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Theoretical Study: Analysis of Automated Flow Lines Using Discrete-Event Simulation

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ABSTRACT

Discrete-Event Simulation (DES) has been used extensively by companies for modelling and analysis of manufacturing systems, especially in evaluating the performance of a proposed system and choosing an appropriate design before actually implementing the proposed solutions. To demonstrate the advantage of DES, it was used as methodology in this project to analyze the performance of an Automated Flow Line, which is one of the basic concepts in manufacturing systems. A relevant artificial case study has been selected as a data source and experimentation on the developed models has been carried out using simulation software package called ServiceModel (version 3.5). Moreover, the result obtained from simulation model was evaluated according to the general terminology for analysis of Automated Flow Lines. The key parameters chosen are cycle time (T_c), frequency of line stop per cycle (F), actual production time (T_p), average hourly production rate (R_p), average blocked (B_p), total hours of downtime (D), and line efficiency (E). Consequently, this dissertation has demonstrated the DES is a good method to analyze the performance of Automated Flow Lines, as well as a decision-support tool for management.

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CHAPTER (1) :

INTRODUCTION

1.0 INTRODUCTION

Since the 1950s, computer simulation has been used to tackle a range of business problems leading to improvements in efficiency, reduced costs and increased profitability. Simulation studies have been carried out in most business sectors, including manufacturing and service industries as well as in the public sector [Robinson, 1994]. Particularly within manufacturing sites, simulation has become a much more familiar tool for the analyst to use to study flow lines and other production systems [Groover, 1987]. The benefit from this is that modelling allows decision markers such as managers or engineers to access the likely effects of their decisions before any significant changes or commitment of fund is made. Moreover, advance features in the latest simulation software packages (e.g. ARENA, Pro Model, ServiceModel) and computer hardware have made simulation more reliable to use as alternative form of analysis to solve a some real-world problem that are too complex and having difficulties to be evaluated analytically.

This project will be conducted as theoretical study to demonstrate the significant role of Discrete-Event Simulation (DES) in the analysis of performance of Automated Flow Line, which is one of the concepts in manufacturing systems for High-Volume Production. This type of manufacturing was concerned with the mass production of discrete products using mechanized and automated flow lines. The detail about the description of study, aims and objectives of this project will be discussed in the following section of this chapter.

1.1 DESCRIPTION OF STUDY

The simulation study will be carried out base upon the data from one artificial case study. This case study is adapted from the book of Automation, Production Systems, and Computer Integrated Manufacturing (CIM), by Mikell P. Groover (1987). The scenario of the problem is defined in the following.

The APSCIM Machine and Faundry operates an automated transfer line with 12 stations. The line is considered to have an efficiency that is unacceptably low. Figure 1.1

is a report of a study on the current line operations. APSCIM would like to improve the efficiency by making the following changes in the line:

i. Change over from the current electromechanical relay-tape controls to a programmable controller. In addition to controlling the line in the same way as before, the new controller would reduce the average downtime by diagnosing the malfunction, thus allowing repairs to be made more quickly. It is *expected* that the average downtime per occurrence will be reduced by 25% using this diagnostic system.

ii. Divide the current line consisting of 12 stations into 2 stages, each consisting of six stations. An in-process storage buffer would be used between the stages so that each stage could operate as an independent transfer line. This is *expected* to improve the overall production rate and line efficiency.

Determine the following:

- The parameters of the line performance as it currently operates (without the improvements). These should include the ideal cycle time, the frequency of line stops, the line efficiency, and the average hourly production rate.

- The effect of the two changes in the line operation described above. Determine the effect of both of the changes together rather than each change separately. Your analysis should result in an assessment of the line performance for each stage (ideal cycle time, the frequency of line stops, the line efficiency, and the average hourly production rate). Also, determine the overall performance of the two-stage system. In your analysis, assume the upper-bound approach. Make any other additional assumptions necessary to solve the problem.

Further explanation regarding to this problem will be discussed in Chapter 3: *Simulation Project Development*.

APSCIM Machine & Foundry, Inc.
Technology Laboratory Report

This will document our two-week study of the APSCIM transfer line. The transfer line was observed for a total of 80 hours (one shift per day). During this period, the line was down for a total of 42 hours, and a total of 1689 parts were machined. The following table lists the operation, the process time (in minutes), and the number of downtime occurrences for each station:

Station	Operation	Process time (min)	Number of downtimes
1	Load (manual)	0.50	0
2	Rough mill top	1.10	15
3	Finish mill top	1.25	18
4	Rough mill sides	0.65	23
5	Finish mill sides	1.05	31
6	Mill surfaces for drill	0.80	9
7	Drill two holes	0.75	27
8	Tap two holes	0.40	47
9	Drill three holes	0.85	30
10	Ream three holes	0.70	21
11	Tap three holes	0.45	25
12	Unload and inspect	0.90	0
	Total	**9.40**	**246**

The transfer line required to move parts from one station to the next is 6 seconds.

Figure 1.1: APSCIM Machine and Foundry Inc., Technology Laboratory Report.

1.2 AIM AND OBJECTIVES

The aim of this project is to demonstrate the significant role of DES as a tool in analyzing the performance of automated flow line. In line with this aim, the following objectives have been set up:

i. **Literature Review**

Review literature to gain knowledge about simulation (especially DES), where it can be applied and what its benefits. In addition, understanding the concept of automated flow line in manufacturing system.

ii. **Develop Simulation Model**

Develop a simulation model for the problem mentioned in section 1.1, using the DES concept and visual interactive simulation (VIS) method.

iii. **Analysis Output**

Analyze the outcome and organize the report. Identify the values to be reported, determine the method of reporting and decide on how the report should be viewed.

iv. **Information Sharing**

Share the lesson learnt, discussion and recommendation about this project, which might be useful to others preferences in future. This part will be discussed more detail in Chapter 5: *Discussion.*

1.3 DISSERTATION REPORT STRUCTURE

The dissertation report structure will be discussed here. In order to give an overview to the reader, it might help them to get better understanding about this project when they go through this dissertation report.

Chapter 1 introduces the project background, what kind of study must be carried out, the aims and objectives, dissertation report structure and ending with summary of chapter. Before simulation modelling can begin, a literature search should be done and all the important point such as a basic concept about simulation and Automated Flow Line will be discussed in Chapter 2.

Chapter 3 will describe the project specification which refers to the each steps in simulation study (Figure 2.2) and explanation on experimental phase. Then followed by theoretical calculation result and simulation output in Chapter 4. The specific discussion about the analysis of outcome in term of practical versus theory and lesson learnt will be touched in Chapter 5.

As a conclusion and ending of the report, all recommendation or suggestion and future work regarding to this project will forwarded in Chapter 6 and all sources of references that has been used during the project such as books, journal and etc will be mentioned in References list.

1.4 SUMMARY

The objective of this chapter is to give an overview or introduction to the project background. The topic about the description of study, aim and objectives and dissertation report structure were discussed.

CHAPTER (2) :

LITERATURE REVIEW

2.0 INTRODUCTION TO SIMULATION

Simulation is the imitation of the operation of a real-world process or system over time [Banks et.al., 2001]. It allows us to collect pertinent information about the behaviour of the system by executing a computerized model [Hamdy, 1997]. The behaviour of the system can be study scientifically by developing the simulation model. This model usually takes the form of a set of assumptions concerning the operation of the system. These assumptions are express in mathematical, logical, and symbolic relationships between the entities, or object of interest, of the system. Therefore, the developed and validated model can be use as analysis tool for predicting the effect of changes to existing systems and as a design tool to predict the performance of new systems under varying sets of circumstances [Banks et.al., 2001].

2.1 ADVANTAGES AND DISADVANTAGES OF SIMULATION

2.1.1 Advantages of Simulation

The ability of simulation to provides a means to create an artificial state of a system in order to analysed and study its operational characteristic are one of the reason why simulation frequently become a technique of choice in problem solving. Another advantage of simulation has written in many relevant books and articles. Here, a list of some of the advantages in general as wrote by Banks et.al. (2001):

i. New policies, operating procedures, decision rules, information flows, organizational procedures, and so on can be explored without disrupting ongoing operations of the real system.

ii. New hardware designs, physical layouts, transportation systems, and so on, can be tested without committing resources for their acquisition.

iii. Hypotheses about how and why certain phenomena occur can be tested for feasibility.

iv. Time can be compressed or expanded allowing for a speedup or slowdown of the phenomena under investigation.

v. Insight can be obtained about the interaction of variable.

vi. Insight can be obtained about the importance of variables to the performance of the system.
vii. Bottleneck analysis can be performed indicating where work-in-process, information, materials, and so on is being excessively delayed.
viii. A simulation study can help in understanding how the system operates rather than how individuals think the system operates.
ix. "What-if" questions can be answered. This is particularly useful in the design of new system.

In addition, Law and Kelton (2000) has listed some specific potential benefits from simulation for manufacturing analyses, as stated below:

i. Increased throughput (parts produced per unit time)
ii. Decreased times in system of parts
iii. Reduced in-process inventories of parts
iv. Increased utilizations of machine or workers
v. Increased on-time deliveries of product to customers

The question might be asked: could these advantages be achieved by other methods such as mathematical modelling or real life experimentation? Robinson (1994) has given a number of managerial reasons for simulation to be used in preference to these alternatives techniques.

- **Simulation versus Real Life Experimentation.**

Experimentation can be performed by changing the inputs of the real life system and measuring the resulting change in behaviour. For example, the number of operators at an enquiry centre could be changed until a satisfactory service level is achieved. There are number if reasons why simulation is preferable to this form of experimentation:

i. *Cost* – Real life experimentation can be very costly. For instance, to install the additional equipment in order to measure the change in throughput, it is certainly costly. Having built a simulation model, the only additional cost incurred is that of the man-time to change the model and perform the experiments.

ii. *Repeatability* – Since the exact conditions in real life experiment are unlikely to be repeated, so there is no opportunity to compare the response to alternative inputs under the same condition. However, in simulation model, we can repeatedly generating the same sequence of events. Therefore, the alternative scenarios can be tested under the same conditions.

iii. *Control of the time base* – When carrying out a real life experiment with the production schedule for a manufacturing plant a month may be required to obtain a result for just one scenario. The same simulation experiment may take a matter of minutes, enabling more scenarios to be examined in a much shorter time period, increasing the possibility of finding a good solution.

iv. *Legality and Safety* – Experimentation with new ideas in, say, a toxic chemical plant can be hazardous and even illegal. With simulation, ideas can be tested and once a solution has been found attention can be paid to the safety and legal requirements for implementation.

- **Simulation versus Mathematical Modelling.**

There are a number of good reasons why simulation in some circumstances, should be used in preference to mathematical modelling:

i. *Dynamic and transient effects* – Frequently more information is required than just the 'normal' or 'steady-state' behaviour of the system in question. For example, when modelling a storage facility it is useful to understand the effects of major breakdowns on a high bay crane. It is the ability of simulation to cope with and provide results on these dynamic and transient effects that makes it more effective than mathematical tools.

ii. *Non-standard distribution* – Data may have been collected on, say, the service time at a supermarket. In queuing theory (as well as other mathematical models) the modeller is restricted to a set of standard service time distributions and so an approximation may have to be made. However, a simulation model can include both standard distributions and distributions based on collected data, enabling the modeller to avoid unnecessary simplification.

iii. *Interaction of random events* – When a machine breaks down on a production line, the stoppage will have significant 'knock-on' effects. Mathematical models cannot easily represent the complex interaction caused by such random events. In general, as the number of random variables increases there is a more than proportional increase in complexity. Simulation is able to handle these complex interactions and predict their effect.

- **The Management Perspective**

It is possible that a problem could be analysed without the use of simulation; however, among the most compelling reasons for its use do managers gain the benefits. The ability, given by VIS, to view the model running and to interact with it at any stage in the run has significantly added to these benefits.

i. *Simulation fosters creative attitudes* – Often, because of the risk of failure, ideas that would give considerable improvement are never tried. However, with simulation, ideas can be tried in a safe environment and at a low cost; this can only help to encourage innovation and improvement.

ii. *Simulation promotes total solution* – There is a tendency for problems to be seen as local issues promoting local solutions. Typically, a build-up of work in progress in one area of a factory is shifted to another department and the problem is 'solved'. A VIS model, showing an overview of the factory, will demonstrate the frailty of local solutions and promote the implementation of total solutions.

iii. *Simulation makes people think* – A major benefit of simulation is that it creates a framework for people to think through specific issues. Indeed, it is possible that 50 % of the benefit is achieved before the first experiment has been run by simply gathering information and building the model.

iv. *Simulation enables good ideas to be communicated effectively* – Many good ideas have been trampled under foot because the benefits could not be demonstrated to a senior manager. The visual aspects of a VIS model prove a powerful tool for communication. It may be that an idea has already been proven but it is deemed necessary to build a simulation model in order to convince senior managers and colleagues of its validity.

2.1.2 Disadvantages of Simulation

Even though simulation has wider acceptance and usefulness, but it still has several impediments or disadvantages. This disadvantages, which mentioned below were listed by Banks et.al, (2001), Law and Kelton (2000). In addition, they give some point in defence and the limitation of simulation can be offset.

i. Model building requires special training. It is an art that is learned over time and through experience. But, this task become much easier when vendors of simulation software have been actively developing packages that contain all or part of models that need only input data for their operations.

ii. Simulation results may be difficult to interpret. Since most simulation outputs are essentially random variables (they are usually based on random inputs), it may be hard to determine whether an observation is a result of system interrelationships or randomness. However, there is some simulation package that have a capabilities to performing very thorough analysis.

iii. Simulation modelling and analysis can be time consuming and expensive. Skimping on resources for modelling and analysis may result in a simulation model or analysis that is not sufficient for the task. But, in recent years, this difficulty is becoming much less severe as computers become faster and cheaper.

2.2 AREAS OF APPLICATION

Simulation has been used in many areas of operational research and management science techniques. The Winter Simulation Conference (WSC) is one of an excellent way to learn more about the latest in simulation applications and theory [Banks et.al, 2001]. Law and Kelton (2000) has listed some particular kinds of problems for which simulation has been found to be a useful and powerful tool:

i. Designing and analysing manufacturing systems.
ii. Evaluating military weapons systems or their logistics requirements.