DISPATCHING RULE FOR FLOW SHOP PROBLEM BY USING BOTTLENECK APPROACH

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A thesis submitted as partial fulfillment of the requirement for The Award of
Master of Mechanical Engineering

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DECEMBER, 2011

ABSTRACT

This paper discusses the problem of dispatching rule in flow shops with bottleneck machines. The presence of bottleneck machines results in the restricted throughput in flow shops. The study focused on three machines flow shop with one machine has high tendency to become dominant machine. The objective is to develop a new dispatching rule for scheduling by taking into account the presence of bottleneck machines. The measures of performance are the minimization of makespan of jobs. The existing selected conventional dispatching rules of First Come First Serve (FCFS), Shortest Processing Time (SPT) and Longest Processing Time (LPT), and the proposed dispatching rule is extensively investigated for their performance by generating a large number of problems of various sizes and bottleneck conditions. The scope covers 6 to 10 jobs flowshop problem. A new dispatching rule was developed using Visual Basic Application in Microsoft Excel that can be used for performance evaluation. As a result, the new job arrangement has produced near optimal solution for 6 and 10 jobs problem respectively. The generated makespan was compared with optimum makespan from lower bound (LB), FCFS, SPT and LPT analysis. 1000 sets of simulated random data within specific limitation being assigned at each job's processing time. The results obtained are divided into three dominance level that is medium, strong and very strong. Based on the results, the dispatching rule is considered as an effective approach in solving six and ten jobs flowshop problems. The performance of NDR is more accurate at very strong dominance level for both problems. The accuracy increases with the increment of dominance level. Furthermore, this method can also be applied for a large number of problems. At present, this method is ideal for industry which consists of three machine flow shop with one machine has high tendency to become dominance machine.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Scheduling is a key factor for manufacturing productivity. It can have a major impact on the productivity of a process. The purpose of scheduling is to maximize the efficiency of the operation, minimize the production time and reduce the costs. This operation is done by telling a production facility what to make, when and on which machine (Conway & Maxwell, 1967). These machines are assumed to set up in series, and the environment in referred to as a flow shop. Although flow shop manufacturing is used widely in production system but it is known that it is not an easy task to finding an optimal solution for flow shop scheduling problem. This project will explore and investigate a manufacturing process scheduling which resembles a three machine permutation flow shop. The study develops a new dispatching rule using bottleneck approach.

1.2 Background of study

Many researchers focused their efforts on the development of dispatching rule that is capable to find near-optimal solution for large-sized problems. There have assumed that the presence of machines which are near-bottleneck with respect to each other which means no machine is assumed to be the bottleneck in the manufacturing system. However, in reality, it is possible that one bottleneck machine (or a couple of machines which are almost equally bottleneck) can be present in the system. In such a case, is worth to be studied solution methodologies with specific consideration to bottleneck machines (Pinedo, 2009).

In flow shop scheduling problems, the operations of every job must be processed on machines *1,2,3,...,m* in this same order. However, for the permutation flowshop the operating sequences of the jobs are the same on every machine considering the makespan as objectives function to be minimized. The development of a dispatching rule can guide production planners to prioritize their tasks to increase the efficiency of all processes. At the same time, it is also possible that one bottleneck machine can be present in the flow shop system. In this case, simulation experiments solution methodologies with specific consideration to the bottleneck machines should be considered be need to carried out and analyzed to demonstrate the effectiveness of the proposed method.

In the scheduling problem, one of the basic assumptions is that only permutation schedules are considered. A permutation schedule has the property that the order of processing jobs is identical on all machines. In other words, once a sequence is established for the first machine, the order of processing jobs on the subsequent machines is governed by the 'first-in-first-out' rule. One of the reasons for focusing on permutation schedules in flowshop scheduling is the difficulty in finding out an optimal schedule which will comprise different sequences on different machines.

The primary reasons for the use of dispatching rules in many studies on scheduling are the associated ease in generating feasible schedules, and implementing and controlling them at the shopfloor level in real-life situation. For these reasons, the current static flowshop scheduling problem has been chosen to study with the stated assumptions, and hence, the development of dispatching rule is considered in flowshops with bottleneck machines. The measures of performance are the minimization of makespan and total flowtime of jobs, considered separately. The existing selected conventional dispatching rules and the proposed dispatching rules will be extensively investigated for their performance by generating a large number of problems of various sizes and bottleneck conditions.

1.3 Problem statement

All jobs are processed on the same sequence of machine in a flow shop, but all jobs can have different processing times. Jobs are able to pass each other while they are waiting in queues at the machines for processing provided that all jobs follow the same order. Permutation flow shop is referred when no passing among jobs is allowed. The minimization of scheduling length is one of the most commonly used optimality criteria. The optimization objective was to minimize the makespan (the length of the interval beginning with the processing on initial operation and ending with completion of the last required operation).

The permutation flow shop represents a particular case of the flow shop scheduling problem, having as goal the deployment of an optimal schedule for n jobs on m machines. Solving the flow shop problem consists in scheduling n jobs (i=1...n) on m machines (j = 1...m). A job consists in m operations and the j_{th} operation of each job must be processed on machine j. So, one job can start on machine j if it is completed on machine j_1 and if machine j is free. Each operation has a known processing time $p_{i,j}$. For the permutation flow shop the operating sequences of the jobs are the same on every machine. If one job is at the i_{th} position on machine 1, then this job will be at the i_{th} position on all the machines.

As continuation work from the literature, this study will utilize the bottleneck-based algorithms as a foundation to develop a practical dispatching rule to solve flowshop scheduling problem. This study will consider flow shop with four jobs to be processed on three machines, M1, M2, M3. In this case, the process resembles a three machine permutation flow shop process routing where one machine will has high tendency of being a dominant machines.

This project is focused to develop a dispatching rule algorithm considering one of process as the dominant bottleneck. It involves the development of a new dispatching rule that can be used to generate solutions that can be compared to the previously developed dispatching rule.

1.4 Objective of study

The main objective of this study is to develop a new dispatching rule to solve the scheduling problem in flow shop with bottleneck machine.

1.5 Scope of study

The scope of this study is as stated below:

i. The study is focused on three machines flow shop
ii. The study involves a development of a computer program that can be used to evaluate the performance of dispatching rule.
iii. The computer program is developed by using Microsoft Excel and Visual Basic for Application.
iv. The performance evaluation of the dispatching rules is done by using makespan computation of six and ten job problems with permutation process.
v. To compare the performance of the result against the previous research.

1.6 Significant of research

This research focuses on the development of a dispatching rule considering one of the machine has high tendency to be the dominant machines. The development of the dispatching rule algorithm will compliment the previous research and can be utilized to develop dispatching rule effective for flow shop in the future.

1.7 Expected result

This research will develop a dispatching rule that can minimize the makespan of a three machine permutation flowshop using absolute bottleneck analysis. The findings from this project will be a first step towards developing a general dispatching rule capable to solve bigger size flow shop scheduling problem.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Scheduling can be defined as an allocation of limited resources to tasks over time. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by developing schedule with the optimal solution. In scheduling, it shown the process of converting a outline plan into a time-based graphic presentation given information on available resource and time constraints. Production scheduling tools greatly outperform older manual scheduling methods. These provide the production scheduler with powerful graphical interfaces which can be used to visually optimize real-time workloads in various stages of production, and pattern recognition allows the software to automatically create scheduling opportunities which might not be apparent without this view into the data. Scheduling outputs can be represented by Gantt charts drawn using machine processing times for each job and ensuring that delay times are taken into consideration. This process is repeated for different sequences until a minimum makespan is found which represents the minimum time taken to complete all the jobs. The corresponding sequence is considered to be optimal.

2.2 Scheduling concept

In scheduling, the limited resources consist of one or more machines and tasks are modeled as jobs that can be executed by the machines. A task (job) first becomes available for processing at its ready time and it must receive amount of processing equal to its processing time. Typically, a problem in scheduling is characterized by the types of machines and jobs in the system, by the constraint imposed and by a desired optimality principle (Szwarc, 1971).

The machine environment characteristic is that a machine can handle, at most, one job at a time, and each job can be processed by only one machine at a time. Generally, a machine can begin its next job immediately after the current job is completed, and there are no machine breakdowns at any moment of time. For this research, preemption is not allowed during the processing of any operation, which means that the execution of a job on a machine will proceed without interruption once it starts. The machine scheduling problem is in fact a sequencing problem where a schedule is completely specified by the sequence in which jobs are performed.

2.3 Scheduling classification

Companies use backward and forward scheduling to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials. Forward scheduling is planning the tasks from the date resources become available to determine the shipping date or the due date. Backward scheduling is planning the tasks from the due date or required-by date to determine the start date and/or any changes in capacity required (Conway & Maxwell, 1967).

2.3.1 Forward scheduling

Forward scheduling is taking a job with a number of tasks and allocates those tasks to resources as early as possible when the resources allow. The first available time that the resource is available to be used the task should make use of it. As with all scheduling methods there are pros and cons on how they work. Forward scheduling may result in jobs being completed earlier then the requested due date because forward scheduling schedules the tasks as early as possible.

2.3.2 Backward scheduling

Backward scheduling is taking a job with a number of tasks and allocates those tasks to resources in reverse orders and schedules the task on the resource. Backwards scheduling requires a delivery date from the customer because the system schedules backwards from the delivery date to arrive at a start date. Backward scheduling tells the manufacturer if this date could be hit based on the allocation of resources.

This method is more complicated than forward scheduling because the possibility of infeasibility caused by creating jobs that should have been started yesterday or even earlier. If the resultant schedule is not feasible, the loading sequences in a backward schedule need to be changed.

2.4 Scheduling criteria

Scheduling in the right technique depends on the volume of orders, the nature of operations, and the overall complexity of jobs, as well as the importance placed on each of four criteria. Those four criteria are:

i. Minimize completion time – This criterion is evaluated by determining the average completion time per job.

ii. Maximize utilization – This is evaluated by determining the percent of time the facility is utilized.

iii. Minimize work-in-process (WIP) inventory – This is evaluated by determining the average number of jobs in the system. The relationship between the number of jobs in the system and WIP inventory will be high. Therefore, the fewer the number of jobs that are in the system, the lower the inventory.

iv. Minimize customer waiting time – This is evaluated by determining the average number of late days.

2.5 Flow shop scheduling problem

Flowshop scheduling problems are a class of scheduling problems with a work shop or group shop in which the flow control shall enable an appropriate sequencing for each job and for processing on a set of machines or with other resources 1,2,...,m in compliance with given processing orders. Especially the maintaining of a continuous flow of processing tasks is desired with a minimum of idle time and a minimum of waiting time.

The permutation flow shop means the processing order of the jobs on the resources is the same for each subsequent step of processing. It represents a particular case of the flow shop scheduling problem, having as goal the deployment of an optimal schedule for n jobs on m machines. Solving the flow shop problem consists in scheduling n jobs (i=1...n) on m machines (j = 1...m). A job consists in m operations and the j_{th} operation of each job must be processed on machine j. So, one job can start on machine j if it is completed on machine j_1 and if machine j is free. Each operation has a known processing time $p_{i,j}$. For the permutation flow shop the operating sequences of the jobs are the same on every machine. If one job is at the i_{th} position on machine 1, then this job will be at the i_{th} position on all the machines (Moslehi & Mirzae, 2009).

In this context, each job has been assigned exactly m operations where as in real situations a job may have fewer operations, certain algorithms propose that the jobs with higher total process time should be given higher priority than the jobs with less total process time. From a review of the literature, it can be noticed that several approaches in the field of flow shop scheduling have been developed to minimize both the maximum flow time and the makespan.

2.5.1 Sequencing method

Sequencing is prioritizing jobs assigned to a resource. The form of the optimal sequencing rule depends on several factors, including the pattern of arrivals of jobs, the configuration of the flow shop, constraints and the optimization objectives. There were four sequencing rules commonly used in practice as:

i) First come first served (FCFS) – Job is processed in sequences in which they entered the shop.

ii) Shortest processing time (SPT) – Job is sequenced in increasing order of their processing times. The job with the shortest processing time is first, the job with the next shortest processing time is second and so on.

iii) Earliest due date (EDD) – Job is sequenced in increasing order of their due dates. The job with the earliest due date is first, the job with the next earliest due date is second and so on.

iv) Critical ratio (CR) – Critical ratio scheduling requires forming the ratio of the processing time of the job, divided by remaining time until the due date and scheduling the job with the largest ratio next.

2.6 Dispatching Rule

Dispatching rules are applied to assign a job to a resource (machine or operator). This is done each time the resource gets idle and there are jobs waiting or a new job arrives at an idle resource. The dispatching rule assigns a priority to each job. This priority can be based on attributes of the job, the resource or the system. The job with the highest priority is chosen to be processed next.

Priority-scheduling rules have been developed and analyzed for many years. They are widely used in industry, especially in complex manufacturing systems. For example, if a dispatching rule is first come-first-served, then an earlier job has a higher priority. Another example is to consider is the processing time in each job. In shortest processing time method, the shorter processing time has higher priority to become first job. While the longer processing time will have higher priority in longest processing time method.

2.7 Previous research

2.7.1 Chandrasekharan Rajendran and Knut Alicke (2006) "Dispatching in flowshops with bottleneck machines".

This paper addresses the problem of dispatching in flowshops with bottleneck machines. The presence of bottleneck machines results in the restricted throughput in flowshops.

The objective is to develop dispatching rules for scheduling by taking into account the presence of bottleneck machines. The measures of performance are the minimization of total flowtime of jobs, the minimization of the sum of earliness and tardiness of jobs, and the minimization of total tardiness of jobs, considered separately. Many existing conventional dispatching rules and the proposed dispatching rules have been extensively investigated for their performance by generating a large number of problems of various sizes and bottleneck conditions. The results of the experimental investigation show that the proposed dispatching rules emerge to be superior to the conventional dispatching rules.

2.7.2 Taketoshi Yoshida and Hideyuki Touzaki (1999) "A study on association among dispatching rules in manufacturing scheduling problems".

There are many scheduling strategies called dispatching rules for manufacturing systems. However, those rules can be applied mainly to simple manufacturing systems. This paper proposed a way to evaluate the effectiveness of such dispatching rules in the environment of complex manufacturing systems in the sense that there exist two performance measures. Defining a new concept of closeness of dispatching rules with respect to a performance measure, the researchers found a set of close dispatching rules for the performance measure. That provided some guidance about which dispatching rules may apply at each dispatching point in a manufacturing system under two or more performance measure in practice.

2.7.3 Ahmed El-Bouri, Subramaniam Balakrishnan and Neil Popplewell (2007) "Cooperative dispatching for minimizing mean flowtime in a dynamic flowshop".

This paper introduced a new cooperative job dispatching approach to minimize the mean flowtime in dynamic flowshops. A dispatching decision taken at any machine is reached collectively through consultation with other machines, and conflicting priorities are resolved by employing a penalty-based procedure. Computer results indicate that the proposed cooperative dispatching gives improvements ranging between 1.5% and 11.4% over other dispatching rules, under different levels of shop congestion, and for flowshops possessing various combinations of intermediate FIFO and non-FIFO buffers.

2.7.4 Chandrasekharan Rajendran and Oliver Holthaus (1997) "A comparative study of dispatching rules in dynamic flowshops and jobshops".

This paper presents a comparative study on the performance of dispatching rules in the following sets of dynamic manufacturing systems: flowshops and jobshops, and flowshops with missing operations and jobshops. Three new dispatching rules are proposed. A total of 13 dispatching rules were considered for the analysis of the relative performance with respect to the objectives of minimizing mean flowtime, maximum flowtime, and variance of flowtime, proportion of tardy jobs, mean tardiness, maximum tardiness and variance of tardiness. First, the researchers carry out the simulation study in flowshops with jobs undergoing processing on all machines sequentially and in jobshops with random routing of jobs. The results of the study reveal some interesting observations on the relative performance of the dispatching rules in these two types of manufacturing systems. Next, the researchers consider flowshops with missing operations on jobs and jobshops with random routing of jobs. The researchers observe some interesting results in the sense that the performance of dispatching rules is being influenced by the routing of jobs and shopfloor configurations.

2.7.5 Christian Hicks and Pupong Pongcharoen (2006) "Dispatching rules for production scheduling in the capital goods industry".

Research on dispatching rules has focused upon deterministic job shop situations or small assembly environments and has ignored operational factors. This work uses data obtained from a capital goods company that produces complex products. The paper first explores the influence of the data update period and the minimum setup, machining and transfer times under stochastic infinite capacity conditions. It then investigates the significance of these factors and the relative performance of eight dispatching rules with finite capacity and stochastic processing times. Dispatching rules and most operational parameters were statistically significant. With finite capacity, the 'best' dispatching rule was different at the component and product levels and varied according to the performance measure used. The shortest operation time first rule generally produced the best results, particularly at product level.

2.7.6 Gary D. Scudder and R. Hoffmann (1985) "An evaluation of value based dispatching rules in a flow shop".

Although investment in inventory has been of primary concern in job shops, little attention has been paid to using value based dispatching rules in an effort to attain satisfactory on time performance while reducing inventory investment. This paper compares performance based on both time and value measures of three usual time based rules with six rules which directly incorporate value information in setting priorities. The results indicate that the value based rules perform their intended function quite well with only slight sacrifice in on time performance in light to moderately loaded shops. In addition, some of these value rules outperform the best time based rules on both dimensions in heavily loaded shops.

2.7.7 H. Sarper, Mc. Henry (1995) "Combinatorial evaluation of six dispatching rules in a dynamic two machine flowshop".

This paper applies permutations of six dispatching rules to a two machine dynamic flow shop operating as a Poisson process. The size of the second queue is later limited to study the effect of limited buffer space. The performance measures examined are mean and maximum flow times, mean tardiness, and the mean absolute lateness. The best permutations for each case are determined statistically.

2.7.8 Salleh Ahmad Bareduan and Sulaiman Hj. Hassan (2008) "Makespan algorithms and heuristic for internet-based collaborative manufacturing process using bottleneck approach".

This paper presents makespan algorithm and scheduling heuristic for an Internet-based collaborative design and manufacturing process using bottleneck approach. The results show at strong machine dominance level and medium to large job number, this heuristic shows better makespan performance compared to the NEH

2.7.9 Muhammad Nurullah (2009) "Bottlenek-based makespan algorithm for re entrant flowshop with dominant machine at middle process".

This project presents the development of bottleneck-based makespan algorithm for re-entrant flow shop. The main objective is to develop an alternative makespan algorithm using the middle process as the dominant machine. The algorithm is specially intended for the cyber manufacturing center (CMC) at Universiti Tun Hussein Onn Malaysia

(UTHM). The CMC system consist of four machine re-entrant flow shop with the process routing of M1, M2, M3, M4, M3, M4 and the middle process, M2 as the dominant bottleneck. The makespan algorithm developed using bottleneck approach uses a few specific conditions. In cases where the conditions are violated, a correction factor is used to ensure that the makespan is accurate. The performance of the algorithms is tested by using 1000 sets of random data generated using VBA (Visual Basic for Application) in Microsoft Excel. The results show that the algorithm with correction factor produces 100% accurate makespan value for the CMC scheduling problem.

2.7.10 Amirul Azre Saire (2009) "Bottlenek-based heuristic for three machine flowshop scheduling with the tendency of dominant machine at the last process".

This research develops a bottleneck-based heuristic for three machine flowshop scheduling. The main objective of this project is to develop bottleneck-based heuristic that can generate near optimal solution for three machines flowshop scheduling with tendency of dominant machine at last process. The bottleneck based heuristic is developed and tested using Macro-programming in Microsoft Excel. A general algorithm of makespan is also developed and the algorithm produces accurate results with specific limiting conditions. These conditions are used to determine an index value which is utilized by the heuristic in selecting job sequence that generate near optimal solution. The performance of the heuristic is evaluated using random data simulation in Microsoft Excel programming. From the result, it shows that the heuristic can produce 90.20% optimum results from a group of strong dominance level jobs.

2.7.11 Hezzeril Hairuddin (2010) "Performance evaluation of M2 Bottlenek-based heuristic for M1M2M3 flowshop using computer programming".

This paper considers 3 machine flow shop (M1M2M3) with tendency of dominant (bottleneck) at M2. The developed bottleneck based heuristic from previous study considered in this case, but was only tested up to 4 jobs problem. As an extension of that research, the bottleneck based heuristic scope is enlarged up to 6 and 10 jobs problem. The main objective is to develop Visual Basic program that can be used to evaluate the performance of bottleneck based heuristic at M2 for M1M2M3 flow shop. The computer program involved were Microsoft Excel and Visual Basic for Applications (VBA) and the test of performance were conducted at 6 and 10 jobs problem. A simulated random data within specific limitation being assigned at each job's processing time produces new recommended job arrangements. The generated makespan was compared with optimum makespan from complete enumerations and lower bound (LB) analysis. Total sets of 1000 simulated data at 6 and 10 jobs were allocated into 3 dominance level of P2DL; weak, medium, and strong. Optimal solutions were obtained based on the total results data that produce ratio of 1. Based on the results, 67.24% of the solution generated is optimum results for case of 6 jobs while 16.67% of the solution generated equals to lower bound for case of 10 jobs. The heuristic is unable to perform effective and efficiently as the number of jobs processed getting larger.

2.8 Summary

This chapter illustrated the previous research related to the computation of makespan, algorithm, scheduling problem, flow shop problem and bottleneck problem. The enhancement of manufacturing industry leads researchers to focus in this type of study.

Table 2.0 concludes the summary of literature review with different scope of work in the previous researches. According to previously conducted research, the main goal is to minimize the makespan. The researchers attempted to utilize various ways in order to get optimum result for the problem. Thus, based on the information and reference from previous research, this project is mainly focus to develop dispatching rule to solve the scheduling problem in flow shop with bottleneck machine. The research methodology elaboration is discussed in the upcoming chapter.

Table 2.0 Summary of literature review

Title	Description
Dispatching in flowshops with bottleneck machines	The objective is to develop dispatching rules for scheduling by taking into account the presence of bottleneck machines
A study on association among dispatching rules in manufacturing scheduling problems	Defining a new concept of closeness of dispatching rules with respect to a performance measure, the researchers found a set of close dispatching rules for the performance measure
Cooperative dispatching for minimizing mean flowtime in a dynamic flowshop	A dispatching decision taken at any machine is reached collectively through consultation with other machines, and conflicting priorities are resolved by employing a penalty-based procedure
A comparative study of dispatching rules in dynamic flowshops and jobshops	The researchers observe some interesting results in the sense that the performance of dispatching rules is being influenced by the routing of jobs and shopfloor configurations.
Dispatching rules for production scheduling in the capital goods industry	The paper investigates the significance of these factors and the relative performance of eight dispatching rules with finite capacity and stochastic processing times

Table 2.0 (continued)

Title	Description
An evaluation of value based dispatching rules in a flow shop	This paper compares performance based on both time and value measures of three usual time based rules with six rules which directly incorporate value information in setting priorities
Combinatorial evaluation of six dispatching rules in a dynamic two machine flowshop	This paper applies permutations of six dispatching rules to a two machine dynamic flow shop operating as a Poisson process
Makespan algorithms and heuristic for internet-based collaborative manufacturing process using bottleneck approach	This paper presents makespan algorithm and scheduling heuristic for an Internet-based collaborative design and manufacturing process using bottleneck approach
Bottlenek-based makespan algorithm for re-entrant flowshop with dominant machine at middle process	This project presents the development of bottleneck-based makespan algorithm for re-entrant flow shop. The main objective is to develop an alternative makespan algorithm using the middle process as the dominant machine
Bottlenek-based heuristic for three machine flowshop scheduling with the tendency of dominant machine at the last process	The main objective of this project is to develop bottleneck-based heuristic that can generate near optimal solution for three machines flowshop scheduling with tendency of dominant machine at last process
Performance evaluation of M2 Bottlenek-based heuristic for M1M2M3 flowshop using computer programming	This paper considers 3 machine flow shop (M1M2M3) with tendency of dominant (bottleneck) at M2

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the details of method that be used in order to achieve the project objective. The methodology consists of some steps including the specification of every work progress for completing the project. It acts as guideline to develop an improvement of dispatching rule for three machine flow shop and test the performance of the algorithm using VBA (Visual Basic for Application) in Excel (Cheng & Steiner, 2001). All information about bottleneck approach for solving the scheduling problem is gathered from source such as previous journals, thesis, internet and related book from library. Based on the previous research, a new dispatching rule is developed to solve for near optimal scheduling sequences where one of the machines has high tendency to show strong dominance.

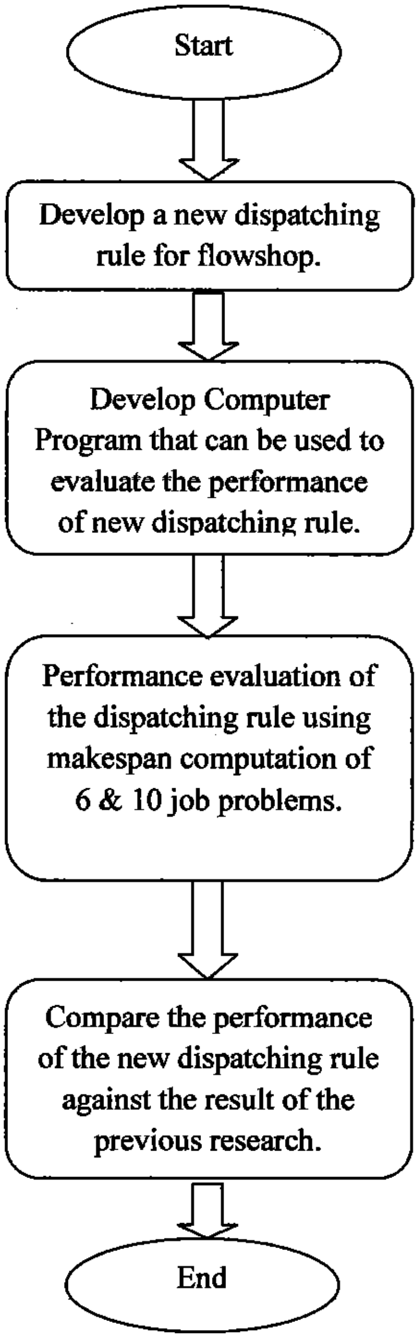

Figure 3.1: Methodology chart

The sequence of research methodology is shown in Figure 3.1. The next step is to evaluate the performance of new dispatching rule by using computer program. The computer program is developed using Microsoft Excel and Visual Basic for Application (Mansfield, 2008). The performance evaluation will be done using makespan computation of six and ten job problems. A similar test is conducted for comparison purposes using the new dispatching rule and completed enumeration. The processing time for each process is randomly generated using uniform distribution pattern on the realistic data ranges obtained from previous literature. A total of 1000 simulation is conducted using the randomly data in order to test the accuracy of the dispatching rule. The result obtained is compared with previous research. There are some assumptions used in conducting this study. The assumptions are:

i. No job can be preempted.
ii. All setup times are included into the job processing times.
iii. All machines are continuously available.
iv. There is a given set of jobs to be scheduled at the beginning of the scheduling horizon, that is, jobs are available at time zero (all jobs that arrive during the horizon will be considered at the beginning of the next scheduling horizon).
v. Machines do not fail (no breakdown of the machines).

3.2 Develop dispatching rule with makespan as the objective by considering the presence of a single bottleneck machine

When a machine becomes free after processing a job, the dispatching decisions can be made. The problem is to identify the job to be taken up for processing on the machine from the waiting line of jobs. The dispatching decision is made by the use of dispatching rules to minimize the makespan of jobs. Apart from this rule, this research is also consider the rule where the priority of a job is given by shortest processing time (SPT), longest processing time (LPT) and first come first serve (FCFS).

In this research, it is considered that there is only one bottleneck machine (BM) in the flowshop consisting of three machines in series. The research will propose three dispatching rules.

i. Rule 1 – if machine 1 is dominant

a) P(1,j)/[P(2,j)+P(3,j)]

b) Min P2+P3 as last job

ii. Rule 2 – if machine 2 is dominant

a) Min P1 as first job

b) Min P3 as last job

c) P(2,j)/P(1,j) or P(2,j)/P(3,j)

iii. Rule 3 – if machine 3 is dominant

a) Min P1+P2 as first job

b) P(3,j)/[P(1,j)+P(2,j)]

3.3 Develop a computer program

To simulate the data and measure the performances of dispatching rule, the research uses computer program. The dispatching performance is tested by using Microsoft Excel with built-in Microsoft Visual Basic. A computer requires programs to function, typically executing the program's instructions in a central processor and enables to develop the dispatching program.

3.4 Performance evaluation of the dispatching rule

The number of jobs to be scheduled in the flowshop, denoted by n, is set to 6 and 10, and the number of machines, denoted by m, is set to 3. Integer processing times of jobs on all machines are sampled from a discrete uniform distribution. The reason for choosing this range of uniform distribution of processing times is that such a distribution generates unbiased and difficult flowshop scheduling problems to be solved, and hence most research works on flowshop scheduling considered this distribution to generate flowshop problems.

The performance evaluations of the dispatching rule using makespan computation of six and ten job problem are executed by using simulation experiment. For six job problem, the best schedule arrangement comes from complete enumerations that provide the minimum makespan value. However, the time taken for this method is too long. Thus, the lower bound was used as an alternative to comparing the results obtained. In order to prove the closeness of lower bound to the optimum makespan, 100 simulations were conducted to compare between the dispatching rule, complete enumeration and lower bound for six job problem.

To measure the overall performance, a total of 1000 simulation were conducted to 6 and 10 jobs problem using this dispatching rule. The results are