OPTIMIZATION OF HIGH-MIX LOW-VOLUME MANUFACTURING SYSTEM USING DISCRETE EVENT SIMULATION

By:

KHAIRUNNISA BINTI KAMARUDIN

(Matric no.: 120790)

Supervisor:

Ir. Dr. Yen Kin Sam

June 2017

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfillment of the requirement to graduate with honors degrees in
BACHELOR OF ENGINEERING (MANUFACTURING ENGINEERING WITH MANAGEMENT)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed .... (Candidate)
Date ....

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated.
Other sources are acknowledged by giving explicit references.
Bibliography/references are appended.

Signed .... (Candidate)
Date ....

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available outside organizations.

Signed .... (Candidate)
Date ....

DECLARATION

I/We declare that the simulation of this project is the end result of our own work in prior of the same company of case study between this thesis and group YKS2 from EPD442 and due acknowledgement has been given in the bibliography and references to all sources be they printed, electronic or personal, in accordance with the academic regulations of Universiti Sains Malaysia (USM).

It is hereby confirmed that the submission is authorized by all members of the group, and all members of the group are required to sign this declaration. I/We also acknowledge that I am/we are aware of University policy and regulations on honesty in academic work, and of the disciplinary guidelines and procedures applicable to breaches of such policy and regulations.

I am/We are aware that each student is responsible and liable to disciplinary actions should there be any plagiarized contents/undeclared multiple submission in the group project, irrespective of whether he/she has signed the declaration and whether he/she has contributed directly or indirectly to the problematic contents. It is also understood that project without a properly signed declaration by all members of the group concerned will not be graded by USM.

Signed……………………………… Khairunnisa binti Kamarudin (940526-03-5612)

Signed……………………………… Lily binti Jamaludin (940114-14-5460)

Signed ……………………………... Nurul Busra binti Awi (940222-11-5082)

Signed ……………………………... Tan Teong Sheng (931031-07-5167)

Signed ……………………………... Yong Cheng Wai (930125-08-5185)

Date………………………………

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude towards my project's supervisor, Ir. Dr. Yen Kin Sam, who has been very supportive throughout this one year. I am thankful to him for encouraging me and giving me advices as well as suggestions along this project. This project would not be completed without the help from my supervisor.

Next, I am grateful to have Muhammad Safwan bin Abdul Aziz and Nurul Busra binti Awi who were always by my side and ready to provide useful advices to me in every stages of this project. Their suggestions and motivations are very useful for me to finish my project. They also helping me to do some troubleshooting on the problems that I face during run my simulation.

Special thanks to Coraza Systems Malaysia and School of Mechanical Engineering, Universiti Sains Malaysia as well for providing me facilities needed in carrying the experiment and simulation. In addition, I am indebted to all staffs and engineers of Coraza Systems Malaysia for their kindness and assistance in carrying out research. Without them, this project would not have completed successfully.

Not forgetting the people who help and give support physically and mentally throughout this project, my coursemates and friends. The ideas and technical knowledge given from you is very helpful when I am stuck at the middle stage. The time spend from you is greatly appreciated in order to make sure my project runs on track. Lastly, I would like to repay my deepest gratitude to my family members for being my pillars of support by giving me endless and unconditional love.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF ABBREVATIONS

Acronyms	Definition
CNC	Computer Numerical Control
CR	Critical Ratio
DES	Discrete-Event Simulation
DFM	Dynamic Forecasting Model
ECT	Earliest Completion Time
EDD	Earliest Due Date
FCFS	First-Come First-Served
FIFO	First-In First-Out
HMLV	High-Mix Low-Volume
LDD	Latest Due Date
LFT	Latest Finish Time
LIFO	Last-In First-Out
LPT	Longest Processing Time
LST	Longest Setup Time
OSD	Operation Synchronization Date
SPT	Shortest Processing Time
SST	Shortest Setup Time
TWR	Total Work Remaining
WIP	Work In Progress

LIST OF SYMBOLS

Symbol	Description/Units
%	Percentage
°	Degree
μ	Mean
σ	Standard deviation
±	Plus-minus sign

ABSTRAK

Tujuan projek ini adalah untuk menilai bagaimana Discrete-Event Simulation (DES) boleh digunakan untuk merancang pengeluaran yang akan diuji pada syarikat perkilangan High-Mix Low-Volume (HMLV), Coraza Systems Malaysia. Fokus kajian ini adalah untuk meningkatkan pengoptimuman sistem pembuatan tanpa mengurangkan produktiviti sistem pengeluaran atau membuat pelaburan kemudahan. Kajian ini memberi tumpuan kepada empat mesin yang terletak di pemesinan kedai CNC. Kajian ini menganalisis masalah penjadualan semasa dan menjana penyelesaian untuk meningkatkan aliran pembuatan semasa. Kajian masa telah dijalankan untuk mengenal pasti prestasi sistem pengeluaran sebenar. Permodelan keadaan semasa adalah dicipta menggunakan taburan kebarangkalian yang diambil daripada data rekod pengeluaran harian. Model semasa kemudiannya disahkan dengan menjalankan "Paired t-test" untuk memastikan ketepatan sistem yang dibina. Untuk menilai potensi perubahan dalam sistem pengeluaran, model DES dibina dan senario yang berbeza telah diuji. Strateginya adalah untuk menukar peraturan penghantaran Tarikh-Akhir-Paling-Awal kepada jenis peraturan penghantaran yang lain. Perbandingan ukuran prestasi dilaksanakan bagi menilai jenis peraturan penghantaran manakah yang membawa paling banyak kemajuan. Keputusannya mendapati bahawa mengubah peraturan penghantaran kepada peraturan penghantaran Persediaan-Masa-Terpendek dapat membawa lebih banyak kemajuan dalam meningkatkan penggunaan keseluruhan mesin dan meningkatkan bilangan produk yang dapat dihasilkan. Kesimpulan dari kajian ini mendapati bahawa penggunaan DES sebagai alat keputusan adalah baik untuk keputusan strategik jangka panjang.

ABSTRACT

The purpose of this project is to evaluate how Discrete-Event Simulation (DES) can be used as a decision support for production planning which is tested at a High-Mix Low-Volume (HMLV) manufacturing company, Coraza Systems Malaysia. The focus of this project is to improve the optimization in manufacturing system without reducing the productivity of the production system or making facility investments. The scope is focusing on the HMLV manufacturing system of four machines at the CNC machining shop. This study analyzes the current scheduling problem and generates possible solutions to improve the current manufacturing flow. Time study has been carried out to identify the actual production system performance. Current state modeling is created using probability distribution obtained from the historical data of daily production records. The current model is then verified and validated by conducting paired t-test to ensure the accuracy of the system built. To evaluate potential changes in the production system, a DES model is built and different scenarios are tested. The strategies are to change the current Earliest Due Date (EDD) dispatching rules to other type of dispatching rules. Comparison of performance measure is performed to assess which dispatching rule is the best with most improvements. It is found that changing the dispatching rule to Shortest Setup Time (SST) brings the most improvement in increasing the overall machines utilization and number of finished parts produced. The conclusion from this thesis is that it is possible to use DES as a decision tool as it is better for long term strategic decisions.

CHAPTER ONE
INTRODUCTION

1.1 Overview

This chapter includes the introduction to High-Mix Low-Volume (HMLV) in manufacturing industries and explanation about the HMLV itself. The concept of Discrete-Event Simulation (DES) for solving HMLV scheduling problem is shown in this chapter. Besides that, problem statement, objectives, scopes of the project and thesis outline are also included in this chapter to give a clear review about this research.

1.2 Introduction

In the machine shop environment, the need to improve manufacturing flow times has always been a critical factor to stay competitive. Most machine shops cannot afford the investment needed to reduce their manufacturing flow time (Glenn and Charles 2011). Therefore, more economical alternative would be of great value to smaller organizations. For this reason, continuous improvements are needed to increase response times to customer changes (Murugan and Selladurai 2011).

The increase of product variety in HMLV manufacturing has increased production complexity in which rapid production changeovers cause the increase of conversion time and the decrease of capacity utilization and productivity. Since product-mix planning affect manufacturing efficiency and productivity, it is important to have a proper product-mix optimizer, particularly in HMLV manufacturing environments (Neoh et al. 2010).

Customization of final products and almost unpredictable behavior of market demands significantly affect the process of production operative control, planning and scheduling (Juraj and Zdenka 2012). The main objective of production management is to increase the adaptability of production system resources. This process is complex as it involves various inputs such as resource utilization, resource limitation, product variety, product characteristics and market demand (Neoh et al. 2004). Thus, production planning and scheduling play an important role in production resources adaptability optimization especially in HMLV manufacturing environments which need to produce more product variety with lower volume in the dynamic production environment.

By using simulation software, the dynamics of a system can relatively be simulated and different improvement ideas may be tested with small efforts (Banks 2004). There are a lot of strategies and factors to take into account while scheduling. Stayer et al. (2011) states that it is possible to make accurate decisions in a production without affecting the system by using DES and also to conduct a sensitivity analysis to monitor different variables and their effect on the production system which provides a foundation for a sustainable future.

1.3 Case Study on Current Manufacturing System

Coraza Systems Malaysia is a global supplier of high precision sheet metal fabrication and assembly. They specialize in service from initial product concept and design, through manufacturing prototypes to complete production, assembly and integration. Their forming services include of punching, folding, stamping, spot welding, clinching, riveting, sanding, CNC turning, CNC milling and assembly. Coraza Systems Malaysia is a high-mix low-volume production company where more than 600 products are fabricated.

In the machine shop, there are four CNC milling machines which run for 16 hours per day, 6 days per week from Monday to Saturday. They are 2 shifts per day, where two operators are assigned for each shift. Occasionally, the operators have to work overtime as a recovery plan to chase the lagged progress. Maintenance is normally performed during Sunday in order to minimize the interruption on production activity.

Currently, the parts which have the earliest due date will be manufactured first. They do not have a fixed routing. When an order arrives in the machine shop, the part will be placed on any available machine. Only one machine is allocated to fabricate the whole process. The next process will only proceed after the ongoing process has finished. The waiting gap between these two processes causes more time to be consumed which will lead to the increasing of the overall lead time. The current machines are not fully utilized to produce the required output. Mostly the idle times are due to installation of the jigs and tools, product assessment, and cleaning chips and burrs.

1.4 Problem Statement

The major difficulties in batch manufacturing are due to high level of product variety and small manufacturing lot sizes. The impact of these products variations is high investment in equipment, high tooling costs, complex scheduling and lengthy setup time. For this purpose, some innovative methods are needed to increase the optimization without making facility investments.

This project will use DES as a decision tool to try to increase the machines utilization without increasing the WIP or making facility investments. Too high of WIP is considered a huge cost and therefore the case study company considered it as a problem that needs to be solved.

1.5 Research Objectives

This present study is to achieve the following objectives:

1. To optimize the existing HMLV manufacturing system in CNC machine shop at Coraza Systems Malaysia by increasing the machines utilization without making facility investments.
2. To simulate the manufacturing system using MATLAB SimEvents® and analyze the existing system performance and proposed strategy.

1.6 Scope of the Project

In this research, scheduling issue encountered by Coraza Systems Malaysia is analyzed and improvements are made on the scheduling and utilization of 4 CNC machines in the CNC machine shop.

Then, simulations are developed by using software to know the percentage of utilization of all the machines. MATLAB SimEvents® software is used to run the simulations. Finally, make comparison of the overall utilization between experimental and simulations. Some discussions are made to clarify the difference in results obtained from experiments and simulations.

1.7 Thesis Outline

Generally, the thesis consists of five chapters. Chapter one gives an outline of the whole thesis which covers the introduction to HMLV manufacturing system. Then, DES is discussed and followed by an introduction to company background. Lastly, this chapter encloses with problem statements and the objectives of this research.

Subsequently in chapter two, literature review is written based on previous researches and studies based on journals and books as references. Detail explanations about this research are described in this chapter.

For chapter three, it includes discussion on the project methodology. Procedures on experiments and simulations will be explained briefly to give a clear view on how they are conducted.

In the following chapter which is chapter four, results obtained from the experiments and simulations will be discussed and verified here. Then, results comparison will be done to see the performance measures between those results.

Chapter five provides a summary of the results obtained in the present study. A brief summary of this project on the objective and the successfulness of this project are discussed. The limitations of the system made in this project are also mentioned in Section 5.2. Some future works that may be done to improve the results of this project are listed in Section 5.3.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter includes previous studies on scheduling rules, classification of dispatch rules, performance analysis of dispatch rules in job-shop scheduling and simulation. The advantages and disadvantages of simulation are also included in this chapter.

2.2 Scheduling rules

A job shop environment is unique in its ability to manufacture. Normally, it does not follow an assembly line approach to production; instead it follows a more functional layout where jobs are processed as they reach the next operation in the process (Glenn and Charles 2011). In many cases, a job shop's advantage over competitors is its ability to process work more efficiently. This ability to improve flow times is critical to their success. Therefore, the issue of flow times is of high interest to a job shop.

There are several types of scheduling rules that have been used to improve flowtimes and meet delivery dates. Many of the most basic rules used in the literature include First-Come First-Served (FCFS) (Leela et al. 2006). Earliest Due Date (EDD) (John et al. 1996), Shortest Processing Time (SPT) (Wang and Tang 2011), and Critical Ratio (CR) (Edward et al. 2001).

The most basic deterministic schedule rule is FCFS. This is considered the simplest scheduling rule to incorporate. It requires the scheduling of jobs based on the time they enter a bin ready for processing. Although many job shops use this as part of their scheduling, it is in many cases the least optimal (Joel and Ram 2000). EDD scheduling rule puts a priority on the job that has the earliest delivery date. It looks to minimize lateness and tardiness (Edward et al. 2001). SPT is the sequencing of jobs in increasing order of their sum of the processing times on all machines. This scheduling rule is considered the optimal choice for the minimization of flow times (Philip and David 2001).

2.3 Classification of dispatch rules

When a machine is available, a job is selected from its input queue based on certain priorities known as dispatch rules. Table 2.1 lists some of the popular dispatch rules with their description according to Omkumar (2014).

Table 2.1: Common dispatch rules

Name	Description
Shortest Processing Time (SPT)	Selects the job with minimum processing time first in the current process.
RAND	It is a random selection of jobs for processing.
First-In First-Out (FIFO)	Selects the job that arrives first to the process queue.
Earliest Completion Time (ECT)	Selects the job that has the earliest completion time considering all remaining processes.
Latest Finish Time (LFT)	Selects the job that has the latest finish time considering all remaining processes.
Operation Synchronization Date (OSD)	Selects the job for processing that has the least OSD value.
Total Work Remaining (TWR)	Selects a job with smallest total processing time for unfinished operations.

2.4 Performance analysis of dispatch rules in job-shop scheduling

A detailed discussion on various dispatch procedures and rules is given by Ramasesh (1990). Dispatch rules used to improve the mean, maximum and variance of flow time and waiting time are known as time based dispatch rules. Early reports (Blackstone et al 1982) have shown SPT rule to be consistently superior in minimizing mean flow time, mean waiting time and perform well with reference to tardiness based objectives too. SPT rule was also found to be robust to imperfections in the estimation of the operation processing times. However, under the SPT rule the variance of the flow times is high and some jobs which have long operation times lead to be very tardy. Alternating SPT with other tie breakers was not effective in overcoming the disadvantage to overcome this deficiency.

Enns (1994) has reported a new paradigm known as the Dynamic Forecasting Model (DFM) for controlling the delivery performances. This method compared the dispatch rules using lead time measure suggesting that if due dates were properly set, the dispatch mechanism chosen may not be all that significant. The model has performed well with a variety of dispatch rules over the utilization range usually considered to be most relevant in job shop research.

Enns (1995) has further extended their DF model for minimizing the expected sum of earliness, tardiness and lead time costs. The study has shown, due-date dependent dispatch rules, such as Earliest Due Date (EDD) and Smallest Critical Ratio (SCR), to earn higher profits than due-date independent rules, such as First-Come First-Serve (FCFS) or Shortest Processing Time (SPT). Second, performance using due-date dependent dispatch is less sensitive to the utilization level being operated at, especially at high utilization levels. Third, the optimal utilization level at which to operate may be slightly higher for due-date dependent dispatch rules.

2.5 Simulation

A simulation model is an imitation of a real world process or system over a time period. By running the simulation over a period of time, an artificial history for the system is created and from observation of that data it is possible to draw conclusions of how the represented real world system behaves.

The state of a DES model is changed in a discrete time point, which means that between specific events in the model, nothing happens (Banks 2004). One of the main benefits of a DES model is the ability to imitate the dynamic of a system (Ingalls 2008). Mahesh et al. (2011) states that usage of DES to test a production system before it is built or used can significantly reduce the economic and environmental cost. In any real life system, there is naturally occurring variations that are not possible to control, e.g. difference in order size (Banks 2004). A statistical distribution is a way to represent these variations with a mathematical model.

2.5.1 Advantages and disadvantages of simulation

Banks (2004) also lists several advantages and disadvantages of simulations. With simulation, when a model of the current state is developed, it is relatively easy to test the effects of a changed policy, procedure method without affecting the production system. It is easy to compare the benefits and drawbacks of different solutions which allow a team to conclude the most desirable result. According to Banks (2004) the cost for creating a simulation model could be only a fraction of the price of a redesign.

Some of the disadvantages with simulation can, according to Banks (2004), be:

- Model building requires training and experiences.
- Simulation results might hard to interpret correctly.
- Simulation modeling and analysis can be time-consuming and expensive.
- Simulation might be used inappropriately when other engineering methods would be a better fit.

CHAPTER THREE
METHODOLOGY

3.1 Case study

First step is to collect information about the production system and the products. Then, all process and handling times are collected and a time study is conducted. The simulation model used the data for four months which have been set based on their probability distribution. The model will be tested with different types of dispatching regulations to identify which sequencing is the best.

3.2 Project approach

To collect the data needed to build a DES model, existing production data are collected and also observed the production system to gather data to analyze. Four months data for processing time, setup time and due date are taken from Coraza Systems Malaysia. The data are set based on their probability distribution created from the daily production record. To be able to test with different scenarios, a DES model is built, verified and validated. The verification is to ensure that the model behaves as intended, while the validation is to ensure it is a good representation of the production system. To find the best solution for the objectives several simulations are developed to gather results that can be analyzed by comparing their performance measures.

3.3 Simulation of the production system

In this project, SimEvents® is the central tool and is used to create and simulate the DES model. The general steps to go through while making a simulation study is described by Banks (2004) and shown in Figure 3.1. The project followed these steps to create the approved DES model, which are more thoroughly described in this chapter.

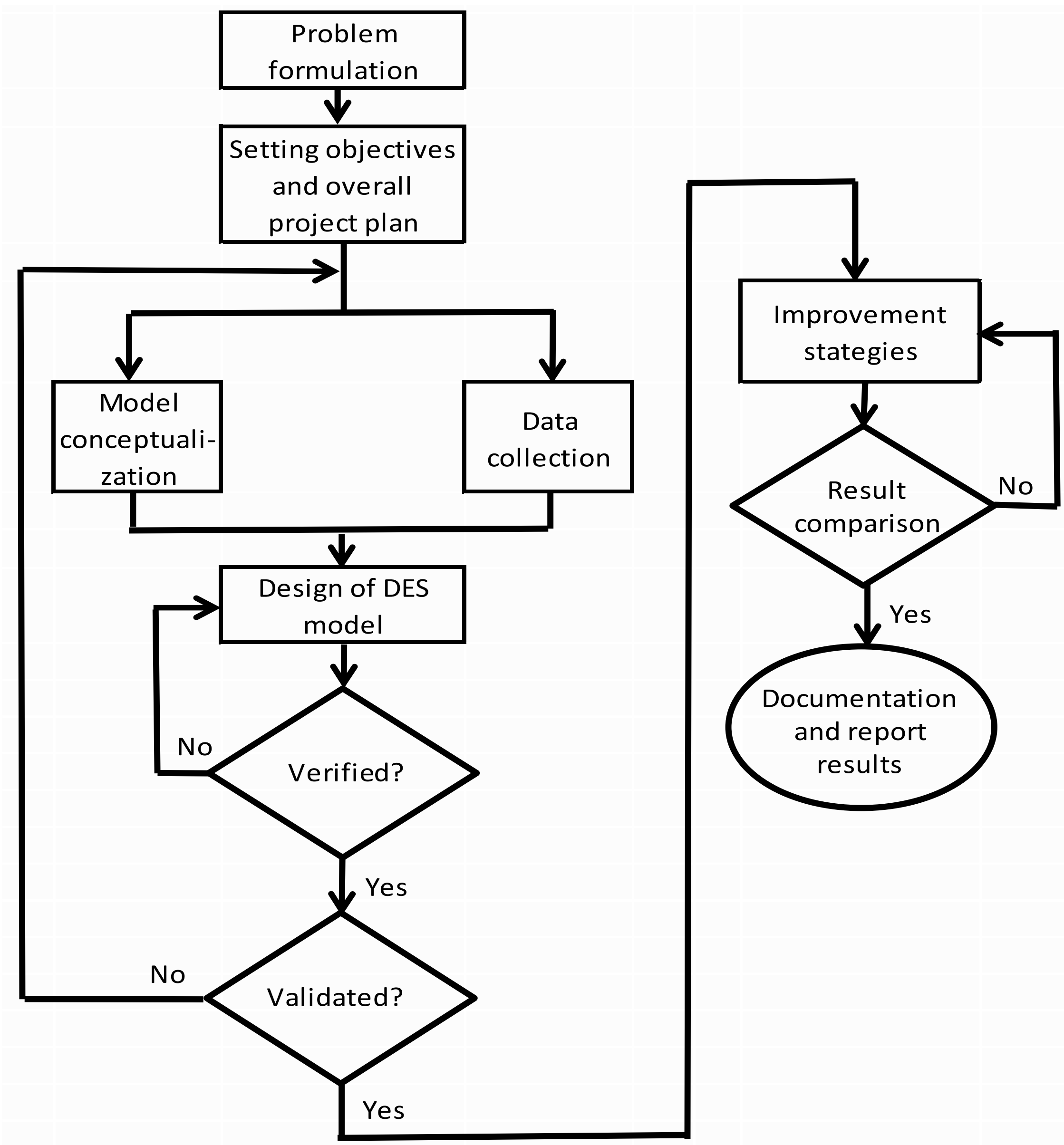

Figure 3.1: Steps in a simulation study inspired by Banks (2004)