Faculty of Manufacturing Engineering

DEVELOPMENT OF A SIMULATION-BASED DECISION SUPPORT MODEL FOR HIGH PRECISION COMPONENT MANUFACTURER

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DEVELOPMENT OF A SIMULATION-BASED DECISION SUPPORT MODEL FOR HIGH PRECISION COMPONENT MANUFACTURER

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DECLARATION

I declare that this thesis entitle Development of a Simulation-based Decision Support Model for High Precision Component Manufacturer is the result of my own reaesrch except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	....
Date	:	....

DEDICATION

To my beloved family members
To my supervisor
To my best friend

ABSTRACT

In this age of global competition, the key to the success and even survival of many manufacturing firms is the ability to respond quickly to the needs of the customers. In the real world, performance measurements are difficult to determine because of the complexity of the manufacturing systems. Simulation has become an indispensable tool which enables engineers, designers, planners and managers, to study, analyze and evaluate complex situations that would not be otherwise possible. In this study the case company operates in a job shop environment characterized by fixed machine configurations but process routes that are different for each job. There are more than 800 different orders with different specifications (process routes, cycle times and lot sizes) that need to be completed for each month. In such configurations, a job may undergo operations only in certain orders of machines and not necessarily at every machine. The complexity is further compounded by the indefinite batch size for each product. With such complex scenario, determination of throughputs, identifications of bottlenecks, completion dates of customer orders and total cost of the customer orders constitute a real challenge to the planners and production managers in the company. Currently the planner of the case company plans the due dates of customer orders by using the manual approach and this has resulted in the inability of the company to meet the due date of all customers' demands. In the face of the difficulties associated with analytic techniques, this research propose the development of a novel simulation-based decision support model (SDSM) to improve the performance in a job shop environment based on the economic approach. This model will account for the intrinsic characteristics and complexities of the job shop by allowing for usage of judgmental decision making and cost-estimation based on the current job shop status. The SDSM is useful to calculate the waiting cost which is too complicated if modelled by mathematical modeling or algorithms. By incorporating the Activity Based Costing (ABC) system into the simulation model, the costing for customer orders is greatly improved. The developed model shows that the company underestimated the cost of the customer orders. Incorporating ABC system into simulation model helps the company to evaluate costs of customer orders more effectively than Traditional Costing (TC) approach. Moreover, the use of simulation enables the study and investigation of the interactive effect of individual components or variables. The model will allow experimentations by changing the overtime and shift pattern in the company. Throughput of the case company was improved by 20.63% by identifying the bottleneck workstation (Wire Cut and Milling workstation). Waiting times at, utilization of, these workstation are improved by adding 4 hours overtime for all milling technicians and 2 hours overtime for all wire cut technicians with total additional cost of RM5700 per month. In addition, the SDSM is also able to determine the completion date of customer orders and the manpower requirement to

achieve the demand by indentifying the bottleneck candidates in the production system. The accuracy for predicting the completion dates of customer orders was improved to 80% by using the simulation model. This because the simulation model provided better understanding about the capacity and the condition of the production flow by including the waiting times.

ABSTRAK

Dalam zaman persaingan global, kunci kepada kejayaan dan juga *survival* dalam sesuatu industri pembuatan adalah keupayaan untuk bertindak balas dengan cepat kepada keperluan dan permintaan pelanggan. Dalam dunia sebenar, pengukuran prestasi adalah sukar untuk menentukan kerana kerumitan industri pembuatan. Simulasi telah menjadi satu alat penting yang membolehkan jurutera, pereka, perancang dan pengurus, untuk mengkaji, menganalisis dan menilai sesuatu situasi yang komplek. Di dalam kajian sesebuah syarikat yang beroperasi dalam persekitaran berciri *job shop* di mana konfigurasi mesin adalah tetap tetapi laluan proses yang berbeza untuk setiap pesanan pelanggan. Bagi setiap bulan, terdapat lebih daripada 800 jenis pesanan dengan spesifikasi yang berbeza (laluan proses, masa kitaran dan saiz lot) yang perlu dilengkapkan. Dalam konfigurasi sedemikian, pesanan pelanggan hanya boleh menjalani operasi pada laluan serta di mesin tertentu sahaja. Situasi yang komplek dirumitkan lagi oleh saiz lot yang berbeza bagi setiap produk. Dengan senario yang kompleks, penentuan *throughputs*, *bottleneck*, tarikh penyiapan untuk pesanan pelanggan dan jumlah kos pesanan pelanggan merupakan satu cabaran kepada perancang dan pengurus pengeluaran di syarikat. Perancang syarikat kes menggunakan pendekatan manual untuk menentukan tarikh penyiapan untuk pesanan pelanggan dan ini telah menyebabkan ketidakupayaan syarikat untuk memenuhi tarikh tamat tempoh untuk semua pesanan pelanggan. Disebabkan masalah yang dihadapi, penyelidikan ini mencadangkan pembangunan *Simulation-based Decision Support Model* (SDSM) bagi meningkatkan prestasi berdasarkan pendekatan ekonomi. Model ini akan mengambil kira ciri-ciri intrinsik dan kompleks sesuatu *job shop* dengan membenarkan pengguna untuk membuat keputusan dan anggaran kos untuk pesanan pelanggan berdasarkan situasi semasa. Dengan menggabungkan sistem *Activity Based Costing (ABC)* ke dalam model simulasi, ketepatan anggaran kos untuk pesanan pelanggan adalah bertambah baik. Keputusan dari model simulasi menunjukkan bahawa syarikat itu kurang menganggarkan kos pesanan pelanggan. Dengan menggabungkan sistem *ABC* ke dalam model simulasi, membantu syarikat untuk menilai kos pesanan pelanggan lebih berkesan daripada pendekatan *traditional costing (TC).* SDSM adalah berguna untuk mengira kos menunggu yang terlalu rumit jika dikirakan dengan algoritma matematik. Selain itu, penggunaan simulasi membolehkan kajian dan penyiasatan kesan interaktif pembolehubah atau komponen individu. Model ini dapat menjalankan eksperimen dengan mengubah jumlah kerja lebih masa dan syif di syarikat. *Throughput* syarikat kes telah meningkat sebanyak 20.63% dengan mengenal pasti stesen *bottleneck* (*Wire Cut* dan *Milling* stesen). *Waiting time*, *utilization*, di stesen kerja ini dipertingkatkan dengan menambah 4 jam kerja lebih masa untuk semua juruteknik *Milling* dan 2 jam lebih masa untuk semua juruteknik *Wire Cut* dengan kos tambahan sebanyak RM5700 sebulan. Di samping

ini, SDSM juga dapat menentukan tarikh penyiapan untuk pesanan pelanggan dan keperluan tenaga kerja yang diperlukan untuk mencapai permintaan syarikat dengan mengenal pasti calon *bottleneck* dalam sistem *job shop.* Ketepatan untuk menentukan tarikh penyiapan pesanan pelanggan telah meningkat kepada 80% dengan menggunakan model simulas. Ini kerana model simulasi memberikan pemahaman yang lebih baik tentang keupayaan dan keadaan aliran pengeluaran dengan mengambil kira *waiting time*.

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CHAPTER 1

INTRODUCTION

1.1 Background

The manufacturing industry is under intense pressure from the increasingly competitive global marketplace. Trends of lower product costs, shorter processing time, and more product variety had resulted in a more challenging manufacturing environment (Chin et al. 2005). In this age of global competition, the key to the success and even survival of many manufacturing firms is the ability to respond quickly to the needs of the customers. One way to achieve this is to reduce the total manufacturing cycle time, which will result in lower inventory level, reduced cost, and faster response to customer orders with increased flexibility.

Another important manufacturing system performance measure is the throughput of the system. The throughput is the rate at which the system produced good parts. Increasing the throughput yields more sales and increases revenue. However, in the real world manufacturing systems cycle time and throughput are difficult to determine because of the complexity of the problem. Furthermore, in a job shop environment, stochastic parameters and constraints coupled with high product mix and complex process routes, makes it impractical to determine system performance by analytic solution methodologies. In this case, simulation can be a useful tool to model the intricate internal interactions among system elements. With a simulation model, a manager can try out the several policy decisions within a short time frame and is a powerful tool to help sort through cause-and-effect relationships and gain a better understanding of what is actually causing a particular problem in the system (Harrell and Gladwin 2007). Once cause-and-effect relationships are identified, changes for improvement can be made more intelligently and effectively.

1.2 Company Background

The case company, located in the Melaka industrial area, is one of the leading manufactures in making high precision engineering and machining for moulds, die, I.C. cavity, trim and form die set, tungsten carbide precision parts and all kinds of precision spare parts fabrication. Precision tools manufactured by the company can achieve an accuracy of ± 2 micron to ± 5 micron on precision parts with complex geometries.

The case company has thirteen workstations, which include milling, turning, CNC milling, EDM, grinding carbide, wire Cut, cylindrical grinding, laser marking, super drills, deburring station, sand blasting and internal heat treatment. The layout for the job shops are shown in

Figure 1.1. Each job shop consists of several machines with variable capacity. An operator is required to operate one or more machines in the job-shop. Moreover, each operator has different level of working skills and experience.

The company produces more than 800 orders per month with different specifications (machine routes). The orders have different quantity, process flow and cycle time. The customers of the company are primarily from the semiconductor and automotive industry. The company strives to achieve uncompromised quality and reduce customer time-to-market and time-to-volume lead-times utilizing process that is flexible and agile.

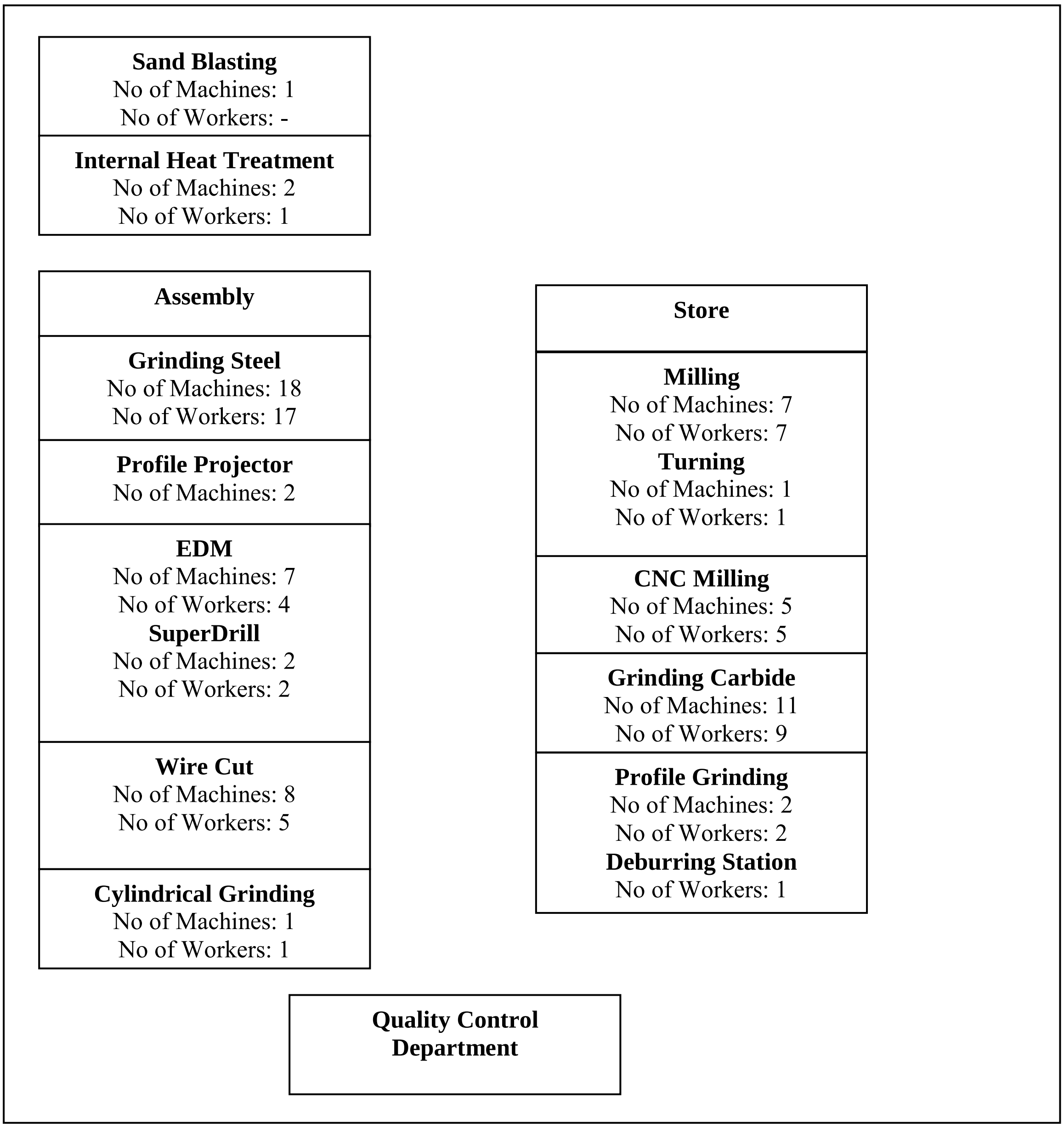

Figure 1.1: Layout of the Job Shops

1.3 Problem Statement

The products of the company are high mix with more than 800 orders per month, each orders with different specifications (machine routes). Currently the planner of the case company plans the production using the manual approach. Due to this inaccurate method, the case company encountered difficulty to meet the due date of customers' orders. The average percentage of lateness is 56% (statistical value reported by the case company). The management is concerned primarily in the computation of the cycle time, throughput, and also meet the due date of the orders.

This research is concerned managing and controlling cycle time and throughput for a manufacturing company that deals with high precision engineering and machining of components. However, is impractical to determine system performance by analytic solution methodologies in the job shop environment. The overall machine configuration is basically pure job shop which is characterized by the fact the routes are fixed but not necessary the same for each job. In such configurations, the job has to visit certain machines and not necessary every machine described in Figure 1.1. In such case, cycle time and throughput and identifying bottleneck constitute a real challenge to planners and planning managers.

1.4 Objectives

This research aims to develop a Simulation-based Decision Support Model (SDSM) to improve the performance of a job shop manufacturing with the following objectives:

- To improve throughput by reducing the bottlenecks.
- To improve the prediction for the completion dates of customer orders.

● To implement the Activity Based Costing (ABC) system into the simulation model.

1.5 Scope of Research

The research focused on customer orders for a period of one month in the case company. Data collection will not include reworks, rejects and machine breakdowns as occurrence of breakdown are very infrequent. The study will employ discrete-event simulation software to model the processes in the company.

1.6 Organization of the Thesis

Overall, the structure of the thesis is organized into seven chapters namely (i) Introduction (ii) Literature Review (iii) Research Methodology (iv) Model Development (v) Simulation Model Experimentation (vi) Results and Discussions (vii) Conclusion and Recommendation.

Chapter 1 outlines the background of the overall research which encompasses the importance for company to improve the performance measures by using simulation model. In addition, this chapter explicitly explained scope of research to be carried out and the objectives to be met as outcome of the research.

Chapter 2 provides an overview about application of simulation in job shop system, type of simulation, advantage and disadvantage of simulation. Besides, this chapter also presented the performance measure in job shop and method to improve the desired performance measure. The literature review also includes related research on activity based costing system by using simulation in the job shop.

Chapter 3 describes the case company model and the research methodology to develop the simulation project.

Chapter 4 presents the development of the simulation model which to present the job shop configuration described in the case company. The simulation was carried out by using the WITNESS simulation software. Model verification and validation has been carried out to make sure the simulation model is an accurate representation of the real life situation for the case company. This chapter also covers the methodologies in developing ABC system. Finally, the development of the Simulation-based Decision Support Model (SDSM) will be fully described.

Chapter 5 carries out three experiments by using simulation model and discusses the methodology to run the experiments. Objective of the Experiment 1 is to achieve the minimum targeted demand by reducing the waiting time and managing the utilization at the identified bottlenecks while Experiment 2 is to improve the accuracy of the prediction for the completion dates of customer orders. The author implemented the ABC system in Experiment 3 to improve the costing of the customer orders.

Chapter 6 focuses on the analysis of experimental results and discussions.

Chapter 7 summarizes the outcome of the research, recommendations and future works for the SDSM.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The main objective of literature review is to offer a broad and extensive picture of the role of simulation method in job shop. This chapter begins by discussing the job shop problem and methods use to solve the job shop problems. The advantages and application of the simulation in manufacturing are presented by the following section. The author reviews the reports on application of simulation in the job shop production system over the 10 years from 2001 to 2010 from established publication. The papers are classified into 4 categories based on the simulation application in the job shop, as listed in Table 2.1. This chapter also included fully-referenced review from the significant literatures with regards to applications of Activity Based Costing (ABC) system, application of ABC system in the job shop, applications of ABC system by using simulation.

2.2 Job Shop

According to Peng (1994), the basic unit of work in the job shop is a step or process step, which is an activity that takes place on a specific machine. Each job in a job shop has a unique routing through the shop and may consist of a different number of process steps. The job shop is the environment where jobs are processed on different machines, such as milling, lathe, drilling and grinding machines. Each process step in a job is mapped to a specific machine. It is well known that job shop problem is NP-hard (Lenstra and Rinnooy Kan 1979) and belongs to the most intractable problems considered (Blazewicz et al. 2001).

2.2.1 Job Shop Problem

Ouenniche and Bertrand (2001) proposed a new and efficient cyclic scheduling solution framework, multiple cycle Gunasekaran et al.(2000) method, based on the assumption that the cycle time of each product is an integer multiple of a basic period to minimize the sum of setup costs, and work-in-process and finished products inventory holding costs while demand is fulfilled without backlogging. To date, no efficient general-purpose heuristics have been developed to solve the job shop scheduling problems with release and due-dates, as well as various tardiness objectives. Mattfeld and Bierwirth (2004) showed that a heuristic reduction of the search space can help the algorithm to find better solutions in a shorter computation time.

Chung et al. (2005) presented a heuristic algorithm that addresses the job shop scheduling problems with due-date constraints, where temporal relaxation of machine capacity constraint is possible through subcontracts. For the sake of efficiency, the algorithm repeatedly executes in two steps—(1) improving the sequence of operations and (2) picking out the operations to be subcontracted—on bottleneck machines. Gao et al. (2007) developed a new genetic algorithm hybridized with an innovative local search procedure (bottleneck shifting) to achieve three objectives: min makespan, min maximal workload and min total workload.

Liaw (2008) examined the problem of scheduling two-machine no-wait job shops to minimize makespan. A two-phase heuristic is developed to solve the problem. In phase 1, the heuristic transforms the problem into a no-wait flow shop problem and solved it by using the Gilmore and Gomory algorithm. Simple tabu search algorithm was used to improve the solution obtained in Phase 1. An effective genetic algorithm for solving the flexible job-shop scheduling problem (FJSP) has proposed by Li and Chen (2008) to minimize makespan time.

Naderi et al. (2009) investigated an extended problem of job shop scheduling to minimize the total completion time. The authors presented a novel meta-heuristic method based on the artificial immune algorithm (AIA) incorporating some advanced features to deal with a specific case of machine availability constraints (MACs) caused by preventive maintenance (PM) operations. No-wait job shop problems with makespan minimization are strongly NP-hard. Zhu et al. (2009) presented an effective method, complete local search with limited memory (CLLM) by integrating with shift timetabling for the sequencing component.

Manikas and Chang (2009) demonstrated that genetic algorithm (GA) can be used to produce scheduling solutions in times comparable to common heuristics but closer to optimal. In addition, GA can be easily applied and modified for a variety of production optimization criteria in a job shop environment that includes sequence-dependent setup times. Chan et al. (2009) proposed an evolutionary approach with genetic algorithm (GA) to solve the problem about part sharing among distinct