MAKING SIMULATION WORK IN THE MANUFACTURING ENVIRONMENT

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Abstract

The role of simulation in the manufacturing environment is to assist decision makers in initiating and implementing changes in the workplace. However, simulation studies in this area frequently yield few tangible benefits due to a lack of user understanding of the results, the failure to consider only feasible solution alternatives, or the failure to address the entire process. Simulation can become a valuable tool by applying it properly within the industrial setting. It must provide timely results, be integrated into the broader decision support project, and be conducted in close contact with the ultimate decision maker.

INTRODUCTION

The ultimate goal of Operations Research/ Management Science (OR/MG) projects in the manufacturing environment is to provide information to decision makers which can assist them in formulating policy, setting operational guidelines, altering the environment or making other decisions. The nature of the project, the specific objectives or alternatives considered and the tools employed vary considerably, but the final project goal always remains the same. Unfortunately, many projects fall far short of this goal, as the decision maker does not or can not use the final recommendations or information provided in the study due to doubts about the accuracy or applicability of the results, a lack of understanding of the methods used or results obtained, or the failure of the project to provide pertinent results relating to the decision to be made. Although all types of projects exhibit periodic failures, one time, non-repetitive projects using simulation as their primary analysis tool appear to have a worse track record than expected. This is especially true in environments where simulation is being introduced for the first time. This paper addresses how to initiate and carry out a first time simulation project in a manufacturing environment to improve the probability of having an impact on the final decision making process.

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Initiating the Project

Once the tentative OR/MS project--defined within this paper as a set of analyses designed to yield recommendations or information pertaining to a specific decision or action--has been identified, the standard first step is to define the objectives and scope of the project and determine the appropriate analysis tools to employ. At this time it is critical to identify the specific decisions and actions which will be impacted by the project. The project objectives then should be formulated to assist the decision maker in deciding on the action to be taken or the decision to be made. Following the definition of the objectives, the project methodology is formulated. The primary step in determining how to obtain the desired information is the selection of the tools and methods to employ within a particular project. As is the case before choosing any tool for use, it is necessary to determine that simulation is the best tool for the job. Since the standard advantages and disadvantages of using simulation are well documented (1, 2, 3), this paper will look at three considerations which are of particular concern when undertaking a simulation project in a manufacturing or production environment.

First, care should be taken that an analytical method or simplified approach does not better meet the needs of the user. In many instances, results are desired quickly so that decisions can be made and operations improved with as little delay as possible. In these situations, approximate solutions which can be obtained quickly may be of more value to a decision maker than more accurate simulation results which take weeks or even months to generate. Similarly, the rather high cost of simulation often makes simpler approaches more attractive. Production units, which have to add the project cost to their direct expenses, can not afford the cost of complex simulation studies. They may desire a cheaper alternative as long as the project objectives are met. In addition, production decision makers usually understand an analytical approach better and are more apt to base their decisions on the results.

The second point to consider is the availability of data. Since simulation requires large quantities of accurate data, it is necessary to check on the availability of existing data or the feasibility of collecting future data before committing to a simulation approach. If required data is unavailable and infeasible to collect, then simulation is not the appropriate tool. This is also true in situations where the data can be obtained, but the cost--either in terms of actually recording the data or in reduced productivity due to the data collection process--of collecting the data exceeds the potential benefit of the simulation.

Third, the entire simulation project should be undertaken only when there is an achievable potential benefit. In certain instances, questions are raised concerning the operation of a manufacturing process or the productivity of a packaging line when no action can result regardless of the answers to the questions. When this is the case, the objectives of the project, and its impact on the environment, should be carefully reevaluated before proceeding. Rarely is the cost of building and analyzing simulation models justified in the situation where no action can be taken upon the completion of the project.

Once the determination has been made that simulation is the appropriate tool in a given situation, the modeling process can begin. However, prior to starting the simulation phase of the project, the analyst must develop a thorough understanding of the process to be modeled and the objectives of the project. This involves studying the process, talking with the people involved, and communicating with the ultimate decision maker. This last point is very important for two reasons. First, the analyst must know what decisions are being made based upon the results of the simulation in order to structure the model to yield the most valuable information. Secondly, the decision maker must be aware of the solution methodology, understand the assumptions inherent in it, and be convinced that simulation can yield results which are applicable to the problem at hand.

One major result of not working directly with the decision maker is a skepticism that the final results are hypothetical or "made-up" and will not reflect reality. By being included in the developmental and model building stages, the decision maker better understands the process and is more likely to believe in the results.

One further idea to consider when using a simulation in an environment for the first time is to start out with a "demonstration" model. If a simulation model can be used to substantiate known facts before looking at "what if" questions, the user's faith in the procedures and willingness to make decisions based on its results will increase. It is important that the decision maker has confidence in the ability of simulation to generate meaningful results before the project is initiated. A skeptical decision maker will be very hesitant to make use of any results which are generated.

Simulation as a Tool Within the Project

As stated previously, the goal of an OR/MS project is to provide information pertinent to making a decision or initiating some action. This goal is independent of the OR tool used during the analysis. Therefore, after choosing simulation as the appropriate tool in a given situation and identifying the objectives and scope of the simulation, it is still necessary to keep the goals of the project in mind. The objectives of the simulation are designed to help satisfy the project goals, but should not replace them. In many instances, these objectives are narrower in scope than the project goals, thus limiting the benefit of the analysis if the simulation study is not augmented with additional analysis.

In particular, during the modeling or data collection steps of the simulation study various questions may arise which impact on the goals of the project. Each of these questions should be addressed in detail outside of their impact on the simulation. The following example illustrates the importance of augmenting the simulation results with the results of related analyses to satisfy the goals of a project.

A project was established to investigate the problem of low net throughput for a particular high speed packaging line. The line, shown schematically in Figure 1, consists of three segments, each of which has the potential to operate independently if internal storage space were available. The goal of the project was to recommend alternative line operating policies, line configurations, or repair disciplines which would improve the net yield of 130 bottles per minute (bpm). Simulation was chosen as the primary analysis tool, where the basic alternatives to test included:

Making Simulation Work (continued)

1. 1 repair person vs 2 repair people.
2. building internal storage at predefined points within the line and running the equipment independently to make use of this surge capacity.

It was assumed that the maximum running speeds and failure rates for the equipment on the line were fixed at their existing levels in the short run. Interest was on how to operate the existing line rather than on how to change its components.

The line depicted in Figure 1 was subsequently modeled in GPSS using failure rate data collected over a several week interval. Running the model for 36 hours of simulated time at the recorded gross line speed of 209 bpm provided the results indicated in Figure 2. It can be seen that the net yield increased as

- the equipment was run independently, where independence implies that a given machine operates as long as it has bottles available to process and a location into which to output the bottles,
- the number of internal storages increases,
- the size of any storage increases,
- multiple failures can be repaired simultaneously.

The maximum potential increase in net yield due to the combination of increased internal storage capacity and an improved repair discipline was found to be 29.4%. However, this requires storage for over 19000 bottles in each of 3 locations. When the maximum storage capacity was limited to a feasible 200 bottles in each location, the net yield increased by only 13.9%.

Although significant, this increase in yield could only be achieved through staffing the line with more repair personnel and restructuring the line to include internal storage. Due to the expense of implementing these alternatives it was recommended that no action be taken. Hence, the simulation study provided information concerning the potential payoff of various line changes, but the improvement noted did not justify altering the line.

At this point however, the project went beyond the standard analysis of the simulation model to look at one other key factor in the net yield equation--the gross running speed. During the entire model building, data collection and simulation stages of the project, the average gross speed was fixed at 209 bpm, where gross speed is defined as the speed at which bottles are packaged when the line is in full operation. Comparing this to the gross speed of 280 bpm quoted in the line operating procedures prompted an investigation as to why the observed gross speed was so low, and how this could be impacting net yield.

Discussions with the packaging line personnel pointed out that the gross speed was reset after each line stoppage by a line attendant who "dialled" up the speed to a level at which the line was operating smoothly. This level varied from 120 to 280 bpm, but never exceeded this level. Investigation into why the gross speed varied over such a broad range and what determined the maximum level indicated that years of experience in running the line had led the operators to perceive that

- the paddlewheel could not run at over 280 bpm, thus fixing the absolute maximum line speed at that level,
- the equipment on the line failed more frequently as the line speed increased, thus reducing running time and consequently net yield.

For these reasons, the gross speed was kept low in the belief that net yield was maximized at some 'reasonable' gross speed rather than at some higher level.

Because of a lack of data to support these two hypotheses, further investigation was carried out to

- determine if the paddlewheel was a bottleneck,
- look at the correlation between failure rates and gross speed, and
- determine the relationship between gross speed and net yield.

The initial study focused on the role of the paddlewheel in limiting line speed. Upon careful observation, it became readily apparent that it operated much faster than 280 bpm, and that the observed bottleneck could be removed by simply increasing the length of the conveyor belt between the paddlewheel and the blower. It would not be necessary to replace the paddlewheel in order to run at speeds in excess of 280 bpm.

The second followup study involved collecting failure data when the line was turned up to a higher speed. Analyzing this data proved the operators correct in that the failure rate measured in failures per unit time increased, but the more important rate of failures per 1000 bottles remained constant. Therefore, although the number of failures per day increased, the mean throughput between each failure remained constant, thus increasing the overall yield. This is illustrated by the fact that net yield increased to 145.8 bpm (a gain of 12.9%) during the second data collection phase when gross speed averaged 227 bpm.

The final conclusions of the project far exceeded the results of the simulation study carried out. Rather than concluding that the line be run as in the past, the conclusion was that the gross speed should be increased. The gain in net yield observed from the minimal increase in average gross speed from 209 to 227 bpm nearly equaled the potential gain of the best simulated alternative, and could be achieved at no extra expense. In addition, the followup analysis indicated that further gross speed increases are not constrained by the paddlewheel. Therefore, the project yielded several tangible benefits although the simulation study was not able to recommend any feasible, cost effective solutions. This points out the critical importance of assessing all of the information gained during the modeling and data collection processes. Many times the underlying hypotheses of the simulation can be modified, leading to significant benefits.

Making Simulation a Successful Tool

Although simulation is simply an analysis tool to be used during a project, it is a very powerful technique which can generate valuable insight into the manufacturing decision making process. However, the ultimate success of simulation models in affecting change in industry is dependent upon how they are developed. The development process must consider the environment which is being studied and include the people affected by any potential change at an early stage. Projects which are disruptive, adversely affect production or are developed without sufficient user interaction are doomed to failure from the start.

The following guidelines have proven beneficial in helping analysts avoid some of the potential pitfalls to completing a successful simulation project.

First, and most importantly, the final decision makers, the individuals affected by the modeling process and the individuals responsible for implementing any future changes all must be involved in the project from the start. In many instances, the success of the study will depend upon the level of involvement. Active participation, with the users working hand in hand with the OR analyst, produces the best results, as the users gain a complete understanding of what simulation can achieve, the assumptions inherent in the model and how they will impact on the results, assist in structuring the model to best emulate the process being studied, have a hand in determining the questions to ask and alternatives to consider, and feel a sense of responsibility for their project. This close cooperation from project inception between the model builder and all the affected personnel leads to more realistic models, feasible solution alternatives and a better chance of implementation upon completion of the project. Contrast this to the situation where the analyst is commissioned by a manager to build a model of a process, and the study proceeds with minimal user input. Although the conclusions reached may be similar, the employees responsible for implementing any changes may be reluctant to do so because of a lack of confidence in the methodology or resistance to outside interference. Cooperation at all levels leads to significantly higher action levels.

Although user involvement is critical to the success of any simulation project, the analyst must carefully evaluate all information obtained from line attendants, operators or other users involved in the process being studied. Many valuable insights into the workings of the operation being modeled, its problems and potential solutions can be gleaned from the people involved, but on occasions their observations may be inaccurate or misinterpreted. The example presented earlier illustrates this point very well. First, the line attendants mistakenly identified the paddlewheel as the bottleneck on the line when the real problem was the interface between the paddlewheel and the following piece of equipment. Secondly, the line speed was kept inappropriately slow due to misinterpretation of the observation that the line failed more frequently as speed increased. It is the responsibility of the analyst to evaluate all information collected during the study. "Facts" concerning the operation of the process being studied should be scrutinized as carefully as hypotheses and casual observations.

The final point to consider involves the collection of the data required to run the simulation. In many production environments the data collection process is disruptive to production and very expensive. For this reason, existing data should be used whenever possible. This minimizes any disruption on the floor, reduces the cost of collecting data and allows the project to proceed at a faster pace. This last point can be very important in situations where decisions have to be made rapidly. A two or three month data collection period may eliminate simulation as a potential decision making tool when the decision has to be reached in two or three weeks.

In situations where the data is to be collected as part of the project, the data collection process must be carefully planned and carried out. The collection procedure must not hinder production or force a change in existing operations. If this occurs, the data is not representative of the process being modeled. In addition, the evaluation of the data must taken into account any possible Hawthorne effect. It is often the case that people work differently when observed, thus altering the production rates, net yields or other factors being measured. This introduces bias into the simulation, as the data used is not representative of the normal state of affairs.

Summary

Simulation can be a very valuable tool for exploring current operations in the manufacturing sector, evaluating alternative policies and assisting decision makers in initiating and implementing change. However, simulation is often ineffective in generating tangible results in the industrial sector due to user resistance or lack of confidence in the results, the failure to generate feasible solution alternatives, or the failure to address the entire process under consideration. These shortcomings can be diminished through the proper use of simulation as a decision making tool. It must be integrated as a tool into a broader decision support project, where the results of the simulation are merged with other information to yield the final project recommendations. The probability of successfully satisfying the project objectives increases when the simulation study is conducted in close contact with all of the people involved in initiating or implementing potential changes in the process being studied.

Figure 1
Sample Packaging Line

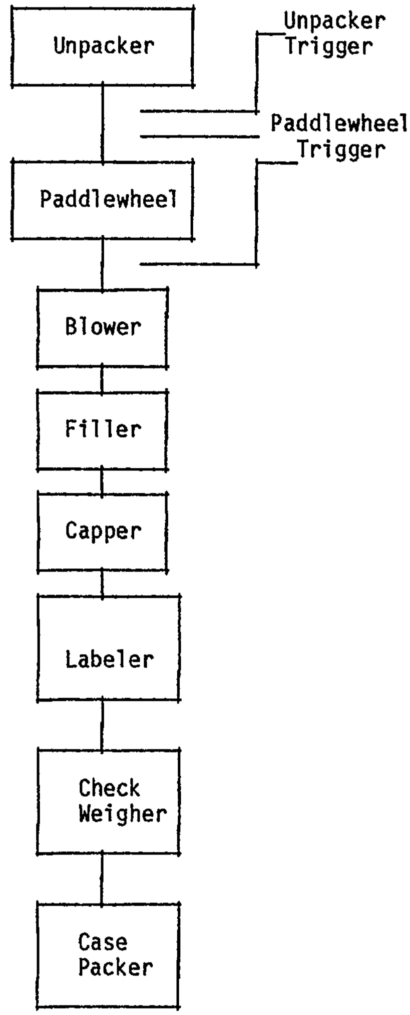

Figure 2
Sample Simulation Results for a Packaging Line

Queue Capacity Preceding			Yield (bmp) with	
Filler	Labeler	Packer	One Repairman	Two Repairmen
0	0	0	129.1	
0	0	400	135.9	140.3
200	0	400	138.9	143.8
200	200	400	140.5	147.1
600	0	400	140.0	146.3
600	600	400	146.2	153.4
0	0	unlimited	137.6	142.4
unlimited	0	unlimited	144.2	149.9
unlimited	unlimited	unlimited	156.3	167.0

REFERENCES

1. Law, Averill M., and W. David Kelton, Simulation Modeling and Analysis, McGraw-Hill Book Company, New York, 1982.

2. Meier, Robert C., William T. Newell and Harold L. Pazer, Simulation in Business and Economics, Prentice-Hall, Inc., New jersey, 1969.

3. Mize, Joe H. and J. Grady Cox, Essentials of Simulation, Prentice-Hall, Inc., New Jersey, 1968.