JOB SHOP TYPE PRODUCTION SCHEDULING BY SIMULATION

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INTRODUCTION

The primary purpose of this paper is to introduce the audience to a concept that is not always appreciated by those skilled in the art of simulation. In contrast to the traditional use of simulation as a study tool, the following discussion will emphasize the potential role of simulation for operational production scheduling in job shop-like environments rather than the research-oriented role now primarily assigned to it.

Simulation techniques have been employed to study nearly all phases of the manufacturing process including forecasting, long-range planning, order release, and the flow of jobs on the production floor. This paper discusses production-floor scheduling of discrete production facilities with job shop characteristics. A job shop is defined as having the following characteristics: 1) there is a set of production or service facilities; 2) jobs consisting of several tasks move between facilities for service; 3) one or more tasks are performed at each facility; 4) the service time for tasks may vary from job to job; and 5) the routing between facilities may vary from job to job.

TRADITIONAL JOB SHOP STUDIES

The primary goal of most job shop simulation studies has been to determine ways to improve the performance of a system from a macroscopic viewpoint. The output from these traditional simulation studies is condensed into statistics showing means and standard deviations of queue times, queue sizes, service times, etc. The primary emphasis has been to devise improved scheduling or dispatching algorithms. These studies are generally "one time," i.e., once the conclusions are reached, the simulation model is shelved until further studies are desired. This work has led to static changes in production facilities, the rerouting and scheduling of ocean-going vessels, etc.

AN OPERATIONAL SCHEDULER

As an operational scheduler the simulator is run frequently. The results of the scheduling run are presented on a task list detailing the tasks to be performed by each machine or machine group on the production floor. The expected time of arrival, processing start time, elapsed processing time, next step in the routing, and other production-related data are printed on the task list. This microscopic view of the simulation is considerably different from the emphasis on gross effects of the traditional study. Some programming implications, effects of the scheduler on the shop, and effects of the shop on the scheduler are discussed below.

Programming Implications

In traditional studies the simulation model is changed frequently. Therefore the emphasis in the compiler is usually toward fast compilation with execution time and core utilization secondary considerations. In operational scheduling the model is seldom changed. The emphasis in the compiler must be toward fast execution time with core utilization a secondary consideration. Compilation time should be given last consideration.

Since languages like GPSS were not designed for an operational environment, the user must determine whether or not a general-purpose simulation language should be used or a specially designed simulator should be constructed for scheduling proposes. There are arguments on both sides which must be carefully weighed before a final decision is made. Some considerations would be the skill of the programming staff, the availability of a computer large enough to handle a GPSS type model, and economic factors such as execution time versus the cost of programming a special simulator.

The Effects of a Scheduler

A scheduler may affect a production facility in many ways. The net effect must be an overall betterment of the financial situation of the corporation. The major effects can be classified as beneficial either through 1) an increased control over the operation of the plant, or 2) the effects brought about due to the priority rules used by the scheduler.

Priority Rule Effects. Priority rules (obtained from traditional studies*) can have several

* The publications of Conway, Gere, LeGrande, Nanot, and Rowe are among the best in the field. References to their work are listed in the bibliography.

effects upon the shop. In most situations it is desirable to have a rule that is designed to minimize the mean and standard deviation of the lateness distribution,* as this has the effect of giving as short a lead time as possible consistent with reliability in meeting promised deliveries. However, there are many situations in which this is not satisfactory, such as the case when early deliveries are of no advantage and are not offset equally by late deliveries. In this case lateness becomes an important measure.

Three major effects of most priority rules are listed below. These benefits may be obtained in varying degrees with tradeoffs possible depending upon the rule chosen.

1) A lowering of the work in process inventory

2) A decreased order flow time through the plant

3) An increased probability of meeting order due dates.

Operational Control Effects. Although the most easily measured effects of the scheduler may be those listed above, it is conjectured that the major benefits of a scheduler are to be derived from the increased information made available. The predictive information provided to management can allow planned action to be taken which avoids problems rather than waiting for them to develop and then reacting to them. This is not meant to belittle the beneficial effects of a priority rule, but simply to say that these benefits will be overshadowed by the intangible benefits of better, more timely information and the capability for control that it provides.

Management has realized for quite some time that either not enough information has been available, or that the available information is either inaccurate or available too late to be of value other than as history. More timely, accurate data enables correct decisions to be made that control rather than react to the operating environment. In addition to providing increased control over the current operation, scheduling systems will enable current management to control an even larger, more complex enterprise than would be possible without them.

Measuring these effects and placing a financial value upon them is a difficult task. An example of a total information system and its effects upon a hypothetical firm has been studied by Boyd and Krasnow.* They simulated a simple firm and its reaction to a changing environment.

* See Donald Carroll, Heuristic Sequencing of Single and Multiple Component Jobs, Ph.D. dissertation, Sloan School of Management, MIT, June 1965. This dissertation also discusses the significance of much of the work prior to 1965.

The Operating Environment

Production Reporting. Important steps in any simulation run are the setting of initial conditions, and the settling period that must elapse before valid results are obtained. In an operational scheduler, these are accomplished by obtaining a status report from the production floor. The report - the status of jobs (the jobs in queues, the jobs on machines and their remaining processing time, etc.) - must be fed into the simulator. The flow of jobs through the shop is then simulated for a specific period of simulated time. The way the status report is obtained is greatly affected by the dynamics of the shop. If job steps are short and queue times are short, the status is more difficult to ascertain. In many cases, production-reporting terminals must be installed on the shop floor and job claims registered by a central computer as they occur, with current status of jobs maintained continuously. In less dynamic operations, it is possible to take the status manually; this may be the case if the shop does not operate three shifts a day.

New Orders. A queue of jobs that have not been started must be provided in order to keep the system busy. Order release is not a function of the scheduler; however, data provided by the scheduler can project bottlenecks and vacuums, and aid in producing an accurate history of actual job-flow times.

Production Standards and Routines. Production standards are required and, up to a certain point, the more accurate they are, the better the scheduling results will be. Conway has shown, however, that some priority rules are relatively independent of processing-time estimates. In many manufacturing facilities, the existing standards and routings are not sufficiently well defined or accurate enough for scheduling use.

Shop Characteristics. Many characteristics of the shop are reflected in the design and operation of a scheduler. The effect of the dynamic nature of the shop upon the production-reporting system has been mentioned. The dynamics are also a consideration in determining the frequency of the scheduler operation. To gain good control over the plant, the time between scheduler runs should be about the same as the average time between operations on a job, unless a high degree of conformity exists between the simulated schedule and the way the work is actually processed through the shop. When jobs go through several operations between schedules, the scheduler has fewer chances

* "Economic Evaluation of Information Systems," IBM Systems Journal, II, March 1963, 2-23.

to exert its influence, and its effectiveness will be reduced if jobs do not closely follow the simulated schedule. Jobs to be reworked can be considered as new orders released to the system. If the schedules are produced frequently, reworks can get back into production with relatively small delays.

The elapsed time between the cutoff for the shop status and the delivery of new schedules to the shop floor may be critical in some shops. If production continues during this period, the shop floor and the simulated schedule begin to diverge as soon as the status is reported. It is important to have this period as short as possible in dynamic shops, since as the shop becomes more dynamic, the divergence increases.

As more product and production facility characteristics are considered, the complexity of the scheduler is increased. An example is setup interaction where the choice of a task to be processed next on a particular machine is dependent upon the previous task, as may be the case when a tooling change is involved. If a choice between several tasks can be made, the tooling changes might be minimized. (Such problems are getting close to those that are solved by linear programming.) A difficult task is to determine where to draw the line between simulating every feature of a shop and not simulating enough to produce realistic schedules.

The effects of a scheduler cannot be achieved without a change in practice on the shop floor. Therefore, the schedules should not be tested by comparing them with manually produced schedules or current practice. Instead, the real test is whether or not the new schedules can be implemented.

MAJOR IMPLEMENTATION HURDLES

It is not a simple task to implement a scheduling system. This is evidenced by the existence of only a few good systems. There are major hurdles that have contributed to the absence of other systems. Some of these are:

1) The lack of and the difficulty in maintaining a good data base (production reporting, standards, and routings)

2) The lack of a simulator, specialized for job shops, that is large enough to handle the problem

3) The fact that there are few simple shops and it is a difficult problem to simulate complex ones

4) The expense and risk of installing systems whose utility has not been clearly understood or widely demonstrated.

FOR THE FUTURE

Given the current state of affairs, there are two directions that should be taken simultaneously.

1) Studies - Those skilled in traditional simulation studies should direct some of their attention to the problems associated with scheduling systems. The effects of the time lags in the system, the dynamic nature of a shop, the conformance of the shop floor to the simulated schedule are but a few of the areas requiring investigation. Such studies will lead to a better understanding of scheduling systems. Those skilled in the design of simulators should direct some of their attention to the design of a system oriented specifically toward scheduling.

2) Implementation - The existence of good schedulers, e.g., at Fairfield Manufacturing Company in Lafayette, Indiana,* proves that such systems can be implemented, and should serve as an example to encourage others. The knowledge gained by those who have implemented systems should be used as a base for other systems.

* Business Week, "Computer Planning Unsnarls the Job Shop," Apr. 12, 1966, pp. 60-61.

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