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APPLYING THE SIMULATION PROCESS: SIMULATION STUDY OF HDA PARTS DEGREASER

Robert Kittell, P.E.
AIC Engineering Services
P.O.Box 189626
Sacramento, CA 95818

Ann Dunkin
Hewlett Packard
P.O.Box 15, MS 760
Boise, ID 83707

ABSTRACT

The steps involved in a simulation study have been well documented in a wide variety of published literature. Though varying slightly in number and detail, there is a proven methodology that contributes greatly to the success of a simulation project. This paper reviews the methodology and describes it in detail through a case study.

1 INTRODUCTION

The purpose of this paper is to define for the reader a methodology for performing a simulation study. Specifically, ten steps in a simulation study will be listed, defined and briefly described. A case study on an automatic degreaser will be presented. The case study is used as a backdrop for illustrating the application of the methodology.

1.1 Literature Review

Several papers have been published listing the steps in a simulation study. Biles (1987) and Balci (1990) have recently described the simulation process. Earlier, Shannon (1975), Pritsker (1979), Kelton and Law (1982), and Carson and Banks (1984) introduced similar methodologies in some of the classic textbooks in the field.

While varying slightly in detail and syntax, the core of the simulation process is consistent throughout: There is more to a simulation study than merely building a model. (Ease of building a model is often a criterion when purchasing a simulation software product, and can quickly become the only focus of a simulation project.) The methodologies described by the above authors address everything from problem formulation to statistical analysis, all of which are necessary evils in getting the best information possible out of a simulation study.

2 PITFALLS OF POORLY STRUCTURED SIMULATION STUDIES

A simulationist must be wary of the "Garbage-in Gospel-out" syndrome. Since the results of a simulation model are generated by a computer, it is easy for the novice or layman to give instant credibility to the output. A poor set of assumptions, bad input data, and modeling compromises (due to a poor fit of software) all contribute to this "garbage." Even if adequate statistical analysis is performed on output data, the result can be nonsense if there is a poor model foundation.

Lack of meaningful output analysis results in more garbage. One must realize that the output of a simulation run is a random variable, and that one run by itself says very little. A classic trap to fall into involves animation. It is easy to just watch "cartoons" for a few minutes to get a feel for system performance without looking at the output data. These "warm fuzzies" are no substitute for sound statistical analysis.

There must be an element of consistency in a simulation study. Model detail should be consistent with the objectives of the study. It is nonsense to bury the model in more detail than is required; the added effort consumes time and resources without adding any information of value to the study. Conversely, if critical details are overlooked, the model will lack accuracy and merit.

Managers and others who fund projects have better things to do than to swim through reams of output data.

The simulation study does not end when the analysis has been done. As a simulation practitioner, your responsibility is to document the model and present results with the objective of getting the project funded. Techniques to "sell" a project include animation, presentation graphics and executive summaries. Save the details as back-up material to present upon request!

3 ADVANTAGES OF PROPERLY STRUCTURED SIMULATION STUDIES

A successful simulation study is one that is accurate, on schedule, and under budget. It uses resources efficiently, receives broad acceptance, and its model is well documented and maintainable. The recommendations of the study are accepted by management and are implemented without delay.

The following section describes ten steps of a simulation study that will contribute to the success of a simulation project.

4 METHODOLOGY REVIEW

The authors of this paper have summarized the various study methodologies into a series of ten steps:

4.1 Problem Formulation

This is a basic statement of the problem. At this point the problem should be bounded; but be prepared to reformulate the problem later if necessary. Members of the simulation team are assembled, including process experts, simulation experts, and policymakers. Agreement among team members is critical at this point in the study. Evaluation criteria for the study is also established here.

4.2 Setting Objectives

These are the questions to be answered by the study. Also a list of tasks should be created and resources assigned to ensure the completion of the project.

4.3 Model Development

This is where a conceptual representation of the problem is developed. A flow chart may prove useful in this step. It may be wise to start simple and progress from there. It is important for the customer to understand the set of assumptions and the level of detail.

4.4 Data Collection

Input variables are defined here. Time studies are an effective way to gather input data. This data can be useful for validating models based on existing systems. Some data are difficult to obtain, so this step should begin early in the process.

4.5 Coding

This is where the conceptual model is translated into a computer model. There are many different types of simulation software packages available, ranging from general purpose languages to special purpose simulators. There must be a good fit between software capability, model detail, and study objectives.

4.6 Verification

This is the process of debugging the computer model. Tests should be made to check model logic and input parameters. Limiting cases where results can be easily calculated is a good way to check model outputs. A trace file is another effective means for verification.

4.7 Validation

Is the model an accurate representation of the system? If there is an existing system to compare the model to, use input parameters that reflect the real system. A line-by-line walk through with someone familiar with the process is a good validation technique. A model with good face validity means that it behaves in the direction anticipated when certain inputs are changed. A good use for animation is to help validate a model.

4.8 Experiment Design

Select the alternatives to be evaluated and decide on warm-up periods and length of runs. Decide on variance reduction techniques (VRTs) and how many replications to run. Since a simulation behaves RIRO (random-in random-out), care must be taken to eliminate as much noise as possible from the output data.

4.9 Production Runs and Analysis

Estimate performance measures and test for significance (hypothesis testing). Are more runs needed? There is latitude here to perform sensitivity analysis and address various "what-ifs."

4.10 Report

Document the model and model assumptions. If possible, paint a "before and after" picture of the system. In the written report be concise, focusing mainly on conclusions and recommendations. Use plenty of graphics and animation if possible. The objective here is to sell and implement the solution.

The remainder of the paper uses a case study of an automatic degreaser to describe these steps in a real world application.

5 PROCESS INTRODUCTION

Parts for an HDA (Head Disk Assembly) production line must be cleaned and sanitized before entering a clean room environment for assembly. (At the time of the study, freon-based degreasing agents were used. Currently, water-based degreasers are being developed.) Hewlett Packard's Disk Mechanisms Division in Boise,ID was facing an increase in production volumes, and recognized that the single degreaser for the HDA facility was rapidly becoming a bottleneck. A decision had to be made whether to modify the existing degreaser to reduce cycle times, or to purchase a second degreaser. It was decided that a simulation study could help assess the impact on system throughput of mechanical modifications to the degreaser.

5.1 Description of System

Pallets (12" by 18") of HDA parts are delivered to the degreaser by a gravity flow conveyor. The degreaser consists of four tanks: one vapor and three liquid. A small percentage of the pallets receive "vapor only" treatment, while the rest receive treatment from all four tanks. Included in the automatic degreaser is a cartesian robot. In addition to bringing pallets into and out of the system, the robot submerges pallets into and retrieves pallets out of each of the four tanks. The retrieval process in tank four includes a slow raise through a vapor zone allowing for final drainage of the pallet.

5.2 Proposed Changes

Install an air cylinder in tank four that would control the entire process cycle of the pallet, both the submersion and slow raise through the vapor zone. This would allow the robot to perform other functions during the slow raise process, and still provide adequate opportunity for reducing freon dragout in tank four.

6 SIMULATION STUDY

The purpose of the study was to investigate throughput capacity of the existing degreaser and of the proposed system. A time and motion study was performed on the degreaser to gather data on current operating conditions and to observe its behavior. The data was used to confirm current throughput capacity estimates and to validate the simulation model.

The time and motion study revealed several apparently unnecessary movements performed by the robot, leading to the following three scenarios simulated:

> Scenario 1: Modify the electric lift in tank four to raise and drain the pallet, rather than burden the robot with this operation. (Eliminates unnecessary overhead on the robot.)
>
> Scenario 2: Install an elevator at the outbound pallet conveyor. The robot transfers pallets to the elevator rather than directly to the conveyor. (Eliminates unnecessary vertical travel.)
>
> Scenario 3: Install an additional elevator at the inbound pallet conveyor.

The simulation model was written in GPSS, a general purpose simulation language. GPSS was chosen because of its ability to model complex control logics within the framework of a process view environment. The model was developed with a data-driven front end that allowed different operating scenarios to be easily implemented.

Assembly line workers, a supervisor, and the production manager were involved in defining system behavior for the simulation model development.

6.1 Model Description

Pallets are introduced to an INFEED station and are allowed to queue up to 99. Pallets are assigned a VAPOR ONLY routing with a given probability. When TANK1 is empty and the ROBOT is available, the pallet at the front of the INFEED queue is brought into the "system." Time-in-system statistics begin at the point after the ROBOT executes its shuttle time to pick up the new pallet at INFEED. The pallet SEIZEs the ROBOT until travel between INFEED and TANK1 is completed. After the vapor treatment in TANK1 is completed the pallet is routed either to TANK2 or to the outbound station (OUT). Pallets are transferred from TANK2 to TANK3 to TANK4 and to OUT by the ROBOT. Time-in-system statistics are terminated after the ROBOT releases a pallet at the outbound station.

The ROBOT is modelled as a FACILITY,and it services pallet move requests on a first-in first-out basis. No look-ahead logic is included. After a pallet move is completed, the ROBOT waits in its current position until another pallet move is requested.

6.2 Input Data

Input data required by the model included:

1. ROBOT travel times
2. ROBOT shuttle and delay times
3. Immersion time in each tank

The total travel envelope of the ROBOT was broken down into a series of contiguous segments. At least three independent observations were recorded for travel times across each segment. Because of the cyclical nature of routes taken by the ROBOT, several visits were required in order to observe travel across all segments. Travel times were recorded separately for both empty and full trips for each segment. Travel times from the outbound conveyor to the inbound conveyor, and from TANK2 to the inbound conveyor were estimated using extrapolation, since neither cycle was actually observed.

Pick-up and drop-off times were measured at the inbound conveyor, the outbound conveyor, and at each of the tanks. Pick-up times were fairly consistent among the pick-up locations. However, drop-off times were quite inconsistent and tended to be of longer duration than pick-ups. The excess time was caused by a delay after the actual drop-off and before travel was resumed. This delay was associated with the controller.

Immersion time in each tank included the time required for the air cylinder/electric lift to lower and raise the pallet into and out of each tank.

6.3 Model Verification

The purpose of the verification effort was to debug the code and assure that the code was performing properly. Several techniques were used to verify the simulation model, including:

1. Simplifying Assumptions
2. Structured Walk-through
3. Trace
4. Interactive Graphics

A simple model of one queue and one tank was written and debugged before an effort was made to model the entire degreaser process. This proved beneficial in inbound queue management when additional tanks were added. A line-by-line walk through was performed with another process engineer familiar with both simulation modelling and degreaser operation. A trace file was used to track transaction counts at all phases (BLOCKs) in the model. Abnormal BLOCK counts indicate logical failures and/or bottlenecks.Interactive graphics were used to display time-in-system statistics (histograms) and resource utilization (bar charts). Time values for ROBOT travel segments not logically permitted were coded as "-1". If such a segment was to have been scheduled to be traversed, the negative time increment would have caused the program to sustain a run-time error.

6.4 Model Validation

Validation techniques were used to determine if the model was an accurate representation of the real system. Efforts were made to establish high "face validity" and to determine how closely the model output resembled real data.

Conversations were held with the in-house experts on the degreaser to learn first-hand why the degreaser behaved as it did. Several hours of observation during data collection proved helpful in further defining the behavior to expect out of the model.

Three statistics were identified as being critical to the validation of the model:

1. Time-in-system
2. Time between exits
3. ROBOT utilization

Real data was collected on these three statistics over a period of 100 continuous minutes, and augmented by data in a report from production line supervisors. The model was set up to simulate the system as it existed, and five replications were made. The validation data follows:

Table 1: Validation Data

	Time-in-system	Time-bet-exits	ROBOTutil.
Real Data	10.02 min	3.90 min	1.000
Simulation	12.01 min	3.67 min	.990

6.5 Experimentation

Five replications were run for each of the three scenarios, in addition to the real system model. Two random number streams were used in each replication- one for generating pallet arrivals, and the other to determine VAPOR ONLY routings. Random number seeds were changed between replications within each scenario. Common random numbers were used across scenarios to facilitate variance reduction. The critical statistic used in the experiments was the total number of pallets to have reached the outbound station at the end of the degreaser. Paired t-tests were used when comparing throughput from one scenario to that of another. The models were run for a one hour warm-up period, and data was gathered on a seven-hour run. Test data appears below:

Table 2:Simulation Statistics

	time in system (min)	time between exits (min)	robot util.	pallets per hour
Real system	10.02	3.90	1.000	15.38
Scenario 1	9.81	3.03	.996	19.80
Scenario 2	9.29	2.88	.996	20.83
Scenario 3	8.78	2.74	.993	21.97

6.6 Sensitivity Analysis

Since the actual cycle time in TANK4 after modification was still only a "best guess" estimate, there was a need the predict system performance over a range of cycle times in TANK4. The sensitivity analysis concluded that the cycle time in TANK4 could have increased by up to 30 seconds without degrading system throughput. It was recommended to go ahead with the modifications immediately, and not to purchase a second degreaser. Given the marginal throughput contributions of scenarios 2 & 3, they would be pursued at a later date only if needed.

7 IMPLEMENTATION

The implementation of the degreaser modifications required a diverse set of skills. Since the changes involved system mechanics, electronics and software, team players were brought in from process engineering, technical support and the model shop. Because the degreaser supported 3-shift production five days per week, the majority of changes were implemented on the weekends.They were also done in phases in order to allow return to the old system if the modifications did not work.

During the course of implementation an intermittent problem occurred that resulted in losses in production. An encoder cable failed (wire fatigue) due to continuous flexing, which caused x-axis encoder information to be incorrect. Though not a direct result of the modifications to the degreaser, it was enough to disrupt the process and raise a few eyebrows. Questions about support were addressed by conducting a formal documentation release for the electronic and software components.

8 WRAP-UP

After the changes were implemented a follow-up study was conducted to assess the true value of the project. The following data was collected:

Table 3: Follow-up Data

	time in system (min)	time between exits (min)	robot util.	pallets per hour
Old system	10.02	3.90	˜1.000	15.38
New System	8.66	3.08	˜1.000	19.48
Simulation (Scenario 1)	9.81	3.03	.996	19.80

The modifications in TANK4 resulted in a 27% improvement in system throughput over the old system. The cost of purchasing a second degreaser was avoided. The simulation model was accurate to within 2% of real system data. In a well managed project with competent team players and automated equipment, results like these are not unexpected.

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AUTHOR BIOGRAPHIES

Robert Kittell, P.E. is a partner in Advanced Industrial Concepts, a simulation consulting firm. Formerly with Hewlett Packard Co., he received his MSIE from Georgia Tech and BSIE from the University of Miami (FL). He has a broad background in manufacturing, distribution and material handling systems. He is a senior member of IIE.

Ann Dunkin is a manufacturing development engineer at Hewlett Packard Co. in Boise, ID. She is responsible for the design and support of manufacturing processes. She received her BIE and MS from Georgia Tech while working for the Material Handling Research Center (MHRC). At MHRC she received the Wunsch award for outstanding Master's thesis in Material Handling. Her interests include automated material handling systems and organizational management. She is a member of IIE.