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DETERMINATION OF FLEXIBLE MEASURES IN ADVANCED MANUFACTURING SYSTEM AND THEIR EFFECT IN PRODUCTIVITY AND RESPONSIVENESS

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TAJUK PROJEK : DETERMINATION OF FLEXIBLE MEASURES IN ADVANCED MANUFACTURING SYSTEM AND THEIR EFFECT IN PRODUCTIVITY AND RESPONSIVENESS.

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ABSTRACT

Managing job shop manufacturing is quite different compared to other manufacturing systems due to its dynamic changes in process routings, cycle times and fluctuations in demand. Managers in job shops face problems in attaining optimum performance of the job shops. These can lead to failure to meet due dates, low machine level utilization and high level of work-in-progress (WIP). These problems can be exacerbated when management has to consider reacting to increase demand, which requires adding additional capacity. Increasing capacity may involve multiple alternatives for which little practical guidelines currently exist. This research investigates, by using simulation approach, the implication of adopting five possible alternatives of increasing job shop capacity and flexibility in terms of their system performance subjected to varying levels of incoming orders and order priorities. The measures of system performance are i) minimization of tardy jobs, ii) level of WIP and iii) machine utilization. A case study of a mold and die machine shop was used as the basis of the research. It was found that the most optimum alternative in increasing capacity is by selectively introducing machines to duplicate existing ones as opposed to replacing existing ones by a single flexible machine capable of performing operations previously done by several machines. The result of the study also serves as a practical guideline to the managers wishing to add capacity in similar circumstances. This however must be taken within the limitations and constraints of the case study.

ABSTRAK

Pengurusan pembuatan *job shop* adalah berbeza dengan lain-lain sistem pembuatan disebabkan oleh perubahan yang dinamik pada pergerakan proses, masa pemprosesan dan masa permintaan yang berubah-ubah. Oleh itu pengurus *job shop* menghadapi masalah dalam mengekalkan prestasi kilang pada tahap yang optimum. Akibatnya pengurus gagal menepati tarikh penghantaran produk, peratusan penggunaan mesin yang rendah dan tahap produk separa siap yang tinggi. Ini mengakibatkan masalah kepada pengurus apabila menerima permintaan yang tinggi yang memerlukan penambahan kapasiti. Kapasiti boleh ditingkatkan melalui berbagai alternatif tetapi pada masa kini masih kurang panduan praktikal yang wujud bagi mengenal pasti alternatif yang paling sesuai. Penyelidikan yang dilakukan adalah menggunakan teknik simulasi untuk menilai lima alternatif strategi pembuatan bagi menambah kapasiti dan fleksibiliti dari segi prestasi sistem yang dipengaruhi oleh parameter permintaan yang berubah-ubah dan prioriti permintaan. Pengukuran prestasi sistem tersebut dibuat berdasarkan kepada i.) pengurangan jumlah produk yang lambat, ii.) pengurangan tahap produk separa siap dan iii) peningkatan peratusan penggunaan mesin. Kajian kes terhadap industri acuan telah di pilih sebagai asas bagi penyelidikan ini. Hasil kajian menunjukkan bahawa alternatif yang paling optima adalah dengan menambah bilangan mesin sedia ada yang serupa berbanding dengan menukarnya kepada satu mesin yang berupaya melakukan lebih dari satu proses yang sebelum ini dilakukan oleh beberapa mesin. Keputusan daripada kajian ini akan dijadikan sebagai panduan praktikal kepada pengurus yang ingin mengubah suai kapasiti sistemnya. Walau bagaimanapun penggunaan panduan ini adalah dalam had-had kajian kes yang dijalankan.

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1. Adopting Flexibility in Sequencing Rules for Better Job Shop System Performance. Workshop on Improving Business Performance Using Computer Aided Simulation. 29th October 2002, Petaling Jaya, Selangor.

2. Guideline for Improving Capacity of a Job Shop Based on Selected Performance Measures. Jurmal Teknologi A (to be published)

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter discusses the problem statement, objectives and scope of the research. Research methodology will also be discussed and the chapter also introduces the rest of the thesis organization.

1.2 Problem And Research Background

Manufacturing systems can be categorized into three major categories, they are flow shop, batch shop and job shop. The job shop manufacturing system is considered to be unique because its routing and processing time are not identical for each product released (Haq, 1994).

Job shop is usually practiced in manufacturing processes, which consist of high product variation with small number of product quantity where each product will have its own process routing and each routing rarely will be exactly the same to each other. Other problems that might occur in job shop manufacturing are new order releases and revisions in due date, which can result in late product delivery, and thus losing customers' confidence. The capability of managing these uncertainties should be the main concern to manufacturers in selecting the right manufacturing strategies.

Management is therefore faced with the problem in making decision in adding more capacity through increase flexibility of a manufacturing system. Different alternatives have different implications such as additional capital cost and increment number of manpower. Improvement on performance measure such as number of tardy jobs, WIP and machine utilization is usually used to measure the effectiveness of these strategies. Thus the effect of various strategies will need to be evaluated before a decision can be made as to which strategy is best for a manufacturing system. Failure to do this will cause in the less than the best strategy to be implemented thus resulting in losses and inefficiencies.

Therefore, it is important to be able to assess the effectiveness of various manufacturing strategies in coping with the randomness that occur in a job shop. Without proper planning and strategies, job shop manufacturing company will experience problems such as product due date cannot be met, large number of work in progress and underutilized machines.

1.3 Problem Statement

Job shop operations are by their own nature complex. Manufacturing managers require evaluation of alternative manufacturing strategies in order to be able to select the best strategy in coping with these complexities such as changes in demand. One such strategy is in increasing the flexibility of the system's capacity. There are many alternatives of doing this and each alternative need to be evaluated extensively and comparison made in order to determine the most appropriate strategy.

1.4 Research Objective

The objective of the research is to investigate the impact of a number of manufacturing strategies under selected conditions. The impact is measured on the resulted number of tardy jobs, WIP and machine utilization. The selected conditions are high and low levels of inter arrival rate of incoming jobs and the level of percentage slack.

1.5 Research Scope

The research scope covers:

a. Job shop manufacturing system only
b. Five alternative manufacturing strategies will be evaluated.
c. The manufacturing strategies will be tested under a selection of inter-arrival rates and slacks.
d. The performance measure used are number of tardy jobs, WIP and machine utilization.

1.6 Importance of Study

The objective of this research is to identify the most appropriate strategy and provide a guideline that will assist management in deciding the most suitable strategies for their manufacturing system. The guideline will take into consideration due date urgency (slack) and level of inter-arrival rate of jobs. The due date will reflect the tightness of schedule and inter arrival rate will reflect the demand on resources of the job shop. The guidelines will assist manufacturers in selecting the appropriate strategy that best suit their manufacturing system.

1.7 Research Procedure

This research aims to evaluate 5 manufacturing strategies under specified conditions. The research procedure applied in achieving the goals of the study can be divided into 4 stages (refer Figure 1.7);

a. The first stage is to conduct literature review on related problems. This literature review is important in understanding the current problems and other related research.
b. The second stage is to identify a case study. A company practicing job shop manufacturing system is chosen as a case study. This will serve as the platform for the research. Relevant data will be collected to be used for simulation modeling.
c. The third stage is to model the existing system. From this conceptual model, another four alternative manufacturing strategies is proposed and modeled. The verification and validation of the model is made. Experimentations are then conducted and analysis made.
d. The last stage is to analyse and evaluate the results of the experimentations and propose the guideline. Discussion and conclusion will be based on the results.

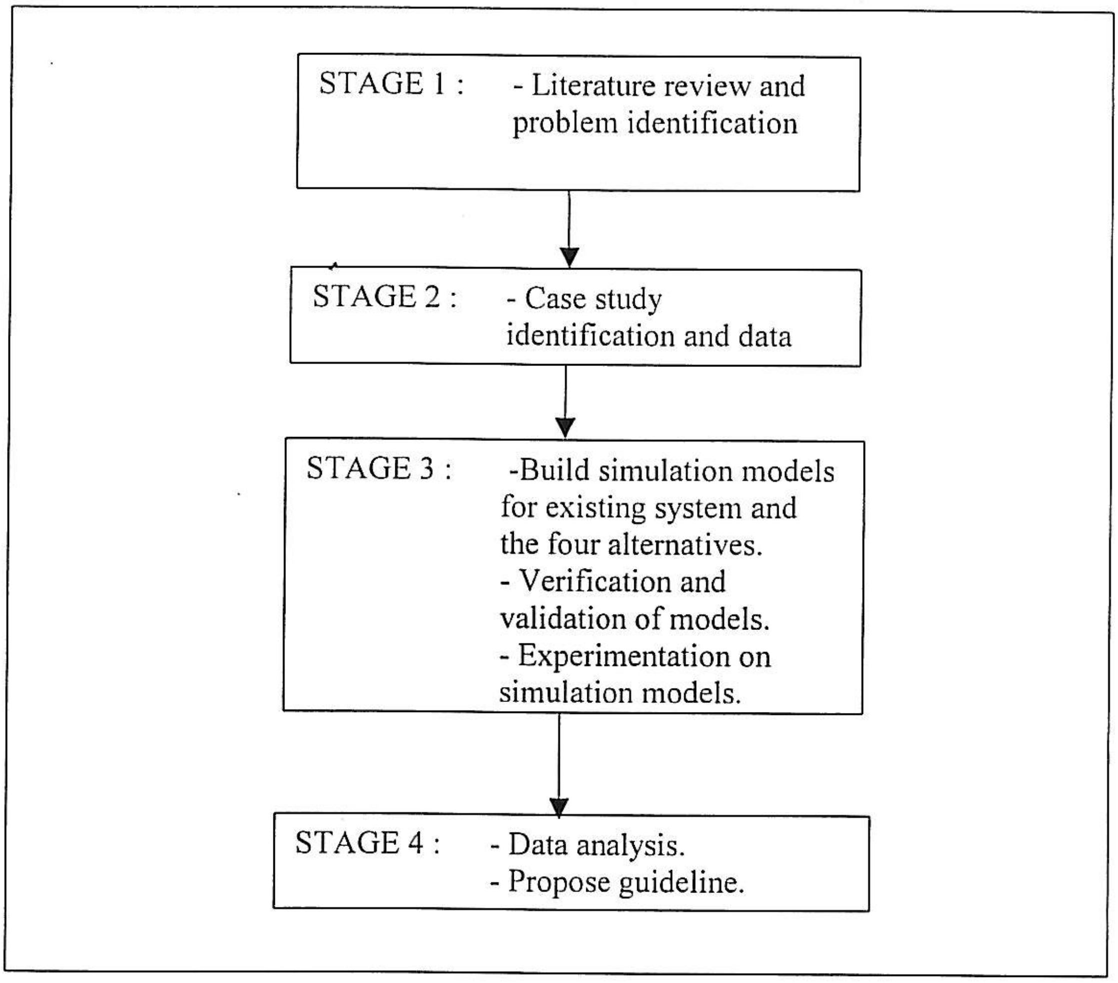

Figure 1.7 Research procedure

CHAPTER II
LITERATURE REVIEW

2.1 Introduction

This chapter begins by discussing different types of manufacturing strategies and then focuses on job shop manufacturing. The definition and characteristics of job shop manufacturing by other researchers is also discussed.

Methods used by other researchers in tackling the job shop manufacturing problem such as the implementation of new scheduling rules, selection of dispatching rules and sequencing rules is also discussed. This chapter reviews the challenges of job shop manufacturing in relation to its dynamics behavior.

2.2 Manufacturing System

Manufacturing systems can be classified into three categories; flow shop, batch shop and job shop (Proud, 1994; Nahmias, 1997; Oey and Mason, 2001; De Souza, 1995; Chen et all., 1999; Glenn, 1998) . The flow shop and batch shop can be classified as manufacturing strategy, which are not usually subjected to random changes in demand and process flow. Therefore the process of forecasting and manufacturing planning is relatively straight forward.

Unlike the flow shop and batch shop, job shop manufacturing system involves random changes in demand, process flow and processing time. This environment contribute to difficulties in forecasting, planning, meeting due date and managing schedules and machine utilization (Subramaniam et.al, 2000; Sanjay and Reha, 1998).

2.2.1 Flow Shop

Flow shop is a form of manufacturing organization in which machines and operators handle a standard, usually uninterrupted, material flow (Proud, 1994; and Nahmias, 1997). The operators generally perform the same operation for each production run. A flow shop is often refered to as a mass production shop, or is said to have continuous manufacturing layout. Some process industries such as chemicals, oil and paint are extreme examples of flow shop. Although each product may vary in material specification, they use the same flow pattern through the shop. Production is set at a given rate, and the products are generally manufactured in bulk (Ballakur and Stedude, 1993).

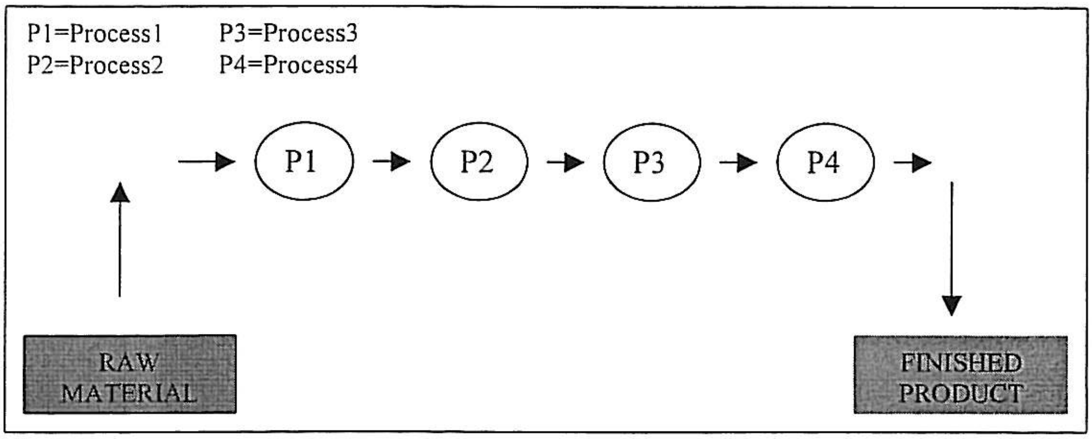

Figure 2.2.1: Flow Shop (Nahmias, 1997)

Figure 2.2.1 shows that in a flow shop, work centers and resources are grouped in the sequence that the work is to be performed. Here, material starts at the beginning of the line and is subjected to processing operations and required material is added as it flows down the line (Nahmias, 1997). Make-to-stock and high volume make-to-order product with minimal product variation mostly uses this approach.

2.2.2 Batch Shop

Batch shop covers the type of manufacturing practiced between the extremes of made-to-order production and mass production. In batch shop, the same part may be reproduced in volume of tens, hundreds, or even thousands. Thus facilites and equipment must be readily adaptable to make a new part within the family of part being manufactured (Nof, 1985).

Figure 2.2.2 shows how in a batch shop , raw material enters to the facility in batches. These are then processed in the required process sequence (Nof, 1985; Ramasesh, 1990).

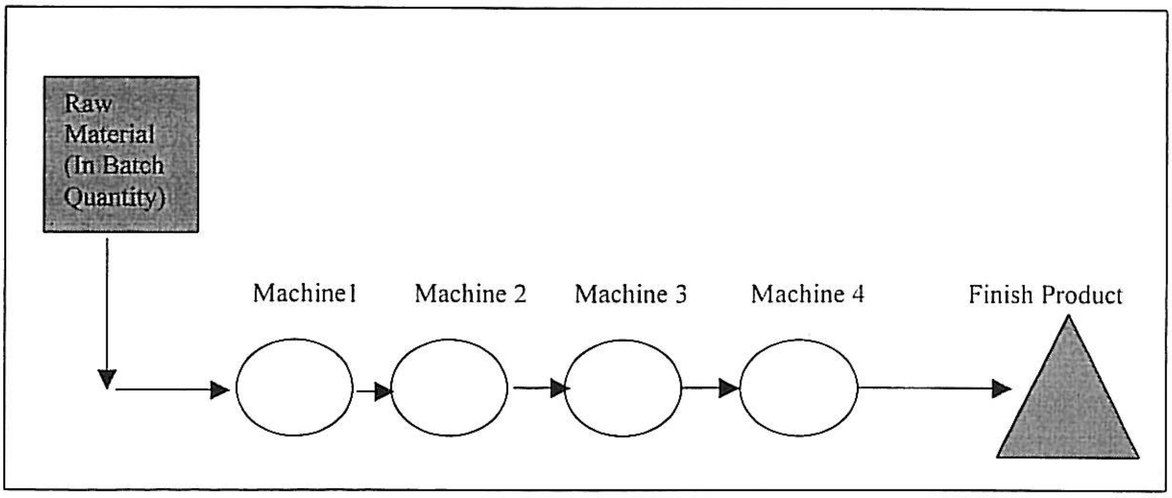

Figure 2.2.2: Batch Shop Manufacturing (Nof, 1985)

2.2.3 Job Shop

Selladurai (1994) and Haupt (1989) defined a job shop as a discrete parts manufacturing facility of fixed production capacity in which component (in low volume) for different orders frequently arrive at irregular intervals, and follow different sequence through the resource centers / machines. These machines are grouped by function in order to accommodate the variety in customer- specialized requirements and fluctuation in demand for product and/or service.

Drobouchevitch (2000) identified that in a general job shop, each job consists of several operations to be processed on all or some of the required machines. The operations of a job have to follow the assigned processing route, specific for each job. Sometimes the routing will skip a process or machine while another machine and process may be visited more than once.

Kiran (1997), Drobouchevitch (2000), Xu and Randhawa, (1998), William and Roda (1994), Ballakur (1993) and, Watanabe, Tokumaru and Hashimoto (1993) identified the characteristics of a job shop manufacturing as:

- Experiencing random fluctuation in demand and order release.
- Producing medium to high variety of product type in very small volume.
- Every product has its own process routing and process time.
- General-purpose machine is usually used.

Figure 2.2.3 shows that in a job shop, work centers and resources are grouped by function, so work flows to the various work centers in the sequence of processes needed to be performed (Nahmias, 1997). Here the manufacturing process begins with material in a stock location.

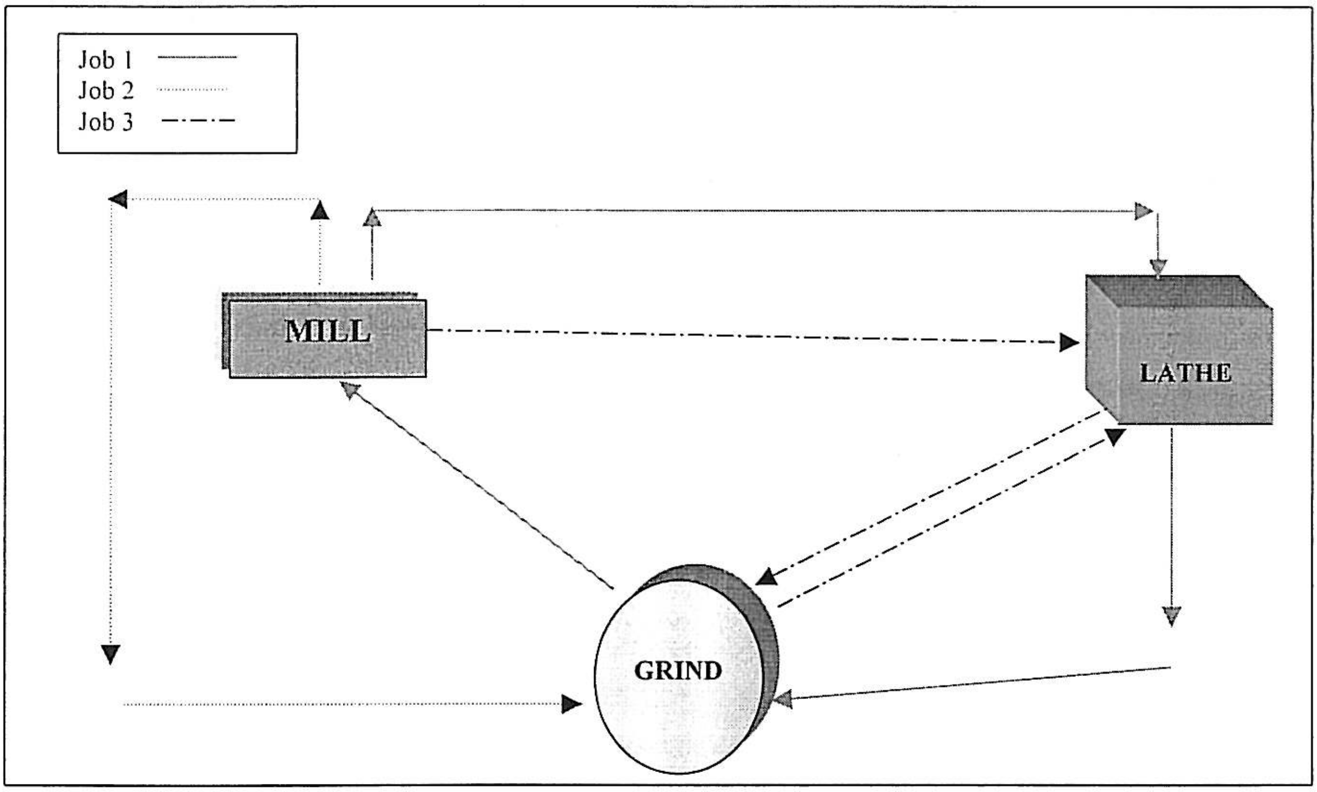

Figure 2.2.3 Job shop manufacturing (Nahmias,1997)

Due to the characteristics of job shop, it is difficult to forecast information n future jobs such as the due date, processing time and routing. Thus many research has been conducted in trying to optimize the performance of job shop manufacturing.

2.3 Previous Research In Job Shop

Many researchers has studied problems related to job shop especially in the areas of scheduling, forecasting and meeting due date (Dubois, 1995; Luh and Zhao, 1998; Baker, 1994; Conway et al., 1987; Dar-El and Wysk, 1982; Panwalker and Iskander, 1977; Randhawa and Zeng, 1996 and Russel et al 1987). Research in scheduling covers investigation on scheduling rules, selection of optimum dispatching rules and sequencing rules for various configurations of resources including parts and machines. The impact of different scheduling approach on the performance of the job shop is evaluated and assessed (Stecke and Solberg, 1981). Several researchers have since evaluated different problems under different sets of rules. The impact of various scheduling methods for a particular problem and the effect of various dispatching rules has been found to vary with several factors such as system layout, system state and the desired performance measure (Dar-El and Wysk, 1982; Wu and Wysk, 1989; Jones et al, 1995).

Studies have shown that using a combination of dispatching rules can produce better performance than a single rule alone (Wu and Wysk, 1989; Matsurra et.al, 1993; and Cho and Wysk, 1993). The dynamic and random nature of job shop can erode the advantages of a particular plan or strategy. For example, Yamamoto and Nof (1985) showed that scheduling/rescheduling approach improved system performance by 2% to 7% as compared to fixed dispatching procedures.

Cho and Wysk (1993) and Jones et.al (1995) suggested using neural network to identify candidate rules for multi-pass simulation analysis. Cho and Wysk (1993) defined five types of scheduling problem in the context of an automated workstation. At each decision point, the neural network generate candidate rules for each problem type and these rules are then evaluated through simulation. Jones et al.(1995) took into account multi-criteria performance measure. When a new schedule is desired, a neural net generate good rules for each performance measure and then simulation is used to predict how each rules does against all performance measure simultaneously. Table 2.3 (a) and (b) listed some of the researches in job shop.

Table 2.3 (a) Research in job shop using mathematical method

Researcher	Problem Studied	Method Used	Performance Measure	Finding / Comment
Subramaniam, Ramesh & Lee (2000 a)	• Studied on 10x10 formal job shop and tested 150x10 machine problem	Mathematical (fuzzy) scheduling.	• Product make span.	• Fuzzy scheduler performs better then other common dispatching rules such as SPT, LIFO and etc.
Subramaniam, Ramesh & Lee (2000 b)	• Six machines problem. Dispatching rules was used to optimized a selection of machines.	Mathematical Job Shop Scheduling	• Mean job cost • Mean tardiness	• Scheduling performance realized when machine dispatching rules are used.
Nuijten (1996)	• Traditional job shop with multi capacitated scheduling	Mathematical	• Due date	• The multi capacitated scheduling contribute to better system performance (due date).

Table 2.3 (b) Research in job shop using approximation method.

Researcher	Problem Studied	Method Used	Performance Measure	Finding / Comment
Drobouchevitch (2000)	• Studied job shop with at most two operation where one of the operation must be performed on bottleneck machines.	Heuristic algorithm	• Product make span	• Heuristic algorithm for two stage job is formulated. • Extend the research to the general two stage job shop • Can be related to flow shop research with parallel machine or assembly problem.
Lun & Chen (2000)	• Studied on the impact of machine breakdown and part routing flexibility on job shop manufacturing	Holonic Simulation Concept	• WIP	• Flexible part routing contribute to the reduction of WIP.
Ip & Fang (2000)	• Understanding the theoretical principal and application on which time series analysis is based on improvement of machine utilization	Stochastic/ simulation analysis	• Machine utilization	• By constructing model which contain the skill judgement and production-scheduling rules of the underlying FMS, a powerful and flexible system can be built.
Arumugam (1985)	• General job shop workcentre.	Simulation	• Due date • WIP	• SPT is best for minimum WIP • SPT dominate other rules

Table 2.3 (b) Research in job shop using approximation method (continued)

Researcher	Problem Studied	Method Used	Performance Measure	Finding / Comment
Steinhofel (1999)	• Allocation of limited resources to tasks with the objective to optimize certain. cost function	Heuristic (simulated annealing)	• Min makespan	• Two simulated annealing based algorithm for solving job shop scheduling problems
Drobouchevitch (2000)	• Studied on job shop with at most two operations where one of the operation must be performed on a bottleneck machine.	Heuristic algorithm	• Product make span	• Heuristic algorithm for two stage job was formulated. • Can be related to flow shop research with parallel machine or assembly problem.
Lun & Chen (2000)	• Studied on the impact of machine breakdown and part routing flexibility on job shop manufacturing	Simulation	• WIP	• Flexible part routing contributes to reduction of WIP level
Jain (1999)	• Traditional job shop with defined sequence operation. Each job needs to visit all machines.	Heuristic	• Min make-span	• The complexity of job shop scheduling remain unsolved with the heuristic method. • Problem is too complicated and time consuming.

Table 2.3 (b) Research in job shop using approximation method (continued)

Researcher	Problem Studied	Method Used	Performance Measure	Finding / Comment
He (1996)	• Studied the effect of running two jobs in one machine	• Heuristic algorithm	Min of job tardy	• The technique reduces total tardiness • Simulation software can be a very helpful tool.
Stylianides (1995)	• Combination of FMS and dedicated machine.	3D simulation with animation	• Queue Length • Machine utilization	• Proposed better design evaluation.
Sadeh (1996)	• Studied the variation on job shop scheduling problem in which operation have to be performed within one or several non-relexable time window.	Heuristic method	• Reduction of search time	• Heuristic method can be overwhelmed for bigger job shop problem.
Werner (1995)	• Studied on classical job shop with n number of jobs and m number of machines.	Heuristic algorithm	• Min makespan	• The developed constructive algorithm yield better result than the selected priority dispatching rules.
Sun (1995)	• Heuristic algorithm on active schedule / active chain	Heuristic algorithm	• Min makespan	• Provide basis for constructing hybrid scheduling system

Table 2.3 (b) Research in job shop using approximation method. (continued)

Researcher	Problem Studied	Method Used	Performance Measure	Finding / Comment
Dorndorf (1995)	• Traditional job shop with unknown operation sequence.	Heuristic	• Min makespan	• The computational time needed restricted the research capability.
Haq (1993)	• Six dedicated machine with two flexible machine.	Simulation	• WIP • Tardiness • Due date	• Processing time has an impact on system performance.

However, these researchers emphasized on finding the right rules or combination of rules to optimize a shop floor with a certain set up (Subramaniam, Ramesh and Lee, 2000 a & b). Thus, the optimum rules that they identified in their research are only valid for these configurations. However, very few researchers have studied the performance of various types of set up used by a shop floor to increase its flexibility in coping with the randomness of job shop environment. This research attempt to evaluate the performance of several manufacturing configurations or strategies that a manager may choose to increase the flexibility of a job shop.

2.4 Performance Measures In Job Shop

Performance measure is important in assessing the performance of a shop floor under certain conditions. Some of the performance measures used to assesed performance of a job shop include make-span, time in system, tardiness, proportion of tardy jobs, work in process (WIP) and resources utilization (Baker and Scudder, 1990;

Nagar et al., 1995; Ramasesh, 1990; and Wein and Chevalier, 1992). For job shop manufacturing, getting finish product on time and minimizing resources is the major objective to be fulfilled (Dar-El and Wysk, 1982).

However, no single scheduling rules has yet been identified that performed best for all these measures of performance (Luh and Zhao, 1998). This is due to the complexity of the job shop problems and the conflicting nature of the performance measures themselves. For example, machine utilization increases, as tool copies are available. However, increasing the number of tool copies will result in an increase in tooling cost and tool idle time. In general, the shortest processing time based rules performed better at high shop load levels and under tight due date setting, while the due date rules performed better under light load condition.

The job shop manufacturing is known for its randomness in process routing and process time. However, inspite of this, manufacturer must deliver goods to the customer in time to avoid any due date penalty. The manufacturer will also need to fully use their facility and reduce machine ideal time.

The three performances measure; due date meeting, machine utilization and WIP represents customer's and manufacturer's needs. The due date meeting is defined as how early the product can be finished compared to the requested date from customer. Machine utilization is defined as the percentage of time all or each of the resources has been used for the production process. WIP is consider as any unfinished product which is still inside the manufacturing system (Nahmias, 1997; and Degarmo et al, 1996). The challenge for job shop is that manufacturer must provided the goods in time so that there will be no penalty related to due date, but yet the manufacturer will also need to ensure the facility in the production floor is fully utilized (Subramaniam, Ramesh and Lee, 2000 a & b; Nuijten, 1996; Lun and Chen, 2000; Ip, 2000; and Haq, 1993).

In this research the three performance that will be used are due date meeting measured in terms of number of job tardy, that is the number of jobs that fail to meet the due date; machine utilization and WIP. Job tardy will reflect how well a job shop is able to fulfill customers' requirement and machine utilization and WIP will indicate how effective resources such as machines and work centers are used.

2.5 Flexibility In Job Shop

There are various methods a job shop can improve its performance, one method is by increasing its flexibility. There are many definitions of flexibility but some of the definitions relevant to this research is listed below (Browne et.al, 1984; Son and Park, 1987; and Sethi and Sethi, 1990);

- Machine Flexibility
  Machine flexibility is the ability of machine to perform various types of operation without requiring prohibitive effort in switching from one operation to another.

- Material Handling flexibility
  The ability of the material handling system to move different parts efficiently for proper positioning and processing through the manufacturing facility.

- Operation Flexibility
  The ability to produce a product using different methods or processess.

- Process Flexibility
  The ability to process a selection of part types without major setups.

- Routing Flexibility.

The ability of a manufacturing system to produce a part by alternate route utilizing the available resources in the system. Routing flexibility will allow an alternative route for a product such that both completion time of the product and the utilization of the machining workcenter can be minimized. Work in progress will also be minimized since on every waiting queue product will be transfered to the next available machining center and processed.

There is a relationship between routing flexibility and machining flexibility. Routing flexibility can only be performed if machines are available for a particular process. On the other hand, capability of machining flexibility will contribute to routing flexibility. That is capability of a machine to machine more then one part generate more alternative routes for that part. By having routing and machining flexibility a job shop may increase its capacity.

In this research, routing flexibility and machining flexibility will be applied to a job shop practicing a selection of strategies and evaluation based on the selected performance measure will be made.

2.6 Research Approach

Previous researchers have used several approaches in solving job shop problems. These approaches may be divided into two categories, they are approximation and optimization approach (Ballakur and Steudel, 1993). Table 2.2 (a) shows some of the researchers who used optimization approach and Table 2.2 (b) shows some of the researchers who used approximation approach.

- **Optimization approach**

Optimization approach is used for dedicated problem formulation. The model is predetermined in detail and no parameter can easily be changed in the model developed. This approach provide exact but static solution to only small-dedicated system. Mathematical approach such as fuzzy algorithm, genetic algorithm and integer linear programming are methods categorized under this category. Optimization approach is also known as mathematical approach (Jain, 1999). It has been applied to job shop of fixed configuration, in general n-jobs/m-machine. The results of these research are restricted to simple problems with no more then ten tasks and ten machines / work centers (Ballakur, 1993). Researchers such as Subramaniam, Ramesh and Lee (2000 a & b), and Nuijten (1996) restricted their research to the number of machine and task associated to at most ten. However such restrictions fail to reflect the randomness of job shop as the results are exact and only apply to the deterministic nature of the optimization approach.

- **Approximation approach**

An approximation approach focuses on arriving at a generic and general formulation. Approximation approach is also known as traditional or heuristic approach. This approach has been used in solving complex job shop problems such as NP hard (Non Terminating Polynomial) problems (Jain, 1999; Drobouchevitch, 2000; Steinhofel, 1999; He, 1996; Sadeh, 1996; Werner, 1995; Sun, 1995; and Dorndorf, 1995). The heuristic approach can also be used for small job shop scheduling problem. For example, He (1996), managed to solve small job shop manufacturing problem in which heuristic algorithm is defined for two simultaneous job in a bottleneck workstation.

Simulation is another technique under approximation method. Although simulation is an approximation approach, it is capable of evaluating a dynamic manufacturing system such as a job shop (Jain, 1999; and Banks and Carson, 1986). Many researchers have used simulation in their study of job shop problems (Lun and Chen, 2000; and Haq, 1993).

Although both approaches have their advantages and disadvantages, in recent years, many researchers have switched to approximation approach rather then optimization approach in job shop manufacturing research. This research will use approximation approach in particular simulation technique. Thus simulation will be discussed further in the following section.

2.7 Simulation Technique

Simulation, according to Shannon (1975), is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (with the limits imposed by a criterion or set of criteria) for the operation of the system.

Ingalls (2001), suggested that the power of simulation is its ability to mimic the dynamics of a real system. Many models, including optimization models, cannot take into account the dynamics of a real system. It is the ability to mimic the dynamic of the real system that gives simulation its strength in analysis. Simulation based has gained acceptance by both researchers and practitioners. This is partly due to its ability to conduct powerful experimentation with reproducible result. Some of the advantages of simulations are;

- Once a model is built it can be used repeatedly for various analyses.
- Simulated data is usually cheaper than data coming from real system.
- Simulation method is usually easier compared to analytical method.
- Simulation models do not require the many simplifying assumptions of analytical model.

Researcher such as Drobouchevitch (2000), Steinhofel (1999), Jain (1999), He (1996), Sadeh(1996), Werner (1995), Sun (1995) and Dorndorf (1995), found that the adoption of simulation technique contribute to faster and realistic result for job shop manufacturing research. The dynamics characteristics of job shop manufacturing justify the use of simulation.

2.8 Conclusion

Although many research has been conducted to study problems in job shop, most are focussed on finding the optimum scheduling and/or dispatching rules for a particular job shop. However, very few study has been conducted to study the optimum strategies that a job shop can adopt to increase its flexibility in its capacity to cope with its dynamic and random nature.

This research will attempt to study and evaluate a selected strategy and its effect on the performance of a job shop. The performance measure that will be used are number of job tardy, machine utilization and WIP. These evaluation will be made using the approximation approach, that is, the simulation technique.

CHAPTER III
METHODOLOGY

3.1 Introduction

This chapter will discuss the methodology used in this research. Detail characteristics of the system to be studied and problem identification will be presented in this chapter.

3.2 Research procedure

The seven steps suggested by Law (2001) will be used as the guideline in this research. The seven steps are;

1. Problem formulation.
2. Data collection and model construction.
3. Verify and validate conceptual model.
4. Program the conceptual model.
5. Verify and validate the simulation model.
6. Design and conduct experiment and analyze results.
7. Document and present results.

- **Problem Definition**

Here the problem to be studied is identified and formulated This has been done as discussed in section 1.2. The objective of the research has also been discussed in section 1.3 and 1.4

The scope of the research will only cover job shop manufacturing system. A company that practices job shop manufacturing will be identified and used as a case study. A company in the mold and die industry is selected. This is because mold and die industry is an industry which extensively practices job shop manufacturing (Haq, 1993). This industry also represents a typical job shop where process time, inter arrival rate and process routing is random and unique.

- **Data Collection And Model Construction**

Relevant data will be collected on the case study job shop. Information on the operation of the job shop is gathered such as type of processes, cycle time for each process, types of product and process routing.

A conceptual model of the job shop of the job shop is then constructed based on the collected data. Model must be able to represent the real job shop.

- **Verify And Validate Of Conceptual Model.**

The conceptual model of the job shop need to be verified and validated to ensure that it represents the real job shop. If there are errors or discrepancies between the real job shop, the model needs to be corrected before it can be accepted and used for further experimentation.

- **Program The Conceptual Model.**

Program the conceptual model into a simulation model using a simulation software or a general purpose programming language. In this research, Witness simulation software will be used as it is capable of presenting the manufacturing system.

- **Verify And Validate The Programmed Model.**

The simulated model need to be verified and validated to ensure that it represents the real job shop. This can be done by running the simulation model and comparing the results with the data collected. If the difference is small, then the simulation model is said to be validated and represents the real job shop.

Sensitivity analyses should be performed on the model to determine the factor that have significant effect on the performance measure and thus have to modeled carefully.

- **Design And Conduct Experiment And Analyze Results.**

Tactical issues such as run length, warm up period and the number of independent model run replications need to be determined. The validated model need to be expanded into several models, each representing the strategies to be tested in the experiment. In this research five more models will be constructed from the basic model to represent five manufacturing strategies. This will be discussed in detail in the following section. Results are then analysed.

- **Document and present results.**

The documentation for the model should include the details of the models and the computer program for future reference.

3.3 Experiment Design And Data Analysis

The simulation experiment is based on terminating system. In terminating system, both the starting condition and the terminating condition are defined by the nature of the system. Because we cannot manipulate the starting condition or the length of each replication, the only decision in controlling sample size is in the number of replication of the simulation to be executed (Shanon and Pegden, 1995). In this research the experiment will be terminated after 500 parts enter the system. At the end of each run, the performance measure, that is, number of job tardy, machine utilization and WIP is observed.

The experimentation is designed to evaluate a job shop under various conditions practising a selected manufacturing strategies. These conditions are;

a) Interarrival rate of jobs

To represent an environment of a busy job shop, the frequency of jobs coming into the system is set at 5 parts/50 unit hours (4 jobs/5 work shifts) and to represent a not so busy job shop, the interarrival rate is set at 5 parts /500unit hours (4 jobs/20 work shift).

b) Slack (due date)

Due date is presented in the form of percentage slack. 0% slack represents a very tight schedule where the due date for the job is equal to the total processing time for the job, that is, there is no slack. While 100% slack means that the due date of the job is equal to twice the total processing time of the job. That is the slack is equal to the total processing time.

The manufacturing strategies that will be tested and evaluated represents five choices of strategies that a job shop may adopt. These strategies ranges from not changing anything (using the existing facilities) to using all flexible machines. The five strategies are listed below;

- **Basic Strategy (existing system)**

This strategy represents the do nothing strategy where the job shop is modeled to behave as the existing job shop. In this job shop there are five general-purpose machine, each capable of one type of process. These processes are milling, turning, drilling, grinding, EDM (Electro Discharge Machining) EDM) and hardening process.

- **Duplication Strategy**

In this strategy the capacity of the job shop is increased by adding another identical general purpose machine to each process that experienced bottleneck.

- **Basic + Flexible Strategy**

In this strategy, capacity of job shop is increased by adding two flexible machines in addition to the existing general purpose The system consists of existing plain system with two additional flexible machines. The first flexible machine can perform milling process and turning process while the other flexible machine is capable of performing drilling, grinding and EDM process.

- **Replacement Strategy**

In this strategy the machines in the job shop is replaced by 3 machines. Two of them are flexible machines. One of the flexible machines is capable of performing milling and turning process and the other is capable of drilling, grinding and EDM process. The third machine is for the hardening process only.

- **Full Flexible Strategy**

In this strategy the system consists of six flexible machining work-center. Each work centers can perform all six processes, that is, milling, turning, drilling, grinding, EDM and hardening. This strategy represents the scenario where the job shop invested highly in the most flexible machineries thus increasing its flexibility considerably.

3.4 Conclusion

This chapter gave an overview on how the research will be conducted. There are five alternative manufacturing strategies that will be evaluated. The correlation of several condition and performance measured will be evaluated using Witness simulation software.

CHAPTER IV
MODEL DEVELOPMENT

4.1 Introduction

This chapter describes the development of the simulation model of a job shop from the case study job shop. The chapter begins with case study company and then discusses the development of the basic model from the case study job shop.

4.2 Case Study Job Shop

The Sparkle Precision Sdn. Bhd. is selected to be the case study job shop for this research because it is a mold and die making industry that practices job shop.

- **Types Of Processes**

The facility involves a complete set of processes adequate in producing mold and die. The facilities are a milling machine, a lathe machine, a drilling machine, a grinding machine, an EDM machine and a hardening work center.

- **Types Of Product**

Mold and die consists of two parts, male and female. Each product is rarely ever identical to each other. However observation and discussion with management shows that product type may be grouped into 5 based on the routing.

Table 4.2 (a) to (e).show the 5 product groups according to their routing and the processing time for each process of each group.

Table 4.2 (a) Group 1

PRODUCT GROUP	PART TYPE	ROUTE	PROCESSING TIME (hour)
1	Male	Mill	15
		Lathe	6
		Drill	8
	Female	Lathe	7
		Drill	12
		Mill	10

Table 4.2 (b) Group 2

PRODUCT GROUP	PART TYPE	ROUTE	PROCESSING TIME (hour)
2	Male	EDM	3
		Lathe	4
		Drill	7
	Female	Mill	5
		Drill	12

Table 4.2 (c) Group 3

PRODUCT GROUP	PART TYPE	ROUTE	PROCESSING TIME (hour)
3	Male	Grind	3
		Lathe	7
		Mill	9
	Female	Drill	8
		Lathe	4

Table 4.2 (d) Group 4

PRODUCT GROUP	PART TYPE	ROUTE	PROCESSING TIME (hour)
4	Male	Lathe	7
		Drill	16
	Female	EDM	4
		Grind	8
		Mill	13

Table 4.2 (e) Group 5

PRODUCT GROUP	PART TYPE	ROUTE	PROCESSING TIME (hour)
5	Male	Grind	3
		Mill	9
		Drill	8
		Mill	6
	Female	Mill	2
		Grind	7
		Lathe	8
		Drill	4

- **Dispatching rules**

The First Come First Serve rule is used by the job shop

Once adequate data has been collected a simulation model of the job shop can now be built.

4.3 Simulation Model

A simulated model of the job shop is constructed based on the collected information. Test run are made and data compared to verify and validate that the model represents the job shop.

The model is developed using WITNESS simulation software. Figure 4.3 (a) shows the flow chart of the basic model (existing strategy).

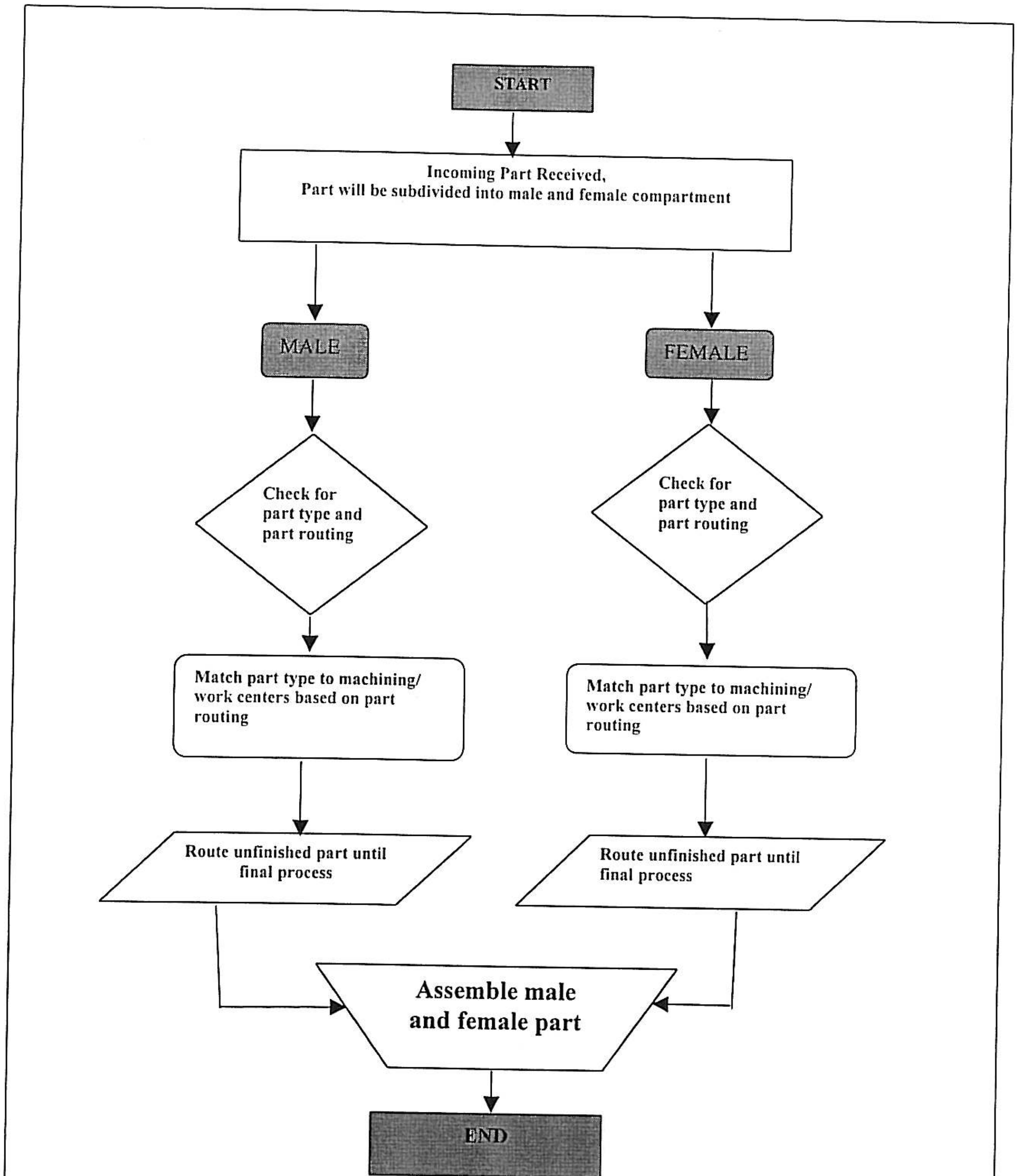

Figure 4.3 (a) Flow chart for basic model

Through the simulation model developed, the basic strategy (existing strategy) is evaluated and analyzed by observing the three-performance measure; WIP, number of job tardy and machine utilization. The experimental design and analysis of the system will be discussed in the following sections

4.4 Verification And Validation

The model is run and results are analysed to validate the basic model. The following section discusses the results of the simulation run. The model is run at inter arrival rate of 5 parts/50 unit hours to represent a busy job shop and at inter arrival rate of 5 parts/500 unit hours to represent a not busy job shop.

4.4.1 Machine Utilization Versus Slack

Figure 4.4.1 (a) to (b) shows the results of the simulation run. The following symbols are used:

MC : 1 is used to indicate milling process.
MC : 2 is used to indicate turning process.
MC : 3 is used to indicate drilling process.
MC : 4 is used to indicate grinding process.
MC : 5 is used to indicate EDM process.
MC : 6 is used to indicate hardening process.

Figure 4.4.1 (a) shows the graph of machine utilization versus slack for inter arrival of 5parts/50 unit hours. It shows that machine 1 (Mill), machine 2 (Lathe) and machine 3 (Drill) are utilized more then 85% of the total production time and machine 4 (Grind), machine 5 (EDM) and machine 6 (Hardening) are utilized between 50% to 60% of the production time. There is no change in the percentage machine utilization as slack is increased from 0 % to 100 %. This is because the amount of slack cannot influence the amount of time the job spent on a machine.

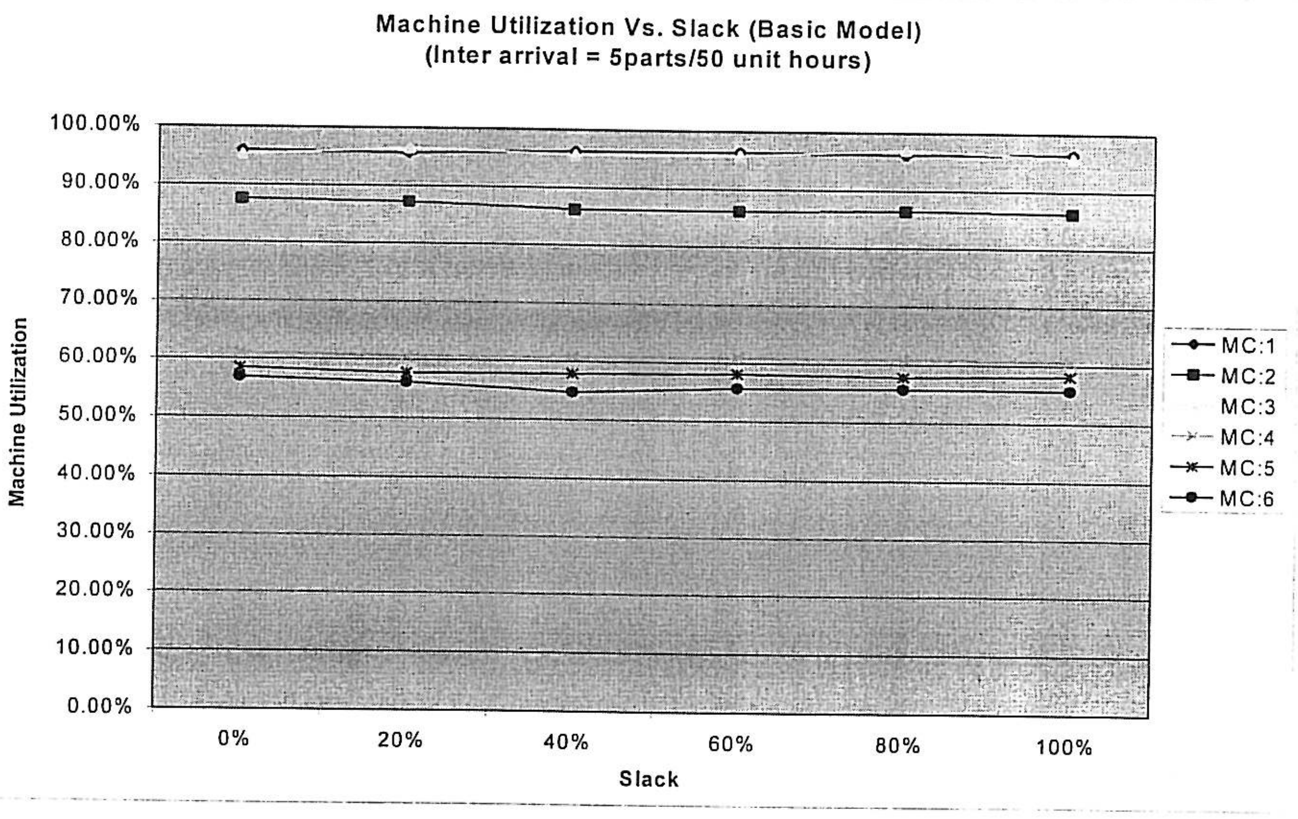

Figure 4.4.1 (a) Machine utilization versus slack (inter arrival rate 5 parts / 50 unit hours)

The experiment is run for inter arrival rate of 5 part/500 unit hours and Figure 4.4.1 (b) shows the result. It shows that the percentage of machine utilization is much lower than in the case of inter arrival rate of 5 part/50 unit hours. The reduction in percentage machine utilization is because as parts get into the system at a slower rate, machine spent more time waiting for parts. However, the same pattern prevails, that is, percentage machine utilization is not influenced by the percentage slack.

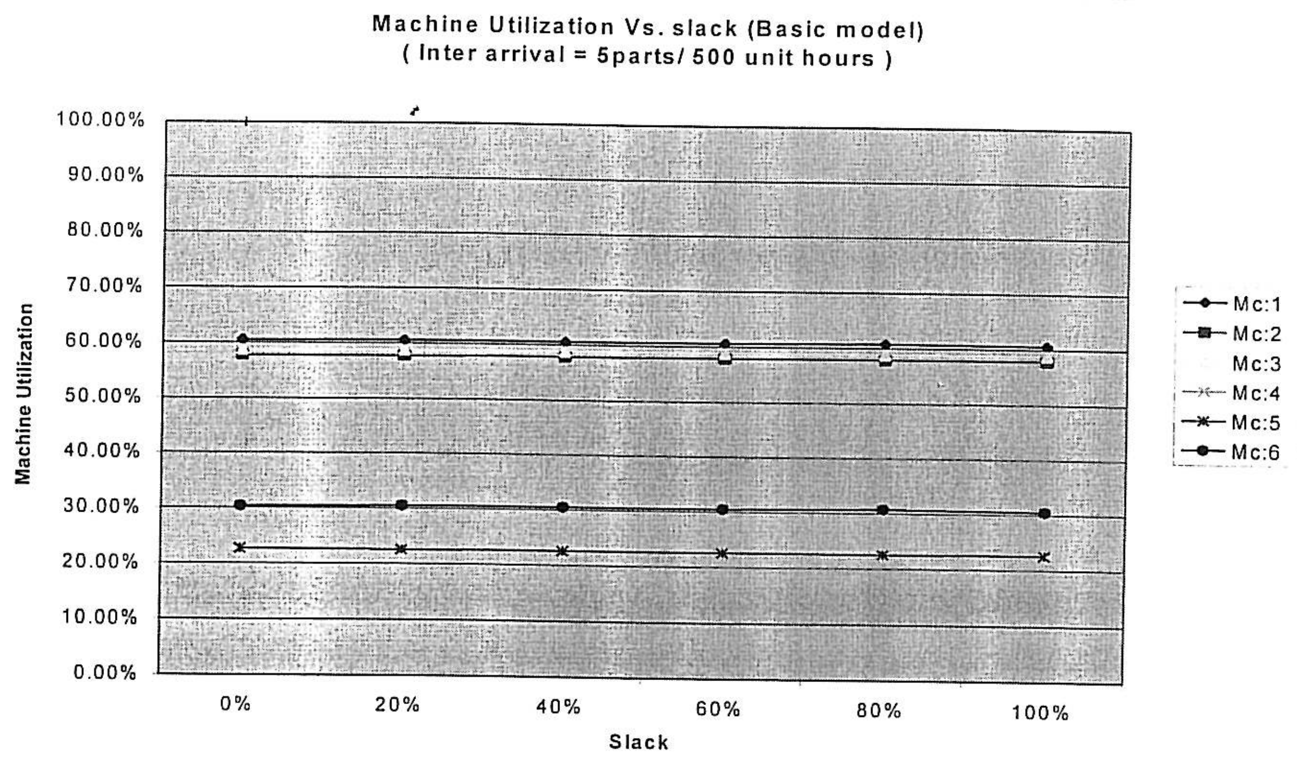

Figure 4.4.1 (b) : Machine utilization versus slack (inter arrival rate 5 parts / 500 unit hours)

These results show that machine utilization is only be influenced by inter-arrival rate but not by the percentage slack. The machine utilization also increases as the inter arrival rate increases.

4.4.2 Tardy Jobs Versus Slack

Another simulation run is made to identify the effect on tardy jobs, slack and inter arrival rate. Figure 4.4.2 (a) shows the results for inter arrival rate of 5 parts/50 unit hours and Figure 4.4.2 (b) shows the result for inter arrival rate of 5 parts/500 unit hours.

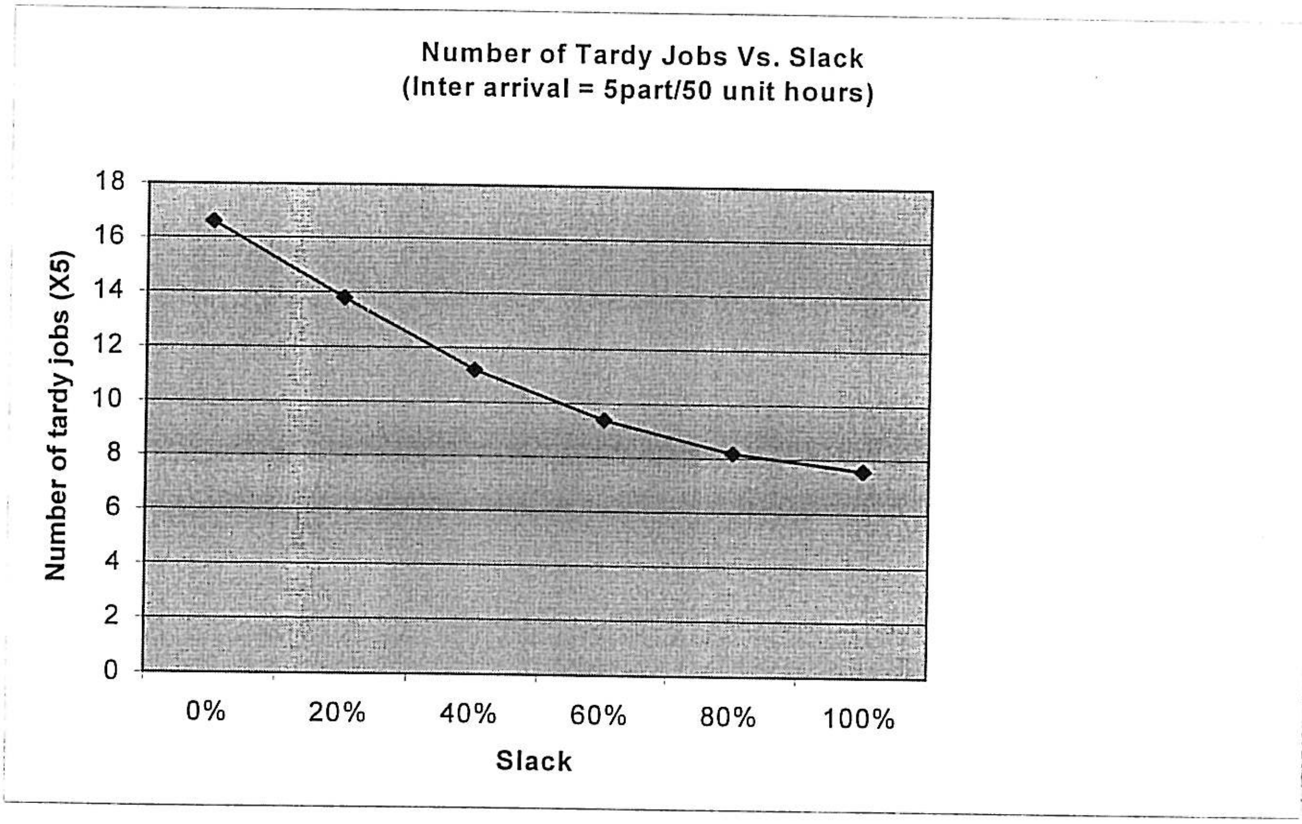

Figure 4.4.2(a) : Number of tardy jobs versus slack (inter arrival rate 5 parts / 50 unit hours)

Figure 4.4.2 (a) shows that the number of tardy jobs is influenced by variation in the percentage of slack. The number of tardy jobs gradually reduces as percentage slack increases. This is because as due date becomes more relaxed, more jobs can be completed on time. Figure 4.4.2 (b) shows the results for the case of inter arrival rate of 5 parts/500 unit hours. It shows the same pattern of reduction in number of job tardy as slack increases.

Comparing both Figure 4.4.2 (a) and (b), the number of tardy jobs for inter arrival rate of 5 parts/50 unit hours is higher than for inter arrival rate of 5 parts/500 unit hours. This is because with a higher inter arrival rate more parts need to queue before it can be processed.

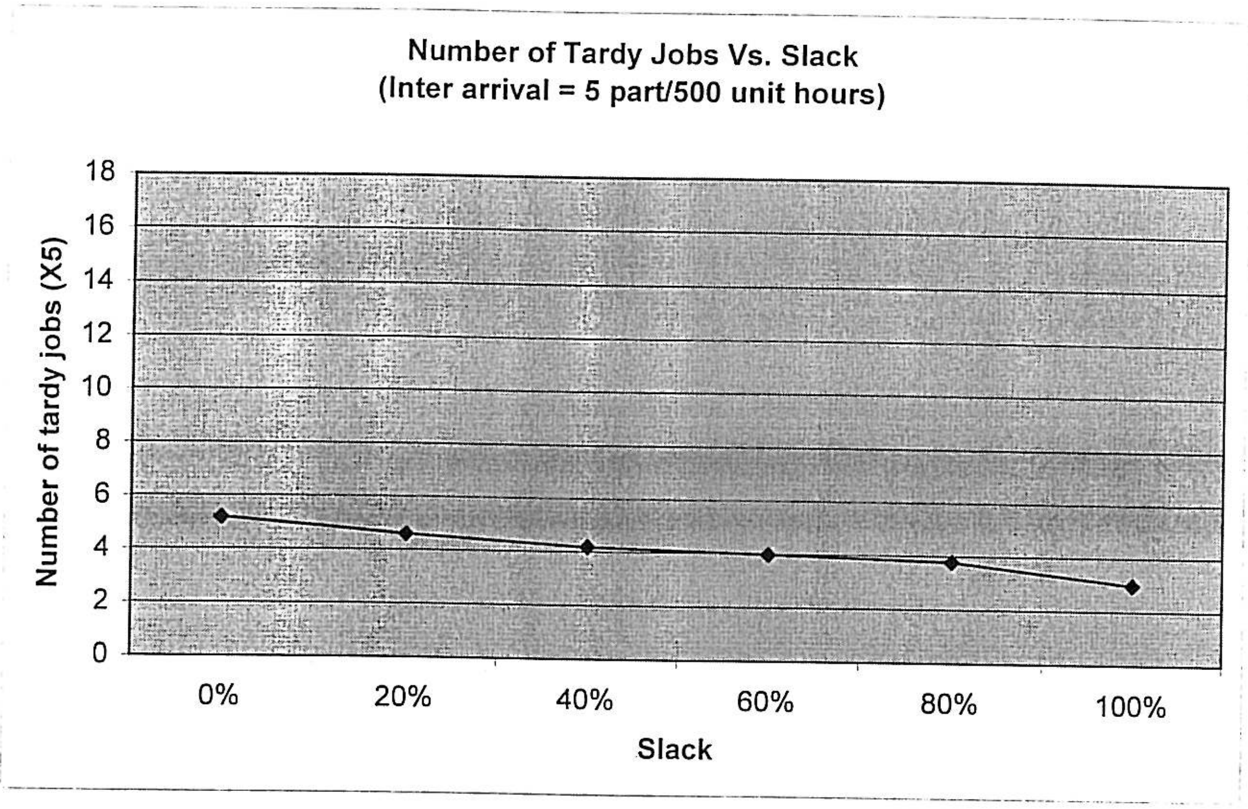

Figure 4.4.2 (b) : Number of tardy jobs versus slack (interarrival rate 5 parts/500 unit hours)

4.4.3 WIP Versus Inter Arrival Rate

Figure 4.4.3 (a) shows the effect of inter arrival rate on WIP at 0 % slack. It shows that WIP decreases as inter arrival rate increases. This shows that WIP is affected by the rate of inter arrival. This is because as parts enter the system at a faster rate, more parts need to queue before it can be processed thus resulting in higher WIP.

Figure 4.4.3 (b) shows the effect of inter arrival rate on WIP at 100% slack. It shows the same pattern as Figure 4.4.3 (a) but a lower value. Comparing both Figure 4.4.3 (a) and (b) they show that WIP is effected by the inter arrival rate but not by the percentage slack.

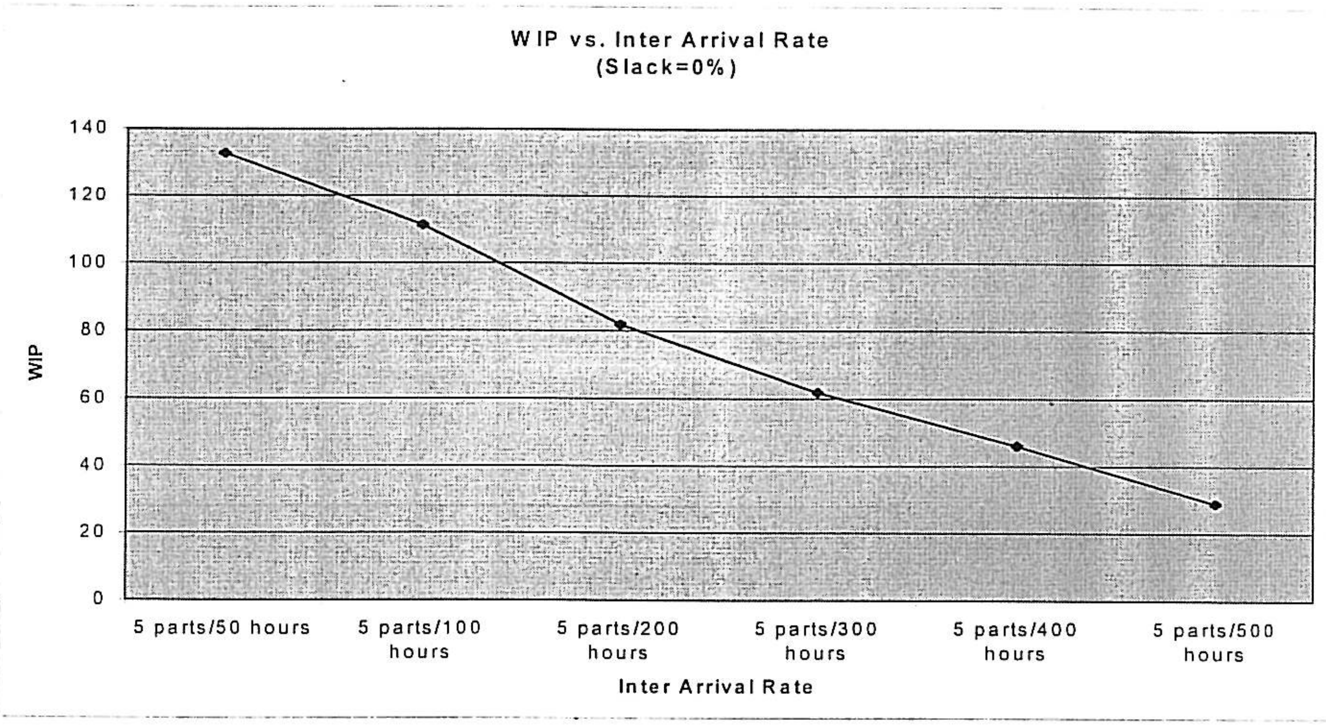

Figure 4.4.3 (a) : WIP versus inter arrival rate (slack = 0%)

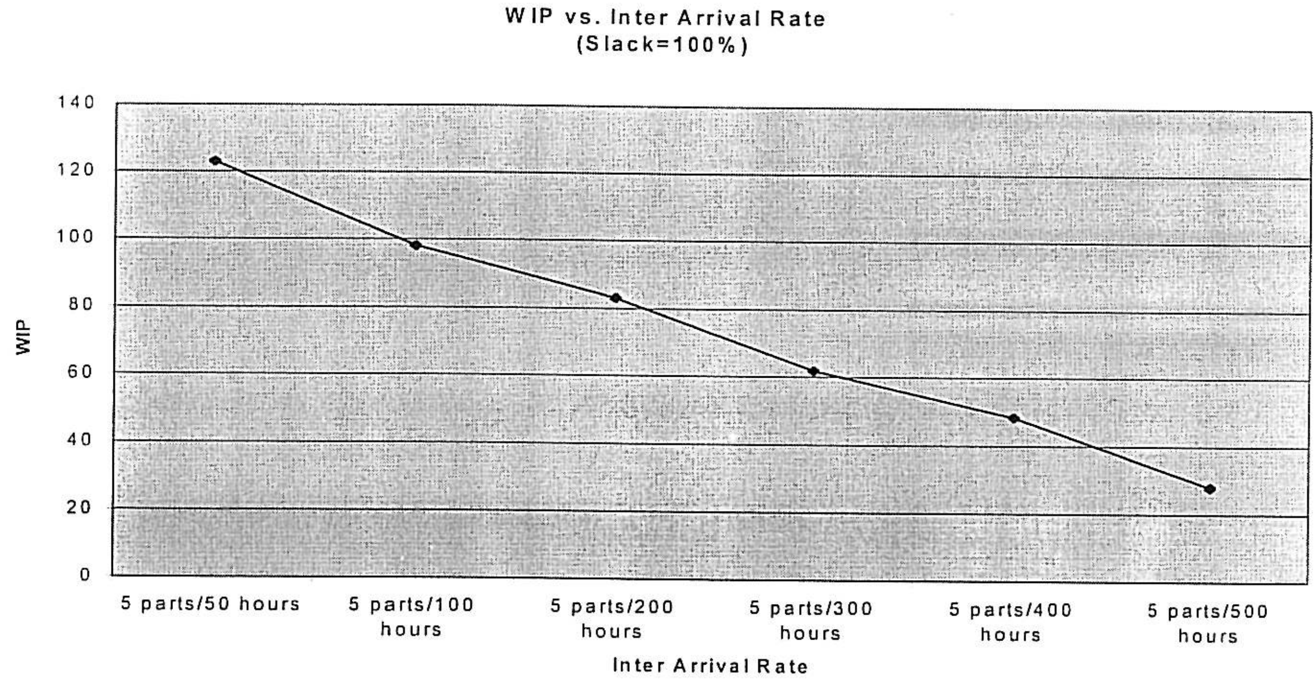

Figure 4.4.3 (b) : WIP versus interarrival rate (slack = 100%)

4.5 Result Summary

Table 4.5 (a) shows a summary of the results. The results shows that the model behaves in the way a real job shop would. This model will now be named basic model for the basic strategy. It will be used to develop four more models to represent the various strategies that may be adopted by the job shop in increasing its capacity thus increasing its flexibility in coping with the random nature of a job shop. In the following chapter, evaluation of these manufacturing alternative will be made based on the simulation results.

Table 4.5 (a) : Correlation of the performance measures with interarrival rate and slack

Performance measure	Inter Arrival Rate	Slack
Machine Utilization	**Increases with inter arrival rate.**	**No influence**
Number of job Tardy	**Increases with inter arrival rate.**	**Decreases with increase in slack.**
WIP	**Increases with inter arrival rate.**	**Not Influenced**

CHAPTER V

EVALUATION OF STRATEGIES AND DEVELOPMENT OF PROPOSED GUIDELINE

5.1 Introduction

This chapter discusses the development of the manufacturing strategies. Experiments are conducted and evaluation of the results made. Finally, a general guideline and recommendation is proposed.

5.2 Manufacturing Strategy

There are five manufacturing strategies, which will be evaluated under a selected parameter and condition. The existing system, which becomes the benchmark is called basic strategy. Under the existing basic strategy there are five single operation machines; milling machine, lathe machine, drilling machine, grinding machine and EDM machine and one hardening work center.

5.2.1 Duplication Strategy

The duplication strategy increase the capacity of the job shop through adding the identical single-operation machine to the process that experienced bottleneck in the basic model. Thus the duplication model consists of the five single-operation machine (mill, lathe, drill, grind and EDM) and one hardening center, with the addition of one machine each for mill, lathe and drill. Altogether there are 8 machines in the system. The duplication of milling, lathe and drill machines are due to the bottleneck at these machines.extensive. The flow chart for the duplication model is shown in Figure 5.2.1(a).

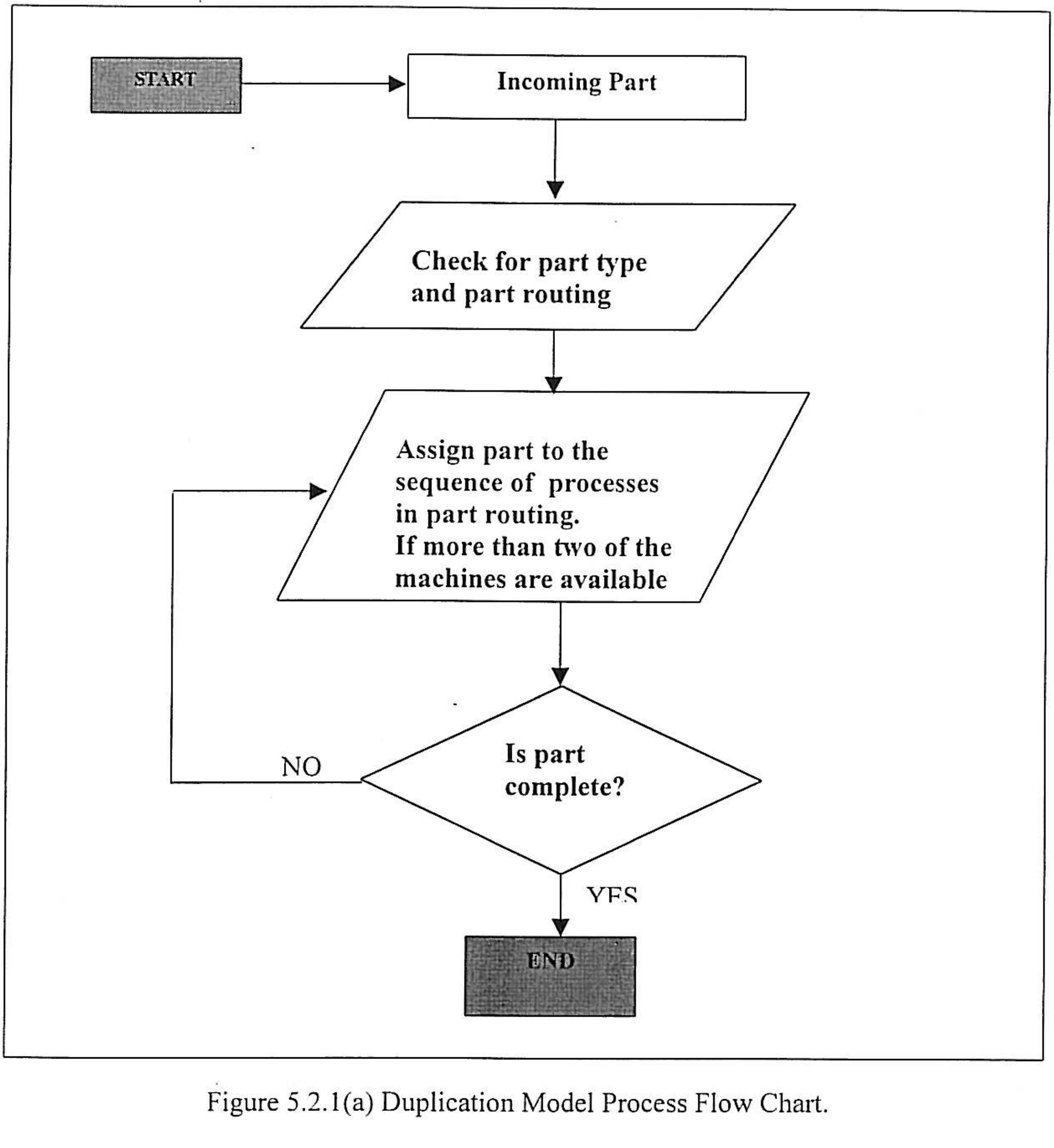

Figure 5.2.1(a) Duplication Model Process Flow Chart.

Figure 5.2.1(b) to (g) shows the results of the simulation run on the model.

a) Effect of slack on machine utilization.

Figure 5.2.1 (b) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack does not have an effect on machine utilization. Figure 5.2.1 (c) shows the same behaviour in a not busy job shop (5 parts/500 unit hours) although the machine utilization is lower than in a busy job shop.

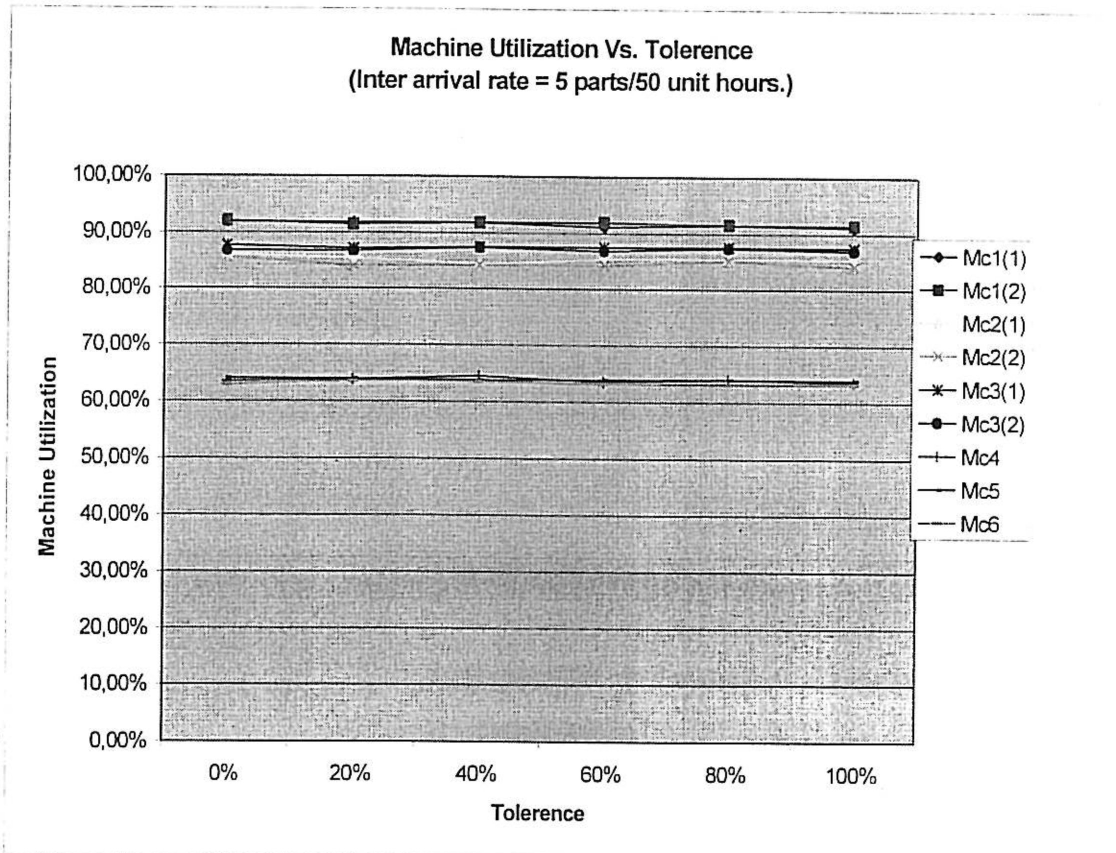

Figure 5.2.1 (b) Machine utilization vs. slack (Inter arrival rate = 5 parts/50 unit hours)

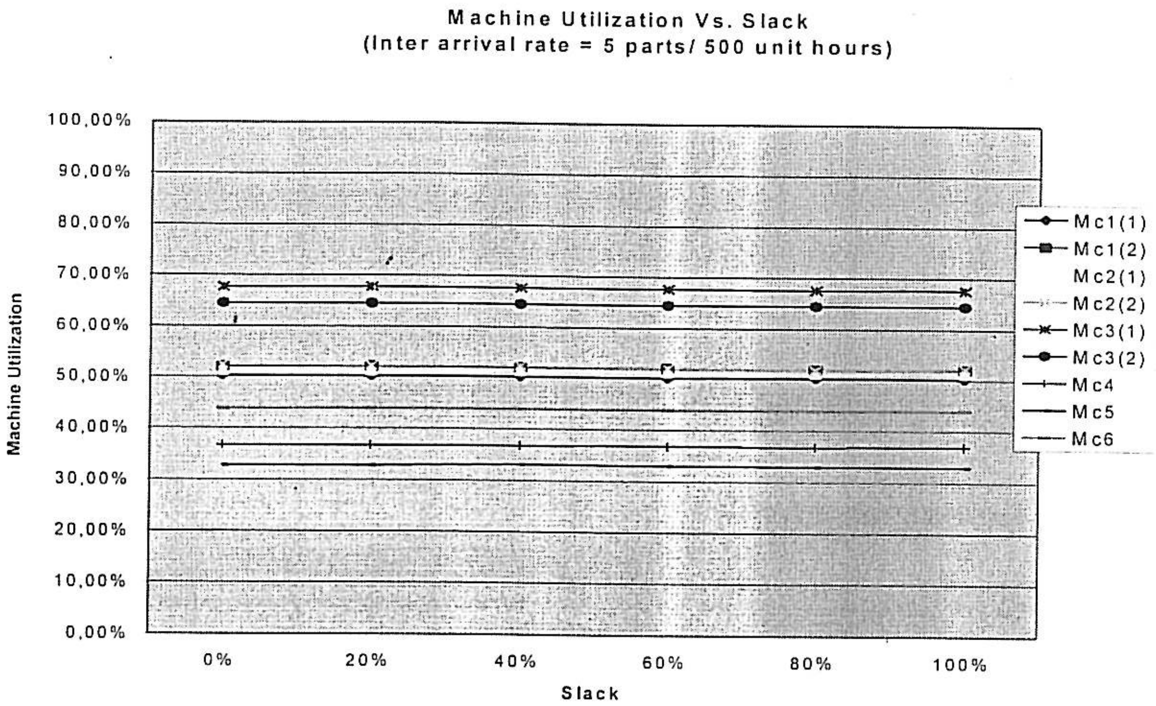

Figure 5.2.1 (c) Machine utilization vs. slack (Inter arrival rate = 5 parts/500 unit hours)

b) Effect of slack on number of tardy jobs

Figure 5.2.1(d) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have an effect on number of tardy jobs. Number of tardy jobs decreases as slack increases. This is because as parts are given more time to be completed, more jobs get completed on time. Figure 5.2.1 (e) shows that the same pattern persisted in a not busy job shop (5 parts/500 unit hours) although the number of tardy jobs is lower than in a busy job shop.

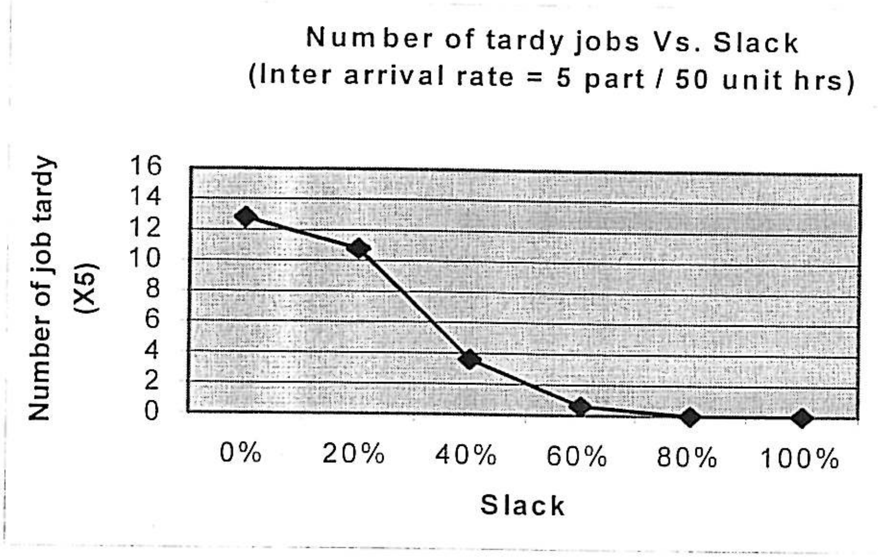

Figure 5.2.1 (d) Number of tardy jobs vs. Slack. (Inter arrival rate = 5 parts/50 unit hours)

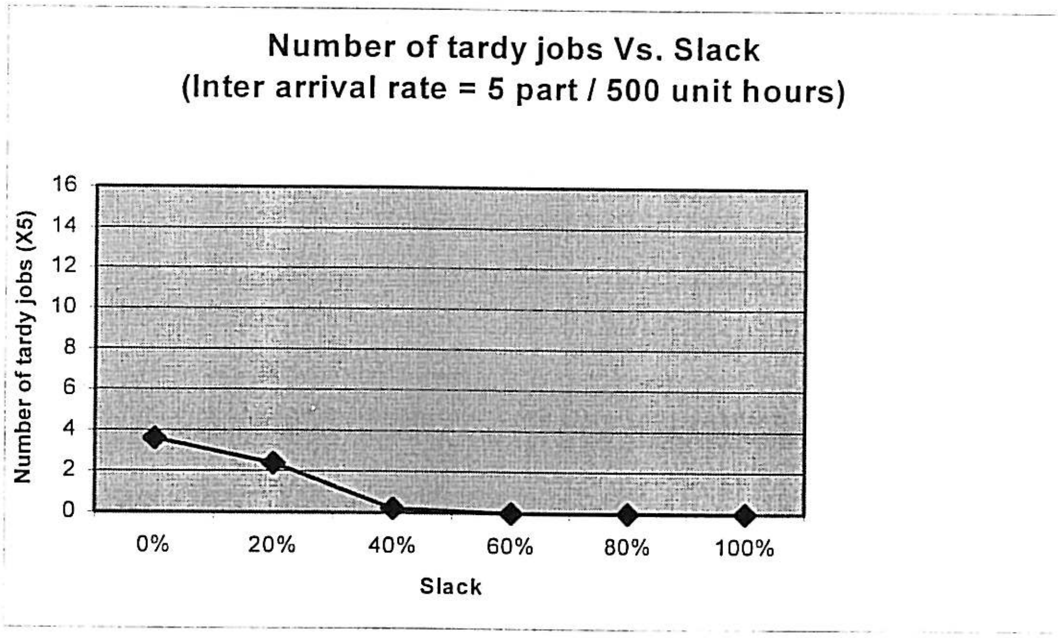

Figure 5.2.1 (e) Number of tardy jobs vs. Slack. (Inter arrival rate = 5 parts/500 unit hours)

c) Effect of slack on WIP

Figure 5.2.1(f) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have only slight effect on WIP. Figure 5.2.1 (g) shows that the same pattern is also observed in a not busy job shop (5 parts/500 unit hours) although WIP is higher than in a busy job shop.

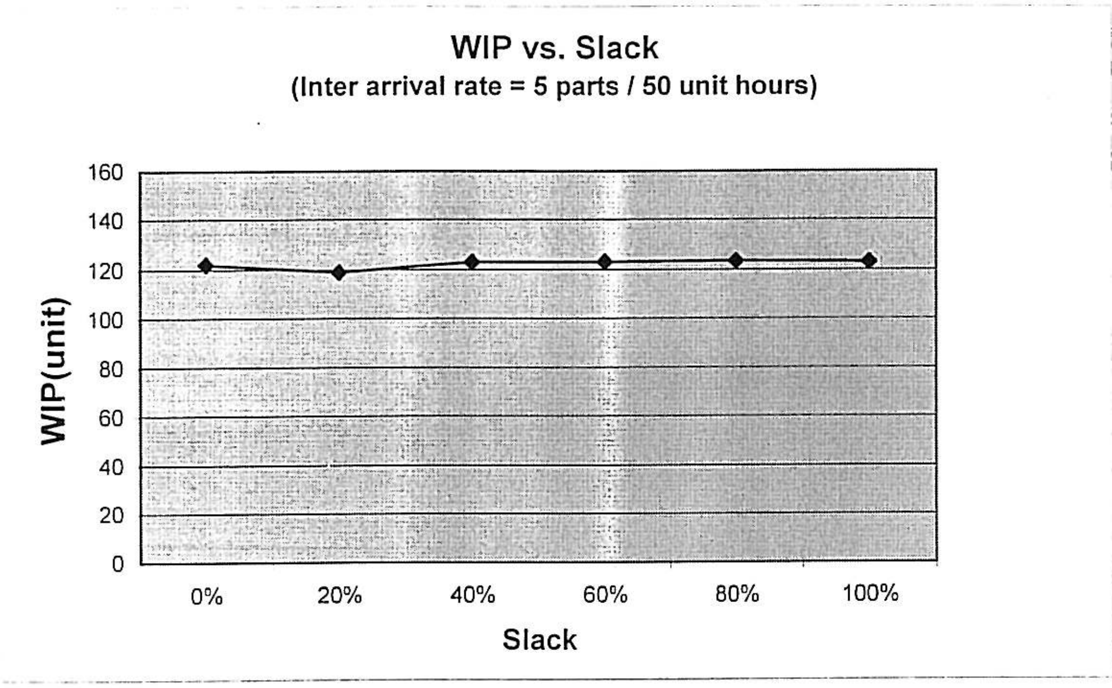

Figure 5.2.1 (f) WIP vs. Slack (Inter arrival rate = 5 parts / 50 unit hours)

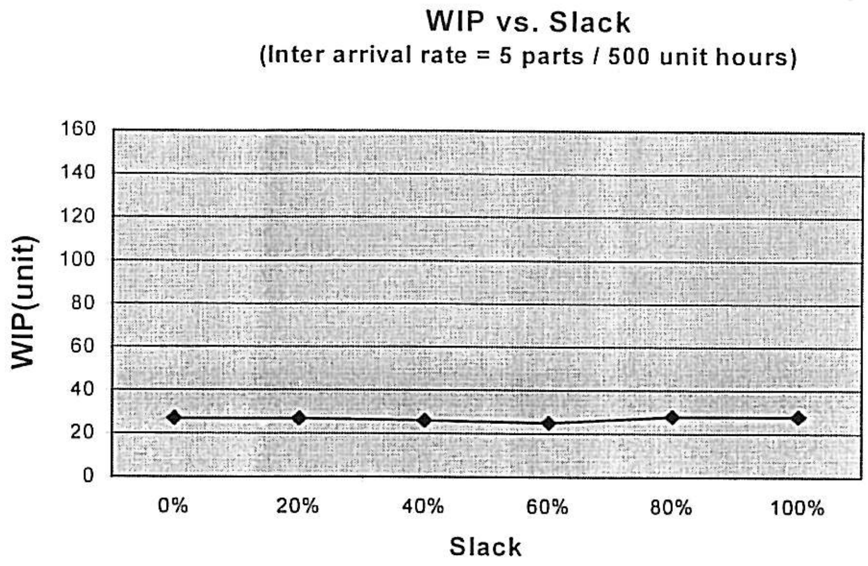

Figure 5.2.1 (g) WIP vs. Slack. (Inter arrival rate = 5 parts / 500 unit hours)

5.2.2 Basic With Flexible Strategy

This strategy increases the job shop capacity by adding flexible machines capable of performing more than one operation to the bottleneck process. The job shop modeled for this strategy has the same single operation machines as the basic model but with the addition of two flexible machines. The first flexible machine can perform milling and lathe operations while the other is capable of performing drilling, grinding and EDM machining. The flow chart of the model is similar to that in Figure 5.2.1 (a). Figure 5.2.2 (a) to (f) shows the results of the simulation run.

a) Effect of slack on machine utilization.

Figure 5.2.2 (a) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack does not have an effect on machine utilization. Figure 5.2.2 (b) shows that the same pattern in a not busy job shop (5 parts/500 unit hours) although the machine utilization is lower than in a busy job shop.

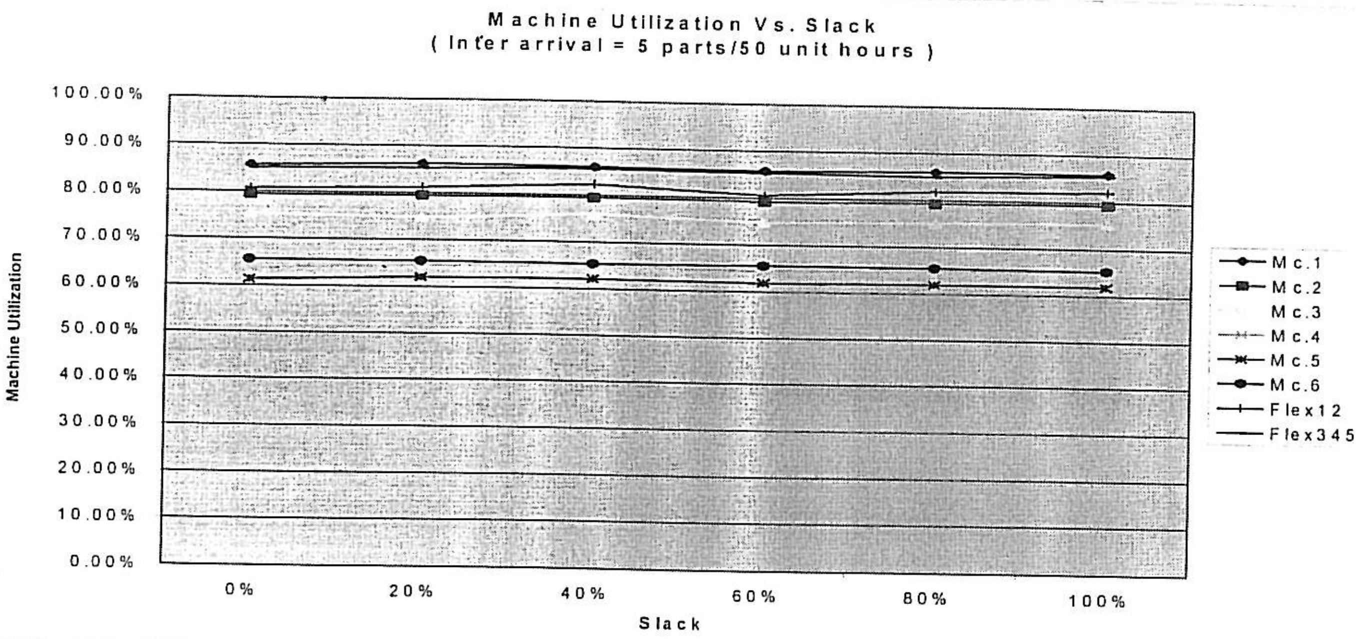

Figure 5.2.2 (a) Machine Utilization vs. Slack (Inter arrival rate = 5 parts/50 unit hours)

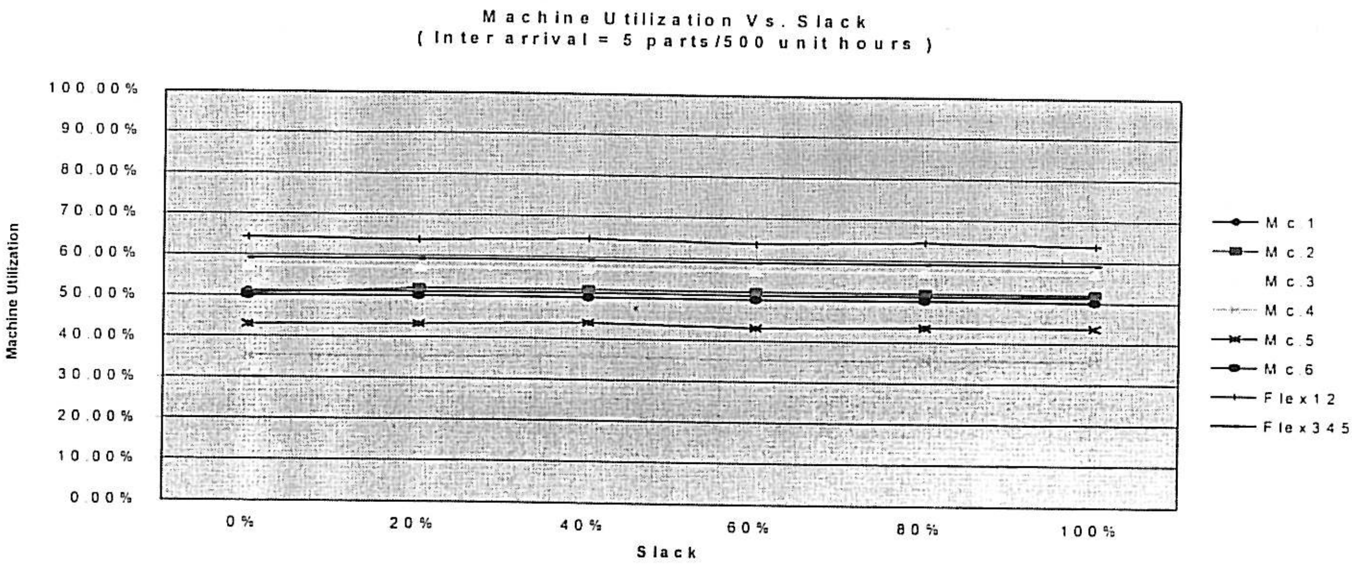

Figure 5.2.2 (b) Machine Utilization vs. Slack (Inter arrival rate = 5 parts/500 unit hours)

b) Effect of slack on number of tardy jobs

Figure 5.2.2 (c) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have an effect on number of tardy jobs. Number of tardy jobs decreases as slack increases. Figure 5.2.2 (d) shows the same behaviour in a not busy job shop (5 parts/500 unit hours) although the number of tardy jobs is lower than in a busy job shop.

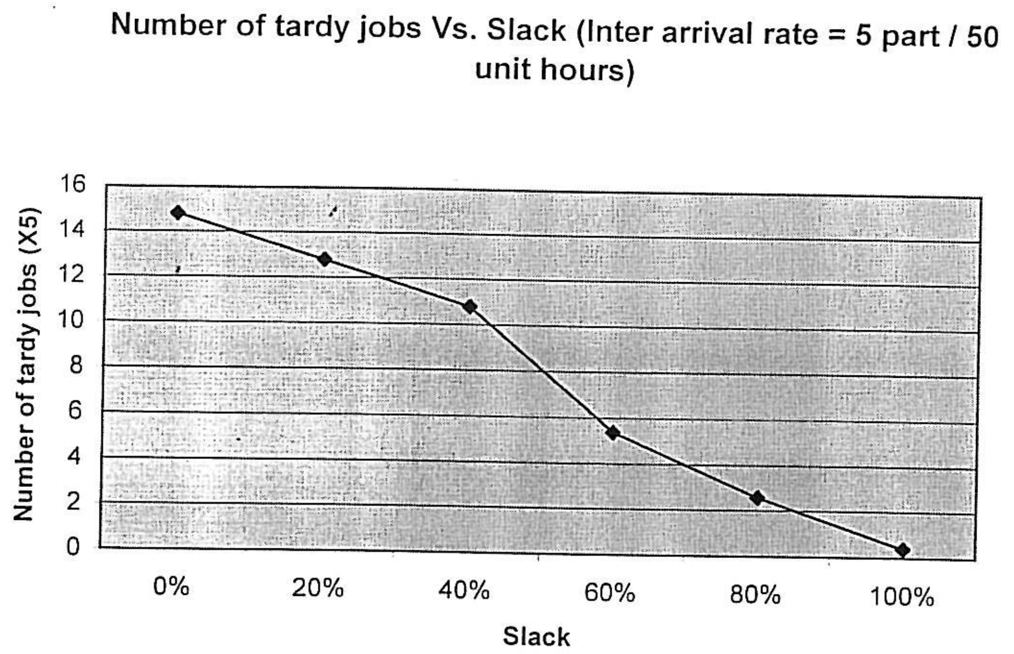

Figure 5.2.2 (c) Number of Tardy Jobs vs. Slack (Inter arrival rate = 5 parts/50 unit hours)

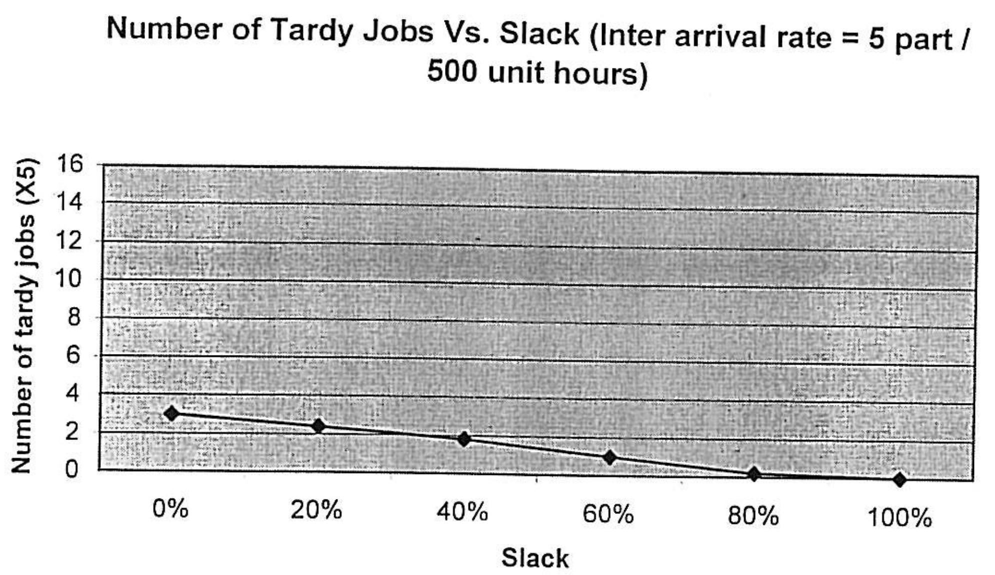

Figure 5.2.2 (d) Number of Tardy Jobs vs. Slack (Inter arrival rate = 5 parts / 500 unit hours)

c) Effect of slack on WIP

Figure 5.2.2(e) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have only slight effect on WIP. Figure 5.2.2 (f) shows that for a not busy job shop (5 parts/500 unit hours) the pattern is the same but with WIP higher than in a busy job shop.

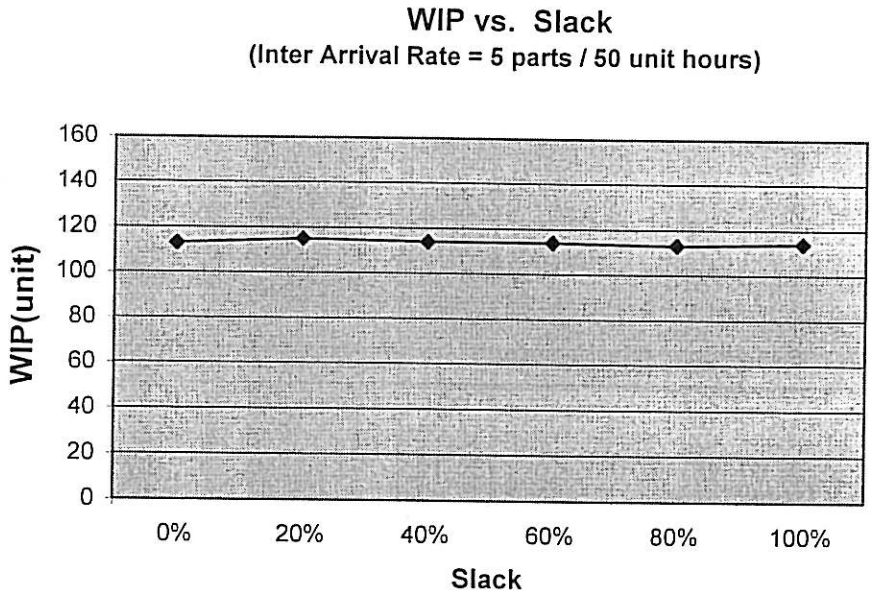

Figure 5.2.2 (e) WIP vs. Slack. (Inter arrival rate = 5 parts / 50 unit hours)

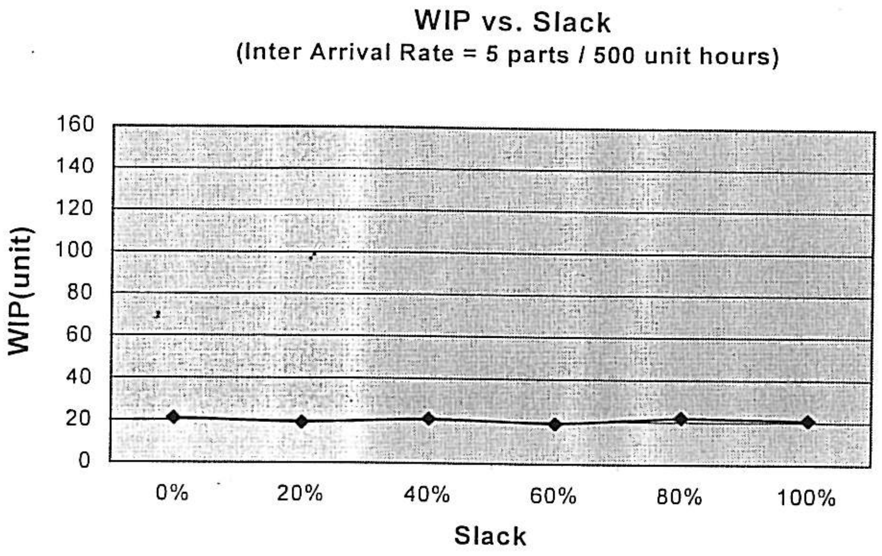

Figure 5.2.2 (f) WIP vs. Slack, (Inter arrival rate = 5 parts / 500 unit hours)

5.2.3 Replacement Strategy

The system consists of two flexible machines and one hardening machine. The first flexible machine is capable of performing milling and turning process while the other is capable of performing drilling, grinding and EDM process. Thus with just 3 machines the shop floor can still process a complete product.

The simulation model developed for replacement strategy is still similar as the previous strategy with the only difference is in the job shop machine configuration. Figure 5.2.3 (a) to (f) shows the results of the simulation experiments.

a) Effect of slack on machine utilization.

Figure 5.2.3 (a) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack does not have an effect on machine utilization. Figure 5.2.3 (b) shows that the same pattern in a not busy job shop (5 parts/500 unit hours) although the machine utilization is lower than in a busy job shop.

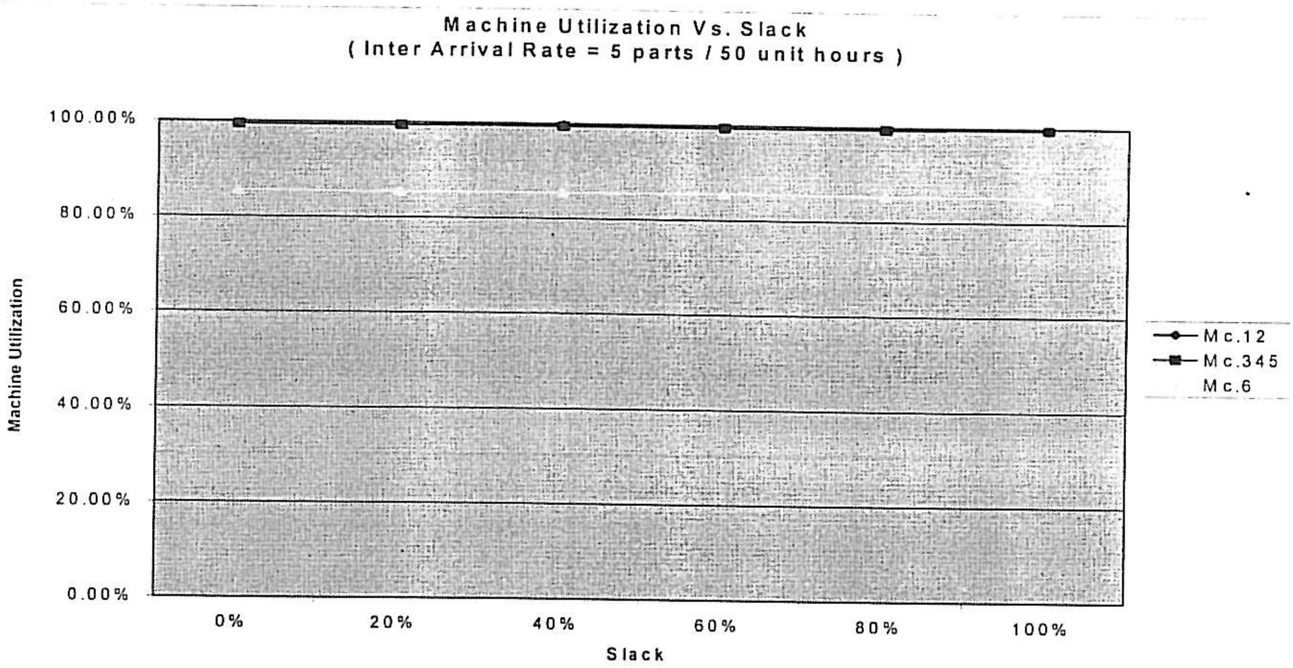

Figure 5.2.3 (a) Machine Utilization vs. Slack. (Inter arrival rate = 5 parts/50 unit hours)

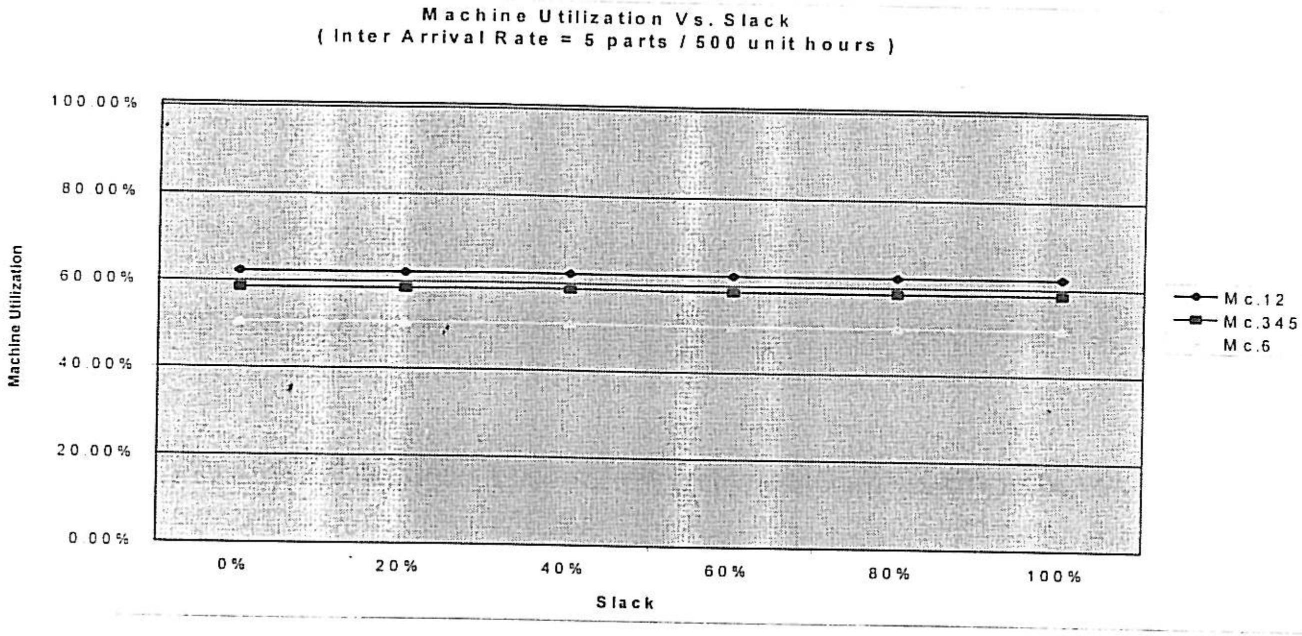

Figure 5.2.3 (b) Machine Utilization vs. Slack. (Inter arrival rate = 5 parts/500 unit hours)

b) Effect of slack on number of tardy jobs

Figure 5.2.3 (c) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have no effect on the number of tardy jobs. Figure 5.1.2 (d) shows that the same pattern persisted in a not busy job shop (5 parts/500 unit hours) although the number of tardy jobs is lower than in a busy job shop.

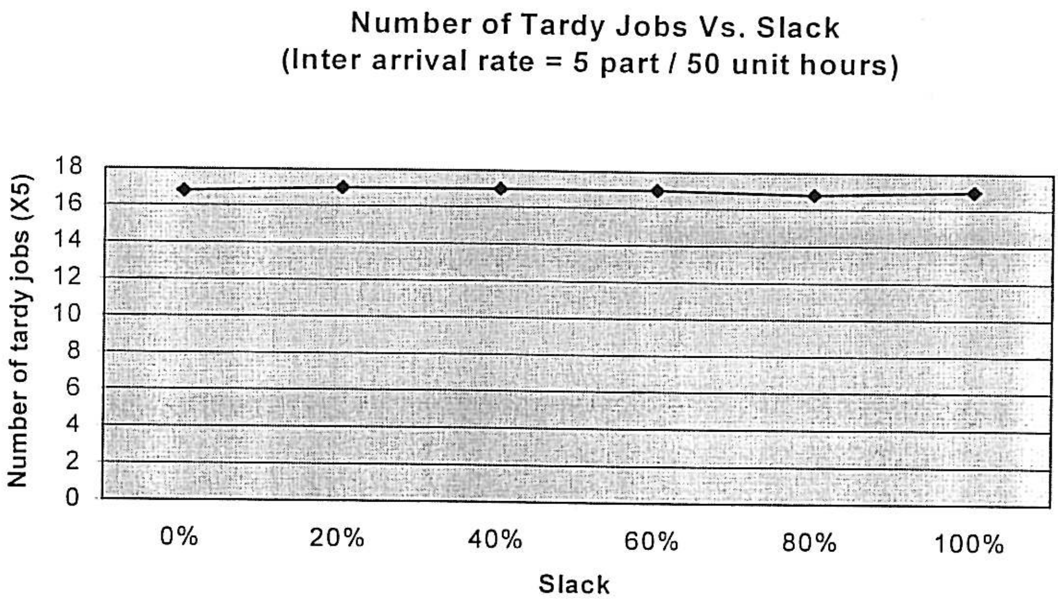

Figure 5.2.3 (c) Number of Tardy Jobs vs. Slack (Inter arrival rate = 5 part / 50 unit hours)

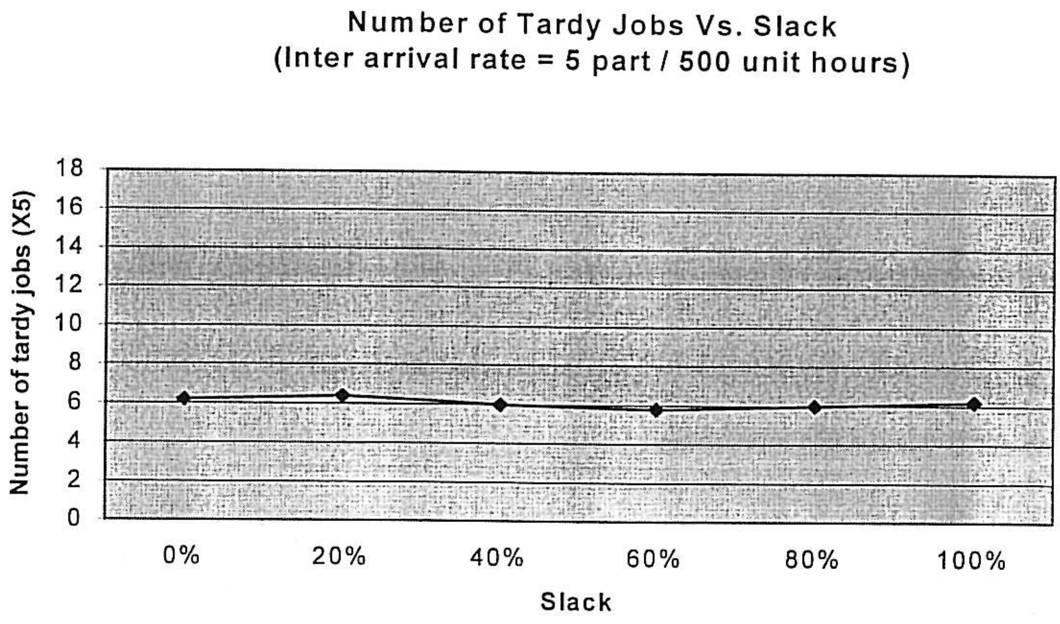

Figure 5.2.3 (d) Number of tardy jobs vs. Slack (Inter arrival rate = 5 parts/500 unit hours)

c) Effect of slack on WIP

Figure 5.2.3 (e) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have no effect on WIP. Figure 5.1.2 (f) shows the same pattern in a not busy job shop (5 parts/500 unit hours) although WIP is higher than in a busy job shop.

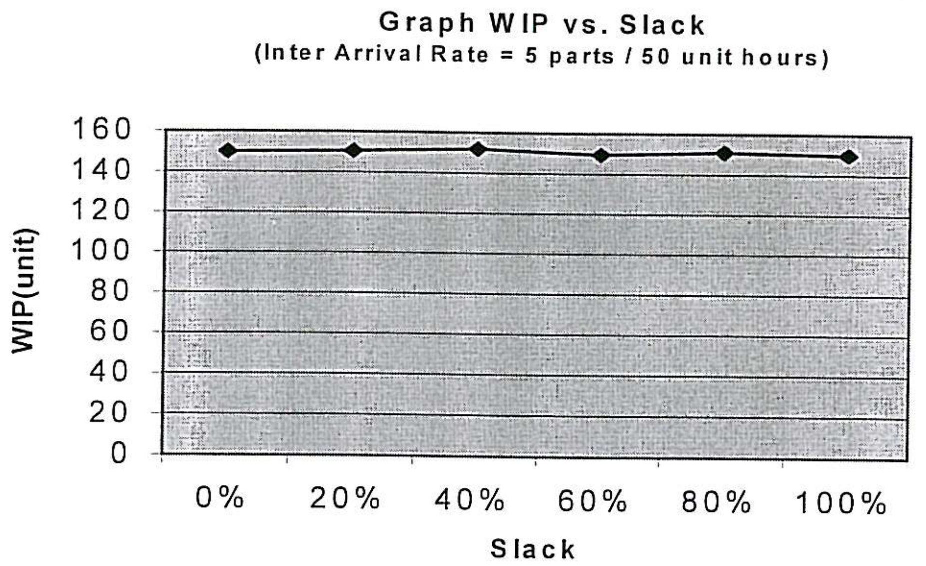

Figure 5.2.3 (e) WIP vs Slack (Inter arrival rate = 5 parts / 50 unit hours)

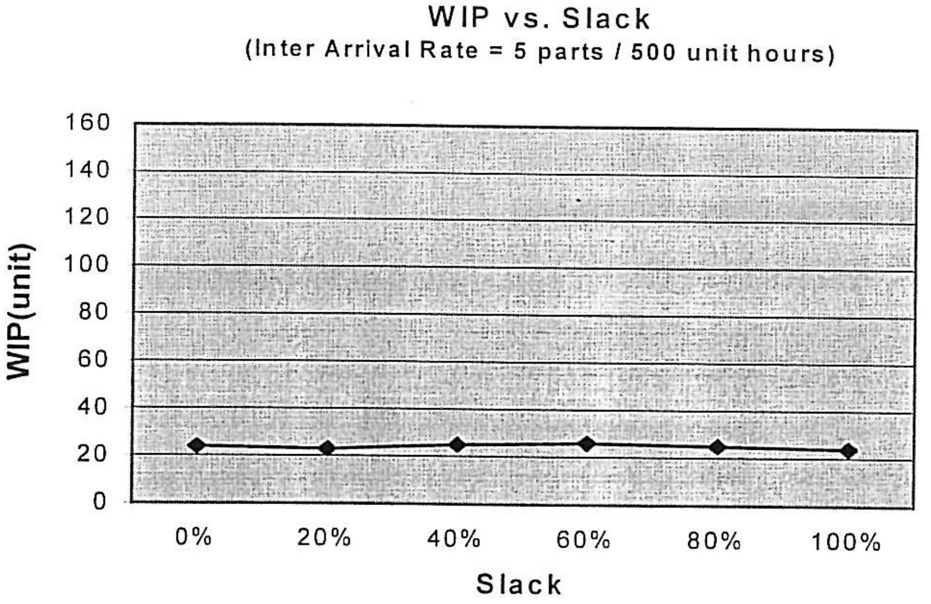

Figure 5.2.3 (f) WIP vs. Slack (Inter arrival rate = 5 parts / 500 unit hours)

5.2.4 Fully Flexible Strategy

In this strategy the job shop consists of six fully flexible machining work-center. Each machining center is capable of performing all six types of machining processes (mill, lathe, drill, grind, EDM and hardening). The job shop does not have any single operation machines. Incoming parts will be routed to any available machine in the system since each machine is capable of processing any incoming part. The flow chart for this model is similar to Figure 5.2.1 (a) except in the configuration of the job shop. Figures 5.2.4 (a) to (f) shows the results of the experimentations on the model.

a) **Effect of slack on machine utilization.**

Figure 5.2.4 (a) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack does not have any effect on machine utilization. Figure 5.2.4 (b) shows that the same pattern in a not busy job shop (5 parts/500 unit hours) although the machine utilization is lower than in a busy job shop.

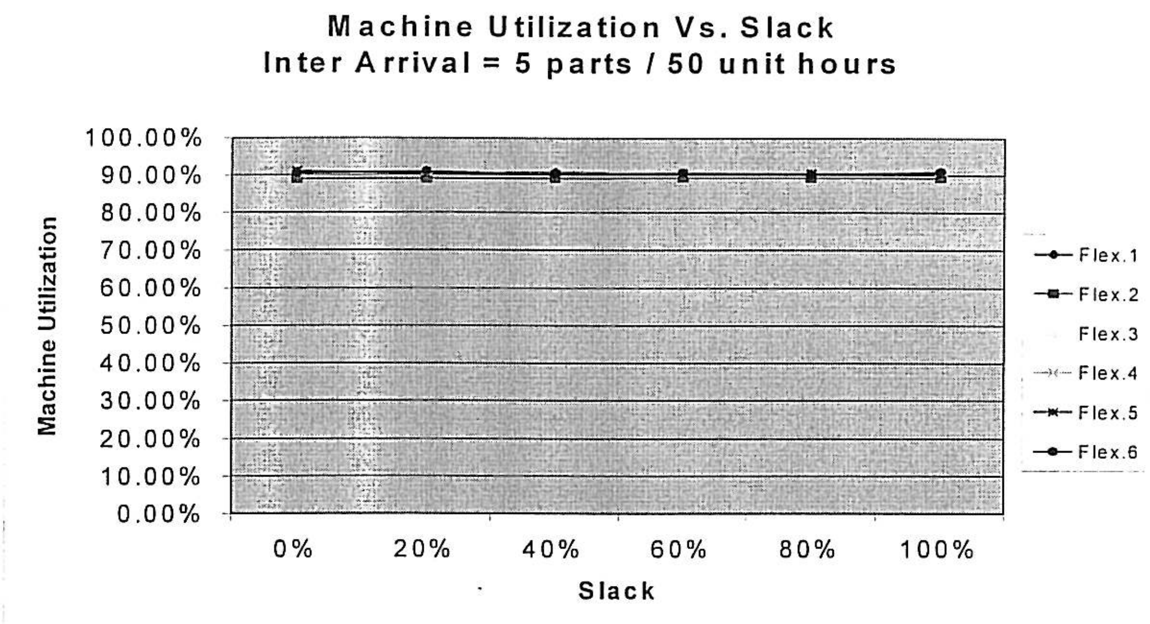

Figure 5.2.4 (a) : Machine Utilization vs. Slack (Inter arrival rate = 5 parts / 50 unit hours)

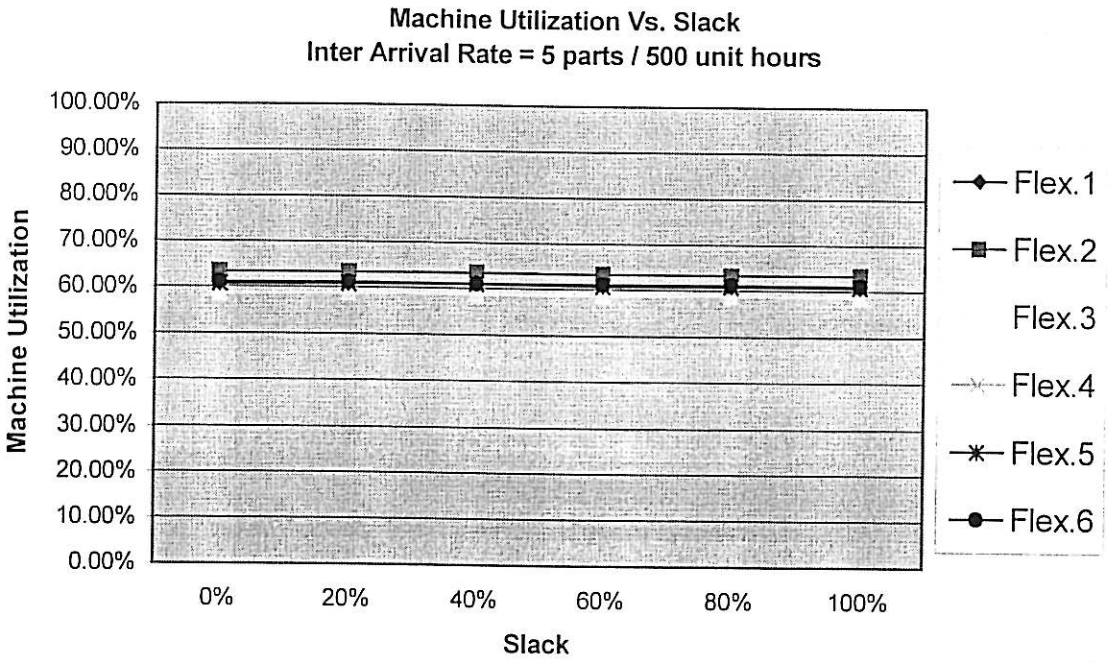

Figure 5.2.4 (b) : Machine Utilization vs. Slack. (Inter arrival rate = 5 parts/500 unit hours)

b) Effect of slack on number of job tardy

Figure 5.2.4 (d) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have an effect on the number of tardy jobs. The number of tardy jobs decreases as slack increases. Figure 5.2.4 (e) shows the same pattern in a not busy job shop (5 parts/500 unit hours) although the number of tardy jobs is lower than in a busy job shop.

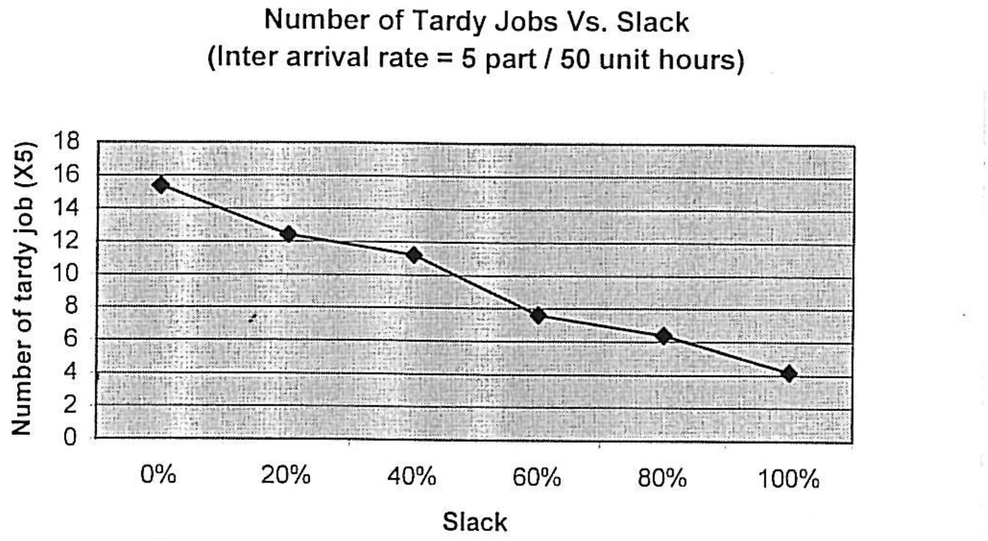

Figure 5.2.4 (d) : Number of Tardy Jobs vs. Slack. (Inter arrival rate = 5 parts/50 unit hours)

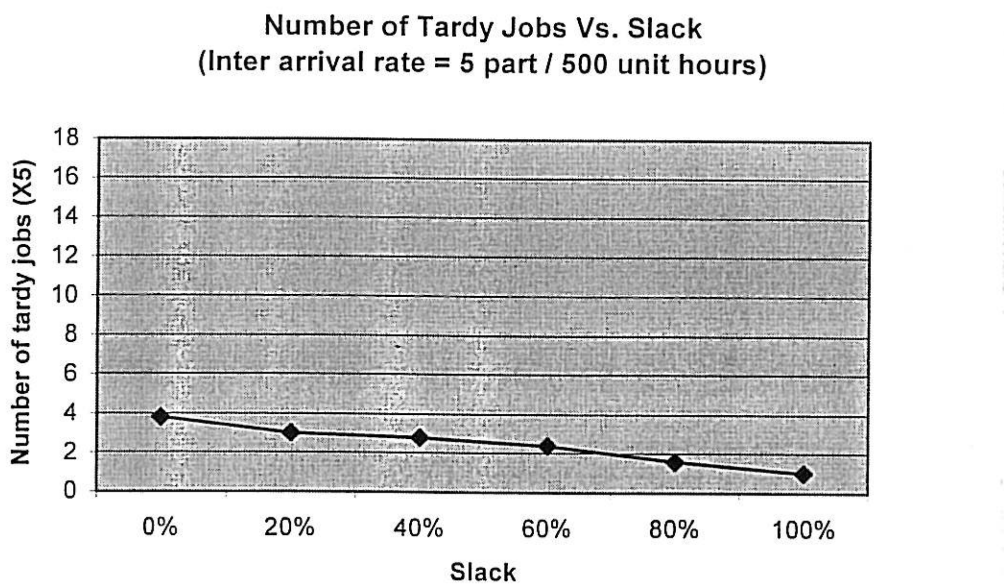

Figure 5.2.4 (d) : Number of Tardy Jobs vs. Slack. (Inter rrival rate = 5 parts/500 unit hours)

c) Effect of slack on WIP

Figure 5.2.4 (e) shows that for a busy job shop (5 parts/50 unit hours), changes in percentage slack have no effect on WIP. Figure 5.2.4 (f) shows that the same pattern in a not busy job shop (5 parts/500 unit hours) although WIP is higher than in a busy job shop.

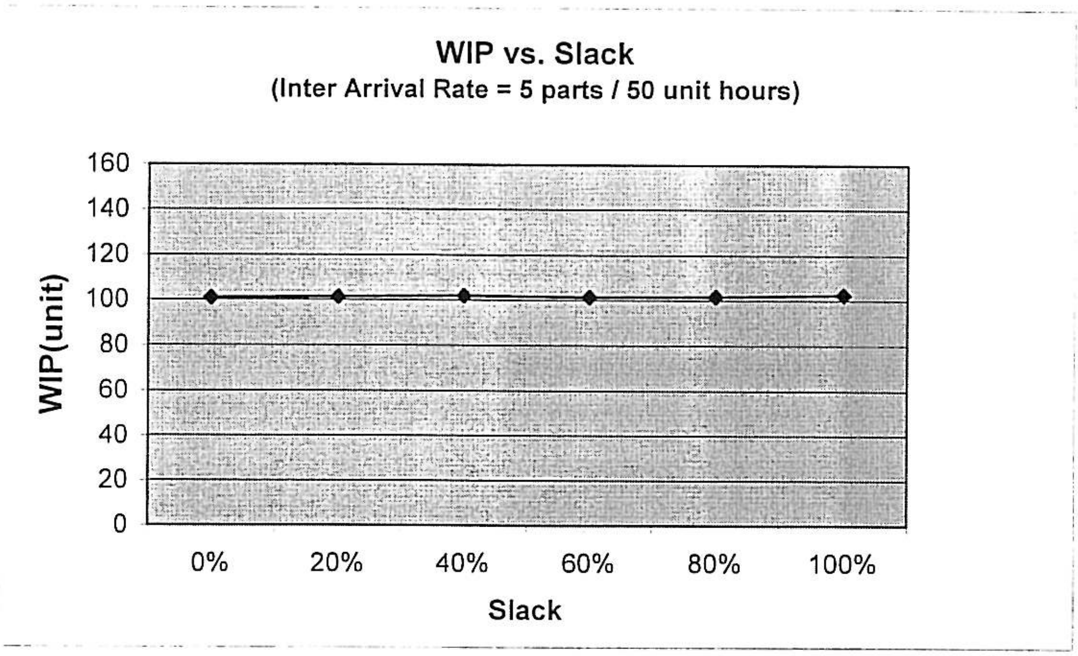

Figure 5.2.4 (f) : WIP vs. Slack. (Inter arrival rate = 5 parts/50 unit hours)

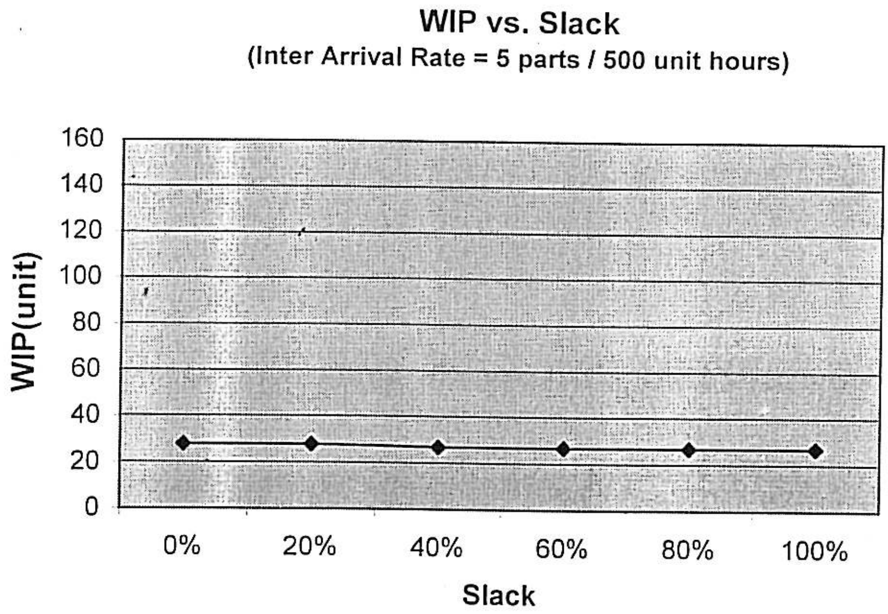

Figure 5.2.4 (f) : WIP vs. Slack. (Inter arrival rate = 5 parts/50 unit hours)

5.3 Comparison Between Strategies

This section discusses the performance of the five strategies in comparison with each other based on the performance measure of number of tardy jobs, machine utilization and WIP. The performance of each strategy is ranked as first, second, third, fourth and fifth from the best to the worst according to their performance measure. There are two extreme conditions which will be compared: a very low demand job shop where interarrival rate is low (5 parts/500 unit hours) with a high slack of 100% and another extreme is a very demanding job shop with very high inter arrival rate (5 parts/50 unit hours) and percentage slack of 0 %.

a) Low demand (low inter arrival rate and high percentage slack)

Referring to Table 5.3 (a) in terms of the number of tardy jobs, duplication strategy rank first as being the strategy with the lowest number of tardy jobs, followed by basic + flexible strategy, basic strategy, fully flexible strategy and the worst performance is by the replacement strategy.

In the case of WIP, duplication strategy still rank first followed by basic + flexible strategy, basic strategy, fully flexible and the strategy with the highest WIP is replacement strategy.

For machine utilization, replacement strategy perform best with the highest machine utilization followed by basic strategy, duplication strategy, fully flexible strategy and finally basic + flexible strategy.

Table 5.3 (a) : Table of Performances Measure comparison under low inter arrival rate and high percentage of slack (low demand job shop).

RANKING	**PERFORMANCE MEASURES**		
	Number of tardy jobs	**WIP**	**Machine utilization**
1ST	Duplication	Duplication	Replacement
2ND	Basic + Flexible	Basic + Flexible	Basic
3RD	Basic	Basic	Duplication
4TH	Fully Flexible	Fully Flexible	Fully Flexible
5TH	Replacement	Replacement	Basic + Flexible

b) High demand (high inter arrival rate and low percentage slack)

Referring to Table 5.3 (b) the ranking of each strategy in terms of number of tardy jobs, WIP and machine utilization is still the same as for a low demand job shop. Thus the results are consistence and shows that the result does not depend on whether a job shop is demanding or not.

Table 5.3 (b) : Table of Performances Measure comparison under high inter arrival rate and low percentage of slack (very demanding job shop).

RANKING	PERFORMANCE MEASURES		
	Number of tardy jobs	**WIP**	**Machine utilization**
1ST	Duplication	Duplication	Replacement
2ND	Basic + Flexible	Basic + Flexible	Basic
3RD	Basic	Basic	Duplication
4TH	Fully Flexible	Fully Flexible	Fully Flexible
5TH	Replacement	Replacement	Basic + Flexible

5.4 Proposed Guideline

The ranking of each startegies against each other can be presented in a web graph as illustrated in Figure 5.4. It shows the most appropriate strategy for a particular performane measure.

- **Number of tardy jobs**

If the priority of a job shop is to achieve the lowest number of tardy jobs, then the best strategy in increasing the job shop's capacity is the duplication strategy. This strategy involves adding another identical single operation machine to the bottleneck process. However in this strategy the low number of tardy jobs is achieved at the cost of a much lower machine utilization.

The worst strategy a job shop may adopt under this performance measure is the replacement strategy. This strategy involves replacing a few machine with one that is capable of the same number of processes that the machine replaces.

- **Work In Process (WIP)**

If the priority of a job shop is to achieve the lowest level of WIP in the system, then the best strategy in increasing the job shop's capacity is the duplication strategy. However, the low WIP level is achieved at the cost of a much lower machine utilization. This strategy involve adding another identical single operation machine to the bottleneck process.

The worst strategy a job shop may adopt under this performance measure is the replacement strategy. This strategy involves replacing a few machines with one that is capable of the same number of processes that the machine replaces.

- **Machine utilization**

If the priority of a job shop is to maximise machine utilization, then the best strategy is the replacement strategy, that is, replacing all the single operation machines with a few multi-operation machines but together they are capable of performing all the required operations to complete a product. However, the high machine utilization is achieved at the cost of high number of tardy jobs and WIP. The worst strategy for maximum machine utilization is the basic + flexible strategy.

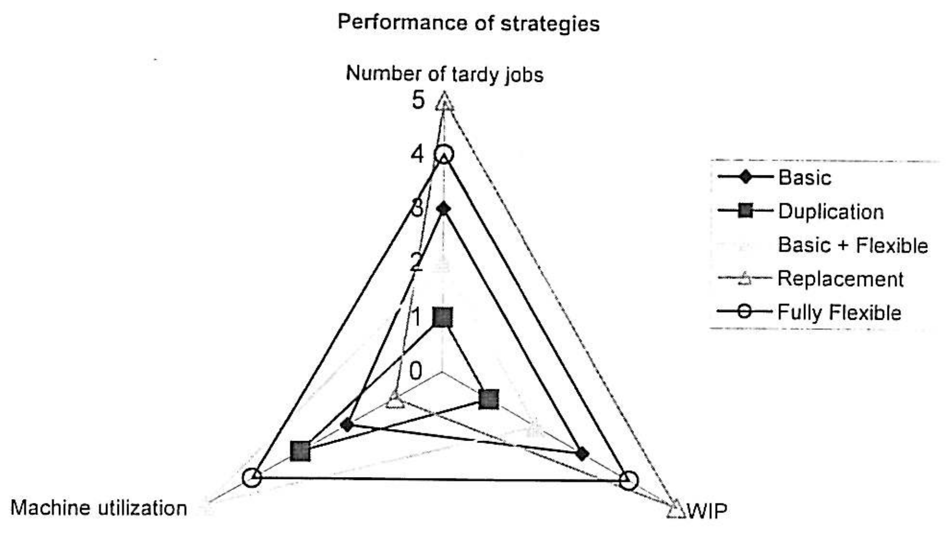

Figure 5.4 Ranking of strategies

There is no one strategy that yielded the best in all three performance measures. The strategy (duplication) that resulted in the best number of tardy jobs and WIP ranked third in machine utilization. While the strategy (replacement) that resulted with the best machine utilization ranked the worst with number of tardy job and WIP. Thus management needs to identify its priority such as minimize number of tardy jobs, minimize WIP or maximize machine utilization.

The existing strategy (basic) is not the worst nor the best strategy. However, should the company decide to increase its capacity the best strategy would be the duplication strategy, that is to add identical machine to the bottleneck machine. Investing in advanced or high tech flexible or multi operation machines does not seem to yield the desired performance. This is probably due to the random nature of a job shop.

5.5 Conclusion

The results of the simulation shows that there is no one strategy that ranked the best for all three performance measures. Decision on the best strategy depends on the performance measure that a company chooses. However the guideline proposed will assist management in making these decisions.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Introduction

This chapter summarizes the research and its outcome. The discussion starts with research findings followed by limitations of the study and recommendations for future research.

6.2 Research Findings

The objective of the research is to investigate the impact of various manufacturing strategies on a job shop based on three manufacturing performance measure, that is number of tardy jobs, WIP and machine utilization. The conditions the job shop is subjected to are slow and fast rate of incoming parts and low to high level of slack.

The results show that none of these strategies produced the best results for all three performance measures. Table 6.2 shows the ranking of these strategies. This can be a guideline to job shop management in selecting the best strategy depending on the performance measure that they desire.

Table 6.2 Summary of results.

RANKING	PERFORMANCE MEASURES	
	Number of tardy jobs and WIP	**Machine utilization**
1	Duplication	Replacement
2	Basic + Flexible	Basic
3	Basic	Duplication
4	Fully flexible	Fully flexible
5	Replacement	Basic + Flexible

6.3 Limitations Of Study

Some of the limitations identified are :

1. The research conducted is focused on job shop manufacturing system and thus the results are only applicable to job shop manufacturing system.

2. The despatching rule used is First come First Serve.

3. The result is based on the assumption that all machines produce the same level of acceptable quality.

6.4 Recommendations for Future Work

The following are the possible direction of future work related to this research.

1. Study on cost analysis of each strategy.

In this research the cost factor of each strategy were not made. Perhaps cost analysis will yield a different ranking.

2. Study the effect of process capabilities.
   In this research it is assummed that single operation machines will produce the same level of quality product as its flexible, multi operations counterparts. The processing time is also assumed to be constant. Further research should be conducted if these are not the case.

3. Study the effect of number of machines in the system to the system's effectiveness.

6.5 Conclusion

Overall, this research has provided a guideline or recommendation for job shop management on the appropriate manufacturing strategy that suits specific criteria of performance measure. At the same time the research has addressed the effect of manufacturing capacity flexibility on a job shop system. Thus it has fulfilled the objective of research.

REFERENCE

Arumugam V., (1985),"A simulation study of job shop scheduling", Modeling, Simulation & Control , AMSE Press, Volume 3, No.2, pp.13-27.

Volume 16, Issue 12, pp. 902.

Baker, K.R., (1994), "Sequencing rules and Due Date assignments in a job shop", Management Science, 30,1093-1104.

Baker, K.R. and Scudder, G.D.,(1990), "Sequencing with earliness and tardiness penalties: a review", Operation Research, 38, 22-36.

Ballakur A., (1993), " Integration of job shop control system: a state of the art_review", Journal of manufacturing System, Vol.3, No.1.

Ballakur A. and Steudel, H.J.(1993), Integration of Job Shop Control System: state of the Art Review, Journal of Manufacturing System, Vol. 3, No.1.

Banks, J., Carson, J.S.,(1986) "Introduction to discrete event simulation", Proceeding: 1986 Winter Simulation Conference, Association for Computing Machinery, N. York, 17-23.

Browne J., Dubious D., Rathmill K., Sethi S.P., Stecke K.E. (1984), " Classification of Flexible manufacturing System", The FMS Magazine, 2 , 114-117.

Chen, H., Ihlow J. and Lehmann, C.(1999), A Genetic Algorithm for Flexible Job-Shop Scheduling", Proceeding of IEEE, International Conference on Robotics and Automation.

Conway, R., Maxwell,W.L. and Miller, L.W.,(1987), "Theory of Scheduling" (Addison Wisely, Reading, MA).

Cho, H. and R.A. Wysk (1993), " Arobust Adaptive Scheduler for an Intelligent Workststion Controller", International Hournal of Production Research, Vol.31, No.4, pp.771-789.

Dar-El, E.M., and Wysk R.A., (1982), " Job Shop Scheduling- A Systematics Approach", Journal of manufacturing System, Vol:1, pp77-88.

Degarmo E.P., Sullivan W.G., Bontadilli J.A. and Wicks E.M.(1996), "Engineering Economy"Tenth Edition, Prentice Hall.

De Souza, R. (1995), "Intelligent optimization of component insertion in multi-head concurrent operation PCBA machines", Journal of Intelligent Manufacturing, Vol.6, pp. 235-243.

Dorndorf, U (1995), " Evolution Based Learning in Job Shop Scheduling Environment", Computer Ops. Res. 22, 25-40.

Drobouchevith I.G., (2000), "Heuristic for the two stage job shop scheduling problem with a bottleneck machine", European Journal of Operation Research, Vol:123, pp.229-240.

Dubious D.(1995), "Fuzzy Constraint in job-shop scheduling", Journal of Intelligent Manufacturing, Vol:6, pp. 215-234

Glenn R. D. and Peters, B.A. (1998), "Simulation As A Planning Tool For Flexible Manufacturing System", International Journal Production Research, Vol. 8, 657-663.

Haupt. R. (1989). " A survey of priority rule-based scheduling", OR Spektrum, 11,3-16

Haq, Faizul (1994), "The sensitivity of rule combination for scheduling in a hybrid job shop", International Journal of Operation and Production Management, Vol.15 No.3, pp 59-75.

He Zesheng, (1996), "An exchange heuristic imbedded with simulated annealing for due date job-shop scheduling". European Journal of Operation Research,Vol:91, pp. 99-117.

Ingalls R. G. (2001), "Introduction to Simulation", Proceeding of the 2001Winter Simulation Conference, B.A. Peters, J.S. Smith, D.J. Medeiros, and M.W. Rohrer, eds.

Rowe. (1958)," Sequential decision rules in production Scheduling", Unpublished Ph.D Dissertation.

Ip W.H., et. al (1999),"An Investigation of Stochastic Analysis of Flexible Manufacturing Systems Simulation",Volume:15, pp 244-250, International Journal of Advance Manufacturing Technology.

Jain A.S., (1999). "Deterministic job-shop scheduling: past, present and future", European Journal of Operation Research, Vol.: 113, pp.390-434.

Jones A, Robelo L, and Y. Yuehwern, (1995), "A Hybrid Approach For Real Time Sequencing and Scheduling", International Journal of Computer Integrated Manufacturing", Vol.8, No.2, pp.145-154.

Kiran A.S., (1997), " Designing Job-Shop Production Systems with Q-GERT Simulation". AIEE Transaction. Vol:23, No.9,pp157-163.

Luh B.P and Zhao,X.(1998), "Lagrangian Relaxation Neural Network for Job Shop Scheduling", Proceeding of IEEE, International Conference on Robotics and Automation.

Lun M. and Chen F.F. (2000),"Holonic Concept Based Methodology for Part Routing on Flexible Manufacturing System",Volume:16, pp 483-490, International Journal of Advance Manufacturing Technology.

Matsurra, H., Tsubone, H., and M. Kanezashi (1993), " Sequencing. Dispatching and Switching In a Dynamic Manufacturing Environment. " International Journal Of Production Research, Vol.31, No.7, pp. 1671-1688.

Nagar, A., Haddock, J. and Heragu,S., (1995)"Multiple and Bacteria Scheduling", European Journal of Operation Research, 81, 88-104.

Nahmias,S. (1997), "Production and Operations Analysis", McGraw-Hill, New York. pp398-406.

Newman,W.R (1999),"Managing the job Shop: simulating the effect of flexibility, order release mechanism and sequencing rules", International Journal of Operation and Production Management,Vol.5, No.10,pp266-275.

Nof, S.Y.(1985) "Handbook of Industrial Robotics",John Wiley and Sons, (N. York), pg.471

Nuijten, W.P.M(1996). " A Computational study of constraint satisfaction for multiple capacitated job shop scheduling", Eueropean Journal of Operational Research, 90. 269-284.

Oey, K. and Mason S.J.(2001), "Scheduling Batch Processing Machine in complex Job shop", Proceeding of the Winter Simulation Conference, , B.A. Peters, J.S. Smith, D.J. Medeiros, and M.W. Rohrer, eds.

Panwalker, S. S., and Iskander, W.,(1977)," A Surveying of Scheduling Rules", Operation Research, 25, 45-61.

Proud, J.F., (1994)" A Practical Guide to Competative Manufacturing", John Wiley and Sons, pg. 313-315.

Ramasesh, R., (1990), " Dynamic Job Shop Scheduling: a survey of simulation research", OMEGA International Journal of Management Science, 18, 43-57.

Randhawa, S.U. and Zeng,Y.,(1996), " Job Shop Scheduling: experimental investigation of the performance of alternative scheduling rules", Production Planning and Control, 7, 47-56.

Russel R.S., Dar-El, E.M. and Taylor, III, B.M., (1987), "A Comparative Analysis of the CONVERT job sequencing rule using various shop performance measure", Int. Journal of Production Research, 25, 1523-1540.

Sadeh N.,(1996), " Variable and value ordering heuristic for the job-shop scheduling constraint satisfaction problem", Artificial Intelligence, Vol:86, pp. 1-41.

Sanjay V. Mehta and Reha M. Uzsoy (1998), " Predictable Scheduling of Job Shop Subject to Breakdown", IEEE transction on Robotics and Automation, Vol.14, No.3

Selladurai V.,(1994), "Dynamic simulation of job shop scheduling for optimal performance", International Journal of Operation and Production Management, Vol. 15, No.7, pp 106-120.

Sethi, A.K. and Sethi, S.P.(1990), "Flexibility in Manufacturing a Survey", The International Journal of Flexible Manufactdring System, Vol.2 , pp. 289-328.

Shannon, R.E.., (1975), System simulation-The Art and Science, Prentice-Hall

Shanon R.E. and Pegden C.D(1995), "Introduction to Simulation Using Siman", McGraw-Hill, Inc., New York, pp167-171.

Son, Y.K. and Park C.S. (1987), "Economics Measure of Productivity, Quality and Flexibility in advanced Manufacturing System", Journal of Manufacturing System, Vol.6. No.3.

Steinhofel K.,(1999), " Two simulated annealing-based heuristic for the job shop scheduling problem", European Journal of Operation Research, Vol:188, pp. 524-548.

Steke, K.E. and J.J. Solberg. (1981), " Loading and Control Procedure For Flexible Manufacturing System", Int. Journal of Production Research, No.19, 481-490.

Subramaniam V., et.all (2000), "Machine Selection Rules in a Dynamics Job Shop", International Journal of Manufacturing Technology, Vol.16, pp.902-908

Subramaniam V., Ramesh T., Lee Wong Hong (2000), "Job Shop Scheduling with Dynamic Fuzzy Selection of Dispatching Rules",Volume 16, Issue 10, pp 759-764 International Journal of Advanced Manufacturing Technology

Subramaniam V. , Ramesh T., Lee Hong Wong (2000 b),"Machine Selection Rules in a Dynamic Job Shop", International Journal of Advanced Manufacturing Technology.

Sun D., (1995), "Effective job shop scheduling through active chain manipulation", Computer Ops. Res. Vol:22, No.2, pp. 159-172.

Watanabe,T. , H.Tokumaru and Y.Hashimoto, (1993), "Job-Shop Scheduling using Neural Network", Control Engineering Practice, Vol:1, No:6, pp957-961.

Wein, L.M., and Chevalier, P.B. (1992), "A broader view of the job-shop scheduling problem", Management Science,38,1018-1033.

Werner F., (1995), " Insertion techniques for the heuristic solution of the job shop_problem", Discrete Applied Mathematics, Vol:58, pp.191-211.

Williams T.M., Roda J.E., (1994), "Neural Network for Job-Shop Scheduling", Control Engineering Practice, Vol:2, No:1, pp31-39.

Wu, D.S. and R.A. Wysk (1989)," An Application of Discrete- Event Simulation to On-line Control and Scheduling in Flexible Manufacturing", International Journal of production Research, Vol.27, 1603-1624.

Xu Z., Randhawa S.,(1998) " Evaluation of Scheduling Strategies for a Dynamics Job-Shop in a Tool-Shared Flexible Manufacturing Environment", Production Planning and Control, Vol:19, No:1, pp74-86.

Yamamoto, M. and Nof S. (1985), " Scheduling and Rescheduling in the Manufacturing Operating System Environment', International Journal of Production Research, Vol.23, pp. 703-713

APPENDIX A

(Adopting flexibility in sequencing rules for better job shop system performance)

Adopting Flexibility ~~in Sequencing Rules for Better~~ Job Shop System Performance

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Abstract

The global era of manufacturing competition and product diversification lead towards many types of manufacturing strategies and selection. However, selecting a very appropriate yet practical manufacturing system strategies will be based on type of manufacturing been practiced and the performance measured which been emphasized most. Whereas, a multi million dollar which been invested in new and sophisticated manufacturing system will just be a redundant and waste of money. This research will be focusing in selecting type of manufacturing system for Mold and Die Company, which practicing job shop manufacturing system. The objective is to reduce number of job tardy in the system, increase resources utilization and to minimized work in progress. To verify the advantages and disadvantages of each manufacturing system proposed, a simulation programming is been used and the result of the simulation output will be used for general guideline in selecting type of manufacturing system for the Mold and Die Company under study.

Keywords

Job Shop, Simulation, Mold and Die, WITNESS.

Introduction

In fact, manufacturing sector is becoming more competitive. Capability of competing in global market has become a main thrust in achieving their successful manufacturing goals or objectives (Nabil, N.G, 1998). Manufacturing companies are required to fulfill customer driven imperatives such as higher product quality, timeliness, product variety and compete globally (Nabil, N.G.,1998). In order to achieve these desired characteristics, manufacturers need to be responsive, flexible and able to produce good quality product with lesser lead-time. The strategies used to achieve that desired characteristics will be differed according to the different types of manufacturing system. Traditionally, manufacturing systems can be categorized into three major categories, they are *flow shop, batch shop and job shop* (Shimon Y. N, 1985). Unlike the flow and batch shop, the job shop manufacturing system is considered to be unique because its routing and process sequence are not identical for each product released (Faizul.H, 1994).

The job shop is usually used in manufacturing processes, which consist of high product variation with small number of product quantity where each product will have its own process routing and each routing rarely will be exactly the same to each other. (Elvers D.A. 1983). In spite of its routing uniqueness, the job shop needs a systematic scheduling technique or strategy so that customers' and manufacturers' satisfaction can be achieved.

This research will attempt to evaluate the effect of flexible routing and sequencing rules in job shop scheduling system on system's performance such as the reduction of number of job tardy and machine utilization.

Research Background

A job shop is a discrete parts manufacturing facility of fixed production capacity in which component (in low volume) for different orders frequently arrive at irregular intervals, and follow different sequence through the resource centers (machine), grouped by function in order to accommodate varying customer- specialized requirement and fluctuation in demand for product and service, V.Selladurai (1995). The characteristic of a job shop can be summarized as Figure: 1

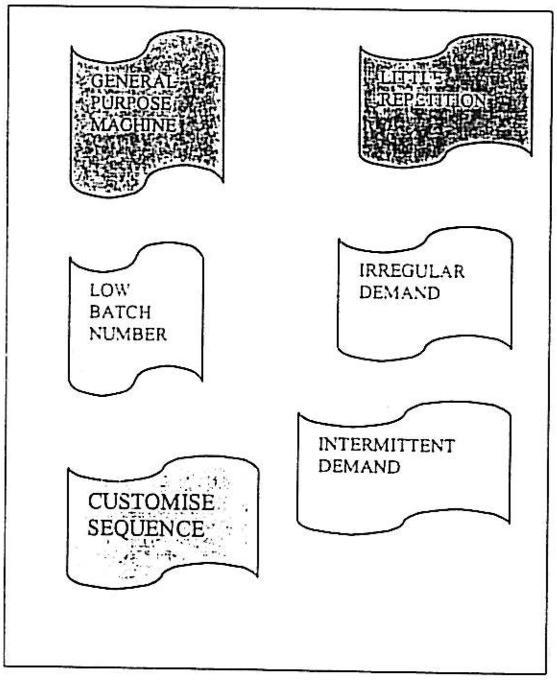

Figure: 1

The uncertainties in job shop manufacturing system basically come from the type and nature of the product, timing of order release and priority of product due date (Nuijten W.P.M, 1996). Due to this uncertainty and unpredictability, better system planning and scheduling need to be emphasized to improve system performance.

Common challenges faced by job shop manufacturing system are to avoid late job completion time and poor planning and manufacturing control, (John F.P, 1994). The technique, which will be used to handle the challenges of job shop in this research are sequencing rules and routing flexibility.

Sequencing rules

Common mechanism used to control the flow of jobs through the shop is the application of sequencing rules. The rules are used by the manufacturer to prioritize jobs locally at each workstation. Traditionally, simple rules have been used that generally perform well on machine utilization and on time delivery. For instance, some of common ones includes first come first serve (FCFS), shortest processing time (SPT), nearest due date (DD) and critical ratio (CR), (Dorndrof, U.1995).

Routing Flexibility

In a job shop manufacturing process, each customized part will have its own machining routing. Thus, the meaning of routing flexibility in this research is in how the machine (machining flexibility) or the product (product flexibility) itself can be reroute to other alternative routing (Kanet, J.J., Hayya, J.C.,1998.) This routing will determine how the product will follow from one process to another until the completion of the product type.

Increase flexibility is another approach manufacturers have taken to deal with uncertainty. Along with cost, quality and dependability, flexibility is seen as competitive priority for manufacturing, (Hill.C, 1994). One problem in understanding flexibility may be the many dimension by which it can be defined and the various ways in which it can be applied. In conducting this research, the flexibility will be focused on a specific type of flexibility to achieve meaningful result where the number of alternate machine selection will be the level of product routing flexibility.

Additionally, routing flexibility improve manufactures' ability to handle changes or variations in product mix since more than one set of equipment is available (Brown, et al. 1984). Moreover, if volume for one type of product change, the impact of the change can be spread over a variety of work-centers (Brown, et al. 1984).

Statement of Problem / Research

Problem Statement

Job shop manufacturing is well known for its uniqueness in producing customizes product. Each product will have its own production routing and sequencing procedure. In fact, these uniqueness entities contribute to very complex job shop floor management because of unpredictable timing and routing for each customizes product. In this research, the adoption of routing flexibility is been tested for complex job shop system and at the same time performance measure such as number of job tardy in the system will be measured.

Research Question

- What are the relative effects of sequencing rules and routing flexibility on a system's performance?
- How the job shop can be better managed to deal with uncertainty?
  (E.g. variability/alternative in routing)

Variable Involved

There are three types variable involved in this research:

Independent Variables are variables, which influence dependent variable.

- Order Release
- Sequencing rules
- Routing Flexibility

Dependent Variables are variable which influenced by *independent* variables

- Time in the system
- Tardiness
- Number of job tardy

Structural Variables and system specification variables.

- Number of machine in the job shop.
- Total operation hour.
- Number of job replication

Research Hypothesis

H1: Different type manufacturing system has significant impact to job shop performance measure under all condition.

H2: Adoption of fully flexible work center will ensure to contribute better job shop system performance.

Objective

The study is intended to propose technique or adoption of flexibility to the Mold and Die Company which practicing job shop manufacturing system. The objective of the study is to study interactive behavior on the effect of flexibility in improving job shop performance measure such as system tardiness, WIP and machine utilization. Then, a general guideline of manufacturing selection system will be provided to the Mold and Die Company under study.

Scope of the Study

Since job shop manufacturing is uncertain, routing flexibility technique seems as a very promising technique in managing production process. Routing flexibility do really involves in machining/product flexibility and sequencing strategies. However the research will only *focus on machining flexibility and selection of sequencing rules.*

The research will attempt to measure the effect of routing flexibility level and sequencing rules on the system's performance. The performance measures, which will be measured, are number of job tardy, WIP and machine utilization.

All economics and cost consideration will not be covered in this research. Generic job shop manufacturing with 6 machine will be modeled as experimentation stage. The model will *consist of general-purpose machine such as lathe, mill, drill, grind, turning and hardening.* This generic shop floor is based on the mold and die industries. This industry is a typical example of job shop as rarely product order is identical to each other, low product quantity and each product having customized product routing.

Through out survey and discussion with potential industrial partner in Southern and Central Area of Peninsular Malaysia (Allied Hori Mold and Die Company, Rawang; On-Semiconductors, Senawang and Bureau of Innovation & Consultancy, UTM.), most of them are very keen in reducing number of job tardy in the system.

Importance of the Study

Failure in delivering goods on time will effect the profit making capacity of manufacturing industries. Due date penalty is seldom been faced by them where penalty will apply to how many days or hours the product delayed. Since most of job shop manufacturer facing this kind of problem (Barker, K.R., 1982), a better approach of managing job shop need to be established. Thus the important of the research are:

- Provide generic rules to assist selection of manufacturing strategies in order to reduce number of job tardy in the system.
- To improve manufacturing flexibility
- For better management of job shop.

Company Background

The Company under study is located at the BIP(Bureau of Innovation and Consultancy), University Teknologi Malaysia, Skudai, Johor, Malaysia. Formerly the company is producing mold and die for in house supply and conducting industrial training for final year student in University Teknologi Malaysia. Common part which been produce by the company are jig and fixture for industrial usage and; mold and die fixture for industrial usage.

In 14th December 1999, the company was officially migrated from University Teknologi Malaysia (UTM) main campus area to Bureau of Innovation and Consultancy area located just west to UTM. From this point on, the company name was change to Tool and Die Room Making. The nature of job processes in the company is remaining the same as before. Mainly, the job shop manufacturing system is practiced. Moreover, multinational company such as Hitachi (M) Sdn. Bhd., Everyday (M) Sdn. Bhd., Three Cast (M) Sdn. Bhd. And Shimano (M) Sdn. Bhd had giving the Tool and Die Room a trust for making their customized mold and die.

In the reason of customized product requisition, the tool room implementing job shop manufacturing system where every part incoming in the system has its own routing throughout the system and non identical cycle-time. Based on outstanding customer demand from in-house and industries, the company having difficulty in maintaining number of work in progress (WIP) and customer due date. Currently the system consists of 4 general-purpose machines, which are mill, lathe, EDM wire-cut and.

Process Description

The job shop system in the Tool and Die Room is following the traditional job shop system where every part has its own routing and non-identical cycle-time. The part associated might visit a general purpose machine more than once while completing its task. The phenomenon of this traditional job shop system leads towards unpredictable completion time for each particular part.

Hardening process is done outside of the Tool and Die Room. The part will be sent to sub-contracted company at Johor Jaya for the hardening process. Usually, the hardening process is the last process of all the other processes. In spite of that, the research will only emphasis on five process which are mill, lathe, EDM wire-cut, drill and grinding.

Part always come in male and female component. Assembly process will take place in the last part of the system cycle. Completion time will be base on the completion of part male and female. Time take in the assembly process is neglected that the assembly process is just a point where finished part waiting for its partner (male or female). Once both male and female part finished, completed part then transferred to shipment.

Problem Definition

Due to the increase of demand, additional machines need to be purchased by the company to fulfil customer demand. Two alternative way of buying either general purpose machine or flexible machine for upgrading the existing system. From the nature of the job shop in the Tool and Die Room, the management seems very unsure weather the addition of general-purpose machine or flexible machine will perform better outcome for the system. Due to incoming demand from potential customer is very demanding, the management doesn't want to stop the system and interrupt the ongoing process. The best way to evaluate the two ***alternative is by using industrial simulation software where the decision making can be done and evaluated without interrupting the existing system.***

In relation, the main objective of the system is to reduce number of job tardy in the system and to evaluate machine utilization of the system understudy.

Methodology

Six types of manufacturing strategies will be proposed to the company. These six types of manufacturing system are including the existing system, which consist of 5 general-purpose machine and hardening machine. The other five systems are:

- Duplication System: The system consists of 5 general purpose machine, 1 hardening machine with additional one machine for each machine mill, lathe and drill.
- Plain + Flexible System (without priority): The system consists of existing plain system with two additional flexible machine. The first machine can perform process milling and lathe while the other flexible machine will be capable in performing process drilling, grinding and EDM machining. The machining queue will be based FCFS.

- Plain + Flexible System (with priority): The system consists of existing plain system with two additional flexible machines. The first machine can perform process milling and lathe while the other flexible machine will be capable in performing process drilling, grinding and EDM machining. The machining queue will be based on shortest processing time in the machining workstation.
- Replacement System: The system consists of two flexible machines and one hardening machine. The fist flexible machine will be able in performing milling and lathe process while the other one will be performing process drilling, grinding and EDM.
- Optimum (Fully Flexible) System: The system consists of six fully flexible machining work-center which can perform all six types of machining processes (mill, lathe, drill, grind, EDM and hardening)

Under these six types of manufacturing strategies, number of job tardy in the system is been evaluated based on the urgency and the frequency of demand from the customer.

Experimental Design

The frequency of demand which will be tested are ranging from 5parts/200unit hours to 5 parts /500unit hours. In relation, the urgency of due date will be from 0% urgency (tight schedule) to 100%(less tight schedule).

The experiment will be terminated after 500 part entering the system and number of job tardy will be measured with relation to machine utilization of every other system.

Data Analysis

Terminating statistical analysis will be used to verified result from the simulation run. Upper and lower bound of performance measure valued are calculated by using student-t confidence interval. In relation, Comparison between two data for terminating simulation run is been conducted in order to verify the strength and weakness of each proposed simulation strategies.

All the statistical analyses are based on the experimental design constraint, which stated in the previous section.

Discussion/Conclusion

There are several advantages and disadvantages which been evaluated from each manufacturing strategies proposed. Mainly the constraint is based on customer requisition and how tight the urgency is.

In short, there is no specific reason in concluding that one system is overrun the others. In fact, the general guideline which will be provided to the company under study will be come an outline in selecting type of manufacturing system based on what the capacity they have and what did the customers request.

Reference

A. Hatchuel, D.S. Kabeche(1988), " Towards a New Planning and scheduling approach for multi stage production system", Int. Jorn. Of Production Research. Vol:35(3),pp867-886.

A.S. Jain, (1999), "Deterministic job-shop scheduling: past, present and future", European Journal of Operation Research, Vol.: 113, pp.390-434.

Arvid Ballakur, (1993), " Integration of job shop control system: a state of the art review", Journal of manufacturing System, Vol.3, No.1.

Averill M. Law (1989), " Simulation in Manufacturing: Pitfall to Avoid in the Simulation of Manufacturing Systems", Industrial Engineering, Vol. 21, No: 5, pp. 28-32.

Banks, J., Carson, J.S.,(1986) "Introduction to discrete event simulation", Proceeding: 1986 Winter Simulation Conference, Association for Computing Machinery, N. York, 17-23.

Barker, K.R., Bertrand,(1982) J.W.M., "A dynamic priority rule for sequencing against due date", Journal of Operation Management, 3, 37-42.

C. Dennis Pegden (1990),"Introduction to Simulation Using SIMAN", Mc Graw-Hill, 2nd Edition, Singapore.

Conway, R.W. (1965),"Priority Dispatching and job lateness in a job shop", journal of Industrial Engineering, Vol:29, pp228-237

Conway,R.W. (1965),"Priority dispatching and work in progress inventory in a job shop", Journal of Industrial Engineering, 16,123-30.

Dake Sun, (1995), "Effective job shop scheduling through active chain manipulation", Computer Ops. Res. Vol:22, No.2, pp. 159-172.

Dorndorf, U (1995), " Evolution Based Learning in Job Shop Scheduling Environment", Computer Ops. Res. 22, 25-40.

Drake, Smith (1998), " Simulation as Planning and Scheduling Tool for Flexible Manufacturing System", Collage Station, pp1-13.

Elvers, D.A(1973), " Job shop dispatching rules using various delivery date setting character", Production and Inventory Management, Vol:4, pp.63-70.

Elvers, D.A.,Taube, L.R.,(1983)" Time Completion of Various Dispatching Rules in Job Shop", OMEGA,11,1, 81-89.

F. Mahmodi and Martin(19900, "A New Shop based and predictive heuristic scheduling for cellular manufacturing", Int. Journal of Prod. Res., Vol:35, pp.313-326

Faizul Haq(1994), "The Sensitivity of rule combimation for scheduling in a hybrid job shop", International Journal of Operation and Production Management, Vol.15 No.3, pp 59-75.

Frank Werner, (1995), " Insertion techniques for the heuristic solution of the job shop problem", Discrete Applied Mathematics, Vol:58, pp.191-211.

Hill.C, (1994), "Routing Flexibility in Discrete Job Shop", Integrated Manufacturing System, Vol:5, No:3, pp. 345-356.

Hung, P.Y., (1984) " A Comparative study of Priority Dispatching rules in a hybrid assembly/job shop", International Journal of Production Research,22, 3, 375-8.

I.G Drobouchevith, (2000). "Heuristic for the two stage job shop scheduling problem with a bottleneck machine", European Journal of Operation Research, Vol:123, pp.229-240.

J. Liu and MacCarthy (1996), " The Classification of FMS Scheduling Problems", Int. Journal of Prod. Res., Vol: 34, pp647-656.

John F.Proud, (1994)," A Practical Guide to Competative Manufacturing", John Wiley and Sons, pg. 313-315.
John F.Proud,(1994)" A Practical Guide to Competative Manufacturing", John Wiley and Sons, pg. 313-315.

K. Steinhofel,(1999), " Two simulated annealing-based heuristic for the job shop scheduling problem", European Journal of Operation Research, Vol:188, pp. 524-548.

Kanet, J.J., Hayya, J.C.,(1998)" Priority dispatching with operation due dates in job shop", Journal of Operation Management, 2, 3, 1982, 155-63.

M. Muraki (1996), "An extended dispatching rule approach in a on-line scheduling framework for batch process management", Int. Journal of Prod. Res, Vo.134 pp329-348.

M.A. Shouman, (2000), "The interactive process between some dispatching mechanisms and interrupted machine centers in FMSs", Journal of Materials Processing Technology, 107,pp.466-477.

M.Lun and F.F. Chen (1999),"Holonic Concept Based Methodology for Part Routing on Flexible Manufacturing System",Volume:16, pp 483-490, International Journal of Advance Manufacturing Technology.

Nabil N.G(1998), "Flexibility and Responsiveness of machining Environments', Integrated Manufacturing System, Vol:9, No.4, pp. 218-227.

Nuijten, W.P.M(1996). " A Computational study of constraint satisfaction for multiple capacitated job shop scheduling", Eueropean Journal of Operational Research, 90. 269-284.

Norman Sadeh,(1996), " Variable and value ordering heuristic for the job-shop scheduling constraint satisfaction problem", Artificial Intelligence, Vol:86, pp. 1-41.

R. Logen(1994)," Celular Manufacturing System Research", Collage Station TX, pp. 1-3.
Rowe, (1958)," Sequential decision rules in production Scheduling", Unpublished Ph.D Dissertation.

Shimon Y. N(1985) "Handbook of Industrial Robotics",John Wiley and Sons, (N. York), pg.471

Shimon Y. Nof,(1985) "Handbook of Industrial Robotics",John Wiley and Sons, (N. York), pg.471

Steven Nahmias, (1997), "Production and Operation Analysis", Boston:Mc Graw-Hill 3rd. edition.

Ulrich Dorndorf, (1995), " Evolution based learning in a job shop scheduling environment", Computers Ops. Res. Vol:22, No.1, pp.25-40.

V. Selladurai(1994). "Dynamic simulation of job shop scheduling for optimal performance", International Journal of Operation and Production Management, Vol. 15, No.7, pp 106-120.

V. Subramaniam , Lee , T. Ramesh , Hong , Wong (2000),"Machine Selection Rules in a Dynamic Job Shop", International Journal of Advanced Manufacturing Technology.

V. Subramaniam , T. Ramesh , Lee , Wong , Hong (2000), "Job Shop Scheduling with Dynamic Fuzzy Selection of Dispatching Rules",Volume 16, Issue 10, pp 759-764 International Journal of Advanced Manufacturing Technology

V.Arumugam (1985),"A simulation study of job shop scheduling", Modeling, Simulation & Control , AMSE Press, Volume 3, No.2, pp.13-27.
Volume 16, Issue 12, pp. 902.

W.H. Ip et. al (1999),"An Investigation of Stochastic Analysis of Flexible Manufacturing Systems Simulation",Volume:15, pp 244-250, International Journal of Advance Manufacturing Technology.

W.P.M Nuijten, (1996), " A Computational study of constraint satisfaction for multiple capacitated job shop scheduling", European Journal of Operation Research, Vol:90, pp.269-284.

Newman,W.R (1999),"Managing the job Shop: simulating the effect of flexibility, order release mechanism and sequencing rules", International Journal of Operation and Production Management,Vol.5, No.10,pp266-275.

Weeks, J.K. (1979), "A simulation study of predictable due dates", management science,Vol:25, pp.363-373.

Zesheng He, (1996), "An exchange heuristic imbedded with simulated annealing for due date job-shop scheduling", European Journal of Operation Research,Vol:91, pp. 99-117.

Law,A, (1982), Simulation Modeling and analysis, McGrew Hill Book Company, Maidenhead.