description includes:

- Identification number
- Work time
- Work time distribution (if any)
- Jam probability (if any)
- Jam time distribution (if any)
- Reject probability (if any)
- Repair path (for inspection stations)
- Upstream source (identification number of the upstream stations or buffers)

A buffer description includes:

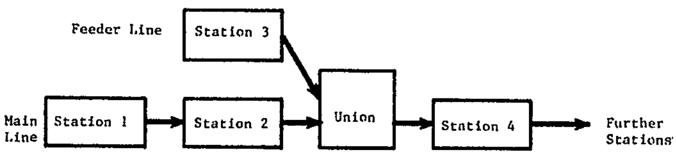
Identification number
Maximum capacity
Travel time (if any)
Upstream source (identification number of the upstream stations or buffers)

Distributions for worktimes and jam times are given as histograms. The term histogram bothers some users, but they soon understand the concept. Many users have never heard of the exponential or Weibull distributions.

The user describes the stations and buffers plus the histograms and the program has the logic to transfer the units through the line. The output for the program describes the simulated performance of each station, including the time it was blocked upstream and downstream, and the simulated performance of each buffer, including maximum and average utilization.

Since 1970, the sponsors have requested several additions to the program. The fifth version is now in wide use. In some systems, it is necessary to merge and assemble mated components, each of which is produced on different segments of the line. The merging capability, called a union, was added to the program, to simulate this situation.

As shown below, a component produced by station 3 is mated with a unit operated on by stations 1 and 2 for assembly at station 4.



On some lines units are transferred by the pallet, so a gatherer was introduced to collect and disperse pallet loads. At some stations downtimes are not random. Tool changes may occur after a given number of units. Scheduled breaks may occur at specified times. Provisions for these requirements and others have been included and are under user option and control.

Advantages and Disadvantages

The primary advantage of the program is that it is easy and inexpensive to use. Line foreman who wouldn't think of using a programming support group will use GALS. Even those who are skilled in simulation languages use GALS because they can set up the input and get results faster. The program is speedy so that rarely is there a problem with inadequate sample sizes. Exceptions to that statement will be discussed later. An auxiliary benefit is that it introduces people to simulation and causes them to think of simulation as a necessary tool.

A disadvantage is that some people use the program beyond its design capabilities. Some experienced users are quite successful in using features for purposes other than their original intention. Other users spend too much time trying to adapt the features when they should turn to a simulation language like GASP or GPSS.

The use of histograms is a mixed blessing. Most of the users can understand them more easily. Histograms for jam times are often derived from maintenance records which tend to exclude jam times of short durations. Users can be warned against that oversight and this can become less of a problem than users of distributions who make no goodness of fit tests. Jam times of long durations are a problem whether they come from a distribution or a histogram. The basic model is no longer valid when a station is down for an extended period. Any number of things can happen. The workers may be sent home. The line may produce another product. In any case the line is not sitting waiting as it would be for jam times of short durations. Again users must be warned about including such events in their model. If these warnings are not heeded, there can be serious problems with inadequate sample sizes.

GALS simulates each unit as it goes through the system. Even though the program can simulate 400 units going through 6 stations in less than 8 seconds on a UNIVAC 1108, there is a problem with simulating a high speed line such as a bottling line where there are hundreds of units a minute. Factoring, that is for example representing 100 bottles as one unit can sometimes be used, but extreme care must be used. This problem is not unique to GALS.

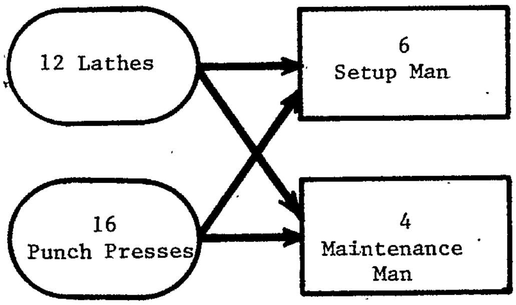
Another problem which is not unique to GALS is that the users do not understand the systems they are trying to simulate. Since we are trying to get down to the end user, we probably have less troublt with that problem than others.

SHARED RESOURCES

The second simulation program developed for the sponsors of Advanced Manufacturing Methods is the Manufacturing Simulator. This program simulates systems where the services of resources (e.g., maintenance men, setup men, fork lift trucks) are shared (demanded) by many users (also called customers) (e.g., departments, machines, operators). Interest in such systems is growing. The resources often represent burden or indirect costs which have been expanding at extraordinary rates.

At the same time concern about machine utilization is also increasing.

A typical system will have one or more customer pools (user pools) which call upon one or more resource pools for service. As illustrated below there are two machine groups (two customer pools, 12 customers and 16 customers, respectively), which call upon setup men and maintenance men (two resource pools, 6 resources and 4 resources, respectively).



It is a queuing system. If a machine calls for a setup man and all the setup men are busy, the machine will be idle unless it can preempt the setup on another machine. In this case the other machine would be idle until a setup man is free. If there are no calls for service, the resources are idle.

As with progressive manufacturing systems, shared resource systems can be described very simply, but it can be difficult to predict how they will perform. Unlike progressive manufacturing systems there are numerous analytical models which can be used to describe shared resource or queuing systems, but most of them make stringent assumptions about the system. Obviously, for a basic system an analytical model would be more suitable than simulation. For more complex systems, a simulation model may be as efficient and effective as the analytical models. Beyond a certain point analytical models have not been developed and simulation is the only recourse.

MANUFACTURING SIMULATOR

The Manufacturing Simulator was distributed in March 1978. Input to the program includes description of the customer pools, descriptions of the resource pools and description of the calls for service which the customers place on the resources. A basic description of a customer pool is the number of customers in the pool. The same format is used to describe resource pools. Availability schedules can be used if the number of customers or resources is not constant over time.

A description of service calls includes

- Time between calls distribution
- Travel time distribution (for service)
- Service time distribution

The description also identifies the customer pool which is doing the calling and the resource pool which is being called upon.

The output describes utilization of the resources and measures of service provided. The measures of service include the number of calls which had to wait, the total time customers spent waiting by customer pool and resource pool, and maximum wait time by customer pool and resource pool.

The program has not been available for very long so the feedback is limited. However, the word is that there are a lot of applications and usage should be heavy.

SUMMARY

In order to expand the use of simulation in manufacturing two programs have been written for the manufacturing engineer or line foreman who has had no computer experience. The systems which these programs cover are quite widespread. The programs are flexible enough to be applicable to most systems within their general area. The acceptance of these programs illustrates the desirability of this approach. There are several other manufacturing areas for which similar programs should be considered.

The acceptance and use of the programs was greatly enhanced when several of the major users made the programs available on time sharing systems (3), (4). Certainly the programs would not be used if the users did not have easy access to the computer system. Reasonable turnaround is another necessary ingredient to effective use of simulation.

It is my hope that no manufacturing system will be installed or modified without prior simulation. In many industries I think that day will be coming fairly soon.

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