SIMULATION-BASED SCHEDULING SYSTEM AT R2 PRINT ENTERPRISE KUANTAN

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SIMULATION-BASED SCHEDULING SYSTEM AT R2 PRINT ENTERPRISE KUANTAN

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Report submitted in partial fulfilment of the requirements
for the award of the degree of
B. Eng. (Hons.) Manufacturing Engineering

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I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Manufacturing Engineering.

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SPECIAL DEDICATION

Dedicated to my beloved parents

SELAMAT BIN A.RAHMAN
NORMAH BINTI AHMAD
and

My Supervisor

DR. MUCHAMAD OKTAVIANDRI

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ABSTRACT

This thesis deals with decision support tool for dynamic job shop scheduling at R2 Print Enterprise, Kuantan. The objective of this thesis is to understand the job shop production in dynamic environment, to develop scheduling system based on real-time data and to implement it in R2 Print Enterprise. The thesis describes the scheduling techniques with aim to delivering jobs on time and can adapt to the rush orders. Here, a printing company with two different jobs are modelled in Arena Simulation Software to study the suitable scheduling heuristic rules to be implemented to the problems. The main heuristic rules studied in this thesis are *First In First Out (FIFO)*, *Earliest Due Date (EDD)*, *Shortest Processing Time (SPT)* and *Longest Processing Time (LPT)*. The performance measures taken in this research are the Total Average Time Delays, Total Average Product Delays, Total Product Flow Times and the Resource Utilizations. The *Large Format Product (LFP)* job considered n = 6 products and m = 4 work centers (6x4) while the *Paper Product (PP)* job considered n = 7 products and m = 3 work centers (7x3). The product sequence and processing time are dependent on each other. The sequence length can vary from three to four operations and there is no flexibility on the sequence. The model is run for 5 days with 9 hours operation time per day. The obtained results indicate that in LFP job, there is no single rule which dominates the others although EDD seems to be more effective than other rules.The summarized results show that the best scheduling rules for Total Time Delays is SPT, for Total Product Delays is EDD, for Total Flow Times is EDD the best scheduling rules for Resource Utilization is SPT. In PP job, there is also no dominant single rule that clearly dominant although the most successing rules are those with short processing times. The summarized results indicate that the best scheduling rules for Total Time Delays is EDD. For Total Product Delays are FIFO and EDD, for Total Flow Times is SPT and for Resource Utilization, the best scheduling rule is SPT, FIFO, LPT and EDD as they give equal results. The results can significantly reduce the time to produce and reduce the delay in delivering jobs.

ABSTRAK

Tesis ini berkaitan dengan alat sokongan keputusan untuk penjadualan job shop yang dinamik di R2 Print Enterprise, Kuantan. Objektif tesis ini adalah untuk memahami job shop dalam persekitaran yang dinamik, untuk membangunkan sistem penjadualan berdasarkan data masa sebenar dan untuk melaksanakannya dalam R2 Print Enterprise. Tesis ini menerangkan teknik-teknik penjadualan dengan tujuan untuk menyiapkan pekerjaan pada masanya dan boleh menyesuaikan diri dengan pesanan yang datang mengejut atau secara tiba-tiba. Di syarikat percetakan ini, dua pekerjaan yang berbeza dimodelkan di dalam perisian Arena untuk mengkaji kesesuaian penggunaan penjadualan heuristik untuk dilaksanakan pada masalah. Peraturan heuristik utama yang dikaji dalam tesis ini adalah *First In First Out (FIFO)*, *Earliest Due Date (EDD)*, *Short Processing Time (SPT)* dan *Longest Processing Time (LPT)*. Prestasi yang diukur dalam tesis ini adalah Jumlah Purata Masa Terlewat, Jumlah Purata Produk Tertangguh, Masa Penghasilan Produk dan Penggunaan Sumber. *Large Format Product (LFP)* mempunyai n = 6 produk dan m = 4 pusat kerja (6x4) manakala *Paper Product (PP)* mempunyai n = 7 produk dan m = 3 pusat kerja (7x3). Turutan produk dan masa pemprosesan adalah bergantung kepada satu sama lain. Panjang turutan produk boleh berbeza-beza daripada tiga kepada empat operasi dan tidak ada fleksibiliti pada turutan. Model simulasi ini berjalan selama 5 hari dengan 9 jam masa operasi setiap hari. Keputusan yang diperolehi menunjukkan bahawa dalam LFP, tidak ada peraturan tunggal yang menguasai peraturan lain walaupun EDD seolah-olah lebih berkesan daripada kaedah-kaedah lain. Ringkasan keputusan menunjukkan bahawa kaedah penjadualan terbaik bagi Jumlah Purata Masa Terlewat adalah SPT, bagi Purata Produk Tertangguh adalah EDD, untuk Masa Penghasilan Produk adalah EDD dan kaedah penjadualan terbaik bagi Penggunaan Sumber adalah SPT. Manakala untuk PP, tidak ada juga peraturan tunggal dominan yang jelas walaupun peraturan yang kelihatan paling berjaya adalah yang mempunyai masa pemprosesan yang singkat. Ringkasan keputusan menunjukkan bahawa kaedah penjadualan terbaik bagi Jumlah Purata Masa Terlewat adalah EDD. Bagi Purata Produk Tertangguh adalah FIFO dan EDD, untuk Masa Penghasilan Produk adalah SPT dan kaedah penjadualan terbaik bagi Penggunaan Sumber adalah SPT, FIFO, LPT dan EDD kerana keputusan bagi kaedah-kaedah tersebut adalah sama. Keputusan-keputusan tersebut boleh mengurangkan masa untuk menghasilkan produk dan mengurangkan kelewatan dalam menyiapkan pekerjaan.

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LIST OF ABBREVIATIONS

EDD	Earliest Due Date
FIFO	First In First Out
LPT	Longest Processing Time
SPT	Shortest Processing Time

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Scheduling is commonly an important tool in manufacturing and production system environments. It may give major impact on the productivity of a process. In real production floor, scheduling is a continuously reactive process which face suddenly or unexpected of any new events. In manufacturing, the production mostly relate to the processing time, costs and quality. Scheduling do play important role to the raising of efficiency in any production system.

Nowadays, many approaches have been developed to resolve the real time events problem. It is more easy to use specific computational tools rather than doing manual scheduling. Most of job shop scheduling approaches focuses on the static environment (deterministic) which cannot react instantly to the problem, while dynamic job shop scheduling (DJSS) is usually intermittent and often stochastic and it can backup any incoming problems.

In DJSS problem, the production will experience high degree of randomness which caused by various forms of uncertainties such as due date changes, random job processing times, inoperable machines, rush orders, material shortage, and job cancellation at anytime. The problems may change over time and can change the system status and affect the performance.

Many companies get difficulties in scheduling their jobs as R2 Print Enterprise has no fixed scheduling system. They usually faced the problem of not delivering jobs on time. Therefore, the decision support tool will facilitate the use of data, models and structured decision process in decision-making to support the problems. The scheduling system is developed by doing simulation using Arena simulation software based on the real-time production.

1.2 PROBLEM STATEMENT

Job shop manufacturing system with facility of processing variety of jobs may encountered many scheduling problems. It is clear that ineffectiveness of production workflow resulting in longer cycle time of the production. Waiting time will be longer if the cycle time increase and will affect the customer. R2 Print Enterprise commonly receives new or rush orders from different customers instead of facing the problem of material shortage and due date changes. When the orders to delivery process are diagnosed, the printing firm may find one or more problem that contributed to the delay. Therefore, scheduling system is created using Arena simulation software to make sure jobs are delivered on time.

1.3 OBJECTIVES

i. To understand the job shop production in dynamic environment.
ii. To develop scheduling system based on real-time data in the R2 Print Enterprise.
iii. To implement scheduling system in R2 Print Enterprise.

1.4 SCOPE OF RESEARCH

The job scopes of this research are:

i. Limited to job shop type of manufacturing system.
ii. Production takes place in Small and Medium Enterprise (SME).
iii. Focus on the process and operation time.
iv. Jobs are dependent.
v. The dynamic of the job shop focuses on job arrival.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this literature review chapter is to provide the overall review of previous researches related to the job shop production (JSP), job shop scheduling problem (JSSP) and dynamic job shop scheduling problems (DJSSP). The reviews are based on the approaches and methods, performance measures, problem size, the sensitivity result of different methods and the simulation of dynamic job shop scheduling (DJSS).

2.2 JOB SHOP PRODUCTION

The character of job shop production are defined as manufacturing of one or few numbers of products that was designed and been produced due to the customer needs or specifications among prefixed time and cost. The typical feature of the job shop can be low volume and high kind of products. A job shop includes of general purpose machines organized into different departments. Every job demands unique technological necessities, demands process on machines in a certain sequence (Kumar & Suresh, 2008). Job shop production mostly describes a manufacturing environment which produces goods in small batches. The job shop production is a common manufacturing in small and medium-sized enterprises (SMEs). For example, job shop in the print shops and the machine shop.

2.2.1 Job Shop Scheduling Problem (JSSP)

Scheduling is specified as the distribution of resources to jobs over time. Scheduling decides the program for operations and it determines the distribution of resources to jobs over time as well as the sequence of operations to be followed. It is a decision-making method with the aim of optimizing one or more objectives. The objective of job shop scheduling is to find out the sequence of parts with the least time to finish off all parts (Nowicki & Smutnicki, 1996). Most of job shop scheduling approaches usually focus on a static environment and assume deterministic and known in advance data. However, in real-world applications, this situation is not often met since data may be subject to uncertainty and it may change over time. Such an approach is called offline scheduling (Said et al., 2015). In the real production, scheduling is more complex due to dynamic or changes of the nuture in manufacturing system. Al-Hinai and ElMekkawy (2011) studied that job shop scheduling problems are among the main thorough combinatorial issues. Job shop scheduling can be categories into two main classes, static or deterministic which known as offline scheduling, and dynamic which is the online scheduling. The minimizing function is tried out to the total production time, but it can also be tried out to reduce delivery time as well as to reduce the inoperable machine. Job shop scheduling problem commonly can be applied to the system by the two approaches: (i) stochastically and; (ii) deterministic mode (Gómez et al., 1996). Stochastic mode works with unknown expectation for the coming of products and processing times in the job floor. In deterministic mode, it is assumed that the processing time of jobs are already known in advance.

2.2.2 Dynamic Job Shop Scheduling Problem (DJJSP)

Dynamic job shop scheduling (DJSS) is usually intermittent and often stochastic. There is a different between the theoretical formulations of the scheduling problem and practical methods use in real world scenarios. In DJSSP, the production will experience high degree of randomness and uncertainty which caused by uncertainties like due date changes, amount of jobs or total number of operable machines changed by any new event. The common job shop scheduling model considered n jobs to be operated on m machine (n x m problem) when minimizing the completion time of jobs (Zandieh & Adibi, 2010). The events may change over time and can change the system condition and affect the performance.

The incoming orders are usually differs on number of order, the designs, the process flow (for example, number of operations, work sequences, setup times and processing times) or urgency. The variations make the production in the companies become more complex as it become hard to predict how the production orders will be divided across the machines when there is high demand on machines and variety order of products. Those problems will cause long waiting times of orders in the production. Therefore, DJJSP involved determining the order or the priority of the jobs that waiting to be processed at every machine to reach the desired target (Vinod & Sridharan, 2011).

2.3 PREVIOUS RESEARCH ON JOB SHOP SCHEDULING

There have been significant research efforts over the years in the dynamic job shop scheduling problems. The previous researches help more in understanding the basis of this research and find suitable techniques to be used.

2.3.1 Job Shop Scheduling

Job shop scheduling is the key in the manufacturing world and exists in most manufacturing sectors. It is very difficult to make whether in practice or in theory. It is supported by the fact that numerous parameters to be examine (Kaban et al., 2012). Renna (2010) had created schedules that satisfy all the restrictions while taking as little overall time as possible. Scheduling theory is distressed with the mathematical formulation and inquiry of various scheduling models and development of related solution methodologies. The dynamic job shop scheduling can be solved using few techniques. In Gupta and Sivakumar (2006), according to the development history, heuristic rule were started first, followed by the mathematical programming technique, then the neighbourhood search and at last to the most recent artificial intelligence approaches.

To cope with dynamic nature of problem and to increase the efficiency and effectiveness of the scheduling method, Zandieh and Adibi (2010) addressed a dynamic job shop scheduling problem that considered the unsystemantic job arrivals and machine failure. Said et al. (2015) only consider problems in the presence of machine breakdown. Dileepan and Ahmadi (2010) selected set of scheduling measure commonly used in scheduling research and develop a set of simple rules that can be simply implemented in relatively small dynamic job shop.

2.3.2 Approach and Method

Many optimization methods have been suggested to the solution of job shop scheduling problem. Renna (2010) developed pheromone approaches for the job shop scheduling problem. The approach is accomplished by Multi Agent Architecture and is compared with a coordination approach. Said et al. (2015) proposed using the data mining based approach to cope with the dynamic job shop problem using historical scheduling data to resolve problem. The classification rule is generated by applying learning algorithm and is compared with another rule to get the best performing rule for the mean tardiness measure. Dispatching heuristic is used in dynamic context because of their ability to ease the implementation and compatibility in the dynamic environment of manufacturing systems. The performance of each rules are compared and summarized to find out the ranking for all the different dispatching rules (Kaban et al., 2012).

Iwamura (2005) and Cowling (2004) have used the scheduling rule and objectives in Multi-Agent theory to develop a scheduling and control model for the complex production system. Byung Jun Joo et al. (2013) use the dispatching rule based algorithm which highlights the quality and real time shop information to cope with the dynamic environment in flexible flow shop. Zandieh and Adibi (2010) comes out with using the artificial neural network (ANN) with a back propagation error learning algorithm to update parameters of the variable neighbourhood search (VNS) at any rescheduling point according to the issues. The method is differentiated with dispatching rules that have been widely used in dynamic job shop problem. VNS is a new neighbourhood search metaheuristic that have been widely used to combinatorial optimization problems in previous years. Dileepan and Ahmadi (2010) use five scheduling criteria for two dynamic production shop environments, namely a job shop with jumbled flow and a job shop with limited jumbled flow: (i) Slack per remaining operation (SPRO), (ii) Priority ratio (PR), (iii) Earliest due date (EDD) (iv) Total work content remaining (TWKR) (v) Smallest processing time (SPT). Each rule has to be known to minimize or maximize the performance of the production. Karafa et al. (2012) use an Evolutionary Algoriths (EAs) based heuristic and a simulation-based Pareto Front (PF) algorithm to minimize the risk component and other problem. Vinod and Sridharan (2011) use four methods which are the dynamic processing plus waiting time (DPPW) method, total work content (TWK) method, dynamic total work content (DTWK) method and random work content (RWK) method, while rules used for the scheduling of jobs are the first in first out (FIFO), shortest processing time (SPT), earliest modified operation due-date (EMODD), combination of critical ratio and shortest processing time (CRSPT), combination of slack per remaining processing time and shortest processing time (SLRPT), processing time plus work in queue of next operation (PTWINQ) and processing time plus work in queue of next operation plus slack (PTWINQSL).

2.3.3 Performance Measures

Every research has performance to be measured. The experimental results in (Said et al., 2015) verify the performance of classification rule for minimizing mean tardiness. In Kaban et al. (2012), the WIP average, total average time required to complete an action and total waiting time average for each part are considered. Shabtay (2010) had researched on batch delivery single machine scheduling problem that consider the due-dates are controllable and do measures in the earliness time, tardiness, holding time, due- date assignment and delivery costs. Vinod and Sridharan (2011) highlighted the measures of mean flow time, mean tardiness, mean absolute lateness, standard deviation of flow time, standard deviation of tardiness, standard deviation of absolute lateness, percentage of tardy jobs, average flow allowance and average flow factor.

2.3.4 Problem Size

Most of case study used between three to ten machines. Routing length can be varies from three to seven operations and there is no flexibility on the routing (Kaban et al., 2012). Job shop scheduling model considers n jobs to be processed on m machine. Said et al. (2015) consider the job shop consisted of the use of four machines and four types of orders (4x4). Zandieh and Adibi (2010) simulated a job shop consist of 10 machines and 10 jobs (10x10). Dileepan and Ahmadi (2010) considered job shops with n = 3 work centers, n = 7 work centers and n = 10 workcenters and each cases has two routing scenarios, Moderate and Complex. Takeshi Yamada and Ryohei Nakano (1997) use example of 3x3 in their research. Vinod and Sridharan (2011) do the simulation based on system with eight individual machines or single function work stations with each machine performed different operation.

2.4 SIMULATION OF DYNAMIC JOB SHOP SCHEDULING (DJSS)

2.4.1 Simulation Tools

Most researchers use Arena simulation software to run the simulation model. Renna (2010), Kaban et al., (2012) and Said et al. (2015) use Arena simulation software to develop the simulation model for the job shop scheduling problem. Dileepan and Ahmadi (2010) use ProModel software to develop simulation model. Vinod and Sridharan (2011) do the model simulation using C programming language and run on PC with Pentium Processor.

2.4.2 Simulation Assumptions

Joo et al. (2013) make few assumptions in their research. Each machine can process one job at a time and preemptions are not allowed. They do not consider the transfer time between stages and the queue of job is unlimited. There is no time delay in movement from one stage to another stage. In Al-Hinai and ElMekkawy (2011), all jobs are assumed ready to start at zero time, machines are always available and never breakdown. Other that that, the setup time is sequence independent and included in any operation processing time. When an operation starts, it cannot be interrupted as machine is set to do only one operation at any time. Zandieh and Adibi (2010) made assumption that there are no alternate routings of a job, the job operations are dependent and the operating processing time and number of operable machine are already known in advance. Renna (2010) assumed that each part has a predefined number of operations performed by the manufacturing cell and each part is assigned a due date. Besides that, the orders for production of different parts arrive randomly with an inter-arrival that is exponential distribution. The machine performs the manufacturing operation with an efficiency, which sets the speed of the operation. The queues are managed by the First In First Out policy to investigate only the pheromone approaches policy. Lastly, the machine can breakdown randomly with an exponential distribution.

2.5 COMPANY BACKGROUND

R2 Print Enterprise is one of the SME companies which run printing services for years and they already have their own regular customers. R2 Print Enterprise prints product in various size of large format product and paper product using latest technology machines. As there are many customers, many new orders will come unexpectedly. Figure 2.1 (a) and (b) presents the main products printed by R2 Print Enterprise.

2.5.1 Product

Large Format Product (LFP)	• Banner • Bunting • Backdrop • Billboard • Sticker • Poster

Figure 2.1 (a): Large Format Products

Paper Product (PP)	• Business card • Flyer • Brochure • Tentative • Ticket • Pamphlet • Invitation card

Figure 2.1 (b): Paper Products

Figure 2.2: Bunting

Figure 2.3: Business card

Figure 2.4: Ticket

Figure 2.5: Tentative

2.5.2 Layout for Printing Area

R2 Print Enterprise has two different working areas to produce their products. The work areas are divided into two: i) The LFP work area as shown in Figure 2.6. ii) The PP work area as shown in Figure 2.7.

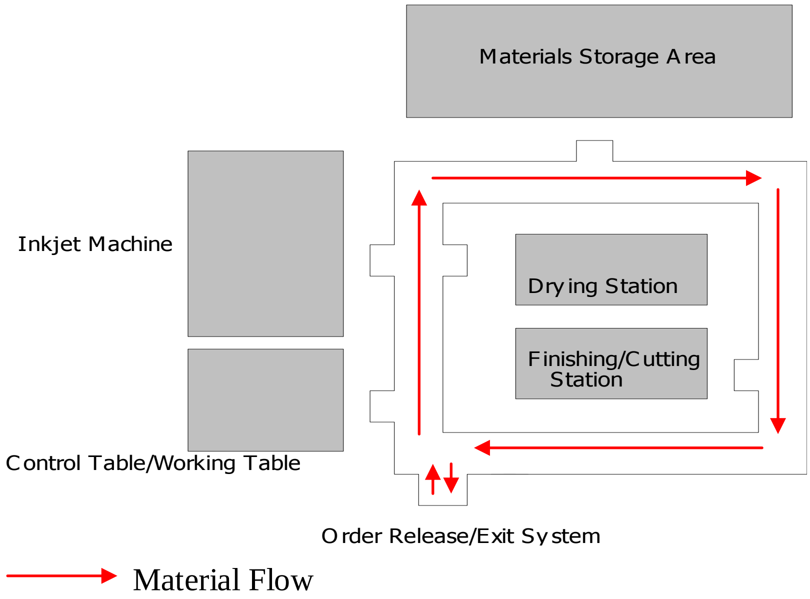


Figure 2.6: The plant layout for large format product

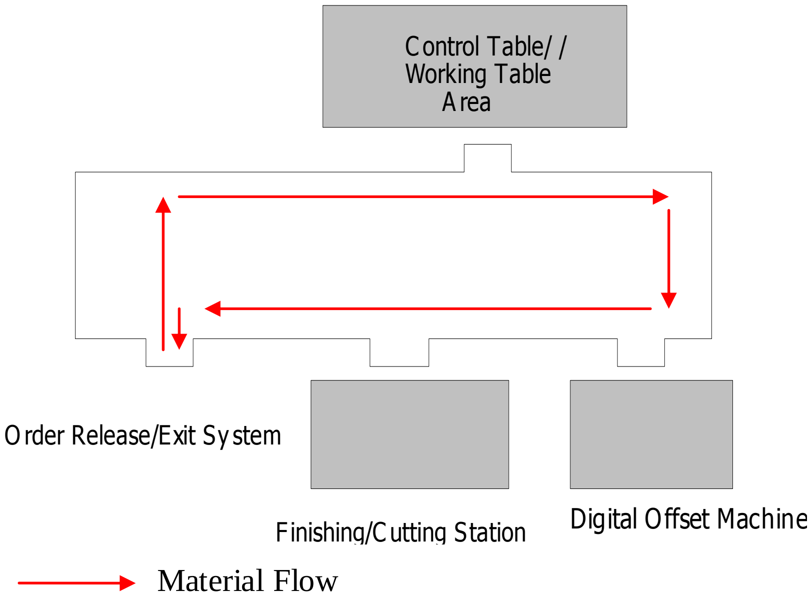


Figure 2.7: The plant layout for paper product

Figure 2.8: Large format inkjet printer

Figure 2.9: The paper product work area. The digital offset printer and cutting machine

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to outline the methodology for this research in dynamic job shop scheduling. This chapter further discusses the research methodology flowchart from the beginning until end of research, the tools and equipment for data collection, the assumption made in this research and ways to optimize the scheduling.

3.2 RESEARCH METHODOLOGY FLOWCHART

Figure 3.1 shows the flowchart that presents the steps involved in doing this dynamic job shop scheduling research.

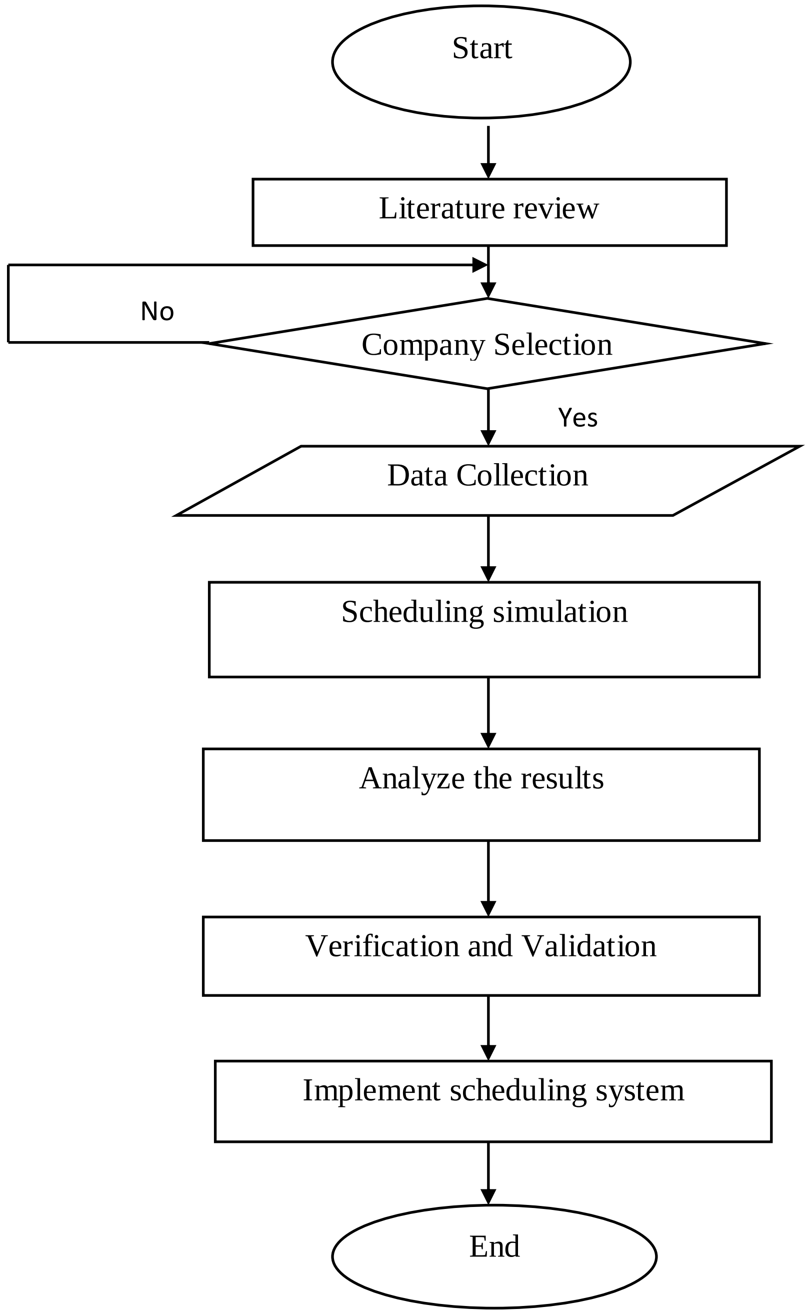


Figure 3.1: Flowchart of research methodology

Literature review does describe, summarized, evaluates and clarified the literature related to the selected area. Understanding the literature review gave a theoretical basis for this research and helps to find related industry in the dynamic job shop manufacturing system. R2 Print Enterprise which runs business in printing services and product is chosen. Data collected from the company is then pre-processed before being optimized by Arena simulation software and being analyzed to get the results. Verification and validation is an important part of the simulation process. The verification and validation process in Arena software is to ensure the model behaves in the way it intended to be where we can trust it to solve the problem as few measures might be smaller or larger than expected and to ensure the model behaves as the real system might be difficult too. To implement the scheduling system is to carry out the scheduling and put it into practice.

3.3 DATA COLLECTION

The important step in this research is collecting the data. The data is based on real-time production. Data is collected manually in a period of observation time as to find more consistent data and there are few ways or tools can be used in collecting the data.

3.3.1 Tools and Equipment for Data Collection

In this research, schedule form is created to collect data. Few components being considered in the form are:

i. Type of form (using blank form)
ii. Type of measurement (Time taken)
iii. Type of work (Each operation involved)
iv. Specifications (Machine performances)

Other than that, Arena® simulation software is used in this research as it can help to indicate, predict and compute system strategies for effective, efficient and optimized performance. Arena simulation software can mimic discrete event simulations that describe process with unique, specific events in time. These flexible, activity-based models can be effectively used to simulate nearly about any process.

3.3.2 Job Environment

In this research, the job shop system consists of two workstations. The first workstation does process on the Large Format Product (LFP) and use the large Inkjet Printer machine. Meanwhile, the second workstation does process on Paper Product (PP) with two main machines which are the Digital Offset machine and Cutting machine. Each machine performed different operations based on the type of product. The job has probability of getting new job at any event. For every job, the operations involved consist of setting up the machine, printing, drying and finishing. Table 3.1 shows the operation plan of each job.

Table 3.1: Operation plan for each job type

<table>
<tr><th>Product Type</th><th>Operation Sequences</th></tr>
<tr><td rowspan="4">Large Format Product (LFP)</td><td>Setup Machine</td></tr>
<tr><td>Printing</td></tr>
<tr><td>Drying</td></tr>
<tr><td>Finishing
(cutting, making holes, pole pockets, hemming, packaging)</td></tr>
<tr><td rowspan="3">Paper Product (PP)</td><td>Setup Machine</td></tr>
<tr><td>Printing</td></tr>
<tr><td>Finishing
(folding, cutting by machine or manually, packing)</td></tr>
</table>

3.4 ASSUMPTIONS MADE IN THE RESEARCH

In R2 Print Enterprise, mostly the problems are delay in achieving due date due to dynamic nature such as new arrival of orders, ineffectiveness workstation usage due to weak planning and overload in some workstations due to insufficient work station and lack of laborers. The workers usually face the problem of cannot delivery jobs on time. New order and rush order from the customer may interrupt the production process.

Therefore, there are few assumptions made under this dynamic job shop scheduling research:

i. Only one operation can be performed on each machine at a time on the job.
ii. The machine cannot be interrupted once an operation has started.
iii. The machines are not identical and perform different operation.
iv. Different type of products.
v. Orders for production of different products can come randomly.
vi. Transfer time between each work centers are zero.
vii. Each product has due date and time.
viii. Machines are in good conditions.
ix. No materials shortage.

3.5.1 Scheduling Heuristic Rule

The scheduling is performed for two different job orders on two workstations, 2 x 2. The model simulation is built based on two jobs consist of large format products (LFP) and paper products (PP). In the first workstations (W1), there are six main products and four work centers (6 x 4) to be processed using inkjet printer machine and in second workstation (W2), there are seven products to be processed on three work centers (7 x 3) by the digital offset machine. In each workstation, setup time is considered before continue processing the product.

The scheduling heuristic rules prioritize all jobs that are waiting to be process on a machine or work centers. The scheduling inspects the waiting jobs and select the job with the highest priority. The four main priority rules used in this research involved the processing times and due date:

i) First in First out (FIFO) which selects the next job from the queue based on their arrival time at the current process.
ii) Earliest Due Date (EDD) which selects the jobs with the earliest due date.
iii) Shortest Processing Time (SPT) which selects the job with shortest time on processes.

iv) Longest Processing Time (LPT) which selects the job with longest time on processes.

In the present production, the products are transport to the locations by the worker himself. Once the product is transported to the next location, it is placed in the FIFO input buffer. Finally when the processes are completed, the finished products depart from the job shop via the shop exit. The dynamic job shop occurred when the queue is changed to other attribute properties. Therefore, the Arena simulation software can mimic those dispatching rules by its queue properties in the Queue Spreadsheet as below:

i) First in First out (FIFO)
ii) Last in First Out (LIFO)
iii) Lowest Attribute Value
iv) Highest Attribute Value

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The purpose of this chapter is to present the data collected, results and elaborate more on the findings of this research. This chapter performed all the methods used with the results based on few performance measures; Total Time Delays, Total Product Delays, Overall Product Flow Time and Resource Utilization. The simulation model results are then presented graphically and being discussed to select the best rule to be used in the scheduling system.

4.2 LARGE FORMAT PRODUCT JOB DATA

The Large Format Product (LFP) workstation produce six main products namely as S1 (Banner), S2 (Bunting), S3 (Backdrop), S4 (Billboard), S5 (Sticker) and S6 (A1 Poster). The LFP job consists of the following station:

- An order release station
- A set up station with single worker
- An inkjet printing station with one machine and single worker
- A drying station with single worker
- A finishing station with single worker
- A shop exit

The product arrives randomly with the distributions of 45% are of type S1, 20% are of type S2, 15% are of type S3, 5% are of type S4, 10% are of type S5 and 5% are of type S6. When the order is released, the product is then dispatched to its sequence of manufacturing operations. Figure 4.1 shows the operation sequences of the LFP products. The processing times and due dates for each type of products is displayed in Table 4.1. All average processing times are taken in minute. In the finishing process, there are few processes to be done such as cutting, making holes, pole pockets, hemming, and packaging.

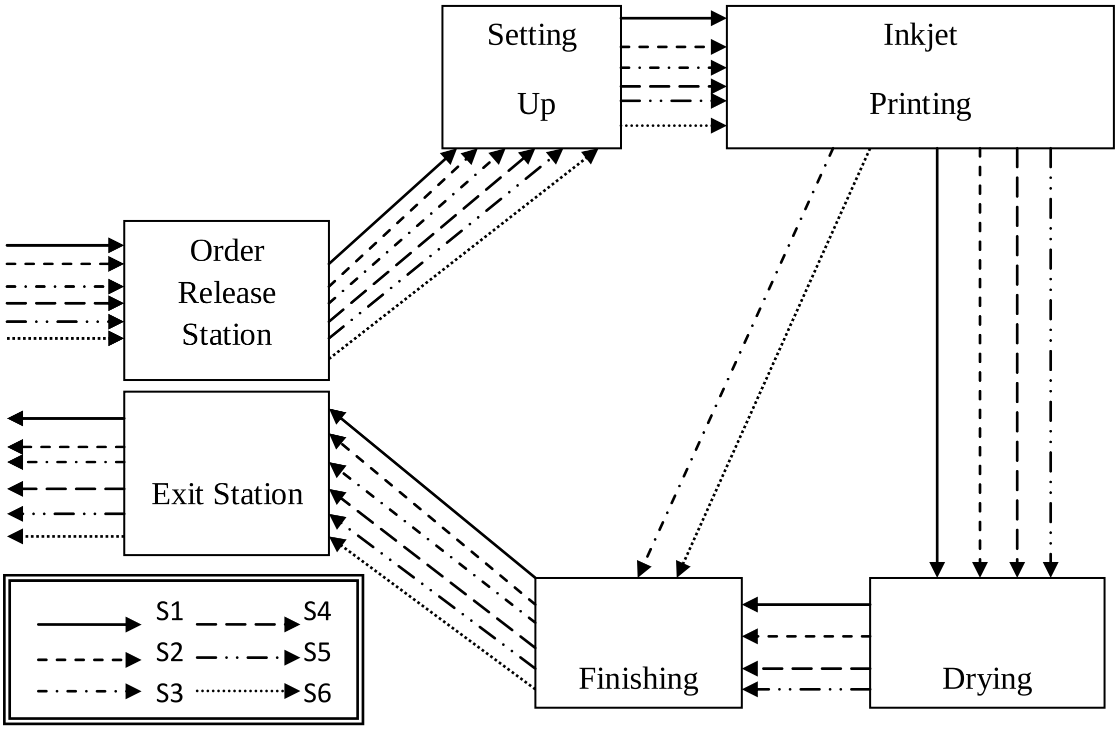


Figure 4.1: Product operation sequences of Large Format Product (LFP)

Table 4.1: Operation plan for each LFP by type

Product Type	Operation Sequence	Processing Time (Minutes)	Overall Processing Time (Minute)	Average Due Date (Days)
S1	Setting up	1.5000	7.7467	4.0
	Printing	2.8300		
	Drying	0.5000		
	Finishing	2.9167		
S2	Setting up	1.5000	7.6667	4.5
	Printing	1.4167		
	Drying	1.0000		
	Finishing	3.7500		
S3	Setting up	2.5000	7.8300	3.0
	Printing	2.5000		
	Finishing	2.8300		
S4	Setting up	1.2500	8.9170	3.0
	Printing	6.1670		
	Drying	1.0000		
	Finishing	0.5000		
S5	Setting up	1.5000	4.8197	2.0
	Printing	1.6330		
	Drying	0.4200		
	Finishing	1.2667		
S6	Setting up	1.5000	3.9167	2.0
	Printing	1.4167		
	Finishing	1.0000		

4.2.1 Simulation Model of LFP Using Arena

Figure 4.2 shows the simulation model which built based on the real production floor (6 products x 4 work centers).

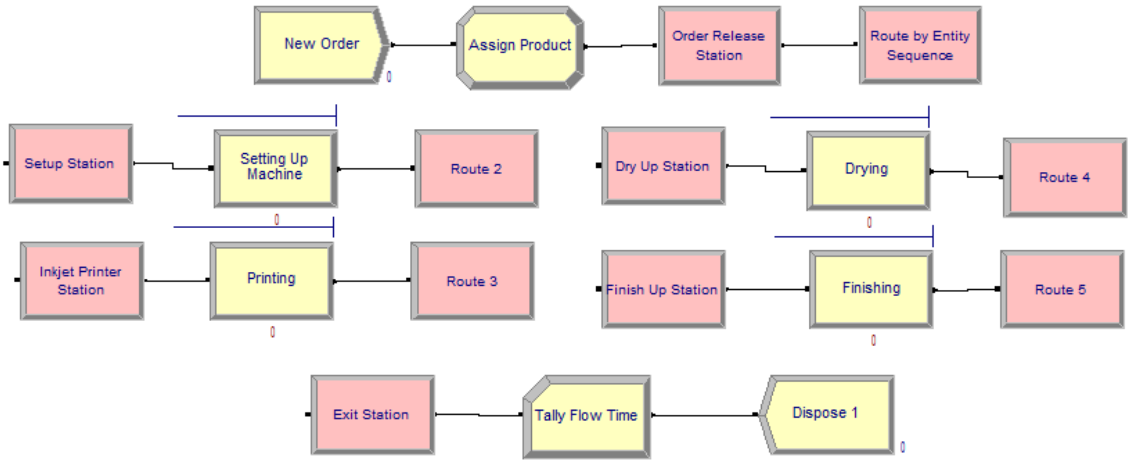


Figure 4.2: Arena simulation model for LFP

4.2.2 Product Arrivals

Product entities are created in the Create module, called the New Order as shown in Figure 4.3. The Type of the product arrival is Random (Expo) where the orders arrive randomly and will wait in the buffer if the machine is busy processing another job. The entities per arrival indicated that the product arrive one at a time. At this step, the sequence is not yet associated with each arriving product entity.

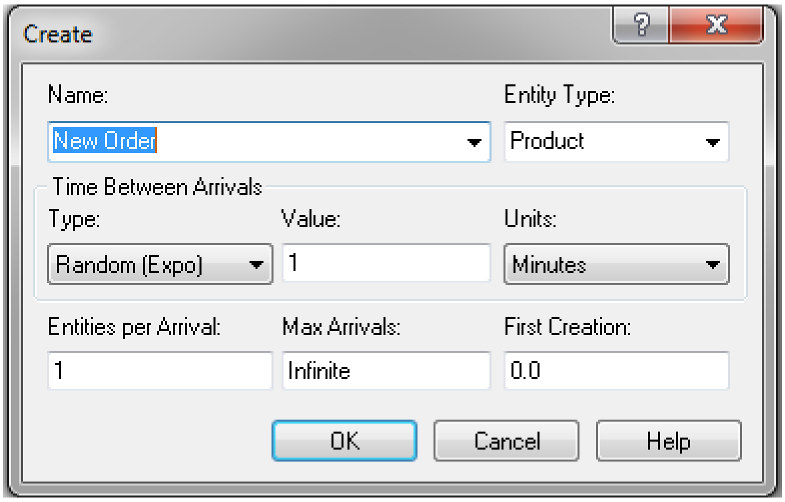


Figure 4.3: Dialog box of the Create Module

The association is made in the Assign module called Assign Product as shown in Figure 4.4. The assignments serve two purposes: to determine which part has arrived and define an index, Part Index that allow to associate the proper sequence, entity type, entity picture, entity due date and entity processing time. The ArrTime attribute is for computing the product entity's flow time. The Part Index is determined by a discrete distribution, DISC. In our problem, the integers are 1, 2, 3, 4, 5 and 6 with percent probabilities of 45%, 20%, 15%, 5%, 10% and 5%. The values are entered in cumulative probability between 0 and 1.

The operations sequences for the product are specified in the Sequence module from the Advanced Transfer Panel as in Figure 4.5. Six product sequences are defined with a series of Steps. The five steps of Product 1 (S1) are displayed in the middle of the spreadsheet. Each step specifies the station name and each assignment specify the associated values (processing time value). The processing time for setting up machine is shown in the top spreadsheet of Figure 4.5. The other product sequences (S2, S3, S4, S5 and S6) did undergo the same steps to insert their processing time values.

Assignments

	Type	Attribute Name	New Value
1	Attribute	Part Index	DISC(.45,1,.65,2,.80,3,.85,4,.95,5,1,6)
2	Attribute	Entity.Sequence	Part Index
3	Attribute	Entity.Type	Part Index
4	Attribute	Entity.Picture	Part Pictures (Part Index)
5	Attribute	ArrTime	TNOW
6	Attribute	Entity.DueDate	Part Due Date (Part Index)
7	Attribute	Entity.PartProcessingTime	Part Processing Time (Part Index)

Figure 4.4: Dialog box of the Assign Module

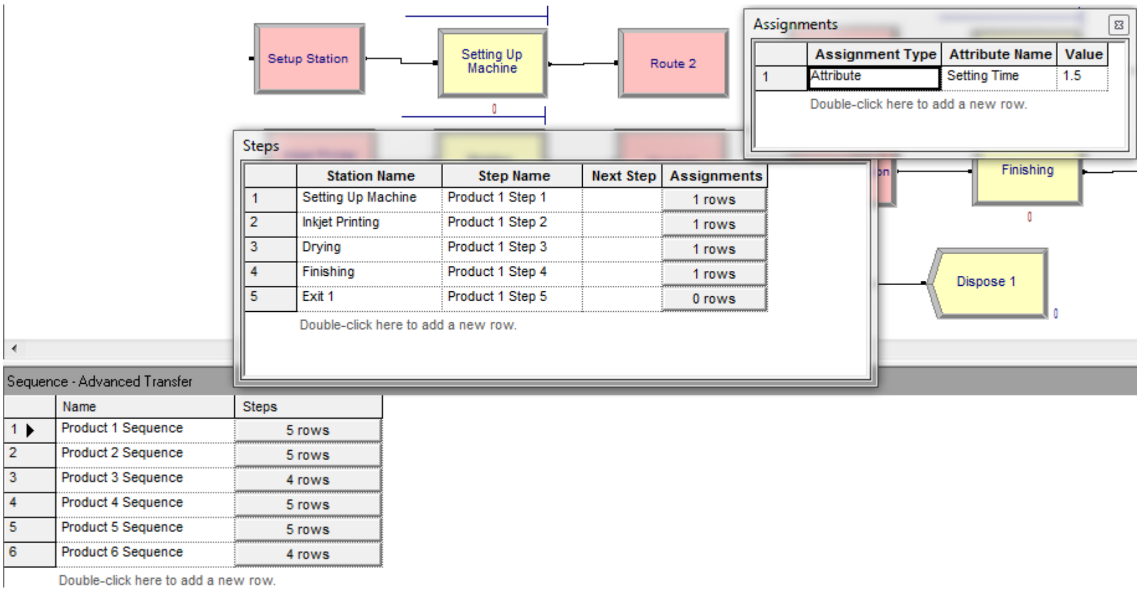


Figure 4.5: Dialog spreadsheet of the Sequence module

4.2.3 Product Processing

The product processing encompasses sets of Station modules. Each station modeled an operation in the sequence from setup to finish up as shown in Figure 4.6. Since all steps have the same structure, only setup operation is explained. The product entity will enter the Station module called Setup Station. It then enters the Process module called Setting Up Machine as in Figure 4.7. The Seize Delay Release in Action field is used to model the product delays at the process. The resource seized is Setting up with worker with the capacity of 1. The product entities move from one operation to another operation according to their sequences.

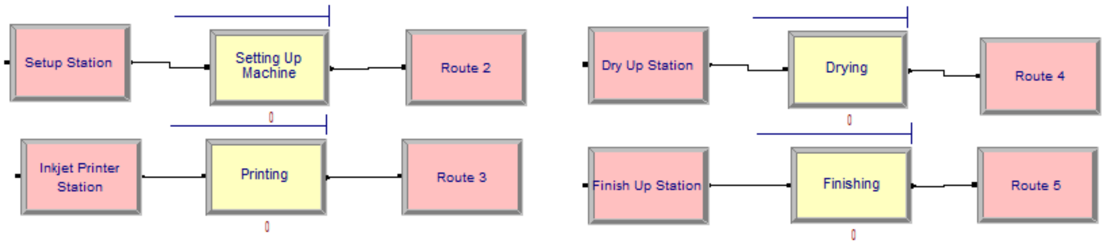


Figure 4.6: The product processing Stations

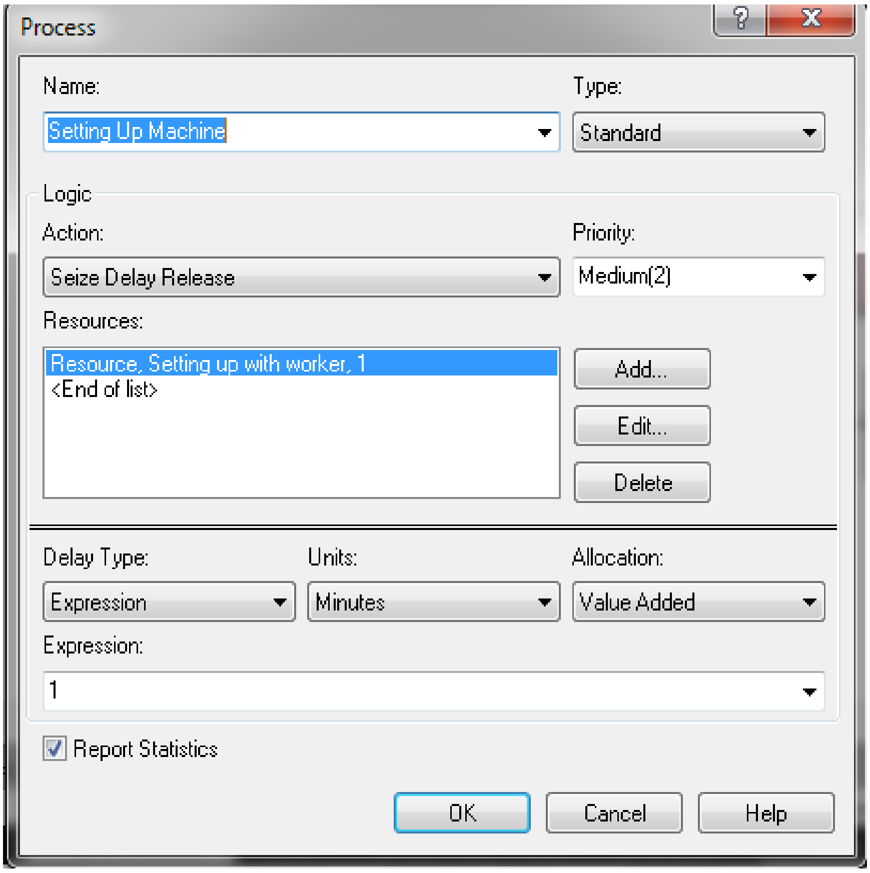


Figure 4.7: Dialog box of Process module (Setting up machine)

When product entity gets to the Process module, the entity will have to queue up. This is where the dispatching rules are implemented. The queue spreadsheet as in Figure 4.8 can be controlled. The discipline used to operate it is shown in the Type list.

The First In First Out is the default queue properties. The queue can be ranked according to the attribute of entities that reside in it. If the Lowest Attribute Value is chosen, the queue will be ranked in increasing order of some attribute. In this research, the queue is set with the specified Attribute as in Table 4.2 below:

Queue - Basic Process

	Name	Type	Attribute Name
1	Setting Up Machine.Queue	First In First Out	Entity.PartProcessingTime
2	Printing.Queue	Lowest Attribute Value	Entity.PartProcessingTime
3	Drying.Queue	Lowest Attribute Value	Entity.PartProcessingTime
4	Finishing.Queue	Lowest Attribute Value	Entity.PartProcessingTime

Figure 4.8: Dialog spreadsheet of Queue module

Table 4.2: The queue properties of dispatching heuristic rules

Rule Name	**Type**	**Attribute Name**
First In First Out (FIFO)	First In First Out	-
Earliest Due Date (EDD)	Lowest Attribute Value	Entity.DueDate
Shortest Processing Time (SPT)	Lowest Attribute Value	Entity.PartProcessingTime
Longest Processing Time (LPT)	Highest Attribute Value	Entity.PartProcessingTime

The Variable spreadsheet defined the Part Due Date and Part Processing Time. The initial values entered are from the collected data. The value can be used whenever it is needed. If the model is modified in the future where the time is set to a different constant, we only need to change the value throughout the model. The initial values of due date and processing time for each product are defined as shown in the top spreadsheet of Figure 4.9.

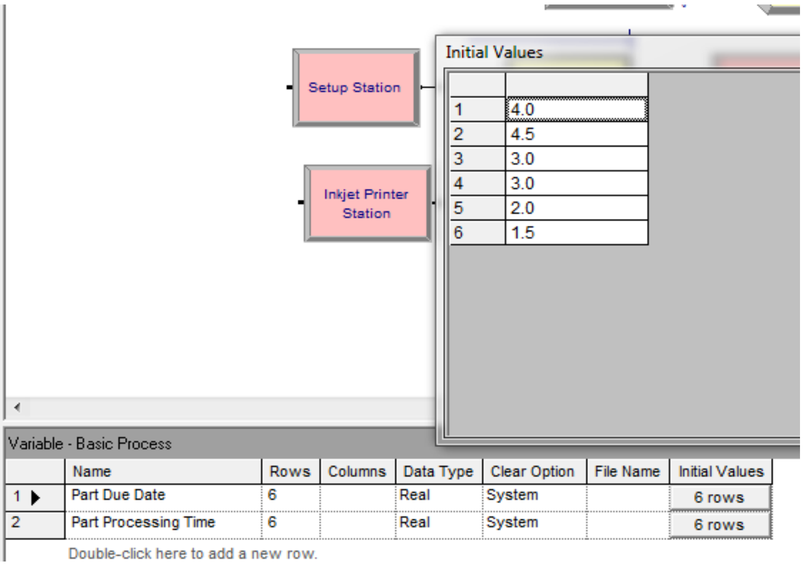


Figure 4.9: Dialog spreadsheet of Variable module

Figure 4.10 shows the dialog box of the Record module called Tally Flow Time. The flow time is tallied with the ArrTime attribute of each finished product entity. The Flow Times set is specified in the Set module spreadsheet from the Basic Process template panel. The Set spreadsheet and its members of Flow Times set are shown in Figure 4.11.

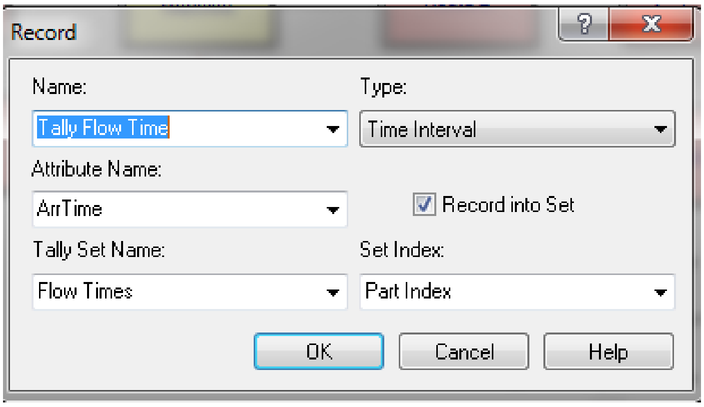


Figure 4.10: Dialog box of Record module

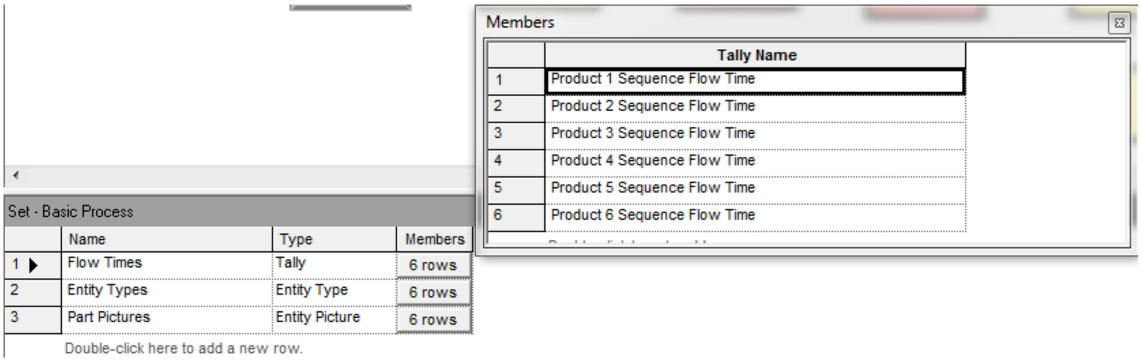


Figure 4.11: Dialog spreadsheet of Set module and the members dialog spreadsheet of the Flow Times

4.3 PAPER PRODUCT JOB DATA

The Paper Product (PP) job produce seven main products namely as S1 (Business Card), S2 (A5 Flyer), S3 (A5 Brochure), S4 (A5 Tentative), S5 (Ticket) S6 (A4 Pamphlet) and S7 (Invitation Card). The PP job consists of the following station:

- An order release station
- A set up station with single worker
- An inkjet printing station with one machine and single worker
- A finishing station with single worker
- A shop exit

There is no drying process in PP job. The product arrives randomly with the distributions of 30% are of type S1, 15% are of type S2, 15% are of type S3, 10% are of type S4, 5% are of type S5, 10% are of type S6 and 15% of type S7.

Figure 4.12 shows the operation sequences of the PP. The processing times and due dates for PP is displayed in Table 4.3. All average processing times are taken in minutes.

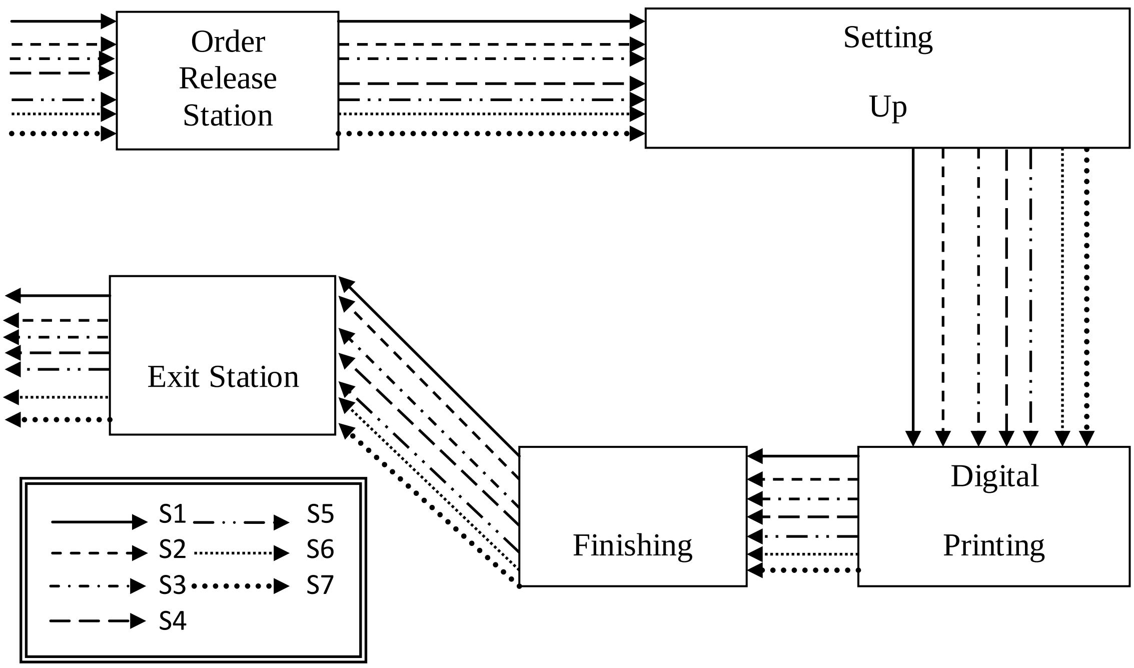


Figure 4.12: Product operation sequences of Paper Product (PP)

Table 4.3: Operation plan for each PP by type

Product Type	Operation Sequence	Processing Time (Minutes)	Overall Processing Time (Minute)	Average Due Date (Days)
S1	Setting up	1.5000	2.7628	3.0
	Printing	0.0705		
	Finishing	1.1923		
S2	Setting up	1.5000	2.5210	3.0
	Printing	0.0210		
	Finishing	1.0000		
S3	Setting up	1.5000	2.5200	4.0
	Printing	0.0200		
	Finishing	1.0000		
S4	Setting up	1.5000	2.5180	5.5
	Printing	0.0180		
	Finishing	1.0000		
S5	Setting up	1.5000	2.4412	5.0
	Printing	0.1000		
	Finishing	0.8412		
S6	Setting up	1.5000	1.7727	3.5
	Printing	0.0227		
	Finishing	0.2500		
S7	Setting up	1.5000	1.7000	10.5
	Printing	0.0325		
	Finishing	0.1675		

4.3.1 Simulation Model of PP Using Arena

Figure 4.13 shows the simulation model which built based on the real production floor (7 products x 3 work centers). The PP undergoes the same simulation steps as in LFP. Only that the processing times are different and the determined Part Index is more than LFP, so the integers are 1, 2, 3, 4, 5, 6 and 7 with percent probabilities of 30%, 15%, 15%, 10%, 5%, 10% and 15%.

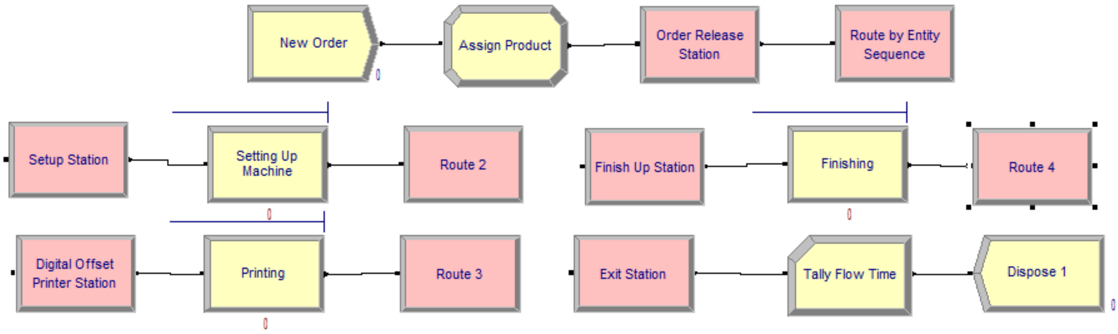


Figure 4.13: Arena simulation model for PP

4.4 SIMULATION CONDITION

The Arena simulation model was simulated for 5 days which equal to 2700 minutes. R2 Print Enterprise operates for 9 hours per day. The parameter of the Run Setup is shown in Figure 4.14. There is Warm Up Period in the simulation which means that the model starts out empty of product entities and all resource are idle. While simulation runs, the product entities can be seen through different stations, waiting for processing and transferred between operations.

After the simulation complete, Arena will generate report automatically. From the generated report, the average total time delays, the average product delays, the average product flow time and the average resource utilization are measured.

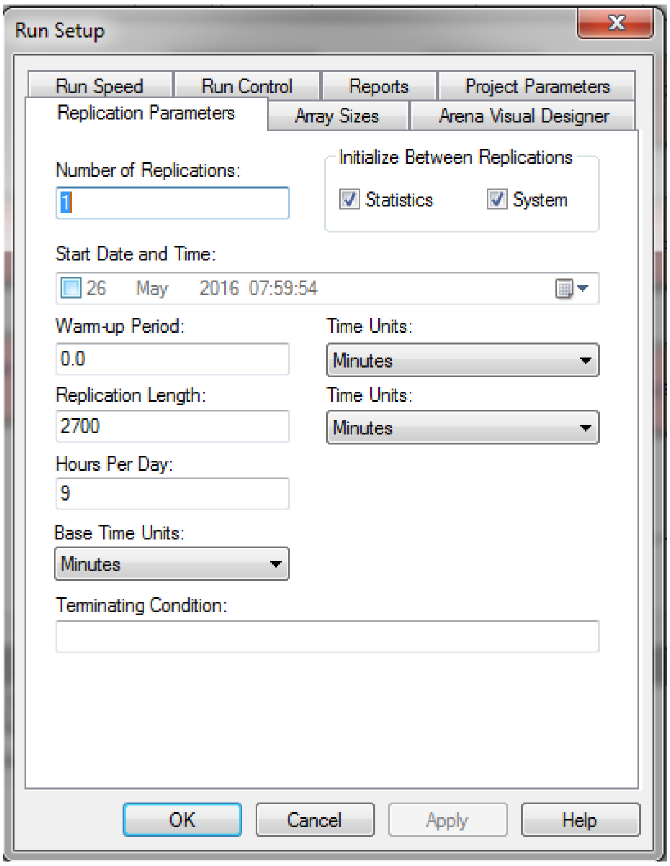


Figure 4.14: Dialog box of Run Setup

4.5 SIMULATION RESULT

The results from the report were analyzed, evaluated and presented graphically. The results shown start from the FIFO rule, followed by EDD rule, SPT rule and LPT rule.

4.5.1 The Large Format Product Job

The output results of Waiting Time or Time Delays are displayed in Figure 4.15, 4.16, 4.17 and 4.18. The summary of the Time Delays result is shown in Table 4.4 and Figure 4.19.

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	0.000000000	0.00	0.00
Finishing.Queue	0.1911	0.015079552	0.00	1.0000
Printing.Queue	0.00	0.000000000	0.00	0.00
Setting Up Machine.Queue	26.1686	(Correlated)	0.00	56.2281

Figure 4.15: The average waiting time of FIFO rule

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	0.000000000	0.00	0.00
Finishing.Queue	0.1795	0.027549417	0.00	1.0000
Printing.Queue	0.00	0.000000000	0.00	0.00
Setting Up Machine.Queue	25.1288	(Correlated)	0.00	283.81

Figure 4.16: The average waiting time of EDD rule

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	0.000000000	0.00	0.00
Finishing.Queue	0.1826	0.016218201	0.00	1.0000
Printing.Queue	0.00	0.000000000	0.00	0.00
Setting Up Machine.Queue	24.4437	(Correlated)	0.00	817.40

Figure 4.17: The average waiting time of SPT rule

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	0.000000000	0.00	0.00
Finishing.Queue	0.1947	0.023182541	0.00	1.0000
Printing.Queue	0.00	0.000000000	0.00	0.00
Setting Up Machine.Queue	24.5080	(Correlated)	0.00	803.29

Figure 4.18: The average waiting time of SPT rule

Table 4.4: The total average waiting time of LFP

Rules	Waiting Time (Minutes)
FIFO	26.36
EDD	25.31
SPT	24.63
LPT	24.70

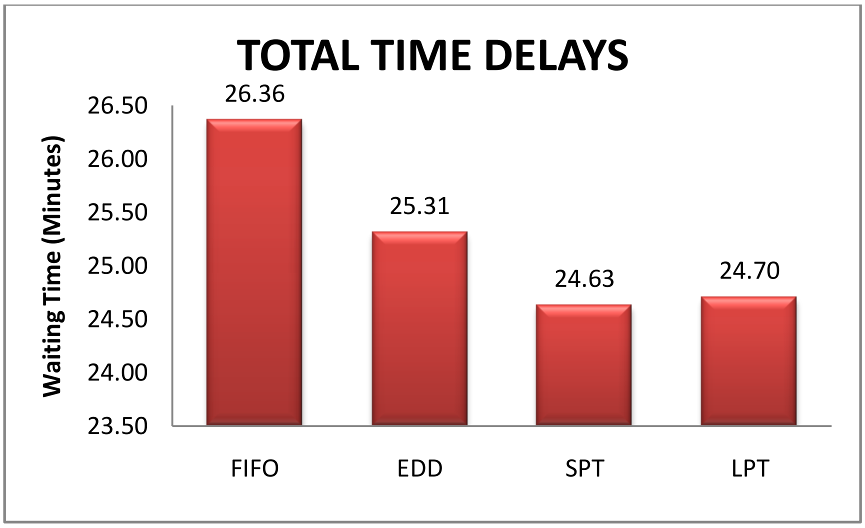


Figure 4.19: The result of total average time delays

The output results of Number Waiting or Product Delays are displayed in Figure 4.20, 4.21, 4.22 and 4.23. The summary of the Product Delays result is shown in Table 4.5 and Figure 4.24.

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	(Insufficient)	0.00	0.00
Finishing.Queue	0.1810	0.014024053	0.00	1.0000
Printing.Queue	0.00	(Insufficient)	0.00	0.00
Setting Up Machine.Queue	26.2268	(Correlated)	0.00	57.0000

Figure 4.20: The average number waiting of FIFO rule

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	(Insufficient)	0.00	0.00
Finishing.Queue	0.1699	0.026724087	0.00	1.0000
Printing.Queue	0.00	(Insufficient)	0.00	0.00
Setting Up Machine.Queue	26.2268	(Correlated)	0.00	57.0000

Figure 4.21: The average number waiting of EDD rule

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	(Insufficient)	0.00	0.00
Finishing.Queue	0.1728	0.016514720	0.00	1.0000
Printing.Queue	0.00	(Insufficient)	0.00	0.00
Setting Up Machine.Queue	26.2268	(Correlated)	0.00	57.0000

Figure 4.22: The average number waiting of SPT rule

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Drying.Queue	0.00	(Insufficient)	0.00	0.00
Finishing.Queue	0.1858	0.023691736	0.00	1.0000
Printing.Queue	0.00	(Insufficient)	0.00	0.00
Setting Up Machine.Queue	26.2268	(Correlated)	0.00	57.0000

Figure 4.23: The average number waiting of LPT rule

Table 4.5: The total average number waiting of LFP

Rules	**Number waiting overall process (unit)**
FIFO	26.408
EDD	26.397
SPT	26.400
LPT	26.413

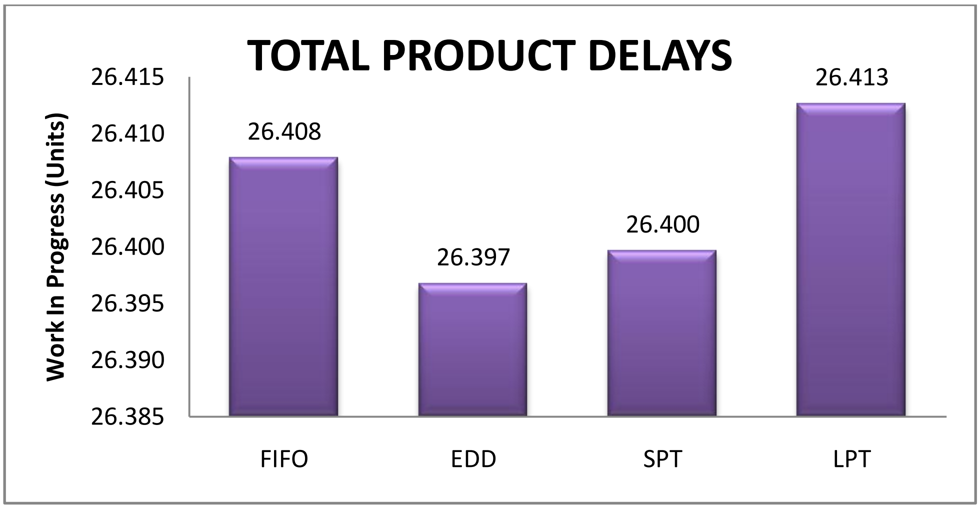


Figure 4.24: The result of total average product delays

The output results of Flow Time are displayed in Figure 4.25, 4.26, 4.27 and 4.28. The summary of the Flow Time result is shown in Table 4.6 and Figure 4.29.

Entity Detail Summary

Time

	NVA Time	Other Time	Total Time	Transfer Time	VA Time
Product 1	0.00	0.00	29.98	0.00	4.00
Product 2	0.00	0.00	29.52	0.00	3.00
Product 3	0.00	0.00	31.29	0.00	4.00
Product 4	0.00	0.00	29.21	0.00	4.00
Product 5	0.00	0.00	30.92	0.00	4.00
Product 6	0.00	0.00	28.93	0.00	3.00
Total	0.00	0.00	179.85	0.00	22.00

Figure 4.25: The product flow time of FIFO rule

Entity Detail Summary

Time

	NVA Time	Other Time	Total Time	Transfer Time	VA Time
Product 1	0.00	0.00	7.93	0.00	4.00
Product 2	0.00	0.00	132.10	0.00	3.00
Product 3	0.00	0.00	4.90	0.00	4.00
Product 4	0.00	0.00	4.84	0.00	4.00
Product 5	0.00	0.00	4.66	0.00	4.00
Product 6	0.00	0.00	3.56	0.00	3.00
Total	0.00	0.00	157.98	0.00	22.00

Figure 4.26: The product flow time of EDD rule

Entity Detail Summary

Time

	NVA Time	Other Time	Total Time	Transfer Time	VA Time
Product 1	0.00	0.00	7.42	0.00	4.00
Product 2	0.00	0.00	4.76	0.00	3.00
Product 3	0.00	0.00	41.90	0.00	4.00
Product 4	0.00	0.00	406.80	0.00	4.00
Product 5	0.00	0.00	4.66	0.00	4.00
Product 6	0.00	0.00	3.56	0.00	3.00
Total	0.00	0.00	469.09	0.00	22.00

Figure 4.27: The product flow time of SPT rule

Entity Detail Summary

Time

	NVA Time	Other Time	Total Time	Transfer Time	VA Time
Product 1	0.00	0.00	5.94	0.00	4.00
Product 2	0.00	0.00	14.59	0.00	3.00
Product 3	0.00	0.00	4.63	0.00	4.00
Product 4	0.00	0.00	4.48	0.00	4.00
Product 5	0.00	0.00	54.75	0.00	4.00
Product 6	0.00	0.00	433.63	0.00	3.00
Total	0.00	0.00	518.02	0.00	22.00

Figure 4.28: The product flow time of LPT rule

Table 4.6: The total product flow time of LFP

Rules	Total Flow Time (Minute)
FIFO	179.85
EDD	157.98
SPT	469.09
LPT	518.02

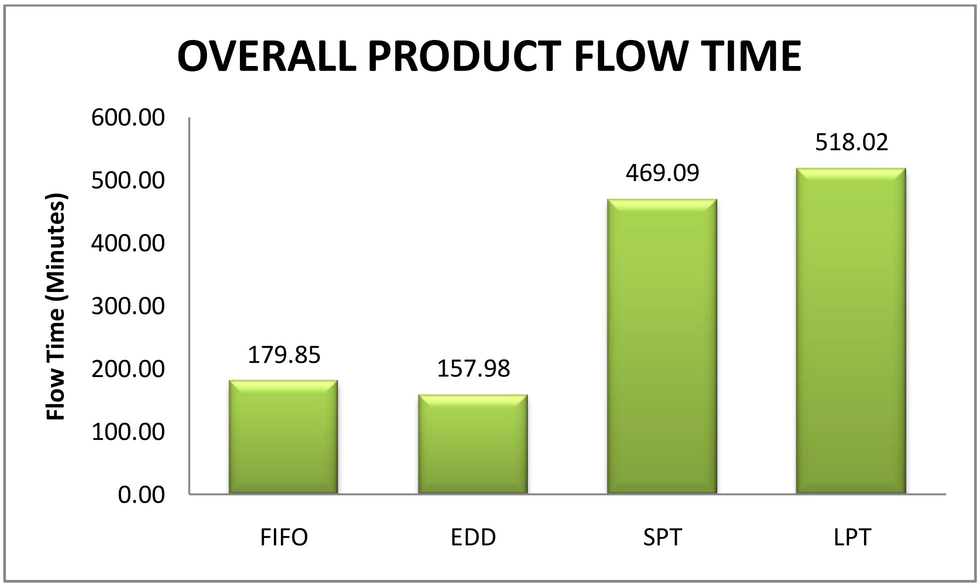


Figure 4.29: The result of the overall product flow time.

The output results of Resource Utilization are displayed in Figure 4.30, 4.31, 4.32 and 4.33. The summary of the Resource Utilization result is shown in Table 4.7 and Figure 4.34.

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Drying up with worker	0.8032	0.017641488	0.00	1.0000
Finishing up with worker	0.9469	(Insufficient)	0.00	1.0000
Inkjet Printing with worker	0.9929	(Insufficient)	0.00	1.0000
Setting up with worker	0.9932	(Insufficient)	0.00	1.0000

Figure 4.30: The resource utilization of FIFO rule

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Drying up with worker	0.8140	0.030421137	0.00	1.0000
Finishing up with worker	0.9462	(Insufficient)	0.00	1.0000
Inkjet Printing with worker	0.9929	(Insufficient)	0.00	1.0000
Setting up with worker	0.9932	(Insufficient)	0.00	1.0000

Figure 4.31: The resource utilization of EDD rule

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Drying up with worker	0.8014	0.020260263	0.00	1.0000
Finishing up with worker	0.9462	(Insufficient)	0.00	1.0000
Inkjet Printing with worker	0.9929	(Insufficient)	0.00	1.0000
Setting up with worker	0.9932	(Insufficient)	0.00	1.0000

Figure 4.32: The resource utilization of SPT rule

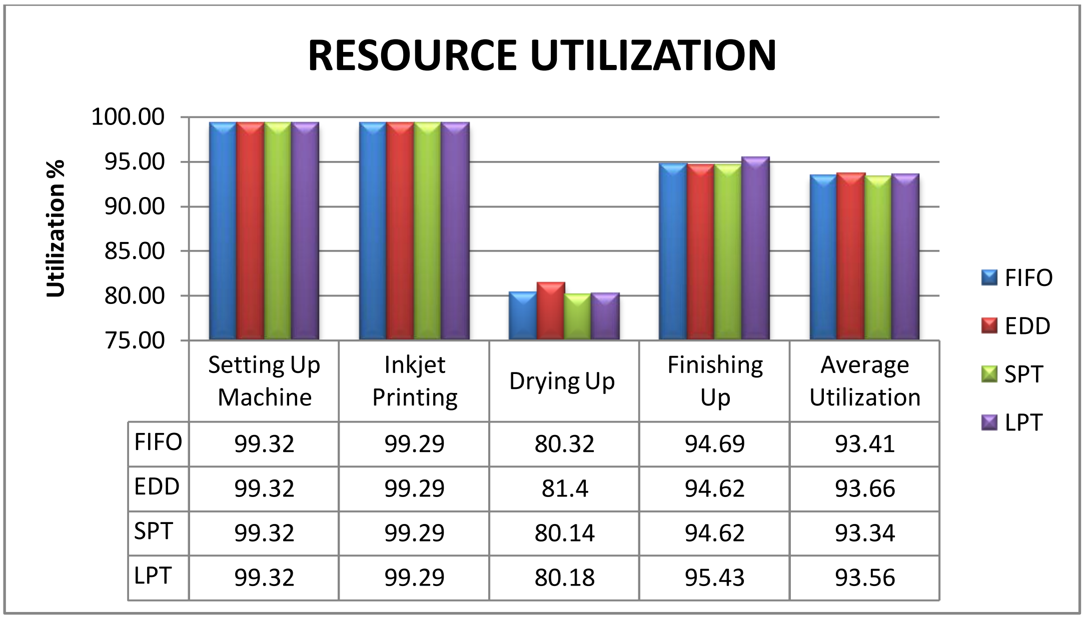
Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Drying up with worker	0.8018	0.024825962	0.00	1.0000
Finishing up with worker	0.9543	(Insufficient)	0.00	1.0000
Inkjet Printing with worker	0.9929	(Insufficient)	0.00	1.0000
Setting up with worker	0.9932	(Insufficient)	0.00	1.0000

Figure 4.33: The resource utilization of LPT rule

Table 4.7: The resource utilization of LFP

Resource Utilization	FIFO	EDD	SPT	LPT
Setting Up Machine	99.32	99.32	99.32	99.32
Inkjet Printing	99.29	99.29	99.29	99.29
Drying Up	80.32	81.4	80.14	80.18
Finishing Up	94.69	94.62	94.62	95.43
Average Utilization	93.41	93.66	93.34	93.56



	Setting Up Machine	Inkjet Printing	Drying Up	Finishing Up	Average Utilization
FIFO	99.32	99.29	80.32	94.69	93.41
EDD	99.32	99.29	81.4	94.62	93.66
SPT	99.32	99.29	80.14	94.62	93.34
LPT	99.32	99.29	80.18	95.43	93.56

Figure 4.34: The result of resource utilization

4.5.2 The Paper Product Job

The paper job product (PP) will display the same structure output as Large Format Product (LFP). The difference is the number of processes that the product went through and the value of the results. Therefore, the simulation results are shown in this sub-chapter respect to the same performance measures as in LFP.

The results of the Waiting Time or Time Delays are displayed in Table 4.8 and Figure 4.35.

Table 4.8: The total average waiting time of PP

Rules	Waiting Time (Minutes)
FIFO	26.17
EDD	25.51
SPT	25.82
LPT	25.51

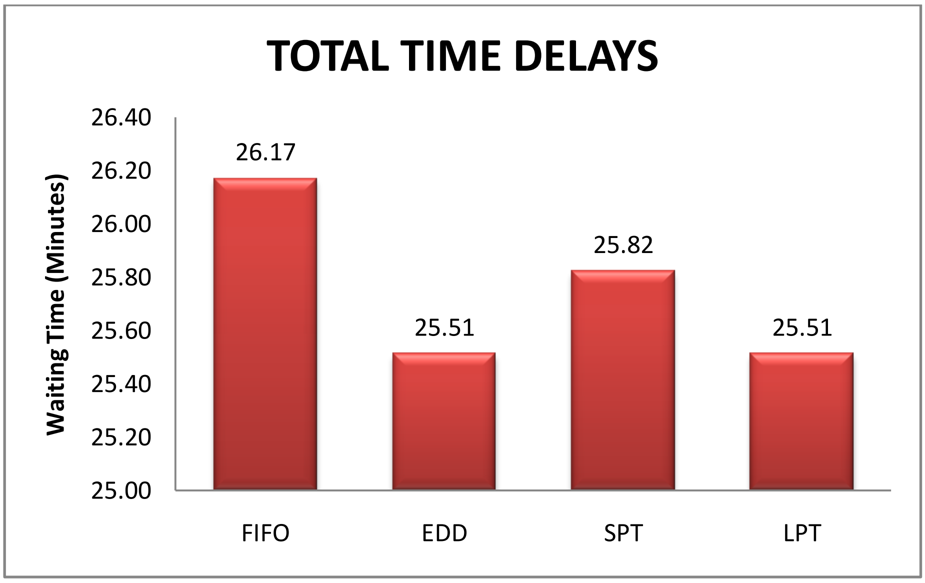


Figure 4.35: The result of total time delays

The results of the Number Waiting or Product Delays are displayed in Table 4.9 and Figure 4.36.

Table 4.9: The total average number waiting of PP

Rules	Number Waiting Overall Process (Units)
FIFO	29.205
EDD	29.206
SPT	29.206
LPT	31.205

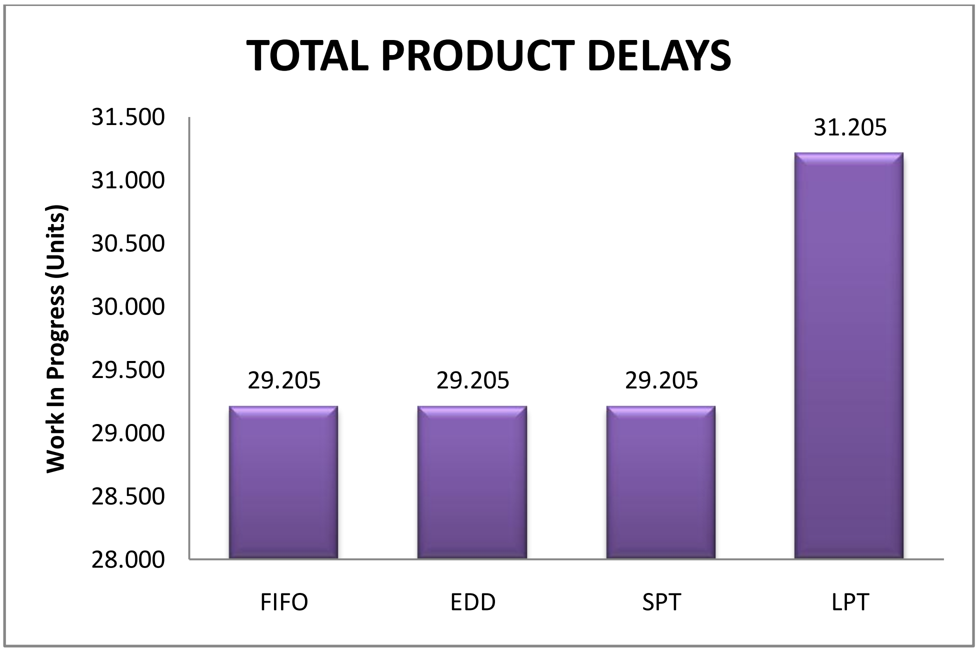


Figure 4.36: The result of product delays

The results of the Total Product Flow Time are displayed in Table 4.10 and Figure 4.37.

Table 4.10: The total product flow time of PP

Rules	Total Flow Time (Minute)
FIFO	204.04
EDD	213.85
SPT	111.93
LPT	215.26

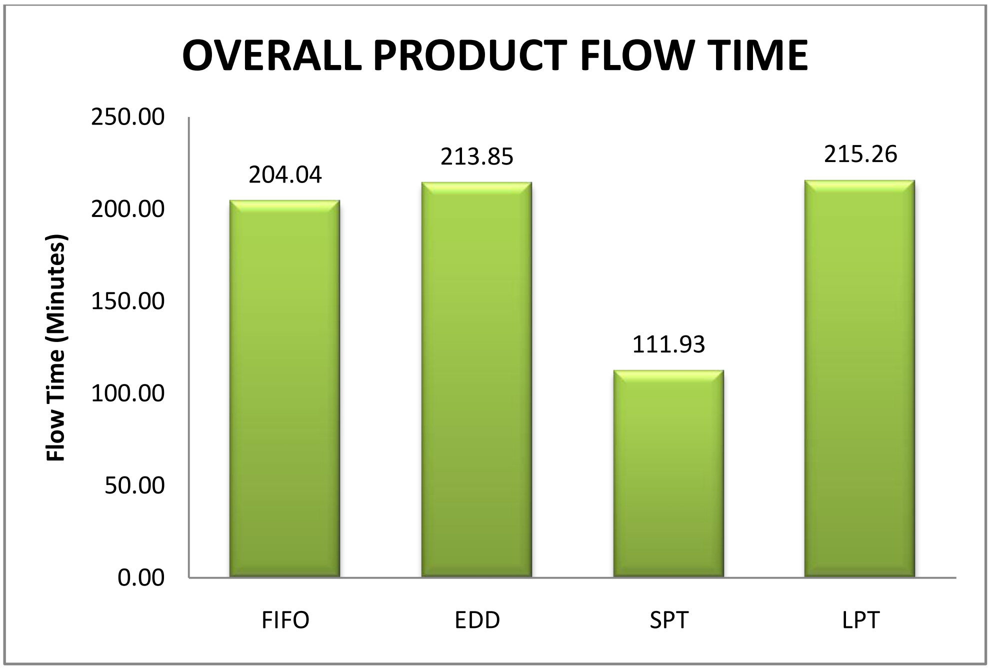


Figure 4.37: The result of overall product flow time

The results of the Resource Utilizations are displayed in Table 4.11 and Figure 4.38.

Table 4.11: The resource utilization of PP

Resource Utilization	FIFO	EDD	SPT	LPT
Setting Up Machine	99.32	99.32	99.32	99.32
Inkjet Printing	99.29	99.29	99.29	99.29
Finishing Up	99.25	99.25	99.25	99.25
Average Utilization	99.29	99.29	99.29	99.29

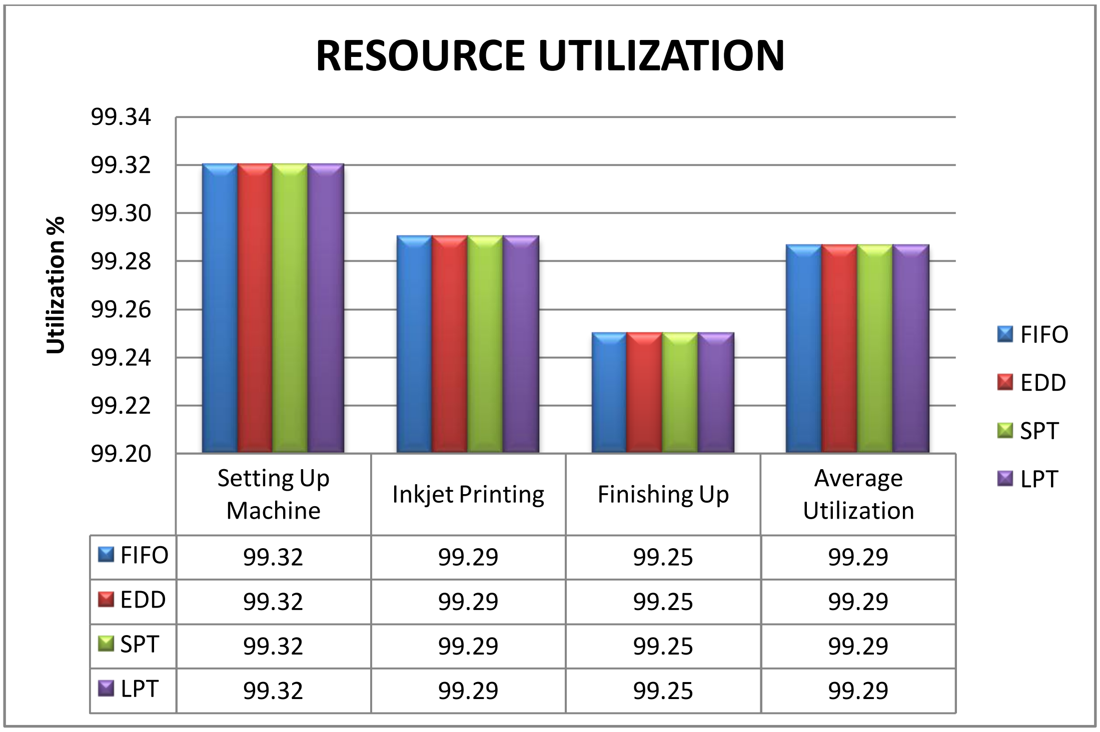


Figure 4.38: The result of resource utilization

The all simulation results data is then summarized into one table as in Table 4.12 and Table 4.13.

Table 4.12: Summary of Large Format Product simulation results

Rules/Performance Measures	**FIFO**	**EDD**	**SPT**	**LPT**
Total Time Delays (Minutes)	26.36	25.31	24.63	24.70
Total Product Delays (Units)	26.408	26.397	26.400	26.413
Total Product Flow Time (Minutes)	179.85	157.98	469.09	518.02
Resource Utilization (%)	93.41	93.66	93.34	93.56

Table 4.13: Summary of Paper Product simulation results

Rules/Performance Measures	**FIFO**	**EDD**	**SPT**	**LPT**
Total Time Delays (Minutes)	26.17	25.51	25.82	25.51
Total Product Delays (Units)	29.205	29.206	29.206	31.205
Total Product Flow Time (Minutes)	204.04	213.85	111.93	215.26
Resource Utilization (%)	99.29	99.29	99.29	99.29

4.6 MODEL VALIDATION

Validation assesses how realistic the modeling assumptions are by comparing the model performance obtained from the model test runs to the counterparts in the system under research. For example, the results of LFP are provided in Table 4.14 for the performance measures of total flow time for the EDD rule as EDD gives the best performance for the scheduling.

Table 4.14: Validation results of LFP for EDD rule

Product Type	**Total Flow Time (Minutes)**		**Error (%)**
	Manual Calculation	**Simulation result**	
S1	7.7467	7.93	2.3662
S2	7.6667	132.10	1623.04
S3	7.8300	4.90	37.4202
S4	8.9170	4.84	45.7217
S5	4.8197	4.66	3.3135
S6	3.9167	3.56	9.1072

The acceptable percentage error is usually below 10%. From the validation results, the percentage errors are some less than 10% and some are big. But overall, the results are still acceptable.

4.7 RESULT VERIFICATION

Verification assesses the correctness of the formal representation of the intended model by test runs and performing consistency checks on the statistics. Since the research involve a conceptual job shop, verification was performed to ensure correct implementation of the model by

i. Debugging the program to trace the entities or product in during model runs as shown in Figure 4.39.

ii. Running the model under different settings of the input parameters and checking whether the model behave in feasible manner using different scheduling rules.

The simulation models are extended runs to assure that the randomness in the model does not create unwanted circumstances or errors when trying to create variety of different situations to verify the models.

Event Time	Entity Number	Description
(2700.0752 Minutes) Tuesday, June 07, 2016 00:00:05	2719	Arrive to block 1 18$ CREATE,1,MinutesToBaseTime(0.0),Product:MinutesToBaseTime(EXPO(1)):NEXT(19$);
(2700.2590 Minutes) Tuesday, June 07, 2016 00:00:16	2680	Arrive to block 40 190$ RELEASE:Finishing up with worker,1;
(2700.2590 Minutes) Tuesday, June 07, 2016 00:00:16	2681	Arrive to block 31 136$ RELEASE:Drying up with worker,1;
(2700.2590 Minutes) Tuesday, June 07, 2016 00:00:16	2682	Arrive to block 22 82$ RELEASE:Inkjet Printing with worker,1;
(2700.2590 Minutes) Tuesday, June 07, 2016 00:00:16	2683	Arrive to block 13 28$ RELEASE:Setting up with worker,1;

Figure 4.39: The debug bar shows product output

The consistency of the output is checked by adding more number of replications. Therefore, the average values of the replication are determined whether they are significantly different from each other. The more number of replication, the more consistent the values to the manual calculations. For example, for the total flow times in LFP for scheduling rule EDD, the number of replications is set to 3 and the result is shown in Table 4.15 below:

Table 4.15: Results for total flow time for each replication

	Number of Replication			
	1	**2**	**3**	**Average**
Total Flow Time (Minutes)	157.98	107.14	89.55	118.22

4.8 DISCUSSION

From the result of Large Format Product job, the least average total time delay is the scheduling rule Short Processing Time, SPT (24.63 minutes), the least product delays is from the Earliest Due Date (EDD) rule (26.397 units), the shortest average product flow time (157.98 minutes) and the maximum resource utilization (93.66%) is the scheduling rule Earliest Due Date, EDD. In essence, the results are summarized as below:

i. Total Time Delays: SPT < LPT < EDD < FIFO
ii. Total Product Delays: EDD < SPT < FIFO < LPT
iii. Total Flow Times: EDD < FIFO < SPT < LPT
iv. Resource Utilization: SPT < FIFO < LPT < EDD

Meanwhile in Paper Product result, the scheduling rule EDD and Longest Processing Time, LPT rule has the same average of total time delays (25.51 minutes). The scheduling rule FIFO, EDD and SPT has the same number waiting which is the same number of products delays. The scheduling rule SPT has the shortest average product flow time and the resource utilizations are all same for each scheduling rules (99.29%). The results are summarized as below:

i. Total Time Delays: EDD, LPT < SPT < FIFO
ii. Total Product Delays: FIFO, EDD, SPT < LPT
iii. Total Flow Times: SPT < FIFO < EDD < LPT
iv. Resource Utilization: SPT, FIFO, LPT, EDD

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

The purpose of this chapter is to general conclusion based on the results achieved in chapter 4. The objectives were all achieved. The job shop scheduling did common occurred in dynamic environment. Then, the scheduling system is created using Arena simulation software and implemented to R2 Print Enterprise.

5.2 CONCLUSION

The Job Shop system in R2 Print Enterprise was modeled in Arena simulation software and the results were generated. After analyzing the result, it was noticed that in Large Format Product job, there is no single rule that dominates the others although EDD seems to be more effective than other rules. For Paper Product job, there is also no single rule that is clearly dominant although the most successing rules are those with short processing times.

So, in Large Format Product (LFP), if want to have shorter waiting time, the scheduling rule SPT is the best performance under all four rules. The next best scheduling rule is LPT. The least total product delays are by using the scheduling rule EDD followed by SPT. If want to have the least flow time and maximum resource utilization, scheduling rule EDD has the best performance.

Meanwhile, in Paper Product (PP), if want to have shorter waiting time, use either scheduling rule EDD or LPT as both give the same good performance. The best performance for having least total product delays are the scheduling rule FIFO followed by EDD. Next, if want to have the least flow time, use scheduling rule SPT and when to get the maximum resource utilizations, use any four scheduling rules whether FIFO, EDD, SPT or LPT.

The advantage of this scheduling using Arena is when there is changed to the environment; the model simulation can be re-run again with the new variables. Therefore, the scheduling system and dispatching rules helped in understanding the behavior of the production environment.

5.3 RECOMMENDATION FOR THE FUTURE RESEARCH

There are still some recommendations proposed for the future works in implementing the job shop scheduling in dynamic environment.

- Further detailed study of Arena software.
- Further research in investigating the performance of the methods and scheduling rules for other experimental conditions such as breakdowns of machines.
- Combine the proposed dispatching rules to generate schedules for dynamic job shop scheduling problem.
- Using the other approach such as the Artificial Neural Network (ANN) that gives high efficiency and effectiveness in a variety of shop floor conditions.

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APPENDIX A

DATA COLLECTED

Table A (a): Data collected of Large Format Product

No.	Product Type	Size (ft)	Unit (s)	Setup Time (min)	Printing Time (min)	Drying Time (min)	Finishing Time (min)	Due date (days)	Notes
1	Banner	8 x 3	10	1.5	28.3	0.5	2.9167	4	make holes at the edge
2	Billboard	4 x 17	2	1.25	12.3333	1	0.5	3	cutting , packaging
3	Backdrop	6 x 3	1	2.5	2.5	nil	2.83	3	make holes at the edge
4	Banting	2 x 6	2	1.5	2.83	1	3.75	4.5	do hemming & pole pocket
5	Sticker (black colour)	2 x 1	6	1.5	1.6333	2.5	1.2667	2	cut into the words shape
6	A1 Poster	1.95 x 2.76	5	1.5	7.083	1	nil	1.5	nil

Table A (b): Data collected for Paper Product

No.	Product Type	Size (inch)	Unit (s)	Setup Time (min)	Printing Time (min)	Finishing Time (min)	Due date (days)	Notes
1	Brochures (A5 size)	8.3 x 5.8	300	1.5	6	1	5	print only one front page and packaging
2	Business card	3.5 x 2.0	300 (13 sheet)	1.5	0.9167	15.5	3	manually cut and packaging into box
3	Flyers (A5 size)	8.3 x 5.8	300	1.5	6.3	1	3	A5 size (no need to cut), print only one front page
4	Tentative (A5 size)	8.3 x 5.8	150	1.5	2.7	1	7	A5 size (no need to cut), print on one page and packaging
5	Ticket	5 x 2.	200 (17 sheet)	1.5	1.7	14.3	7	machine cut and packaging into box
6	Pamphlet (A4 size)	8.3 x 11.7	300	1.5	6.8	75	3	print both sides, fold and packaging
7	Invitation cards (A6 size)	4.13 x 5.82	800 (400 sheet)	1.5	13	134	5	fold and packaging into envelope.