A PRODUCTION OPERATIONS SIMULATOR - LOW YIELD, HIGH VOLUME

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Abstract

In high technology production the effect of yield in such areas as schedule, cost, learning, line balancing and equipment requirements is often overlooked. The authors have developed a simulation routine, designed primarily for computer utilization, which concentrates on a convenient handling of yield. In this paper the authors address the method used, the problems which led to the development of the model, and the results obtained in use.

The authors define what is considered to be low yield, high volume operations so that the user can identify a potential application of this simulator as opposed to some alternative. Yield and the effect of learning are considered as they relate to the type of process flow under consideration.

After addressing the individual factors the authors delve into the workings of the modeling technique. A step-by-step approach shows how the model is developed. An example and a case history are included to clarify the development.

INTRODUCTION

To coin a new phrase, "Necessity is the mother of development". The simulator presented in this paper was developed in response to a perceived need to estimate and control costs in the Optical Component Center of Martin Marietta Aerospace, Orlando, Florida. The simulator was based upon information (data) already available to the industrial engineers concerned. It was designed to run on the TSO computer utility available to them. At the time of this writing, it was being revised for utilization on a microcomputer. Expansion of the use of the simulator to the Microelectronics Center at Martin Marietta Orlando was also contemplated.

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DEFINING THE PROBLEM

It is necessary to understand the type of operation for which this modeling technique was designed. This will be a first indicator as to whether this model will be more cost effective to use than other models. A high volume production operation, for our purposes, is one that repetitively manufactures the same product, after methods have been fixed and the learning is on a segment of the learning curve which approximates being flat. High volume, therefore, is more indicative of an established process having been achieved than a high physical count being produced. The sense of aerospace high volume is hundreds as opposed to multi-thousands in mass production industry.

Low yield is defined as an output that is very dependent to chance. All conditions being equal, the probability of getting a good part is 50% or less. This is commonly accepted in the manufacture of precision optical components and state-of-the-art microelectronic components. The yield (or fall out) per individual operation can be predicted using past history and the laws of probability.

A high volume process line with a more normal yield would have a small fall out. As the yield becomes lower and fall out increases, additional reprocessing paths for handling fall out become feasible. The rejected parts can be reworked or scrapped, depending upon cost. Due to the nature of the process, rework may be subjected to the same yield situation as the original process and would be modeled in a similar manner. This iteration can make the use of many standard modeling programs difficult.

WHAT IS YIELD

Total yield for our purposes is defined as the output of good, usable parts related to the number of parts input into the process.

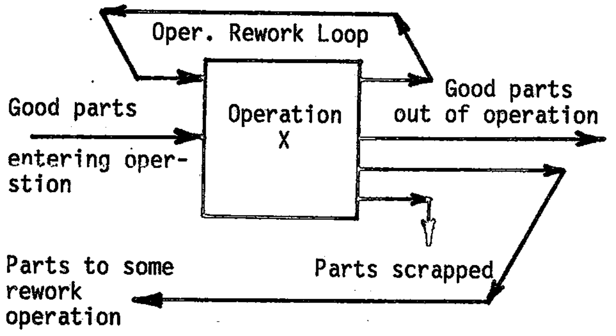
Total yield is the primary concern for purchase of raw materials and lead time. However, total cost and time are dependent on the cumulative yield of individual operations. Thus, individual operation yield will be the building block for our simulator.

DIAGRAMMING A MODEL

Having defined yield as the ratio of good parts to total parts started and having established individual operation yield as our building block, we are ready to establish a flow of parts. By addressing individual operation yields first and then combining them into a system model, we account for the yield variations inherent from one operation to the next. We are also able to study the effect of yield change in one operation upon other operations which are related to it.

To illustrate we shall describe an operation and the various outcomes which may befall a part processed through it. The example operation is shown in FIGURE 1, below.

FIGURE 1

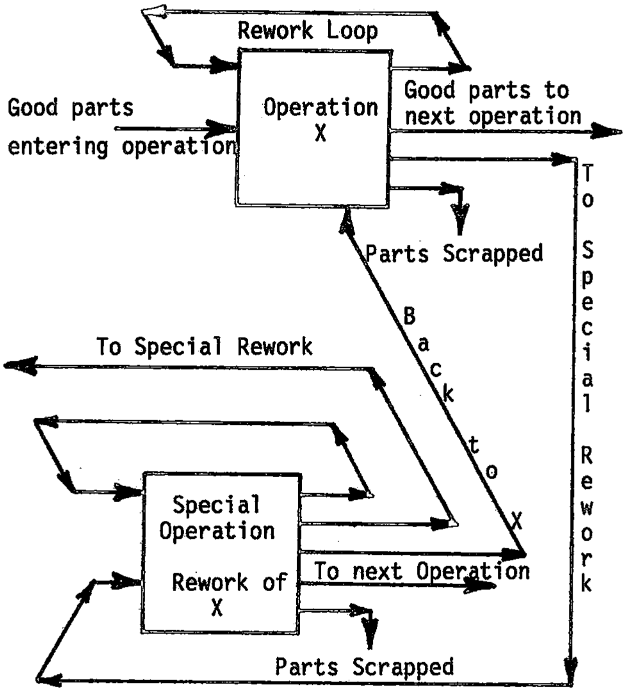


In our illustration good parts entering the operation face four possible outcomes. A part may: 1) Complete the operation successfully and be sent to the next step; 2) be reworked through the same operation (recycled); 3) be reworked through a separate rework loop; 4) be scrapped. Each individual operation in a system can be represented by a similar flow with more or less paths as required by the complexity of the operation.

It now becomes the task to assign probabilities to each outcome of an operation. The probabilities are ideally obtained from historical data. When historical data is not available, or on a new or proposed operation, it becomes necessary to develop an engineered estimate or even a management judgement. Whatever the source, the total of the probabilities of the paths leaving an operation must sum to one, indicating that all parts exiting are accounted for.

We can further expand upon the example of FIGURE 1 by adding the details of the separate rework operation and its possible outcomes. This expanded diagram is shown in FIGURE 2, below.

FIGURE 2



As can be seen from FIGURE 2, the exit paths from the rework operation have grown to five. However, the probability of a second special rework would be very low in most cases. For purposes of modeling, it is considered and included to determine all possible outcomes and effects on cost and schedule. Reviewing FIGURES 1 and 2 it is easy to envision the dilemma of the manager making decisions with even a few operations such as described while the computer can easily sort through the mathematics of such a maze.

By varying the probabilities on the identified paths, a maximum, minimum and most likely outcome can be determined. The effect on cost and schedule can be predicted by inserting the cost and time for each operation. Rework operations can be added or deleted to determine their impact on cost and schedule. Duplicate operations can be added to examine the effect of line balancing on cost and schedule.

COST AND THE EFFECT OF LEARNING

Having defined the flow of the operation through diagramming the model, we will examine further the application of cost. Through analysis of the operation, a pre-determined time standard can be applied, or a time study may be performed. Analysis of the operation will also separate the man controlled and machine controlled portions of the activity. This becomes important in correct application of cost to each operation, as the learning associated with each type of activity differs. Obviously, activity which is man controlled is subject to learning and a reducing cost trend with repetition. Machine controlled activity is not subject to the same type of reducing cost trend. Thus, learning curve cost reduction trends are applied only to the appropriate human controlled activities.

A second point is to be made here regarding learning. Learning occurs on the part of a human on every repetition of a motion pattern. However, many machines in our processes run multiple parts per cycle and a careful analysis must be made as to whether the human learning portion is once per part of once per machine cycle batch of parts.

A third point is the speed at which learning takes place or the rate of cost reduction, This information is needed to determine the learning curve and starting performance to use, or the point at which no further learning takes place, that is, the standard is reached. This information influences the model significantly in determining cost and schedule.

It is important to note that learning is assumed to have no direct effect on yield. By our definition, the factors affecting yield are related to the technology of the operation. Learning has an effect on the rate of the motion pattern, and in this manner affects cost.

For the accuracy of the model it is important that the learning curve usage be as realistic as possible. Historical custom or textual reference are common sources of learning curve values. A third source recommended here is precedence based on historical data in the facility being considered. In a previous article by the authors entitled, "The Learning Curve--Do Your Own Thing", **Proceedings of the 1981 Annual Spring Conference, American Institute of Industrial Engineers,** May 1981, this approach is described together with the steps necessary to develop your own curves.

COMPLETING THE MODEL DIAGRAM

For a fuller understanding of the modeling technique, let us review a typical optical component and the flow through a portion of the fabrication area. In this example we will choose a precision optical part. We will not identify tolerances and specifications, per se, but will refer to yields. The optical component is a lens produced on multiblocked tooling. The multiblocked tooling has seven part capacity at one operation and nineteen part capacity at another operation. The multiple capacity blocking tools require queueing since it is required that the tools be filled when run in the process.

In a typical application the parts will queue at a holding and blocking station. In our example nineteen parts are blocked to a tool. The loaded tool is mounted to a curve generator to develop the larger radius of the lens. In subsequent steps the blanks on the multiblocked tool are fine ground, polished, deblocked and cleaned. The parts (finished on one side) are moved into queue at a second holding and blocking station. The blocking tool used to generate the second side of the lens holds seven parts. (Note: Number of parts per block varies because of diameter and radius.) The loaded tool proceeds through the same steps as the sequence described for the first blocking tool.

Identifying with our previous discussion we note that learning occurs per part when the part is handled individually, as in the blocking operation. When the parts are attached to the blocking tool, learning takes place as the block is processed. In our first case, nineteen individual parts are blocked together for learning purposes to form one new part. Thus, our operator is no smarter after the nineteenth part than after the first part for those operations in which nineteen parts are blocked to a tool.

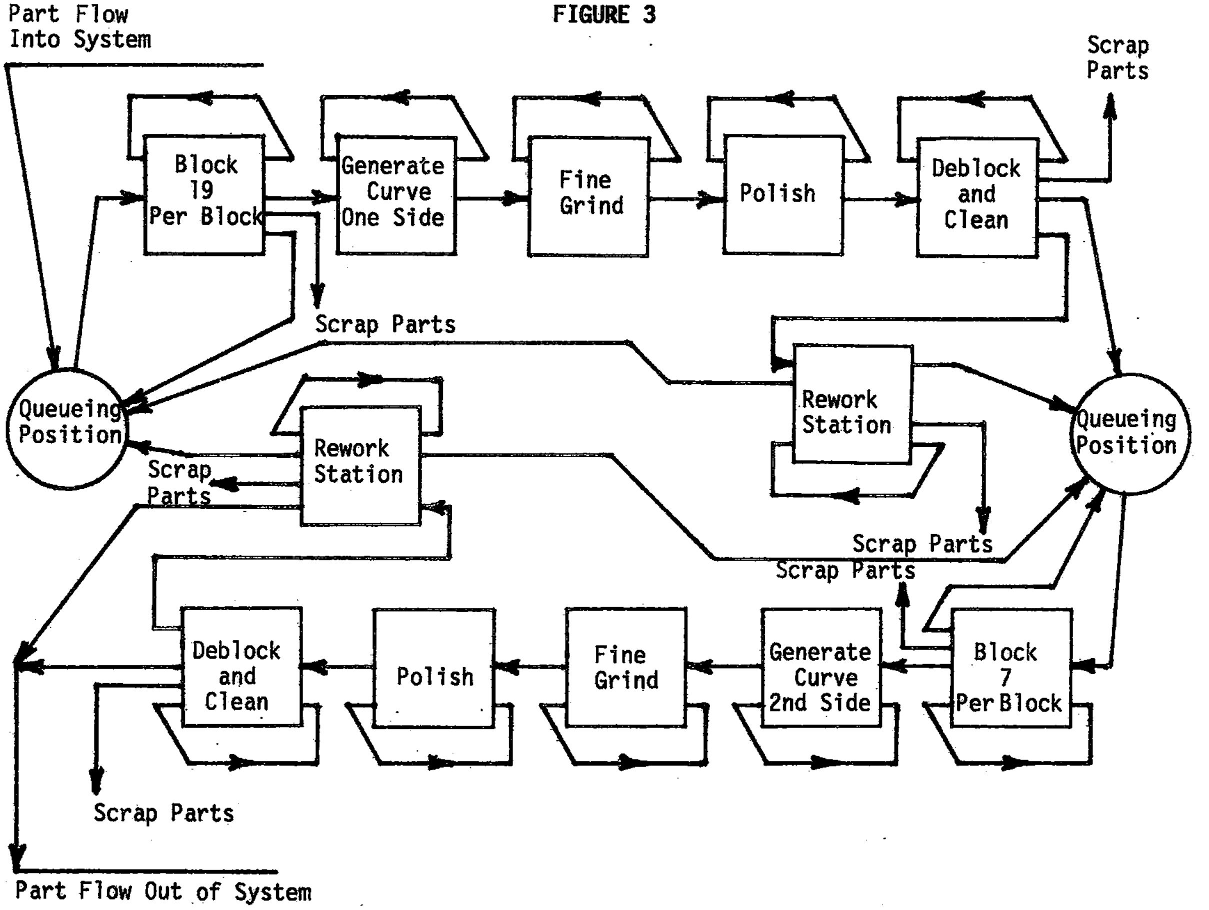
FIGURE 3 (See next page) illustrates the part flow of the operations just described. It is obvious at a glance that manually assigning probable yields, operation times and learning predictions to several likely outcomes is a laborious task indeed. Since operations are interdependent upon the other operations in the network, a minor change can, and often does, result in a major change in network outcome. The very complexity of the interactions in the network defy an intelligent, quick, unaided management decision. The use of the computer to simulate even such a relatively simple example as shown here becomes an absolute necessity.

The network shown in FIGURE 3 is, of course, part of a larger network. From knowledge of the entire operation it was determined that this segment could be separated for solution to cost minimization. It can later be recombined into the total network with this segment having been maximized to management's satisfaction.

A CASE HISTORY

The usual goal of such an exercise is to maximize profit by minimizing cost. It becomes necessary to determine cost at different points within the total operation so that decisions can be made as to appropriate product flow paths. In further explanation of the use of our simulator, the case history of

FIGURE 3



an optical filter processed in the Optical Component Center of Martin Marietta Orlando Aerospace is presented.

During the engineering development phase of a product cycle, it was determined that a particular filter had a much lower yield than had been predicted. The optical filter had two thin film depositions, a bandpass and blocker coating, on the two surfaces. A relatively successful rework procedure was developed to remove bad thin film depositions from failed filters. The procedure was proven effective in removing either thin film deposition and in preparing the substrate for reapplication. Once the part was placed back in queue for recoating, it was impossible to tell a rework filter from a new filter unless it was marked in some way. A simple flow of this case is shown in FIGURE 4, below.

FIGURE 4

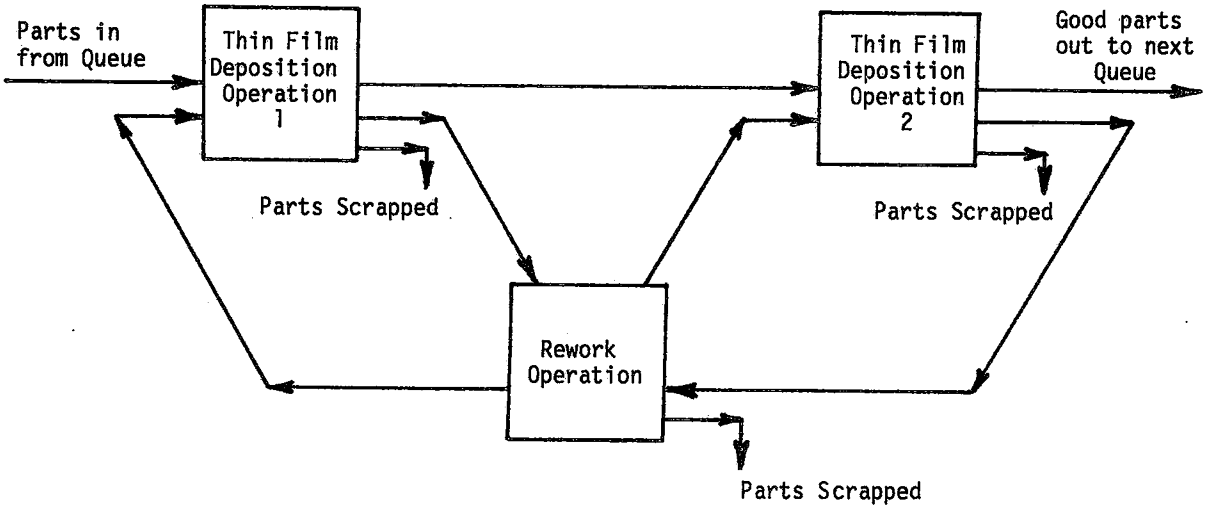


FIGURE 4 shows the two operations under discussion and the rework operation which serves both. By establishing the flow and assigning probabilities and costs to the operations, it became clear that the cost of rework was a significant factor in the total part cost. The rework was also a significant delay in the total cycle time because of the additional processing in the rework operation.

After performing the simulation, the cost of the rework operation was traded against the cost to procure additional glass substrates to be processed without rework. It was found that purchasing and processing additional substrates was more economical than reworking substrates. This rather simple example could have been rationalized without using the simulation. However, use of simulation presented a more quantified solution with the confidence gained from use of maximum/minimum conditions in the assumptions. The use of the simulation also related this single decision to the context of the entire system.

DO NOT USE IF . . .

We have briefly described the why, when and how of the use of this simulator and presented a case history of its beneficial use. It is the opinion of the authors that the conditions for not using this simulator are: 1) A clear process flow is not evident; 2) there is a high probability of success. A secondary consideration might be the lack of rework paths or similar type alternatives which can prove difficult to incorporate in some other simulation systems, but which were a major consideration in the development and use of this simulator.