DEVELOPMENT OF A SIMULATION AIDED SCHEDULING FOR PACKAGING PROCESS AT TEACHING FACTORY

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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DECLARATION

I hereby, declared this report entitled “Development of A Simulation Aided Scheduling for Packaging Process at Teaching Factory”
is the results of my own research except as cited in reference.

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Date : 26 January 2023

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Bachelor of Manufacturing Engineering (Hons.). The member of the supervisory committee are as follow:

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(IR. DR.-ING. AZRUL AZWAN BIN ABDUL RAHMAN)

ABSTRAK

Projek Tahun Akhir ini berkaitan dengan penjadualan dengan menggunakan Simulasi untuk proses pembungkusan di Teaching Factory. Matlamat kajian ini adalah untuk membangunkan teknik penjadualan bantuan simulasi untuk operasi pembungkusan Teaching Factory dan untuk mengenal pasti keberkesanan dengan betul dalam proses pembungkusan Oleh itu, pengetahuan mengenai perancangan pengeluaran termasuk teknik penjadualan adalah penting untuk melaksanakan kajian ini. Projek ini menerangkan kepentingan peraturan penghantaran seperti masa pemprosesan terpendek (SPT), masa pemprosesan paling lama (LPT) dan tarikh tamat awal (EDD) dalam meningkatkan prestasi TF. Keberkesanan setiap peraturan dibandingkan dan diringkaskan untuk menentukannya berdasarkan ukuran prestasi dengan menggunakan rumusan matematik. Simulasi akan digunakan untuk membangunkan model dan melihat bagaimana sistem berubah dan sejauh mana ia akan berfungsi apabila berlakunya perubahan dalam pembolehubah. Perisian Tecnomatix Plant Simulation digunakan untuk mensimulasikan pemodelan sistem dalam TF dan untuk mengenal pasti masa setiap produk dengan menggunakan carta gantt. Keputusan menunjukkan bahawa peraturan masa pemprosesan terpendek (SPT) berprestasi baik dalam meminimumkan purata masa harian, meminimumkan bilangan kelewatan kerja, meminimumkan bilangan kelewatan dan memaksimumkan bilangan purata hari lebih awal

ABSTRACT

This Final Year Project is dealing with the Development of a Simulation Aided Scheduling for Packaging Process at Teaching Factory (TF). This study aims to develop a simulation aid scheduling tool for TF packaging operation and to identify the effectiveness of a proper planned of sequence operation by using dispatching rule. Therefore, knowledge regarding production planning, including the scheduling technique, is essential to carry out in this study. This project describes the importance of dispatching rules such as shortest processing time (SPT), longest processing time (LPT) and earliest due date (EDD) in improving the scheduling in TF. The effectiveness of each rule is compared and summarized to determine their performance measure by using a mathematical formulation. Discrete Event Simulation will be used to develop a simulation model that can be used to figure out on how the system change and how well it will work as well as the changes in the process variables. Tecnomatix Plant Simulation software used to simulate the system modelling in TF and to identify the makespan of each product by using gantt chart. The result shown that shortest processing time (SPT) rule performs well in minimizing the average flow time, minimizing the number of job delays, minimizing number of lateness and maximizing the number of average days early.

DEDICATION

Only

my beloved father, Abd Razak Bin Ahmad

my appreciated mother, Norain Binti Md Nor

my adored sister and brother, Fadila and Fikri

for giving me moral support, encouragement and also understanding

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LIST OF ABBREVIATIONS

TF	-	Teaching Factory
DES	-	Discrete Event Simulation
GMO	-	Global Maintenance Order
VMS	-	Value Based Maintenance
RMO	-	Reliability Maintenance Order
PM	-	Preventive Maintenance
MOGA	-	Multi Objective Genetic Algorithm
GUI	-	Graphical User Interface
SPT	-	Shortest processing time
LPT	-	Longest processing time
EDD	-	Earliest due date
FIFO	-	First in first out
FCFS	-	First come first serve

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays in today's market competition, ongoing research in production planning and control is critical for achieving a competitive advantage in the marketplace. Due to fluctuating market demands, manufacturing is challenging since companies must produce with the fewest resources possible to provide high-quality products and promptly adapt to market demands. The users expected us to supply them with greater quality, flexible orders, lesser pricing and quick responsiveness (Erengüç *et al.*, 1999). Production planning and scheduling can also optimize and control the entire supply chain. Production planning and control are concerned with all of the actions that take place during the packaging process at TF UTeM. It includes estimating production, handling materials, developing production schedules and scheduling other jobs. This is one of the essential parts of deciding how to manage the resources such as equipment, utilities and manpower among competing activities over a given period to accomplish one or more goal (Hien *et al.*, 2022). As a result, it is critical to keep up with the latest technologies, approaches, and tactics in order to ensure a regular flow of production process. The important aspect in a production planning and control system is to establish a production flow that is correctly coordinated so that there is no need to rush orders to meet deadlines owing to a disorganized plan.

Effective production planning and scheduling is very good for all industries, because it leads to production efficiency, lower labor costs, and less energy and waste (Georgiadis *et al*., 2021).

Simulation-based scheduling is the use of a digital model to simulate the flow of a real-world process. Simulation-based scheduling means that schedules for several hours to a day are made by running simulations. It is heavily reliant on the capacity to generate simulation models that accurately describe the packaging process. Due to the growing variety of product, smaller orders, shorter delivery time and a limitation of workers might cause the task of planner in the packaging process become difficult. People always use scheduling method to make sure they use up all of their limited resources over time. The purpose of scheduling is to minimize the packaging time and reduce cost by telling the production capacity when to finish the output, how many people to make it and on which equipment to use. In the decision-making process, there are one or more outcomes are maximized through the use ofscheduling.

Simulation may be defined as imitation of a dynamic process within a model to arrive at results that may be transferred toreal system (Bangsow, 2016). Simulation is a low-cost, safe, and quick tool for analysis. By using simulation modelling, real-world issues can be safely and effectively addressed. Besides, it can be proved that simulation can help to see how the packaging process flows from the beginning to the end. These studies will describe how the simulation will be used as a planning and scheduling tool. The simulation software approaches in these studies is Discrete Event Simulation (DES) (K Glanz, 2015). DES software also can be applied to improve the productivity (Raed El-Khalil, 2015). DES software can also be used to figure out on how the system change and how well it will work as well as changes in the process variables such as number of workers that will affect the packaging process. Other than that, it attempted to increase production and predict the amount of time needed to meet the needs of clients.

1.2 Problem Statement

The packaging process at TF are getting more complex and facing more challenges due to the increase in customer requirement. The packaging process is an important part in the production flow process because it involves the quality of product. Product packaging serves to protect the product inside the packaging. The packaging process is important to be completed accordance to the customer specification.

The problem to be addressed through this study is when the packaging process at TF has higher customer requirement that cause a wide variety of incoming product comes in every week. The goal of this study is to find out how often new products come in each week and figure out which ones need to be finished first. The production planning at TF is ineffective since it cannot track and determined how long it will take to complete every incoming product and how to priorities which products must be completed in a timeframe within a week that given by supplier. It is hard to figure out the way to standardize the number of workers needed each day in two shifts as to finish of orders in one week without being delayed.

In addition, it is impossible to determine the average time needed to complete the packaging process for any product because of a few factors. As demand for the product increases, there are not enough workers to fulfil all of the factors that influenced the product to be completed on time. The main cause of delay product in TF because of the ineffective scheduling which was arranged manually based on their experience. The worker that must be assigned for the work is a part time worker causing the number of workers each day can be different where it can be a major problem issues that product cannot be completed on a timeframe. A lower work rate can lead to the poor performance of workers which in turn might affect the quality of packaging process and its delivery time.

The inconsistent number of workers each day is because the part time worker did not show up on the day and time that they are supposed to come due to some reason causing the less efficiency in the packaging process and it can cause the number productivity in the packaging process to become low. A company total factor of productivity may also be affected by the utilization of part-time work (Devicienti *et al.*, 2018). The variety of incoming product and quantity for each product is different in each week causing planner cannot targeting the amount of worker needed each day in order to complete the order.

Besides, the packaging procedure for each of the product is definitely not same andit will be based on the standard operating procedure (SOP) from customer that need to be followed. This condition necessitates a rise in the number of workers to handle the complex product with detailed packaging. Packaging had to be completed in order to meet strict quality control standards. The complexity of product can be a major problem where planner needs to come out with a solution to predict the assigned worker at given time.

1.3 Objective

a) To develop a simulation aid scheduling tool for TF packaging operation.

b) To identify the effectiveness of a proper planned of sequence operation by using dispatching rule.

1.4 Scope

The Scope of this research are as follows:

a) The simulation software will be used to visualize make span or lead time to complete the packaging process for each product

b) The simulation software used is Discrete Event Simulation technology to model the physical process of packaging process at TF.

c) The scheduling based on dispatching rule of SPT, LPT and EDD.

d) The products packaging was categorized into six family product which is Elastic, Snap fastener, Ball pin, Safety pin, Circular needle and Hook

1.5 Important of Study

The finding of this study will redound to the potential benefits that can be gained by TF after completion of this study. The packaging process at TF concerns itself with determining the amount of product to be completed in a given time period. Developing the scheduling technique during this study has become important to enhance the packaging process. The effective project scheduling plays a crucial role in ensuring the product successfully completed their packaging process within time frame. This scheduling technique can help to ensure that the production and operations are carried out as planned and resolve any issues if it is not followed the plan. In addition, by using this scheduling technique it can help to establish and controls the amount of time needed to complete each of the product and ensure that all of necessary resources and workers are in the right place and in the right time. Based on the simulation that has being developed in packaging process at TF which include the input data such as, numbers of workers each day, quantity of product, deadline for the product to complete can help in order to come out with a Gantt chart that can show each job flow through the system and can increase the productivity. This Gantt chart can help the planner to make any changes to the schedule that the simulation makes by adjusting all of the input. Using this scheduling technique, the issue related to the shortage of part time worker can be resolved by determined the number of workers needed per shift and prepared with the available part timer to complete all of the incoming product within timeframe.

Chapter 2

LITERATURE REVIEW

2.1 Product Packaging

Packaging can be described as the process of designing and creating a container for a product. The package is the covering used to store, transport, and protect the product from external influences such as sunlight, moisture, and damage (Lee and Lye, 2003). There are three different types of packaging. Primary packaging is the part that comes into direct contact with the product such as perfume bottles. Secondary packaging is made up of one or more primary packages and is used to protect the product. It is normally discarded when the product is used or consumed. Following the previous example, this would be the cardboard box that contains the perfume bottle. Lastly, there is tertiary packaging, which is made up of the first two. Its function is to protect the product throughout the commercial chain. Its job is to distribute, unify, and protect products all along the commercial chain. This would be the cardboard box that contains several bottles (Ampuero and Vila, 2006).

2.1.1 Packaging procedure

People often wonder how to package something. The right steps and methods can go a long way in the packaging process. Regardless of the products that need to be shipped, it should be expect that the product will arrive at destination in the same condition as it is shipped. In order to maintain the safety of product, there are a few packaging procedures that need to be followed.

(a) Organize

A workspace should be big enough to move the package around and close enough to all the packaging materials that need to use. In an ideal situation, the space should have shelves to hold a wide range of materials, since different types and sizes of products will need different materials.

(a) Measure

Before selecting the box for the product, it is very important to measure the product. Add approximately 2 inches to the width, height, and length of the product to determine the optimal box size. This ensures that it will have sufficient space to wrap each product and fill the box with additional cushioning to protect products during transport.

(b) Select

During this stage, it is crucial to select a right box that suitable with product.

(c) Protect

After selecting the packaging of product, it is important to protect the product. There are many types of protective packaging that can be used such as bubble wrap. In order to choose the protective packaging, it is crucial to consider type of product that suit with the protective packaging.

(d) Seal

Now when the product is properly protected and fits into the right size box, it is crucial to seal up the box in order to secure it. Never use cellophane or duct tape to seal the box because neither of it is strong enough. Instead, find the right tapes or glue to seal the box. Make sure the product is completely sealed before shipped it out.

(e) Label

Labelling is the last step in the packaging process. It is important to place a right labelling on top of the box and double check the recipient address again to prevent from mistake in labelling.

2.1.2 Importance of packaging

First impression is really important and product packaging is often considered the first element that customer wants to see. As a result, many companies must never underestimate the importance of product packaging. The significance of product packaging is varied and may go a long way toward providing a good first impression and enduring brand loyalty. There are four type importance in packaging such as protect the product, display and promotes the product, attract buyers and differentiate the product from competitors.

Packaging is important to keep the product safe. The packaging must keep the product safe when it is being shipped from the factory to the retail shop and keep it from getting damaged even though it is on shelf. It is important for product packaging to be reliable and strong. Several companies use seals and locks to keep people from messing with their products and make sure they stay safe and protected. The product packaging is the better ways to protect inside product as a consumer always want their product to function well.

One more useful thing about packaging is how it promotes and reveals the product inside. For example, product such as food may contain a list of ingredients and information about how healthy they are and for other product they will be an instruction on how to set up and use the product. It is very important to put some information about the product for people to see it because it helps to manage their expectation and can make customer satisfied with the product. The more information provided regarding the product, the better the buyer understands what they are purchasing.

When determining the importance of product packaging, it is essential to consider requirements of the consumer. Eventually, the objective of designing any product is to attract people and convince them to purchase it. It is crucial to select a suitable packing material with a highest quality as well as design and colour that will attract consumer to buy the product. The packaging of a product reflects the product itself and the brand as a whole. Therefore, while developing product packaging, many companies perform significant consumer research to ensure that their packaging is appealing and compelling.

2.2 Simulation

Simulation is arising as key technologies for industrial production in the 21st century. Many researchers have done their research studies related to the performances of industrial production via simulation techniques since early 1960. Simulation is a method that imitates the operation of a real-world system or process over time. Simulation involves the implementation of a model, where the model represents the main characteristic or behaviour of the selected system or process and the simulation shows the models evolution through time. According to Shannon (1975), simulation can be defined as a process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or evaluating various strategies within the limit imposed by a set of criteria for the operation of the system. Benedettini (2008), describe that simulation can also be used to predict the performance of an existing or planned system and to compare the alternatives solution for a particular design problem. Computer simulation used to enhance the simulation method, new processes and can make the production system become more effective, cost effective and globally competitive (Robert *et al*., 2019). The important goal in simulation is used to quantify the system. The common measures used in system performance includes a few elements such as system cycle time, bottleneck of operation, effectiveness of scheduling system and staffing requirement.

2.2.1 Discrete Event Simulation

Discrete event simulation (DES) represents the real world quantitatively that helps to stimulate its dynamics on an event-by-event basis and makes a detailed report of its performance. The function of DES can be defined as the system will begins at the initial states and upon the occurrence of event can cause a directly changes in the system to a new set (Janius and Mir, 2016). It has been seen as one of the most popular computer-aided decision-making tools for a long time now (Babulak and Wang, 2010). DES is a common approach for engineers to study on how the system actually works in the early stages of design process. Following Figure 2.1 shows how the DES system can be studied. Most of the system is studied by experimenting with a real model or an actual system model.

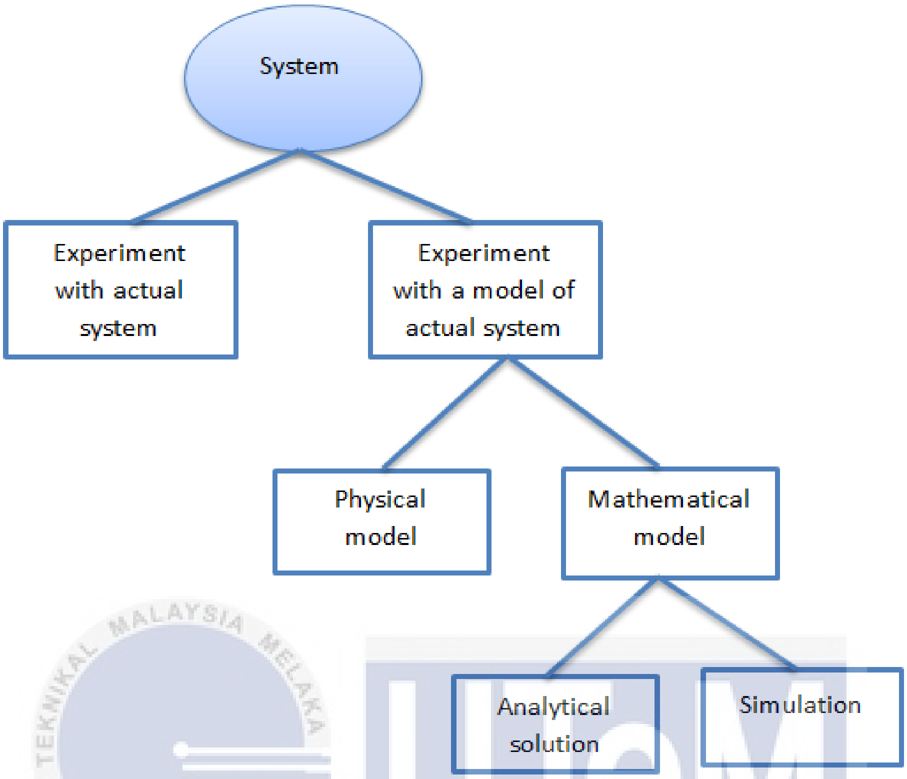

Figure 2.1: Ways to study a system (Babulak and Wang, 2010).

2.2.1.1 Application of Discrete Event Simulation

The DES can be implemented in variety of applications include the industrial application. Common application of DES include the manufacturing, education, healthcare, economics and logistic (Straka *et al.*, 2017). In the early 1980s, advanced manufacturing technology such as the use of DES has grown quickly. As a result, many companies invested a lot of money into this new technology to make their manufacturing operations more flexible. DES is a set of tools that enable most companies make a good decision. Every production manager aimed to increase their productivity in terms of higher throughput, shorter lead time, low work in process and high resource utilization (Slack, 2005). Via simulation, the behaviour of a manufacturing process can be evaluated under various conditions and "what-if" scenario analysis can be conducted to determine the optimal physical configuration and operating policies. Up to this point, the following application of DES software has been discovered in the following areas (Babulak and Wang, 2010).

(a) Design and planning of a new system in manufacturing process
(b) Implementation of enhancement to the existing production process
(c) Establishment of optimum operational policies
(d) An algorithm that aids in the production planning and scheduling of manufacturing

2.2.1.2 Simulation Software

Simulation software such as Siemens Tecnomatix Plant Simulation provides the discrete event simulation and analytical approaches to improve the material flow, logistics, the use of the machine and requirement of the worker. The German company Siemens PLM Software created Tecnomatix Plant Simulation, which is an object-oriented 3D programme. Siemens Software is the leading global provider of software for product lifecycle management and manufacturing operations management. Tecnomatix Plant Simulation was made so that discrete production processes could be simulated and turned into digital models. Plat Simulation can help create a model that can run through different scenarios to see how the production system works and does not require any changes in the manufacturing system. Plant simulation also has good analytical tools that make it easier to analyse the system, and it can import 3D geometrical models from Computer-Aided Design so that the whole manufacturing system, including workstations and transportation can be seen (Siemens, 2016).

2.2.1.3 Procedure of Simulation

The packaging industry uses modelling and simulation as method that can support the packaging process to discover more about their packaging process in order to make a better decision making. Each of projects that use the simulation has to follow a few steps to get the input data to a simulation results. According to Shannon (1998a), there are 13 procedures that involve in the modelling and simulation in manufacturing system. From Figure 2.2 illustrate the simulation procedure map.

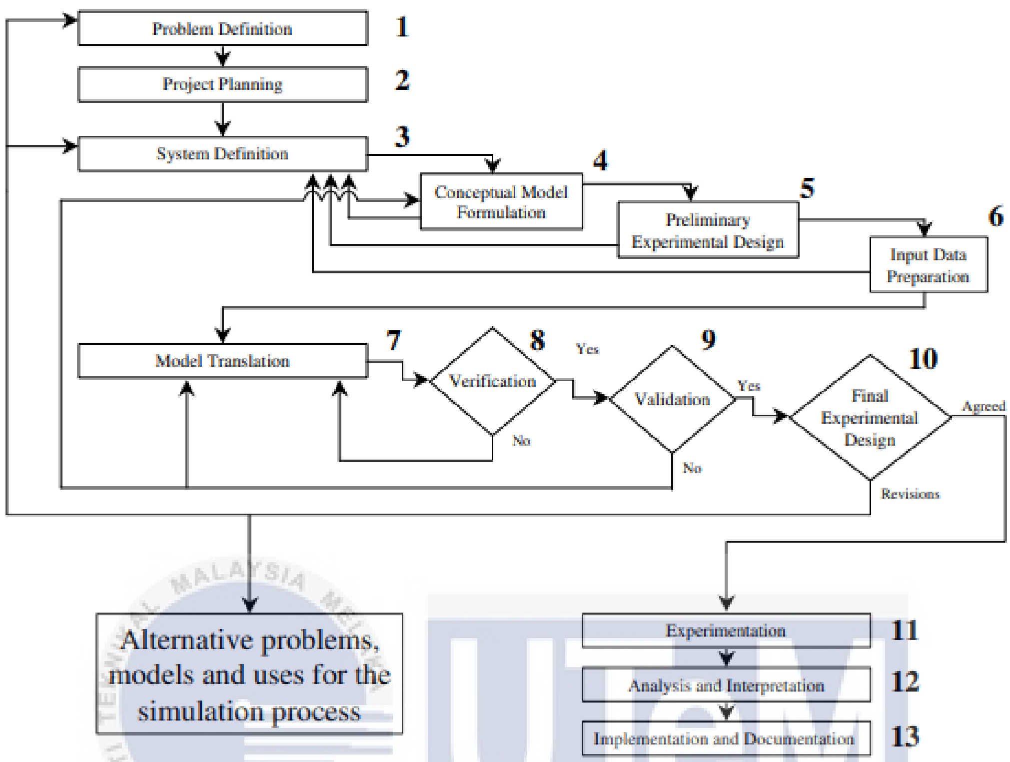

Figure 2.2: Simulation Procedure Map (Shannon, 1998b)

From the Figure 2.2 below, Shannon (1998b) has proposed 13 steps in the simulation procedure map. The method has start with the problem definition (1). Then the project planning is defined where user starts to figure out the objective of the study (2). The third step is a system definition where the goal of this step is to identifying the system component that needs to be modelled and the performance measured to be studied (3). However, at this point, the simulation analyst can start to observe the real system operates and build a conceptual model (4). Next step is preliminary experimental design where it is crucial to select any factors to be varied such as type of data that need to collect from model (5). Then, collect all the necessary input data that needed by model (6). The next step is a model translation, where the conceptual model is transforming into a computer model (7). The following procedure is model verification (8). If the verification rejects the computer model, the procedure should return back to seventh step (model translation). However, if the verification is verified, then it will continue to the next procedure namely validation (9). Similarly, if the validation rejects the computer model, the procedure will return back to the seventh, sixth, fifth and fourth step. Otherwise, it will continue to the next step where the final experimental design is made (10). Then the following step of experimentation describes the simulation need to be run get the required information and to perform the sensitivity analysis (11). For the next step, the conclusion is made from the all the data obtained (12). Finally, all the data obtained from simulation is documented (13).

Shannon (1998c) has proposed thirteen steps of procedure in simulation. By contrast, for VDI 3633 (2007) has recommended eight steps that start with Formulation of problems (1), test of simulation (2), formulation of targets (3), data collection and data analysis (4), (5) modelling (5), execution of simulation runs (6), result analysis and result interpretation (7) and documentation (7). In order for better understanding the differences procedure in simulation, both approaches are confronted in Table 2.1.

Table 2.1: Comparison of simulation procedure

(Shannon, 1998)	(VDI 3633, 2007)
1. Problem Definition It is the first stage that uses to figure out the objective of the study and the problem that need to be solved.	**1. Formulate the problem**
2. Project Planning Ensure that have sufficient and suitable resources in terms of employees, management support, computer hardware and software resources in order to complete the job.	**2. Test the simulation worthless**
3. System Definition The goal of this step is to identifying the system component that need to be modelled and the performance measured to be studied.	
4. Conceptual Model Formulation Observe on how the actual system operates and it is essential to identify the criteria of model in order to develop the right model. Creating a flow chart of the system is crucial aid understanding of all variables that involved and identifying the	**3. Formulation of Targets**

interaction of each variable.	
5. Preliminary Experimental Design Selecting the effectiveness measurement to apply, the factors to manipulate and the amount of those factor to studies.	
6. Input Data Preparation Collect the data. The new data or existing data need to be gathered.	**4. Data collection and data analysis**
7. Model Translation Translation of the model into simulation language and coding the data.	**5. Modelling**
8. Verification Verification is the process to verifying that the model perform as expected.	
9. Validation It verifies that the simulation does not have any differences between the model and the actual system.	
10. Final Experimental Design Designing an experiment that will produce the needed data to identify how each of the test runs stated in the experimental design will be carried out.	
11. Experimentation Run the simulation the get the information needed and to perform the sensitivity analysis.	**6. Execution of Simulation Runs**
12. Analysis and Interpretation Make conclusion from the data obtained by simulation.	**7. Result Analysis and Result Interpretation**
13. Implementation and Documentation Report the results and documenting the model.	**8. Documentation**

2.2 Scheduling

Scheduling is the main part in the production management which seems to be a way to maintain the production system running smoothly and discover more on its potential capacity. Scheduling is a process of planning, selecting, and timing resource usage in order to complete all of the tasks required to achieve the optimal outcomes of activities and operations, while rescheduling is defined as a process of modifying an existing production schedule as a result of disturbances and any circumstances (Valledor *et al*., 2018). Every day, people deal with a scheduling problem. For examples, the situation at airport where someone is in charge for assigning plane at the right gates and for manufacturing facility where someone is responsible in assigning jobs to machine. Priorities and capacity are two of the most important issues in production scheduling, which means "What should be done first?" and "Who should perform the task". (Franco and Martin, 2021). The scheduling can be defined as determining the time to accomplish a task and observing various scheduling in the manufacturing industry, including the detailed scheduling that indicates which operation must begin first. The scheduling outcome provides resource allocation for each time value as well as the sequence of task execution (Toader, 2017). Appropriate production scheduling enables quicker project completion times, increased capacity efficiency, and overall performance, consequently increasing profits (Vinod and Sridharan, 2008).

There are many methods to overcome scheduling problems, such as analytical techniques, meta-heuristic algorithms, rule-based method, and simulation method (Yan and Wang, 2007). By using the analytical techniques algorithm can help in order to find the better solution, yet it takes a lot of times to figure out when there is a complex problem in scheduling and it cannot be describe the dynamic or stochastic characteristic in the production system. In addition, the rule- based method is popular in industry due to its simplicity and the effectiveness. Over a hundred scheduling rules have already been researched and come to a conclusion, but most people agree that no single rule is the best in all situations. Moreover, the effectiveness of a rule depend on a various factor such as performance criteria, system setup and system load levels (Sabuncuoglu, 1998). However, simulation method can be used as a planning and scheduling tool. Since simulation can accurately represent the performance of the production system, it is commonly used to evaluate the efficiency of scheduling rules.

2.2.1 Simulation-Based Scheduling

Simulation-based scheduling is the use of a digital model to simulate the operation of a real system across time. The procedure entails creating a simulation model of the physical process and populating it with the specific events and processes that occur in reality. The simulation model can then be performed to provide an optimum manufacturing schedule. The simulation-based approach to scheduling has used a simulation model of facility instead of using a set of mathematical constraint. A simulation-based method has generated the schedule through modelling the flow of activities through the facility model.

Any expert engineer who possesses simulation software can create a finite capacity scheduling tool that is more robust and far less costly than a commercially available product. However, it is essential to adopt a different approach when identifying the models structure and input data while developing such a model. Standard simulation software can only be used for analysis and contains all data specifying the system, products and layouts. Figure 2.3 illustrate the general structure of simulation based scheduler that being developed at textile clothing company (Charnes *et al*., 1996). All of the information regarding the system definition, product definition, list of actual customers' orders, and the current status of Work In Progress (WIP) is stored in the external files. By keeping data in external databases like excel spread sheet or database systems can help a user to change or update the scheduling scenario quickly and easily without adversely impacting the simulation model (Heilala *et al*., 2008).

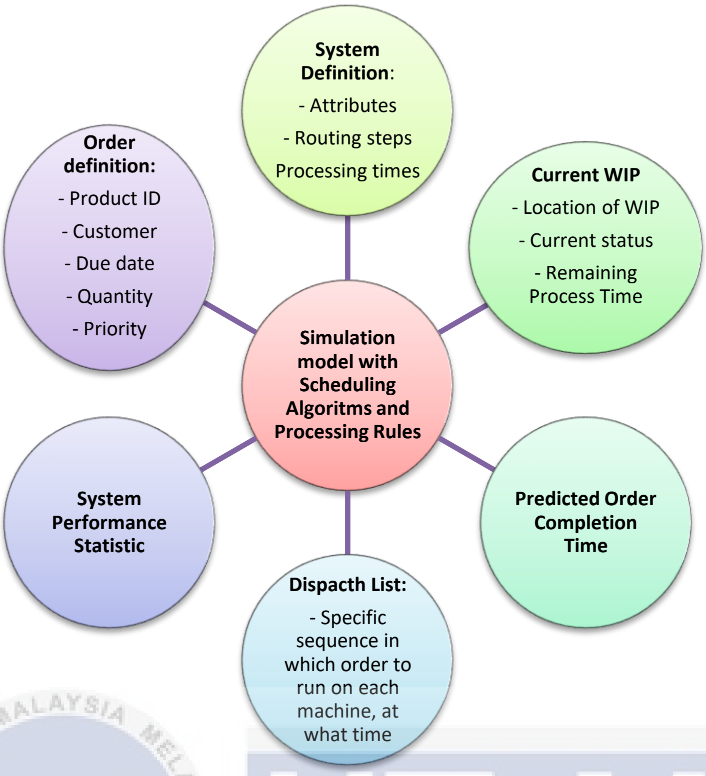

Figure 2.3: Structure of simulation-based scheduler (Charnes *et al.*, 1996).

2.2.2 Planning and Scheduling

This section will demonstrate how simulation may be utilised as a planning and scheduling tool using a hands-on method. For planning and scheduling, there is a way to learn on how to design a simulation model and how to manually produce different schedules using simulation. The tactical advantages of employing simulations will be demonstrated. Creating a simulation model that may be utilised for planning and scheduling is relatively straightforward. These are the primary component of the model that must be defined (Sims, 1997):

(a) When are people, machines, vehicles are available to do work?
(b) What product needs to be made or service needs to be performed?
(c) What is the process to make the product or perform the service?
(d) What resources are required to complete or perform the process examples like machine, people and tooling.

(e) How many parts do we need to make for each customer or what services does the customer need? When do they need the products delivered or the services performed?

Determining the rules that are being used to assign work to the resources (schedule) in the model is the last and most critical component of the model. These rules may be as simple as:

(a) Select the task that is due the soonest EDD.
(b) Select the task that requires the least amount of time to complete SPT.
(c) Select the task that requires the least amount of setup time or clean up time or travel time.

These rules could alternatively be extremely complicated (as is typical in the real world), such as:

(a) Choose the task with the earliest due date, unless there are tasks to be done for Customer A. In that case, all tasks for Customer A should be done first.
(b) Choose the task which has the same technique, colour, and due date as the last task that a certain resource finished.
(c) Choose the task that gives you the most time to finish or start preparing the resource for another task.
(d) Choose the person that has the best combination of all the skills needed to do the job.

As it has being appointed out that complex rules are frequently just exceptions for combinations of simple rules. These combinations and exceptions make scheduling and planning complicated. By documenting or applying the rules in a simulation model, the planner or scheduler can ensure that all possible combinations and exceptions are examined and that its objectives are accomplished. For example, when there is an individual who planned their day in the morning and frequently simulate when each task will begin and finish. They will create a list of everything they need to accomplish today and then assign specific activities to specific times. For instance, one worker may determine that a monthly report due tomorrow Earliest Due Date should have the highest priority and must be done first. Another worker (who must also complete a similar report) may feel that completing his expenditure report is more important since he wants to get paid and knows he may submit the report at least two days late. These simulations can be limited in size and their runs can be brief. These simulations can be small, and their runs can be short. Nevertheless, the result is a workable plan for the day that helps individuals achieve their objectives. If something goes wrong throughout the day such as insufficient number of workers, user can revaluate the length and priority of each task and run a new simulation.

2.2.3 Technique of scheduling

The scheduling technique is necessary to make sure that all parts of the project work in sync with each other. A schedule must be in sequence with how long the project is supposed to take and all of the resources of the project must be used in the good possible way. A project schedule helps assign priorities to the work put into a project and ensures that it is completed on-time manner. A project schedule also enables to find out what work needs to be done first and how to get it done in an orderly manner. Scheduling can also be seen as a standard queuing problem if the following conditions are met:

(a) Each request is added to the end of the queue with first-in and first-out priority
(b) The longest duration of task is always performed first.
(c) Jobs may be assigned based on the earliest possible delivery date.

By using the above criteria, the following methods such as Gantt chart can be used to make a schedule.

2.2.3.1 Gantt chart

Gantt charts are commonly used to illustrate the sequence, facility load, or progress of a work activity over a well-defined time period. The Gantt chart illustrates the planned and actual production over a period of time for a variety of parameters. The Gantt chart illustrate on how each of the machine is schedules to complete various job orders. In order to get an idea on time required to complete the given task on a given day, it is crucial to identify time required to complete on each activity. All of the information in important for Management to utilise the data and determine if there are any issues and then take the appropriate steps to reschedule it as soon as possible. The Gantt chart is a rectangle chart that divided by parallel horizontal and vertical lines. The vertical lines or columns separate the horizontal lines into time units, such as hours, days, weeks and month. The width of the column indicates the duration of activity or operation. The width of the column shows how long an action or operation took. The direction of time in Gantt chart starting from left to right. The row will represent numerous numbers of activities from top to bottom. The length of the lines refers to the quantity of accomplished work. Consequently, Gantt charts are sometimes referred to as Bar charts however Gantt chart is simpler to create and interpret. Based on Figure 2.4, there are three things of schedule dependencies highlighted in red colour as shown in Gantt chart below and a percentage to complete the indication.

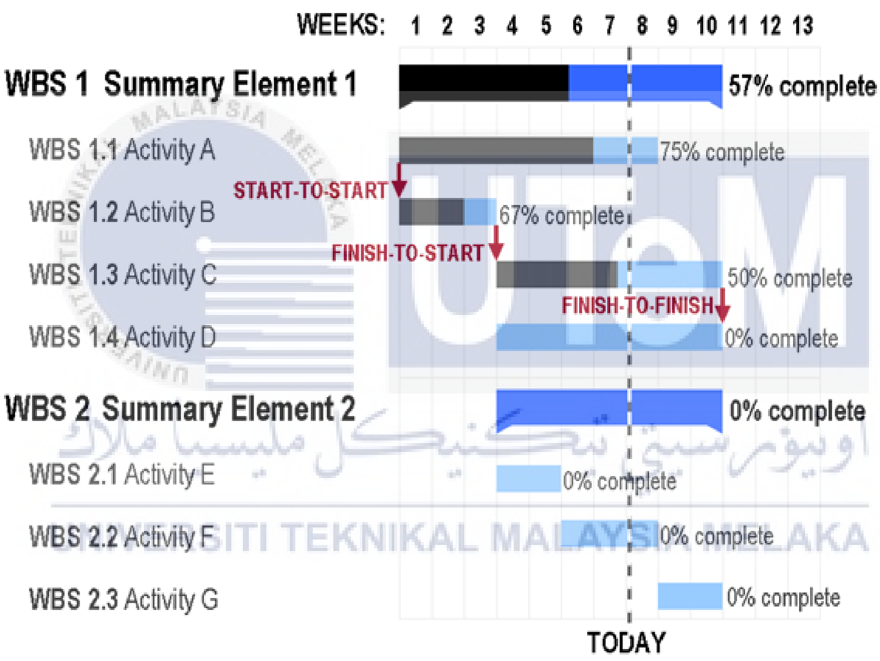

Figure 2.4: Gantt chart

2.2.4 Dispatching Rule

Scheduling is the basis for assigning jobs to the work centre. Sequencing which is also called as dispatching rule is the process of figuring out which jobs should be completed at each centre. People often use the terms "dispatching rules," "scheduling rules," "sequencing rules," and "heuristics" synonymously (Rolf *et al*., 2020). Priority rules are ways of putting jobs in order that are used to send them to a workstation. Scheduling problems are causing the manufacturing industry to use dispatching rules a lot. The steps that are meant to help solve complex problems effectively in a real-time production environment (Gupta and Sivakumar, 2006). Some of the prominent dispatching heuristic are SPT, LPT and EDD. There has been a lot of research on dispatching rules over the past few decades and many new rules have been made.

The SPT rule puts jobs in order of how long it will take to do them. When a machine is free, it will start working on the shortest job that is ready. This algorithm is the better way to find the least amount of total and weighted time to finish. In a single-machine environment where all jobs have a ready time of 0, this algorithm is better for minimising the average flow time, the average number of jobs in the system, the average time jobs spend waiting between when they arrive and when they start to be processed, the maximum time jobs spend waiting, and the average amount of time they are late.

Based on the LPT, the jobs are put in order of how long they take to do. When a machine becomes available, it will start working on the biggest job that is ready at that time. This algorithm is a rule of thumb used to find the schedule's minimum makespan. It puts the longest jobs on the schedule first so that one big job doesn't "stick out" at the end and make the last job take a lot longer to finish. EDD can be defined as sequence of the job is based on the ascending order of due date or due time. In a single-machine environment where all jobs have a ready time of 0, the earliest due date rule tells the computer to start with the job with the earliest due date and work its way up to the job with the latest due date.

Here, only a brief overview of scheduling in semiconductor manufacturing is provided. According to Uzsoy (1994) presented a computational investigation of dispatching rules for semiconductor testing operations for a variety of due-date and cycle time-related performance measures. This study examines the following dispatching rules of

SPT and EDD. It has considered performance metrics include mean cycle time, average tardiness, number of late jobs and maximum tardiness. Analytical techniques have a hard time explaining how the dispatching process affects the queueing network. However, by utilising computer simulation, the study of the dynamic job shop scheduling has advanced quickly. In these methods, simulation is used to compare various dispatching rules or other scheduling policies (Rajabinasab and Mansour, 2011).

The Dispatching Heuristic was able to provide not only a good solution, but also the optimal solution for the observed system. As a result of their ease of implementation and compatibility with the dynamic nature of manufacturing systems, dispatching rules play a significant role in the dynamic context. Heuristic rules have strong advantages in that these are easy to understand, easy to apply, and require relatively little computer time.

2.3 State of Art Research

The Table 2.2 below shows the state of art research related to the topic.

Table 2.2: State of Art Research

No	Tittle	Author	Finding
1	Using Simulation-Based Scheduling To Maximize Demand Fulfilment In A Semiconductor Assembly Facility	(Potoradi *et al.*, 2002)	This research has conducted a study on how to identify product that need to schedule in the parallel on a pool of wire-bond machine to meet a weekly demand. Other than that, to develop system schedule weekly production in the assembly plan of semiconductor manufacturer. By implementing a scheduling technique using Gantt chart in Discrete Event Simulation (DES), the result shows that it can prove a significant improvement in the factory tardiness performance which result in reducing number of tardy jobs from 14% to 11%. In addition, it can help to prioritized lots based on due date and include additional resources for setups to ensure that the schedule generated is feasible.
2	Design of job scheduling system and software for packaging process with SPT, EDD, LPT,CDS and NEH algorithm at PT. ACP	(Gozali *et al.*, 2019)	This paper discussed about the PT. Avesta Continental Pack which is a manufacturer of flexible packaging for pharmaceutical products faces ineffective production scheduling and repeatedly failed to finish orders at the expected time limit. Customers requesting orders in different finishing time contributes in causing delays in the delivery process. Therefore, a more advanced scheduling system will assist the company in managing the delivery time. The purpose of this research is to establish the most effective job scheduling arrangement to minimize mean tardiness as well as mean lateness job. As the production process uses flow shop method, this research applies heuristic methods, such as Earliest Due Date (EDD) method, Short Processing Time (SPT), and Longest processing time (LPT). The result shows that SPT method provides the most optimum outcome, specifically by reducing mean tardiness by 801.81 minutes or 85.57% and decreasing mean lateness job by 2 or 66.67%. The best job sequence is subsequently job 8 - job 4 - job 1 - job 6 - job 7 - job 5 - job 2 - job 3, which minimizes the average delay time from 937.05 minutes to 135.24 minutes.
3	Assessing the Priority Rules of Scheduling Application in Job Shop Manufacturing Company	(Nazif and Hafizuddin, 2012)	This research has conducted a study on assessing the priority rules of scheduling application has been conducted that aimed to determine the most efficient and reliable scheduling practise. This study targets on job shop manufacturing companies and data on the workshop processing time were analyzed according to different priority rules. The finding result from this, by applying SPT as the new priority rules helps in increasing the capacity of the production where it allows the jobs with SPT to be processed first and reduces the amount of work which awaits capacity at the end of the work schedule. In justifying SPT yield the most efficient reading amongst all aspect is taken into consideration where SPT yield the lowest average amount of lateness. Thus, it is proven that SPT is the best rule to be applied in improving the current scheduling policy SPT since it is able to schedule for a lower average of job processing time thus processing the job with rapid progress, records the highest percentage on average hours early, lowest average number of job and also having the lowest average on job lateness. This indicates the SPT is able to serve better for their

			customers due to lower job processing time and promises production efficiency. It also helps in reducing the cost in lowering the work in process and inventory.
4	Simulation Approach to Enhance Production Scheduling procedures at a Pharmaceutical Company with large Product mix	(Kaylani and Atieh, 2016)	The paper discussed in this study is to purpose a simulation approach to enhance production scheduling procedures at a pharmaceutical company with large product mix. The method carried out using this study is by using Simulation software namely Arena-Rockwell software v. 14 to create a discrete event simulation model. The finding result from the simulation run in this study will evaluate the following performance measures such as: • Product cycle time • Start delay • Identify time periods for each process in which this process is constantly busy, with utilisation values exceeding 90 %, and which may cause schedule delays. • Resource utilization such as operator utilization and machine utilization.
5	Trends in Simulation and Planning of Manufacturing Companies.	(Bako and Božek, 2016)	The article describes the possibilities of using computer simulation during production scheduling. Changes in simulation model inputs result in changes on simulation production outputs, these can be easily compared with outputs of the original versions of production plans due to their archiving. The objective was to construct a simulation model that after improvement will be used for future production planning. The developed simulation model can be fully controlled via a GUI (Graphical User Interface) which is fully opened for implementation of further optimization and scheduling algorithm with the aim of future enhancement of the simulation. By implementing this method, prove that the Simulation has great potential as a tool for aiding planning since it can identify possible problems earlier to make an action that allowed the production planner sufficient time to make any necessary adjustments.
6	Using Dynamic Priority Rules for Optimization of Complex Manufacturing System	(Wisniewski *et al.*, 2012)	The article describes about how much changes of priority rules that effect the system performances. Dynamic priorities were considered in a study by Cakar and Yildirim (2005). They proposed a neuro-genetic decision support system coupled with simulation to design a job shop manufacturing system to obtain the optimal number of resources in each workstation in conjunction with the right dispatching rule to schedule. Four different priority rules were used - EDD, SPT, Critical Ratio (CR) and FIFO. Yildirim *et.al.*, (2006) proposed a framework that utilized parallel neural networks to make decisions on the availability of resources, due date assignments for incoming orders, and dispatching rules for scheduling. Jobs were scheduled in a work center according to one of the following priority rules of SPT LPT, FCFS.

CHAPTER 3
METHODOLGY

3.1 Process Flow of the Project

The process flow of this project has been developed as shown in Figure 3.1 to overview the project procedure. There were eleven activities compromised in this project as illustrated below. The activities are based on the simulation procedure use to accomplish the project. Therefore, the define of the problem (3.2) and project planning (3.3) has contributed to the beginning of the project. The objectives of this project have been assigned to all other activities. From define problem to development of tools are focus on the objective 1 and the rest starting from model translation to documentation focused on objective 2. To develop the simulation model in the production system there are a few steps need to accomplish include preparing of data collection (3.4), model conceptualization (3.5), model translation (3.6), verification (3.7) and validation (3.8). Based on the valid simulation model, the analysis has been conducted with simulation run (3.9). There is a gantt chart that was made to compare the time it takes to make each product based on the simulation run to see the makespan of each product. Then, the data from simulation will be compared based on the mathematical formula to identify the effectiveness of each priority rule (3.10). Last but not least, documentation and reporting (3.11) have been used to find the better priority rule that can be implemented in TF. The project flowchart shows all of the activities in detail.

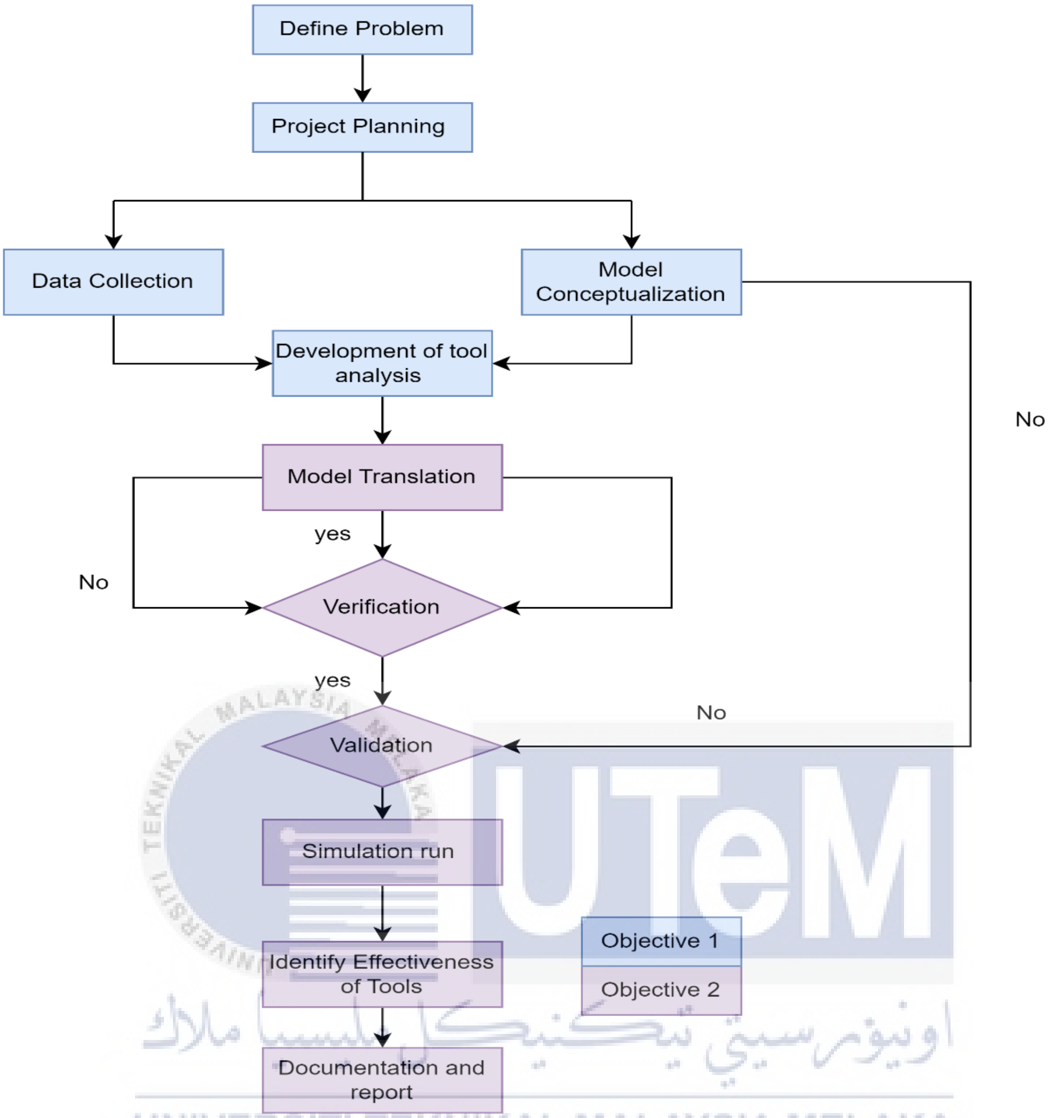

Figure 3.1: Process flow of project

3.2 Define Problem

The problem statement for this project has been discovered and elaborated in section 1.2. Overall, the project was dealing with a problem linked to the packaging process at TF. The production planning at TF is ineffective since it is unable to track and determined how long it will take to complete every incoming product and to prioritise which product needs to complete its packaging process within the timeframe given by the supplier. The second problem is impossible to determine the duration needed to complete the packaging process of any product because the worker that must be assigned for the work is a part-time worker. In addition, the third problem that happen in TF related to the packaging procedure for each of the product is definitely not the same and it will be based on the standard operating procedure (SOP) from the customer that needs to be followed. This condition necessitates a rise in the number of workers to handle the complex product with detailed packaging.

3.3 Project Planning

This project has complied with the guidelines established by University Teknikal Malaysia Melaka for the final year project FYP I and FYP2. To comply with the requirements of the FYP, a milestone plan was performed to arrange the timetable of project. The detailed of Gantt charts of project is attached at Appendix A and B.

3.4 Data Collection

Data collection is an important step that needs to be done at this stage. Data collectioncan be defined as process of collecting and measuring data about variables in this study in a systematic way that allows one to answer stated research questions, test hypotheses, and evaluate results. The data was collected through analyzing the product that delivered by TF as shown in Figure 3.2. The data collected by measuring of a quantitative data below such as, types of products, number of workers, working time, quantity of the product, starting date, completed date, and number of work cell. The product has been classified into six type of family product such as hook, ball pin, safety pin, circular needle, elastic and snap fastener.

Week	No	Item Description	Quantity	Starting Date	Remark
Week 7	1000	sew on snap fasteners prym	1000	16/11	
	2500	sew on snap fasteners prym	2500	16/11	
	1000	sew on snap fasteners prym	1000	16/11	Top Urgent
	1200	alu circ ndl gray (3.00/60)	1200	16/11	
	100	alu circ ndl gray (3.00/60)	100	16/11	Top urgent
	800	alu circ ndl gray (3.00/60)	800	16/11	
	260	br cir.ndl (5.00/80)	260	16/11	Top urgent
	800	alu circ ndl gray (3.00/60)	800	16/11	
	1440	pin sfty crvd nkl oltd stl	1440	16/11	Top Urgent
	1920	pin sfty crvd nkl oltd stl	1920	16/11	
	1920	pin sfty crvd nkl oltd stl	1920	16/11	
	6330	Elastic	6330	16/11	
	1152	Steel Crochet Hook IMRA No. 2	1152	16/11	Top urgent
	1152	Steel Crochet Hook IMRA No. 4	1152	16/11	Top urgent
	2000	Steel Crochet Hook IMRA No. 12	2000	16/11	Top urgent
	840	Pink Ball Pin	840	16/12	Top urgent

Figure 3.2: Data collection at TF

3.4.1 General Data

Shift in Teaching Factory

The production management in the TF applied a two- shift model which is Morning shift start at 9.00 a.m to 13:00 pm and Evening shift start from 2:00 pm until 6:00 p.m for the production system. Thereby, not every workstation operates in both shifts. Within the 4 hours per shift, there implemented a break time of 1 hour to do their own activities before entering the second shift. The schedule for the Morning and the Evening shift is shown in Table 3.1. According to 570 minutes for the entire working day, the operational time is only 8 hours.

Consequently, single-shift workstations operate for 4 hours a day and double-shift workstations operate for 8 hours a day. This data table does not include unscheduled breaks or events caused by technical problems.

Table 3.1: Working Shift Hour

Type	Time	Minutes
Morning shift	9:00-13:00	240
Break	13:00-14:00	90
Evening shift	14:00-18:00	240
Total		570

3.4.2 Data for each of Product

Figure 3.3: Product Elastic

Table 3.2: Procedure of packaging process for Elastic

Step.	Operator	Action	Average time (Sec)
1	1	Stamp outer	0.5
2	1	Paste label on outer	1.27
3	1	Fold outer	0.35
4	1	Fill cards into outer	2.57
5	1	Cantonizing including labelling and taping	0.63

From Figure 3.2 shows an Elastic product in TF and Table 3.2 shows the procedure of packaging process for family product of Elastic. There are five procedures in this packaging process include stamp outer, paste label on outer, fold outer, fill cards into outer and cantonizing. Each of the procedure has different number of average times in second as shown in Table above. There is one operator assigned for the packaging process of this product.

Figure 3.4: Safety Pin

Table 3.3: Procedure of packaging process for safety pin

Step.	Operator	Action	Average time (Sec)
1	1	Fill blister with pin	21.43
2	2	Fill blister with pin	20.56
3	3	Weigh and place the pin	10.48
4	4	Blister sealing and filling outer and carton and outer labelling	9.34

From Figure 3.4 shows the safety pin product in TF and Table 3.2 shows the procedure of packaging process for family product of safety pin. There are four procedures in this packaging process include fill blister with pin, weight and place the pin and blister sealing. There are three operators assigned for the packaging process. Operator one and two will be assigned for the same procedure which is fill blister with pin. Each of the procedure has different number of average times in second as shown in Table above.

Figure 3.5: Circular needle

Table 3.4: Procedure of packaging process for circular needle

Step.	Operator	Action	Average time (Sec)
1	1	Insert Card to Pouch	6.12
2	2	Insert Needle to Pouch	78.06
3	3	Insert To Outer and Check	4.74
4	3	Open Carton and Tape	0.1
5	3	Closing Carton, Tape and Label	0.13

From Figure 3.5 shows the circular needle product in TF and Table 3.4 shows the procedure of packaging process for family product of circular needle. There are five procedures in this packaging process include insert card to pouch, insert needle to pouch, insert to outer and tape, open carton and tape and for final step in closing carton, tape and label. Each of the procedure has different number of average times in second as shown in Table above. There are three workers are assigned for the packaging process. Worker three will completed three step of packaging procedure for insert to outer, open carton and close the carton.

Figure 3.6: Hook

Table 3.5: Procedure of packaging process for hook

Step.	Operator	Action	Average time (Sec)
1	1	Apply sticker to product	44.44
2	2	Check and Fill to outer	8
3	2	Open Carton and Tape	0.1
4	2	Closing Carton and Tape and Label	0.13

From Figure 3.6 shows the hook product in TF and Table 3.5 shows the procedure of packaging process for family product of hook. There are four procedures in this packaging process include apply sticker to the product, check and fill to the outer, open carton and tape and closing carton, tape and label. Each of the procedure has different number of average times in second as shown in Table above. There are four workers are allocated for the packaging process. Each process will have one worker in order to complete all of the procedure in the packaging procedure.

Figure 3.7: Ball pin

Table 3.6: Procedure of packaging process for product ball pin

Step.	Operator	Action	Average time (Sec)
1	1	Counting Pins and placing in box, different color each operator.	28.05
2	2		
3	3		
4	4	Close plastic box, placing box in card and stapler card	13.47
5	4	Fill outer and place in carton	11.22

Figure 3.7 shows the ball pin product in TF and Table 3.6 shows the procedure of packaging process for the family product of ball pin. There are five procedures in this packaging process including counting pins, close the plastic box and fill outer and place in the carton. Each of the procedure has different number of average times in seconds as shown in Table above. There are four workers are assigned to the packaging process. Workers 1,2 and 3 will complete the process of counting pins and worker four will continue with the process of filling outer and place it in the carton.

Figure 3.8: Snap fastener

Table 3.7: Procedure of packaging process for snap fastener

Step.	Operator	Action	Average time (Sec)
1	1	Labelling Outer	0.73
2	1	Opening card holes	6.26
3	2	Placing stud and socket in card	63.17
4	3	Opening outer and place card inside outer	2.87
5	3	Cartooning labelling and taping	0.63

Figure 3.8 shows the snap fastener product in TF, while Table 3.7 shows how the snap fastener family product is packaged. There are five procedures in this packaging process including labelling outer, opening card holes, placing stud and socket in cards, opening outer and place card inside the outer and cartooning. There are three operators are in charged for the packaging process of snap fastener. Operator one will complete the procedure of labelling outer and opening card holes. For the next process, one operator will be assigned for the job and operator three will assigned for procedure of opening outer and cartooning. Each of the procedure has different number of average times in seconds as shown in Table above.

3.5 Model Conceptualization

The model conceptualization for this packaging process was essential in the simulation because it is already defined the object and variables that make up the system. For this project, the simulation includes the entire packaging process to identify the number of workers needed each day to complete the packaging process of each product. All the workstations (work cell) in the packaging process are included in this simulation. According to the simplification, the model has been created using a TF production layout as shown in Figure 3.9.

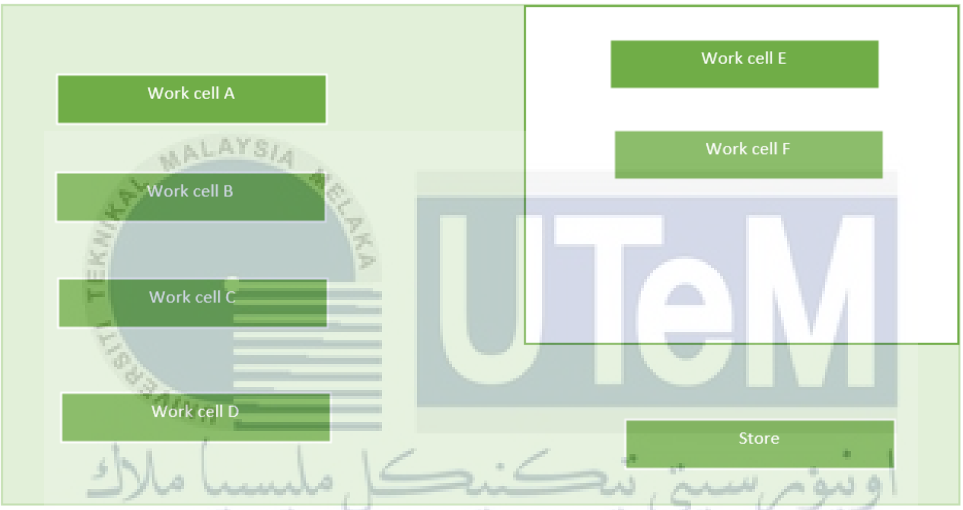

Figure 3.9: Layout of Packaging Process at TF

3.6 Development Tool Analysis

The model needs some initial data and settings along with objective function. This includes the schedules of the workstations and the number of products, types of products and number of the available worker. The schedules given then go through process simulation and by using a dispatching rule such as SPT, LPT and EDD. The scheduling problem contain four decision variable that consider of type of product, quantity of product, duration to complete the product (start and end date) and number of workers needed. These four decisions are made at the same time by combining all variables to identify the effectiveness of dispatching rule used. The Figure 3.8 shows the dispatching rules that are taken into account in this study since they are recommended (D. Y. Lee and DiCesare, 1994). A schedule shows the order in which all operations for packaging process at TF. Before the simulation process can start, several schedules that are likely to work are needed as the main data for creating the simulation model. In this study, these possible schedules were made using a heuristic method. They included the process plan for each type of product, a time schedule that showed how long each operation would take, a plan for each workstation that showed which type of product would be done, and a due date schedule that showed when to deliver order to customer. For scheduling analysis using the priority rules, the data required in the order list for the product has been studied and it has been arranged according to each of the chosen rule such as SPT, LPT and EDD.

Table 3.8: Dispatching Rule

Dispatching Rule	Explanation
EDD (Earliest Due Date)	Select the job that have the earliest due date First
SPT (Shortest Processing Time)	Select the job that has the shortest processing time of the first process.
LPT (Longest Processing Time)	Select the job that has the longest processing time of the first process.

3.7 Model Translation

The model translation step can be used in field of performance of modelling. This shows the necessity of converting one model of a system to another model that captures the system using a different set of concepts as shown in Figure 3.3. During the model translation, the results of the data collection and model conceptualization were put together to make a simulation model. The software used for this Discrete Event Simulation in this project was Tecnomatix Plant Simulation. In order to make the process become easier, it is necessary to make an assumption.

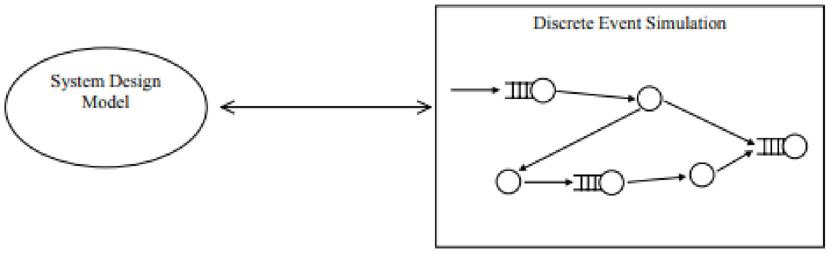

Figure 3.10: The model Translation (Akehurst,2000).

3.8 Verification

Verification seems to be an iterative process that determines if the product of each step in the simulation model development meets all of the requirements imposed by the previous step and is internally complete, consistent and correct enough to support the next phase (Sinde and Ho, 2008). A comparison has been made between the simulation model and the model conceptualization. The simulation model should have all of the parts in the model conceptualization. The most important part of this project is figuring out how the functional parts or product move through the packaging process in the simulation. So, the logical structure of the material flow has been carefully looked at to make sure that the translation in the simulation software is correct. By going back to the model translation, the discrepancy and wrong behaviour of the flow material were fixed. The simulation was run at low speed in order to check the properties and keep track of all material flow entities.

3.9 Validation

The validation phase used to check if the behaviour of parts of a system matches the behaviour of the same parts in a simulation model of the system and if the differences are acceptable given how the model will be used. The process of making the monthly production schedules is complicated and takes a lot of time. In order to help the upper management, evaluate the efficiency and compare the different option, it is important to check the validity of the production schedule because it will affect the production plan. Validation is the second and last controlling loop in the simulation model. It consists of all the physical components and control functions necessary to automatically adjust the value of a measured process variable to equal the value of a desired set-point. A realistic simulation model perfectly describes the packaging process and the simulation runs can be used to replace the production system. Model validation was an essential step for ensuring the quality of the study and project results. As a result, process data and simulation model data were compared for the most significant attributes. There are two very important validations for the packaging process which is the number of units made in the production line (workcell) and the flow of materials between the input and output of the production system. As a result, reaching the production quantity at the packaging process would validate the simulation model, given that the primary characteristics of the packaging process have been determined.

3.10 Simulation Run and Data Analysis

If the validation stages are achieved, the simulation model is finished to continue for simulation analysis. The software of Tecnomatix Plant Simulation provides the simulation run and analysis tool that has been used in this project. With the event controller, the simulation time has been set up according to the incoming product and its delivery time. To develop the analysis of the simulation model, the software of Tecnomatix Plant Simulation will provide a statistical report for each workstation in the model. In Addition, a graphical graph known as a Gantt Chart as shown in Figure 3.11 were generated based on the simulation run to analyse the makespan (how long the project needed to be completed of each product). This Gantt Chart is essential for helping teams plan their work around deadlines and allocate resources effectively (Genua *et al.*, 2005). Plant Simulation Gantt is an application for visualising and dynamically modifying activity sequences. The Gantt chart allows the user to choose between the order view and the resource view, as well as extra information such as shift times. By clicking the bar on the Gantt Chart, it can give more information such as the start time, the end time, and the name of a specific product.

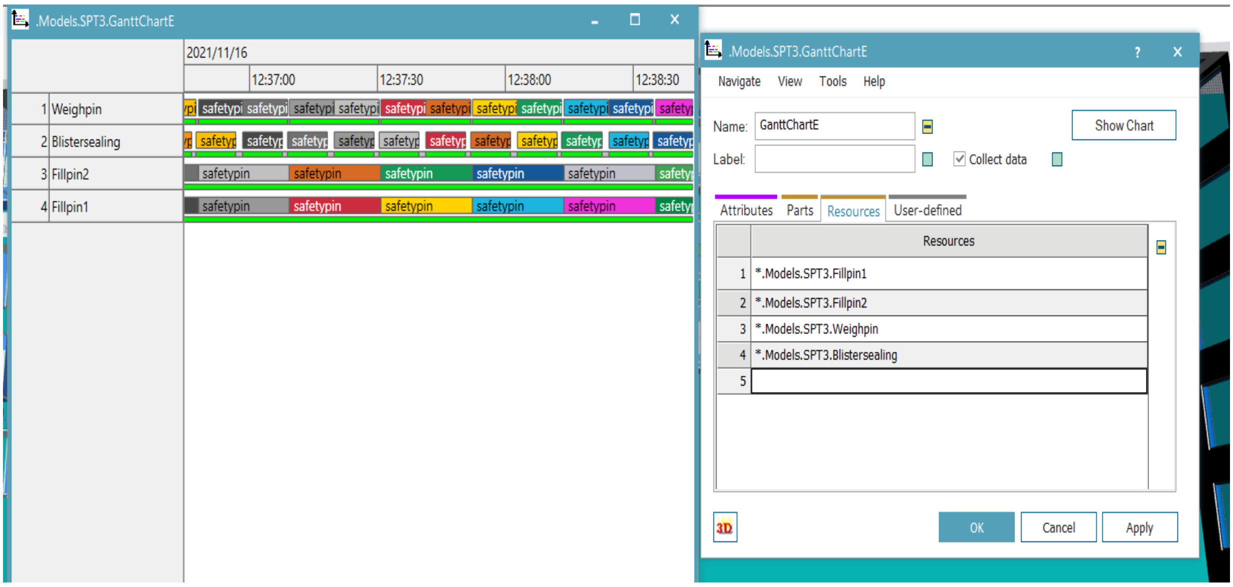

Figure 3.11: Example of Gantt Chart generated in Tecnomatix Plant Simulation of safety pin

3.11 Identify the Effectiveness of Tool

In getting the right decision to propose for the alternative, the proposed mathematical formula is used as the measure of the effectiveness for all the priority rules as shown in Equation 3.1, 3.2 and 3.3

$$\text{Average flow time} = \frac{\text{Total number of flow time}}{\text{Number of jobs}} \quad \text{Equation 3.1}$$

$$\text{Average days early} = \frac{\text{Total day early}}{\text{Number of jobs}} \quad \text{Equation 3.2}$$

$$\text{Average days past due} = \frac{\text{Total days past due}}{\text{Number of jobs}} \quad \text{Equation 3.3}$$

This study aims in minimizing the job average completion time, average number of job, average number of lateness and to maximize the average hours early. Thus, these measures will become the main benchmark that shows the effectiveness of each priority rules.

3.12 Documentation and Report

This thesis contains all of the documentation for this final year project. The methodology has been thoroughly described to ensure that the simulation trials can be understood and repeated. As a result, this report includes all required input data and simulation object parameters. The outcomes have been classified in accordance with the objective of this study. Following the outcome of the simulation-based scheduling, the final task was documentation and reporting.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Development of Simulation Model

The constructed simulation model has been evaluated in order to accept the data quality for the analysis, thereby achieving the project's original objective. Validation ensures that the simulation model can adequately replace TF packaging process. As a result, the data received from the simulation model based on the product's expected arrival date has been compared with the important criteria of the dispatching rule that being chosen.

Conceptual modelling is the abstraction of a simulation model from the part of the real world it is representing and in other words, it means whether to decide what to model and what not to model. It is important because the objects and variables that make up the system can be described in advance. The idea for this model came from the TF at UTeM and its simplification. So, the model must include all of the details about the packaging process and must outline all of the workstations that are used.

The model of simulation in was built based on the current observation in the TF during the data collection process. All of the information regarding the data fit, capacity of the buffer and number of workers has been included in this simulation model. The number of work cell available also depend on the current actual layout. There are several products that must be included in this model based on the data collection. All types of data that related to the product are used in each station and the process in each station is depend with the type of the product. Figure 4.1 shows the development of model based on the layout of TF. Each of the work cell currently was assigned with 6 types of family product and each type of product has their own quantity number of worker with their own processing time for each workstation. Each type of family product was assigned on its work cell due to distinct of sequence process in each work cell.

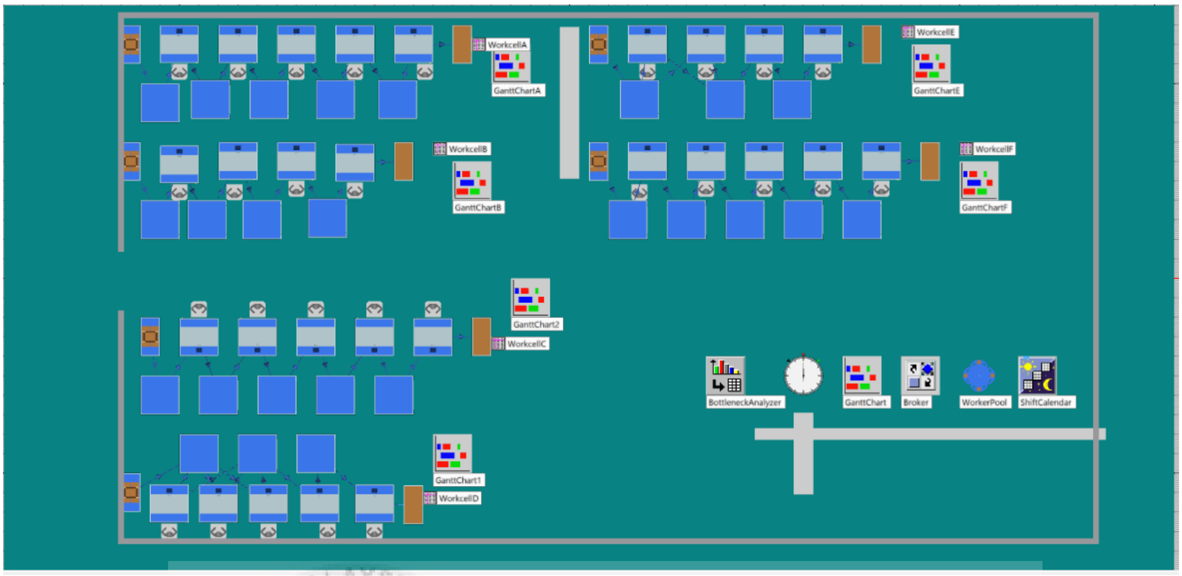

Figure 4.1: Simulation model

The model is being set with the working shift for 8 hours a day. By following the effective hour that has being calculated using total working time minus with the break time. Working days in TF is five days per week from Monday to Friday. In the simulation, the shift calendar is used to set up the working days for the worker. Each work cell contribute to one type of product. The Gantt chart is used to visualized the makespan of each product.

4.1.1 Buffer on every station

A buffer is used in this packaging process for each of the workstation in order to adjust the variation in the packaging process. Buffer is used to ensure that the production line can continue run smoothly despite of unforeseen factors that coming into play. Each of the buffer at the station acts as a place to store the products so that the packaging process can be completed more often. It is also a good approach to eliminate bottlenecks when personnel are packaging the product. Aside from that, each station's buffer zone serves as a storage area for packed items, making it easier for supervisors to count and distribute goods and products to each station.

4.1.2 System Modelling

From Figure 4.2 to Figure 4.7 below shows the system modelling for each of family product elastic, hook, snap fastener, circular needle, safety pin and ball pin.

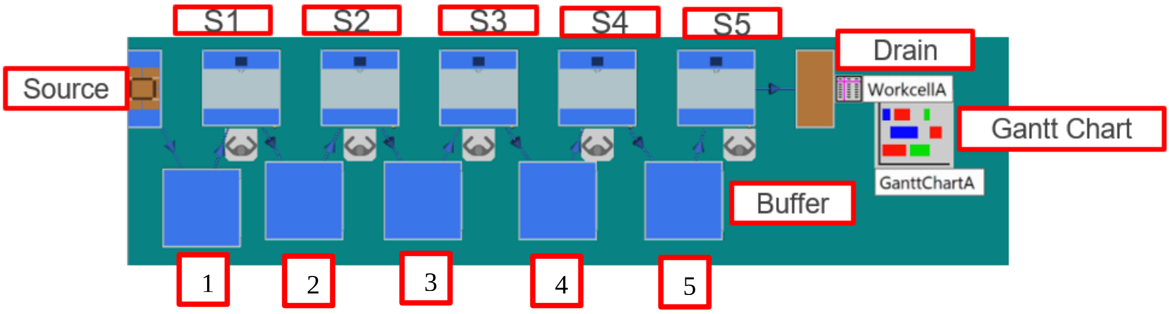

Figure 4.2: Simulation model of workcell A for product Elastic

The workcell A for the product Elastic is depicted in Figure 4.2 from the simulation model. This workcell has five stations in accordance with the five steps in the packaging process. This workcell had one employee assigned to finish the packaging. Each station is connected by 5 buffers. The processs part flow begins with the product's entry into the source. The starting date for each of product is set up in the data table in this workcell. Product from source will go through buffer 1 and proceed to station 1for process of stamping the outer then pass to the buffer 2. Then from buffer two it will go through station 2 for process of paste the label into outer for 1.27 seconds and pass the product to buffer 3. From the buffer three, the part will go through the station 3 for process of filling card into outer and pass to buffer 4, then the part will transfer to the station 4 for process of folding the outer. For the final procedure in this packaging process, the part will go through station 5 and the completed product will go into drain. Drain will remove the parts which the source produced after they have been processed.

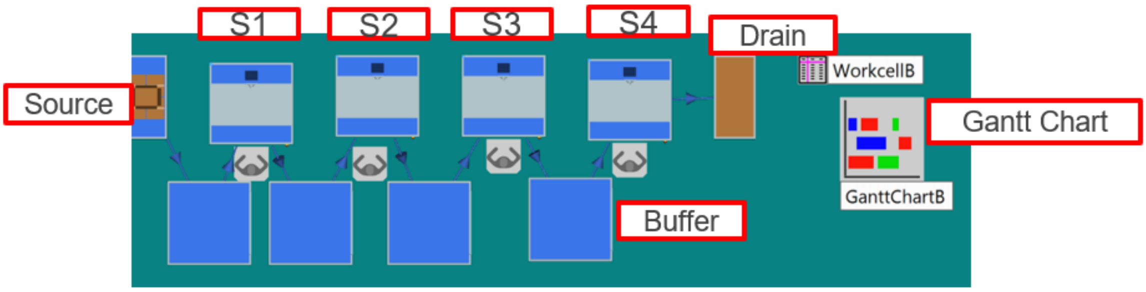

Figure 4.3: Simulation model of workcell B for product Hook

Based on the system modelling in Figure 4.3 shows that the simulation model of workcell B for product hook. There are four station in this workcell depend on the number of process. There are four SOP in order to complete the packaging process of Hook. Two number of workers was assigned in this workcell. Worker 1 will complete the packaging process in station which is process of applying sticker. Then, worker two will proceed with the process in station 2 for checking and filling the outer, station 3 for opening carton and taping and station 4 for closing the carton. The flow of the part will follow by the connector in the simulation stating from source to the buffer 1 then proceed to the station 1. From station 1 the part will go through buffer 2 and pass it to the station 2. After completed the process in station 2, the part will go to the buffer 3 and pass the part to station 3 the complete the procedure on the station. After that, part from previous station will go through buffer 4 and pass to station 4 to complete the final process in the packaging procedure. The completed product will glo through drain. The makespan for product hook will be shown in the gantt chart because it can help to visualize the starting date, end date and time completion for the product.

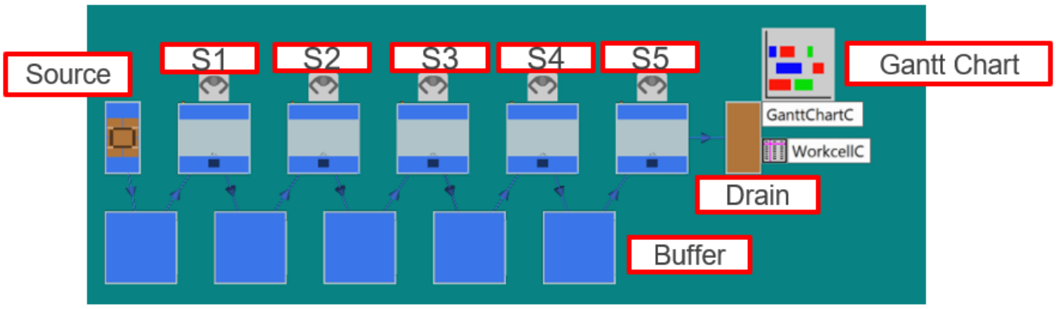

Figure 4.4: Simulation model for Workcell C for product snap fastener

From the Figure 4.4 above shows the simulation model for workcell C for product snap fastener. There are five stations based on five SOP for packaging process of snap fastener. There are three number of operators assigned in this workcell. Operator 1 was operated in station 1for process labelling the outer and station 2 for opening the card holes. The packaging process in station 3 was placing stud and socket in card which done by operator two. Operator three will be assigned for station 4 and station 5 for process of opening outer and cartooning. The flow part of the product is based on the connector in the model.

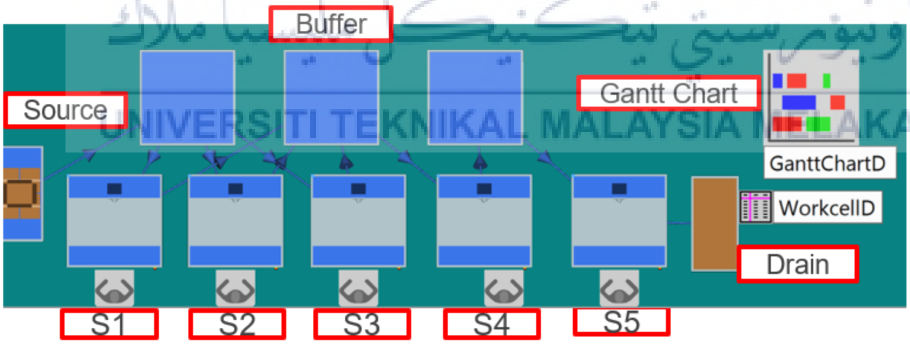

Figure 4.5: Simulation model of Workcell D for ball pin

Figure 4.5 shows the simulation model for workcell D for product ball pin. There are five stations in this workcell. The number of workers in this workcell was 4 four workers. There are three buffers in this workcell. Worker 1,2 and 3 were assigned for station 1,2 and 3 for process of counting pins and placing it into the box. The average time for the process is 28.05 second. The flow of the part will start from the source to buffer 1. Then, from buffer 1 it will past through the product to the station 1, station 2 and station 3 for the same process at different workstation with different number of workers. Then the part from station 1, 2 and 3 will go through buffer 2 and then pass to the station 4 for process of closing the plastic box and placing box in the card. After completed the process in station 4 the parts will transfer to the buffer 3 and then pass the part to the final workstation 5 for process of filling outer and place it in the cartoon.

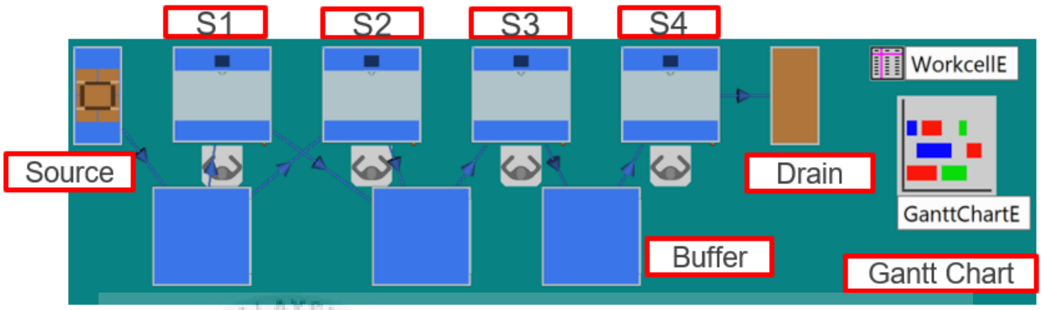

Figure 4.6: Simulation model for Workcell E for safety pin

The above Figure 4.6 shows the simulation model of workcell E for product safety pin. There are four workstation in this workcell based on the SOP for the product. The number of workers for this workcell were four worker where every station has one number of worker. Station 1 and station 2 will do the same process which is filling the blister with pin. The flow of the part starting from the source to buffer 1 then the part will be separated to the station 1 and station 2 depend on the availability of the station. The part that completed the process in station 1 and station 2 will pass to the buffer 2. From buffer 2 the part will go through station 3 for the process of weighting the pin. The average time for this station was 10.48s. After finishing the process in station 3 the part will go through buffer 4 and send it to station 4 for the final process of blister sealing. After completed the packaging process, the product will be send to drain.

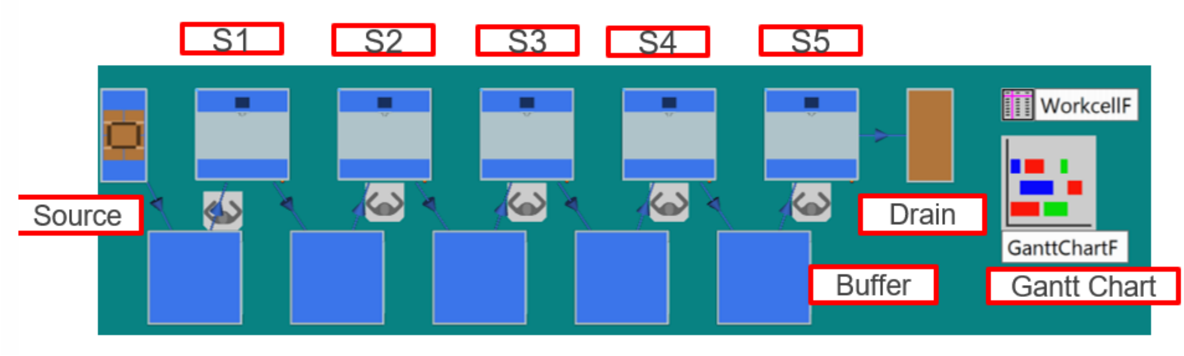

Figure 4.7: Simulation model for Workcell F for circular needle

The above Figure 4.7 shows the simulation model of workcell F for product circular needle. There are five workstations in this workcell based on the SOP for the product. The procedure for the packaging process of circular needle consists of five processes. There are three number of operators assigned in this workcell. Operator 1 will be assigned in station 1 for process of inserting card to pouch. The process of inserting needle into the pouch in the station 2 will be completed by operator 2. Process of station 3 which is inserting to outer and check, process in station 4 open the carton and tape and process in station 5 which is close carton tape was done by the operator 3. The flow of part according to the connector in the simulation. Part that come in from source will go through buffer 1 and proceed to the station 1. From station 1, the completed part on that process will pass the part to buffer 2 and proceed to the next station which is station 2. Then, from station 2 the part will go to the buffer and proceed with station 3. The flow of part is repeated again from station to buffer until the part completed all the process and the complete product will go through drain.

4.2 Arrangement of Incoming Product in TF

The incoming product consists of 16 products with 6 types of family product. There are a few products with the same family product but with different size however the packaging process is still the same. The simulation was done by inserting the quantity for each type of product with their starting date. As the result as shown in Table 4.1, it can be identified the completion date for each of the product and identify the product make span (exceed the due date or not). Each of the product in the simulation was conducted batch by batch. Following the completion of one batch of product, the simulation's data table will be modified based on the quantity of product and its starting date.

Table 4.8: Data in Teaching Factory

Product Name	Type	Status	Quantity	Arrival Date	Starting Date	Completion Date	Due date
sew on snap fasteners prym	A		1000	16/11	16/11 9:00	18/11 10:33	22/11
sew on snap fasteners prym	B		2500	16/11	16/11 9:00	23/11 12:50	22/11
sew on snap fasteners prym	C	Top Urgent	1000	16/11	16/11 9:00	18/11 10:33	19/11
alu circ ndl gray (3.00/60)	D		1200	16/11	16/11 9:00	19/11 11:00	22/11
alu circ ndl gray (3.00/60)	E	Top urgent	100	16/11	16/11 9:00	16/11 11:10	17/11
alu circ ndl gray (3.00/60)	F		800	16/11	16/11 9:00	18/11 10:20	22/11
br cir.ndl (5.00/80)	G	Top urgent	260	16/11	16/11 9:00	16/11 15:38	18/11
alu circ ndl gray (3.00/60)	H		800	16/11	16/11 9:00	18/11 10:20	22/11
pin sfty crvd nkl oltd stl	L	Top Urgent	1440	16/11	16/11 9:00	16:11 14:17	22/11
pin sfty crvd nkl oltd stl	M		1920	16/11	16/11 9:00	16/11 15:43	22/11
pin sfty crvd nkl oltd stl	N		1920	16/11	16/11 9:00	16/11 15:43	22/11
Elastic	O		6330	16/11	16/11 9:00	19/11 10:20	22/11
Steel Crochet Hook IMRA No. 2	P	Top urgent	1152	16/11	16/11 9:00	17/11 16:12	18/11
Steel Crochet Hook IMRA No. 4	Q	Top urgent	1152	16/11	16/11 16:04	17/11 16:13	22/11
Steel Crochet Hook IMRA No. 12	R	Top urgent	2000	16/11	16/11 9:00	19/12 9:41	19/11
Pink Ball Pin	S	Top urgent	840	16/11	16/11 9:00	16/11 15.46	16/11

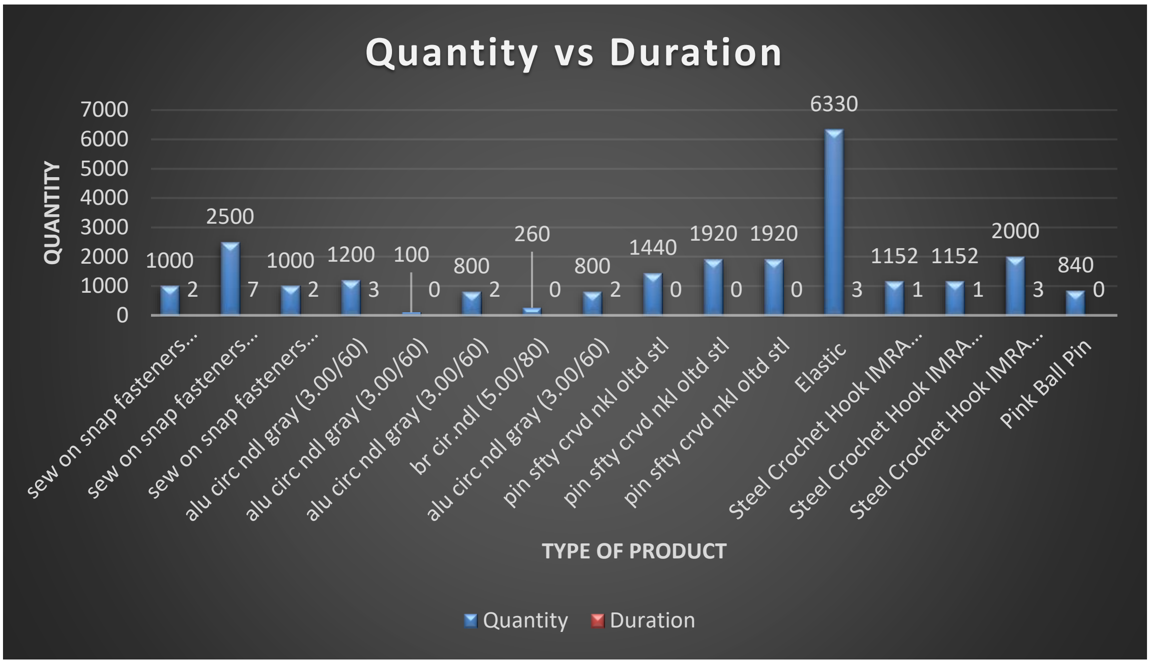

Figure 4.8: Duration for each product to be done

Based on the Bar graph in Figure 4.8 above, 16 number of products has run in the simulation one by one accordingly based on their type of product in each workcell and the result for this simulation, shows that the duration for each of the product when it is set with the arrival date. The first run simulation was done without using any rule in order to identify the duration need for each of product to complete the packaging process before implement the three types of dispatching rule. From this data, the product that has the same family product will be run in the same work cell with the number of workers that has being decided. From simulation, it is easy to identify the duration of the product to be done by looking at their ending time in simulation. Different quantity influenced the number of durations of the product to be done. From the data above shows that there are five type of product that completed its packaging process within 0 duration which means that it can complete on the day it started. Product type of elastic, circular needle (3.00/60) and hook IMRA No. 12 has duration of three days in order to complete the packaging process. Moreover, there are four product that have a duration of two days to complete the packaging process which is two batch of snap fastener with quantity of 1000 each, 2 batch of circular needle (3.00/60) with 800 units each. The higher duration for the incoming product in this week is snap fastener with 2500 quantity with duration of 7 days. Three dispatching rules approaches namely LPT, LPT and EDD were adopted to analysis and compare the results in order to find the suitable dispatching rule to be implemented in TF.

4.2.1 Shortest Processing Time (SPT) Approach

The simulation was run with the first dispatching rule of SPT. This rule was used to set the sequences of jobs that need to be processed on a resource in the ascending order of their processing time. The result for this dispatching rule as shown in Table below. All 16 products will be distributed to each of work cell according to their family product. The product of the same family product will do their packaging process in the same work cell. The outcome is discovered by looking at the simulation's Gantt chart to identify time for packaging process of the product ended. From the result of the simulation, the number of make span (different between start and finish of sequence job or task) and number of job delay can be obtained.

Work cell A

- Number of workers = 1

Table 4.2: Packaging process in Work cell A

Product Name	Status	Type	Quantity	Arrival Date	Processing Time (days)	Start date	Complete Date	Due Date
Elastic		O	6330	16/11	3	16/11 9:00	19/11 10:20	22/11

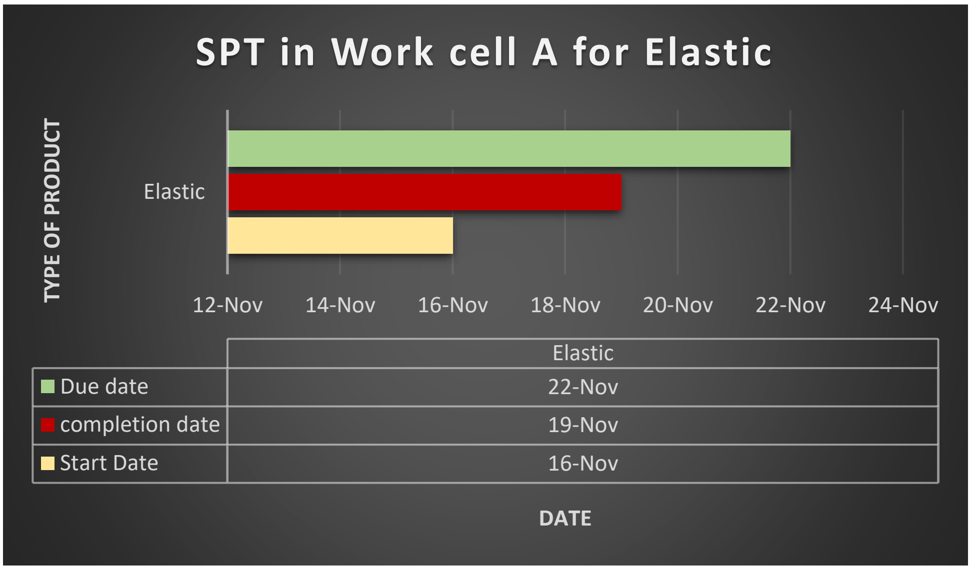

Figure 4.9: Dispatching rule SPT in workcell A for elastic

Based on Table 4.2 above, the product of Elastic has run in work cell A with one number of workers. The simulation was run with quantity of 6330 of elastic product. The starting date for this product to be done was 16/11 and it takes three days to complete the packaging process where the completion date is 19/11. From Figure 4.9 shows that elastic product has completed its packaging process within due date and the number of job delay is zero. The processing time in each of the procedure in the packaging process of elastic is shorter and due to this situation, it can complete within time even with one number of workers.

Work cell B

- Number of workers =2

Table 4.3: Sequencing of operation using approach SPT in workcell B

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
P	1152	16/11	16/11	1	17/11	1	18/11	1	-
Q	1152	16/11	17/11	2	19/11	3	22/11	3	-
R	2000	16/11	19/11	5	24/11	8	22/11	-	2

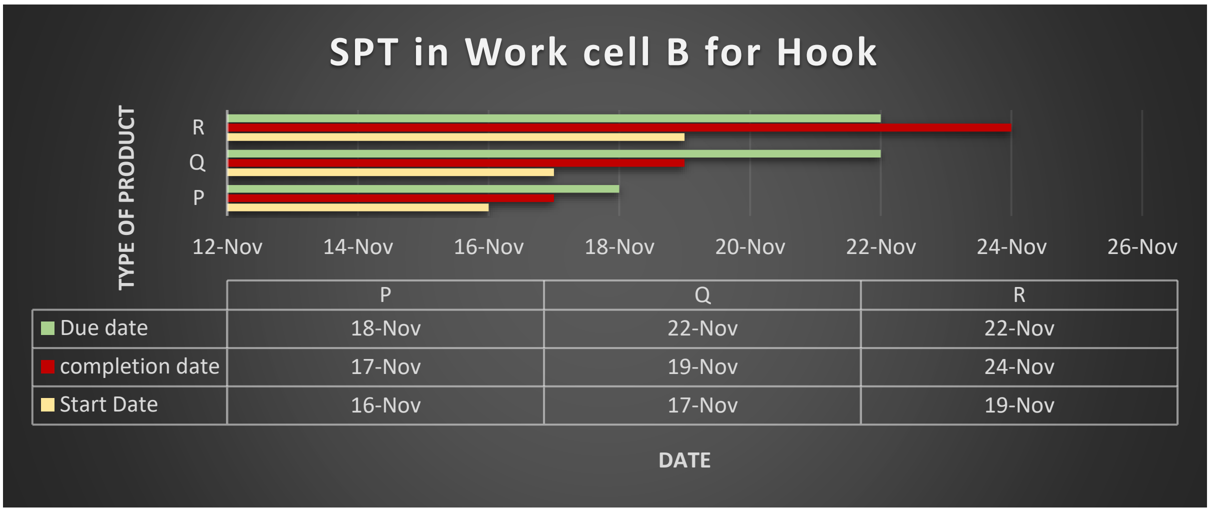

Figure 4.10: Dispatching rule SPT in workcell B for hook

From the above Table 4.3, there are three batches order of Hook with different type of size. All three batch of product Hook done the packaging process in the Work cell B with two number of workers. These packaging process contain four SOP that need to be done. This product done the packaging process starting with product Hook P, Q and R based on its shortest processing time. The arrangement of product is based on the shortest processing time (days) for the product to complete their order. However, from bar graph shown in Figure 4.10 displays that there are one number of delay job in this work cell which is job R because the packaging process was done on 24 November which exceed its due date of 22 November.

Work cell C

- Number of workers = 3

Table 4.4: Packaging process in Work cell C

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
C	1000	16/11	16/11	2	18/11	2	19/11	1	-
A	1000	16/11	18/11	4	22/11	6	22/11	-	-
B	2500	16/11	22/11	7	29/11	13	22/11	-	7

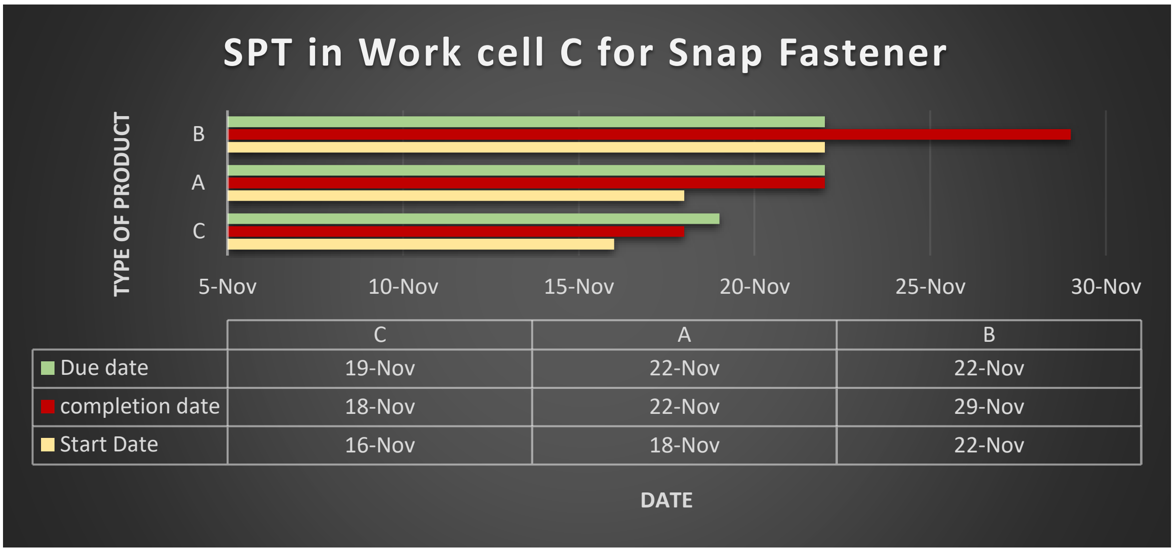

Figure 4.11: Dispatching rule SPT in workcell C for snap fastener

From the above table, it shows the result of snap fastener which done their packaging process in work cell C. There are three number of workers were assigned in this workcell to complete the packaging process. There are three batch of product snap fastener A,B and C. The sequence starts with the product snap fastener (C) that has the shortest processing time and it ends with product snap fastener (B) that has longest processing time. From Figure 4.11 there is one delayed product in this workcell, the snap fastener (B) that is delayed by seven days.

Work cell D

- Number of workers: 4
- Number of job delay = 0

Table 4.5: Packaging process in Work cell D

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
S	840	16/11	16/11	2	16/11	0	16/11	1	-

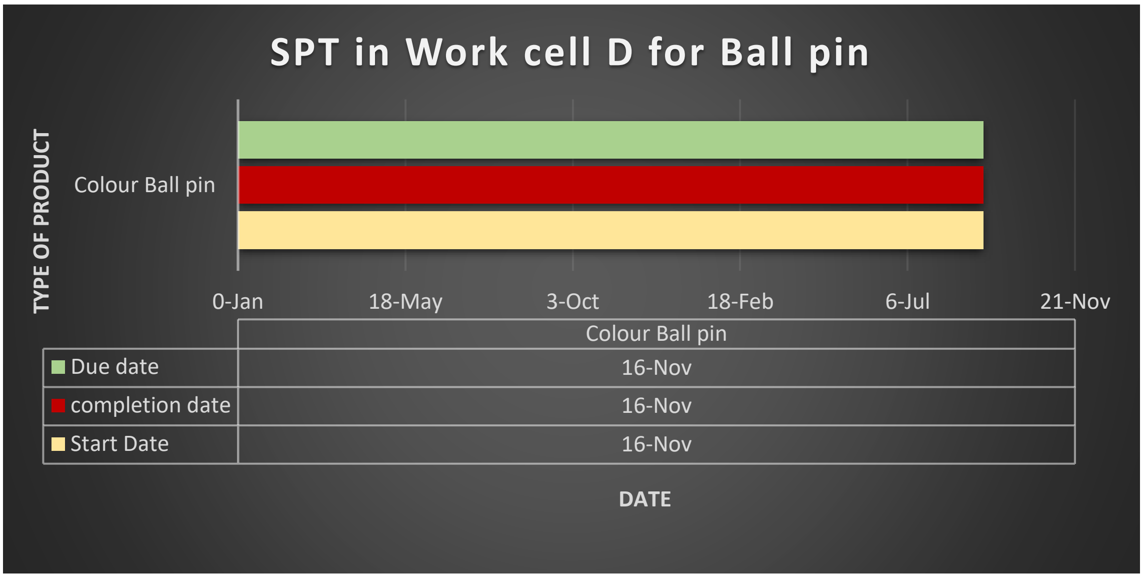

Figure 4.12: Dispatching rule SPT in workcell D for ball pin

The Table 4.5 above displays the results of TF packaging process for product types of ball pin. The arrival date of product is 16/11. Product ball pin packaging was completed on November 16, which falls within the deadline. This product is of the utmost urgency, so the customer will expect us to complete it within the time given. According to the bar graph shows in Table 4.12, there are no number of job delay in this workcell.

Work cell E

- Number of workers: 4

Table 4.6: Sequence of operation using approach SPT in Work cell E

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
L	1440	16/11	16/11	0	16/11	2	18/11	2	-
M	1920	16/11	16/11	1	17/11	6	22/11	5	-
N	1920	16/11	17/11	0	17/11	13	22/11	5	-

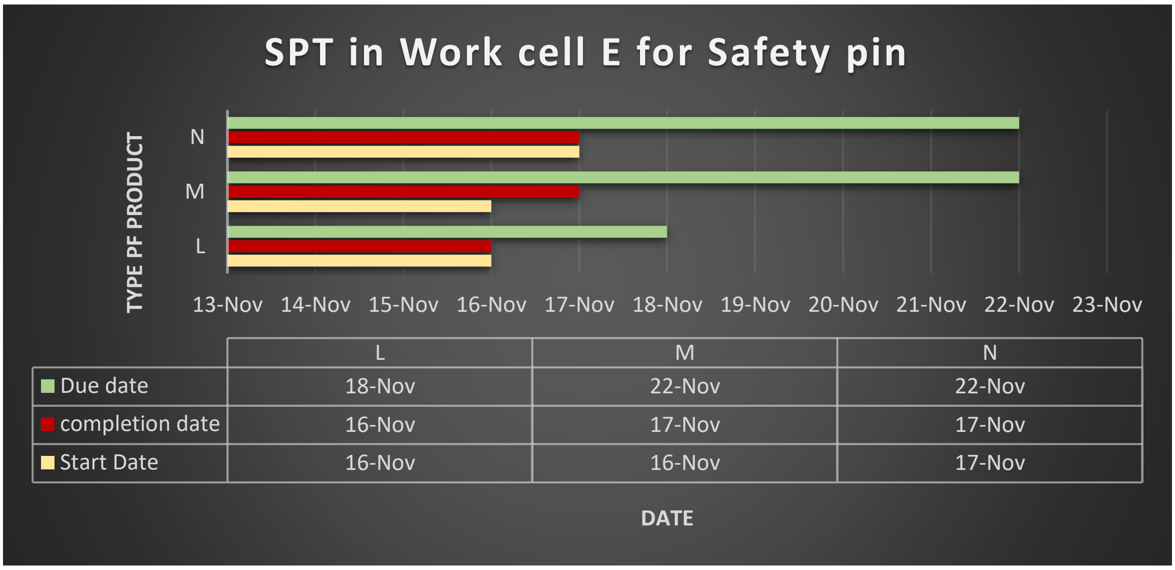

Figure 4.13: Dispatching rule SPT in workcell E for safety pin

The Table below shows result of safety pin has done the packaging process in Work cell E. There are four number of workers needed to complete the packaging process in this work cell. According to Figure 4.13, the graph shows that all batch of safety pin in this work cell manage to complete the packaging process without any lateness. The sequence starts with product safety pin (L) with quantity of 1440 and end with product safety pin (N) with quantity of 1920. The sequence of product is based on the processing time for each product.

Work cell F

- Number of workers = 3

Table 4.7: Sequence of operation using approach SPT in Work cell E

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Past	Early
E	100	16/11	16/11	0	16/11	0	17/11	-	1
G	260	16/11	16/11	0	16/11	0	18/11	-	2
F	800	16/11	17/11	2	19/11	2	22/11	-	3
H	800	16/11	19/11	4	23/11	6	22/11	1	-
D	1200	16/11	23/11	3	26/11	9	22/11	4	-

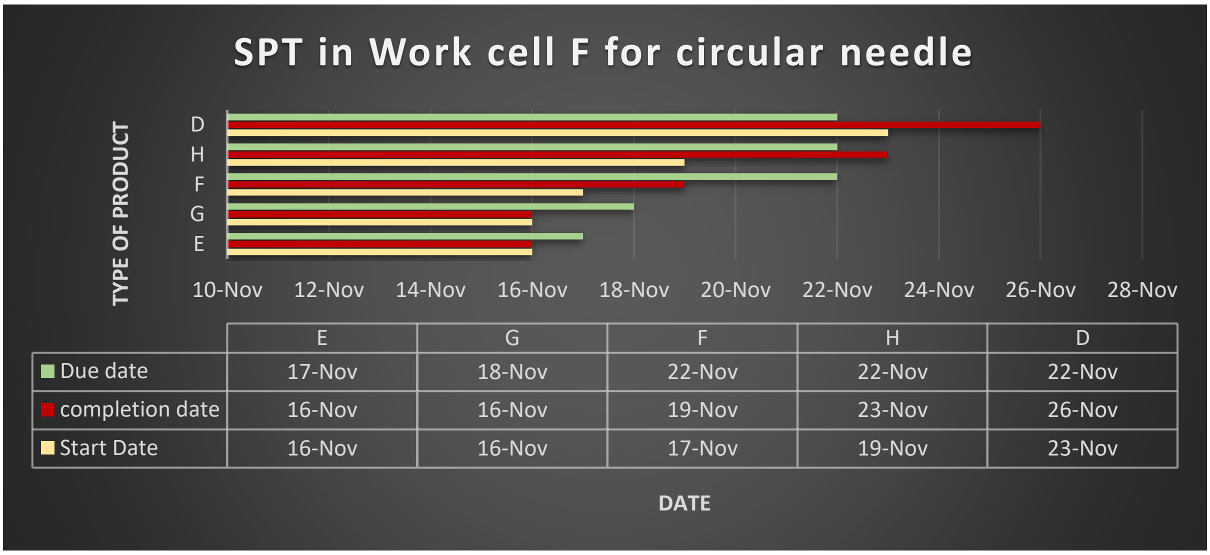

Figure 4.14: Dispatching rule SPT in workcell F for circular needle

Table 4.7 above shows that, the packaging process of circular needle in work cell F with three number of workers. All product done their packaging process in the sequence of E,G,F,H,D based on its shortest processing time (days). However, there are two number of delay job in this work cell based on Figure 4.14. Product circular needle (H) has due for one day late from the promised date and product circular needle (D) has due four days from the promised date.

The result above shows the dispatching rule of SPT, it can be concluded that the maximum number of job delay in SPT is 4 jobs with 14 days of lateness where the jobs that exceed their due date is product circular needle (H) and circular needle (D) in work cell F, product snap fastener (B) in work cell C and Hook (R) in work cell B. Result shows that total work cell used for the above data was 6 workcell with 17 number of workers.

4.2.2 Longest Processing Time (LPT) Approach

The experiment of simulation was then run with second dispatching rule of LPT. The rule with the longest processing time orders the jobs by decreasing processing times. Whenever a work cell becomes available, the largest available job will begin processing. This algorithm is a heuristic used for finding the minimum make span of a schedule. From the result of the simulation, the number of make span (different between start and finish of sequence job or task) and number of delay job can be obtained.

Work cell A

- Number of workers = 1

Table 4.8: Packaging process in Work cell A

Product Name	Status	Type	Quantity	Arrival Date	Processing Time (days)	Start date	Complete Date	Due Date
Elastic		O	6330	16/11	3	16/11 9:00	19/11 10:20	22/11

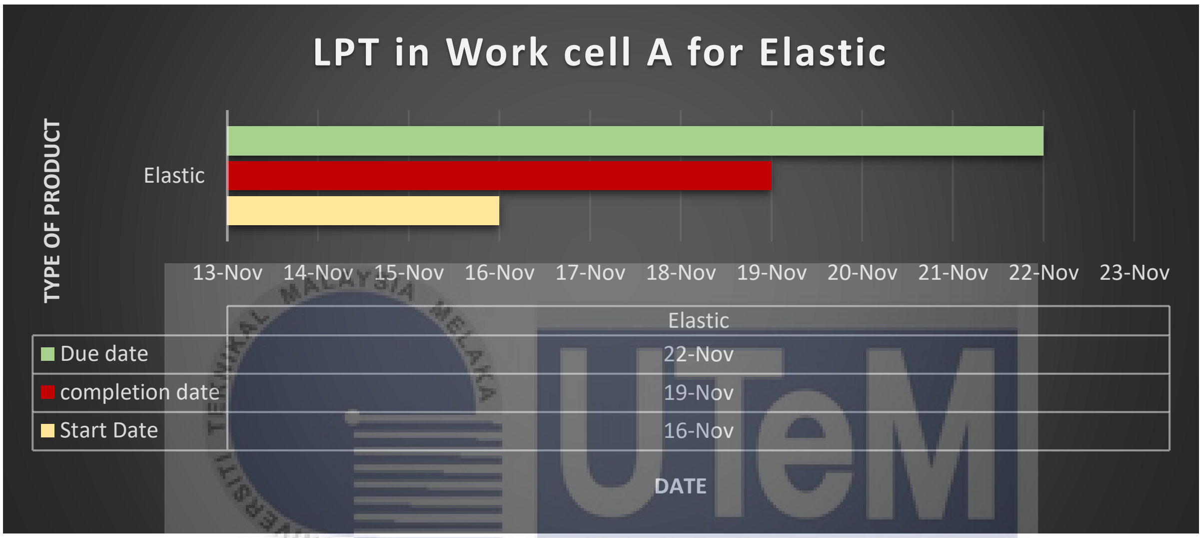

Figure 4.15: Dispatching rule LPT in workcell A for elastic

Table 4.8 above shows the product Elastic has done its packaging process in Work cell A. It takes three days to complete the packaging process with one number of workers. The packaging process of Elastic will start in 16 November and ended in 19 November. This process does not exceed its due date. Therefore, there are zero number of job delay based on Figure 4.15.

Work cell B

- Number of workers = 2

Table 4.9: Sequence of operation using approach LPT in Work cell B

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
R	2000	16/11	16/11	3	19/11	3	22/11	3	-
P	1152	16/11	19/11	3	22/11	6	18/11	-	4
Q	1152	16/11	22/11	2	24/11	8	22/11	-	2

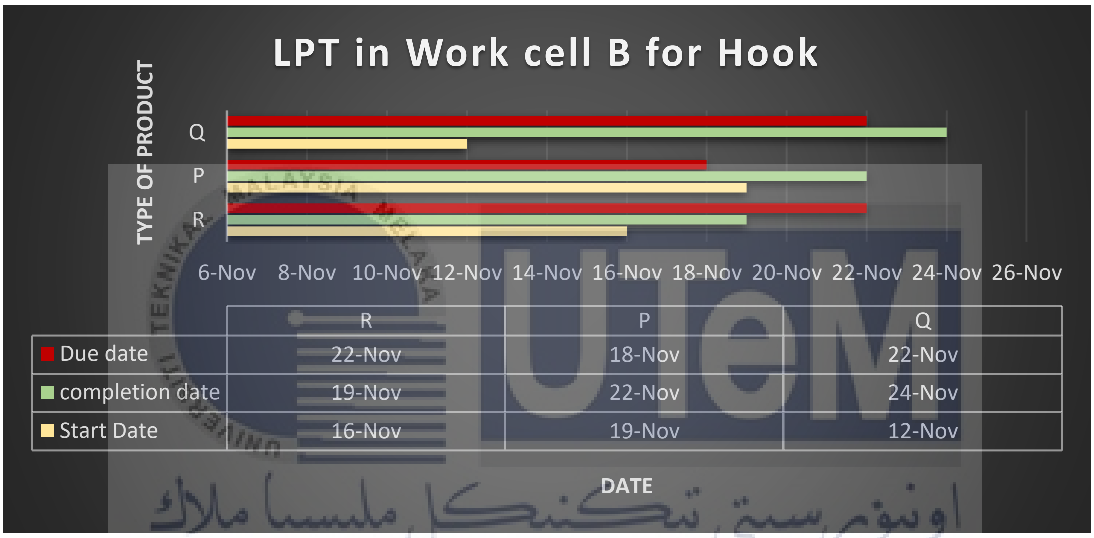

Figure 4.16: Dispatching rule LPT in workcell B for hook

From the Table 4.9 above shows the result packaging process of Hook in work cell B done the packaging process by two number of workers. The scheduling for Hook product in this work cell based on the processing time (day). Product with highest processing time (days) will complete its packaging process before the other two product. The arrangement of the product is R, P and Q. Product Hook (R) and (P) has completed its packaging process within their due dates, however for product Hook (Q) has exceed its promised due date by two days late according to Figure 4.16.

Work cell C

- One number of workers = 3

Table 4.10: Sequence of operation using approach LPT in Work cell C

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
B	2500	16/11	16/11	5	23/11	7	22/11	-	1
C	1000	16/11	23/11	3	26/11	10	19/11	-	7
A	1000	16/11	26/11	4	30/11	14	22/11	-	7

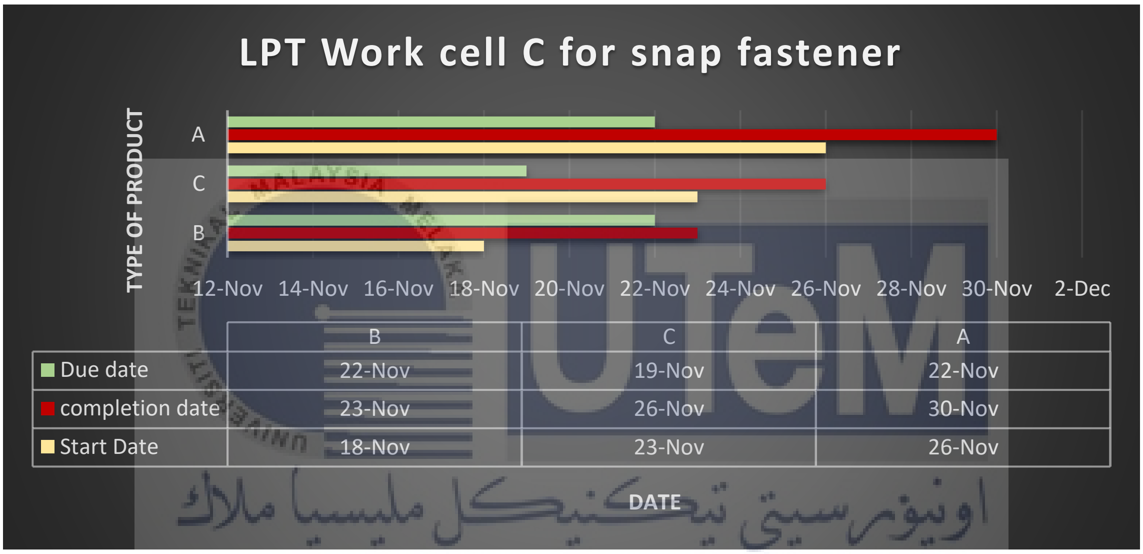

Figure 4.17: Dispatching rule LPT in workcell C for snap fastener

Product of snap Fastener has done its packaging process in the work cell C as shown in Table 4.10 above. The sequence of the product in this rule depends on the processing time. The longer the processing time will start packaging process first and followed by the other two. In this work cell C, the sequence of product will start with B,C and A. There are three workers assigned in this work cell. This product starts its packaging process in 16/11 until 22/11 in order to complete all three batch of products. However, using this LPT rule lead to higher number of job delay which is 3 job delay of B, C and A based on Figure 4.17.

Work cell D

- One number of workers = 4

Table 4.11: Sequence of operation using approach LPT in Work cell D

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
S	840	16/11	16/11	2	16/11	0	16/11	1	-

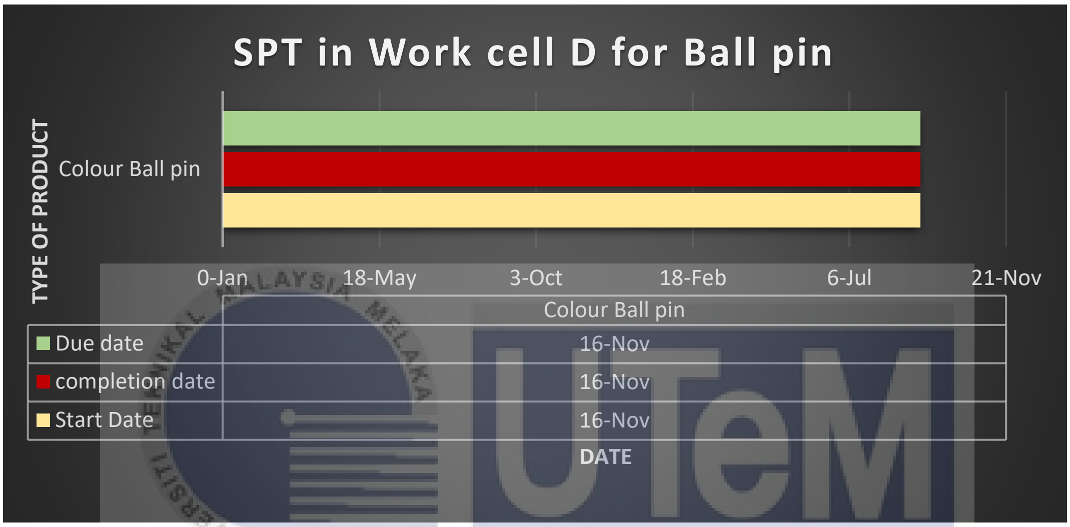

Figure 4.18: Dispatching rule LPT in workcell D for ball pin

The results simulation of packaging process for ball pin product are shown in Table 4.11 above. The product will arrive on November 16th and the product ball pin packaging was finished the packaging process by the day it arrives, meeting the deadline. The client will expect us to finish the project by the deadline because it is of the utmost urgency product. There are no job delays in this workcell, as shown by the bar graph in Table 4.18.

Work cell E

- One number of workers = 4

Table 4.12: Sequence of operation using approach LPT in Work cell E

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
M	1920	16/11	16/11	0	16/11	0	22/11	6	-
N	1920	16/11	16/11	1	17/11	1	22/11	5	-
L	1440	16/11	17/11	1	18/11	2	18/11	-	-

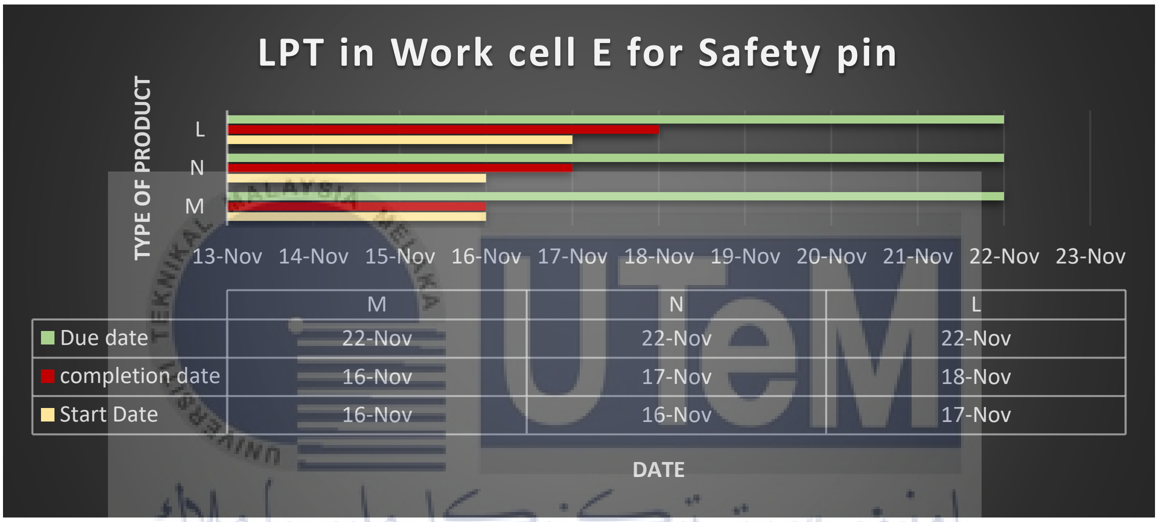

Figure 4.19: Dispatching rule LPT in workcell E for safety pin

From the result Table 4.12 above shows the sequence of safety pin product completed its packaging process in the work cell E with total number of four workers. The sequence of the product start with Safety pin M, N, and L based on the longest processing time (day) for each product. The packaging process start in 16 November and ended by 18 November for three batch of safety pin product without any job delay issue. Based on Figure 4.19 the product has successfully completes the packaging process within the due date.

Work cell F

- One number of workers = 3

Table 4.13: Sequence of operation using approach LPT in Work cell F

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Past	Early
D	1200	16/11	16/11	3	19/11	3	22/11	-	3
F	800	16/11	19/11	4	23/11	7	22/11	1	-
H	800	16/11	23/11	2	25/11	9	22/11	3	-
G	260	16/11	25/11	1	26/11	10	18/11	8	-
E	100	16/11	26/11	0	26/11	10	17/11	9	-

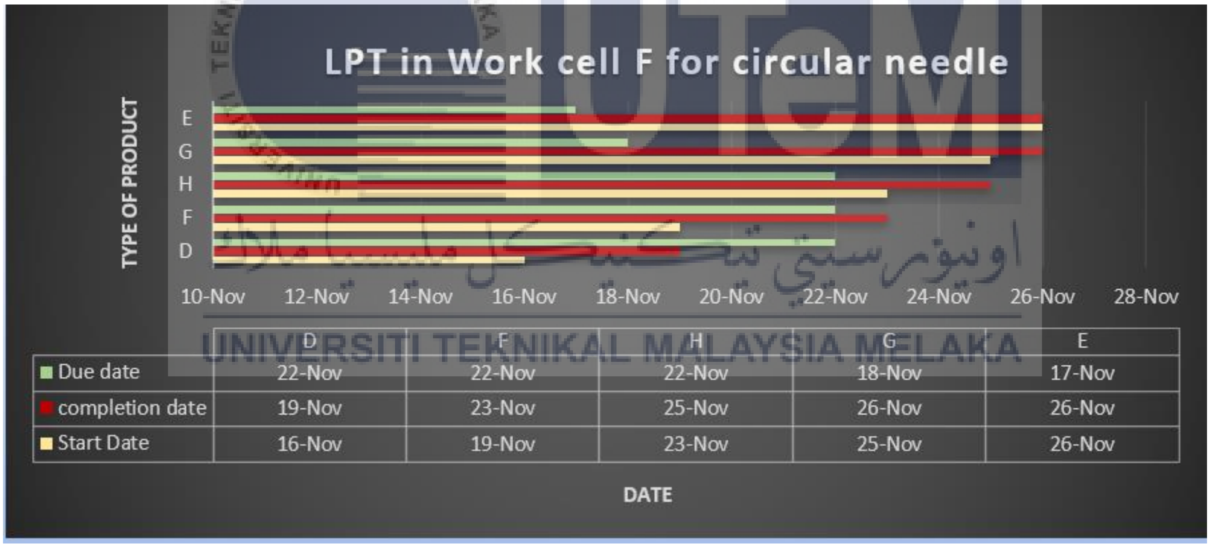

Figure 4.19: Dispatching rule LPT in workcell F for circular needle

Table 4.13 shows the result of Circular needle type D, F, H, G and E. The difference between the type is the dimension of the product. The quantity for each product different between each other. Due to that, the processing time (days) to complete the packaging process will be different. Based on the dispatching rule of LPT, the product will run according to the highest processing time(days) which the product start with Circular needle D follow by F, H and G and ended with circular needle E. From Figure 4.19 there are four jobs delay in this work cell based on the completion time that exceed with the due date. All product that run after circular needle F product will be delay too because if the first job delay, it will cause the other job to delay as well.

The above result shows that in order to use the dispatching rule of longest processing time (LPT) can cause higher number of job delay as this data has resulted nine jobs with three different types of family products that are over the due date. The circular needle family product has a higher number of job delays, which is four. Due to high customer demand on that week, it has been shown that the packaging process for circular needle products cannot be done in time within the same work cell. There are total of 17 workers needed to finish the packaging process. However, by using this dispatching rule LPT might result in higher lateness of product to be done within their timeframe.

4.2.3 Earliest Due Date (EDD) Approach

The experiment of simulation was then run with third dispatching rule of earliest due date (EDD). This rule is useful for reducing tardiness on the job. The job with the earliest deadline is completed first. Each batch of the incoming product in TF gets an estimation of how long it will take until it achieved the end of the production. The value will be compared with the promised due dates. If the batch is late or about to be late, it will get prioritized first so that it will move faster than the other batches. The result for this dispatching rule as shown in below.

Work cell A

- Number of workers = 1

Table 4.14: Packaging process in Work cell A

Product Name	Status	Type	Quantity	Arrival Date	Processing Time (days)	Start date	Complete Date	Due Date
Elastic		O	6330	16/11	3	16/11 9:00	19/11 10:20	22/11

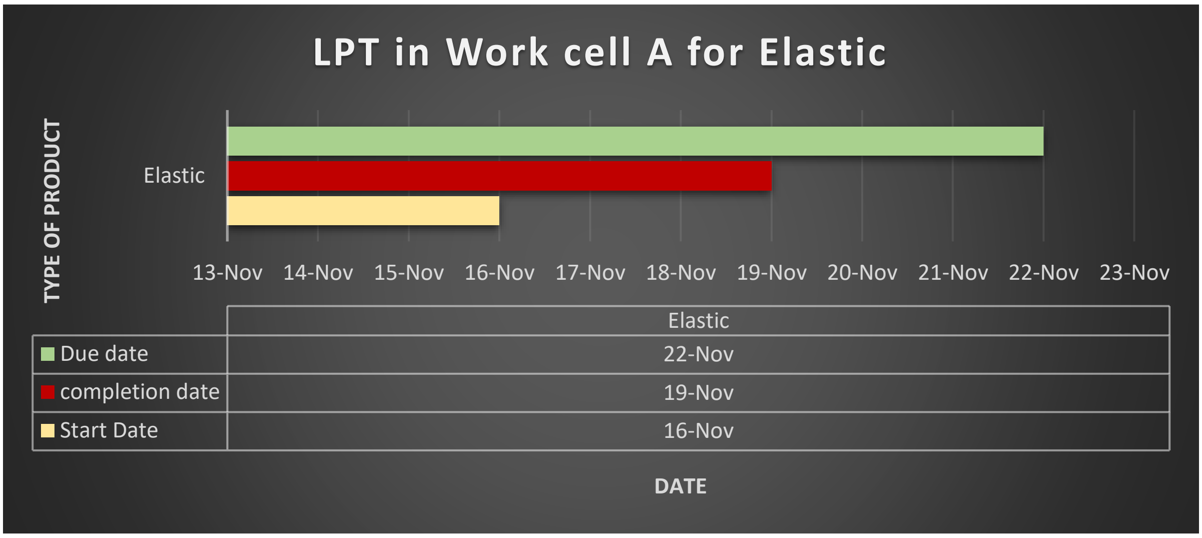

Figure 4.20: Dispatching rule EDD in workcell A for Elastic

Based on the information in Table 4.14, the product of Elastic has been run in work cell A with one worker. 6330 of elastic product were used to run the simulation. The work on this product began on November 16, and it takes three days to package it, so the date it will be done is November 19. Figure 4.20 shows that the packaging process for the elastic product was done by the due date, and there were no job delays. In the packaging process for elastic, each step takes less time to do, so it can be done on time with just one worker.

Work cell B

- Number of workers = 1

Table 4.15: Sequence of operation using approach EDD in Work cell B

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
P	1152	16/11	16/11	1	17/11	1	18/11	1	-
R	2000	16/11	17/11	5	22/11	6	22/11	-	-
Q	1152	16/11	22/11	2	24/11	8	22/11	-	2

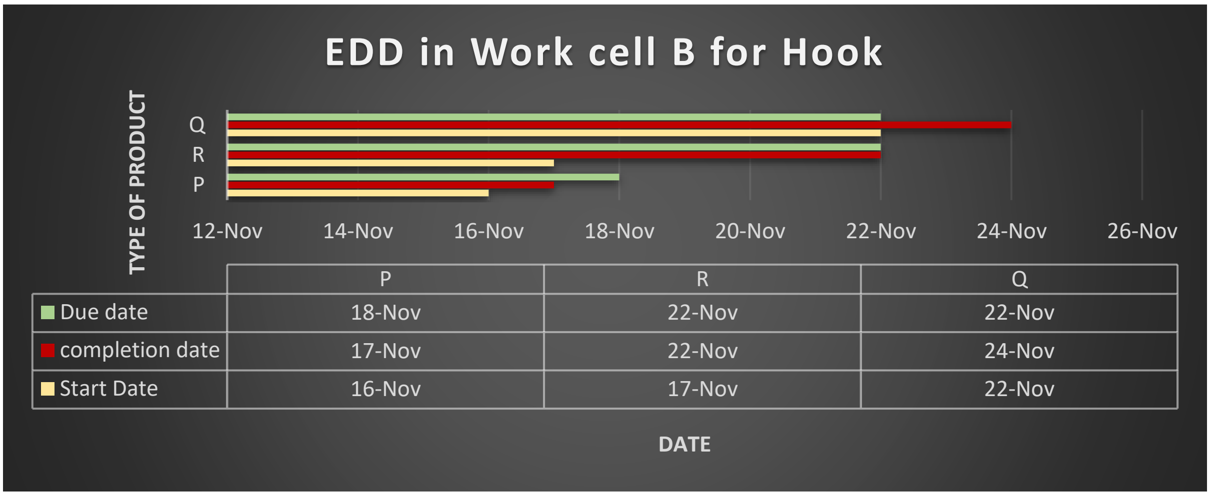

Figure 4.21: Dispatching rule EDD in workcell B for Hook

Table 4.15 displays the outcome of Hook for type (P,R,Q). The order of each product based on the customer-specified delivery date. The packaging process begins with product Hook (P) due to its 18 November due date, which is earlier than the other two products which has due date of 22 November. When two products have the same due date, packaging will begin with the product that has a greater quantity and a completion time that is closer to the due date. Therefore, product Hook (R) with a quantity of 2,000 will undertake packaging process follow by product Hook (Q). From Figure 4.21 shows one job delay for product Q where the completion date exceeds the due date.

Work cell C

- Number of workers = 3

Table 4.16: Sequence of operation using approach EDD in Work cell C

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
C	1000	16/11	16/11	2	18/11	2	19/11	1	-
B	2500	16/11	18/11	7	25/11	9	22/11	-	3
A	1000	16/11	25/11	4	29/11	13	22/11	-	7

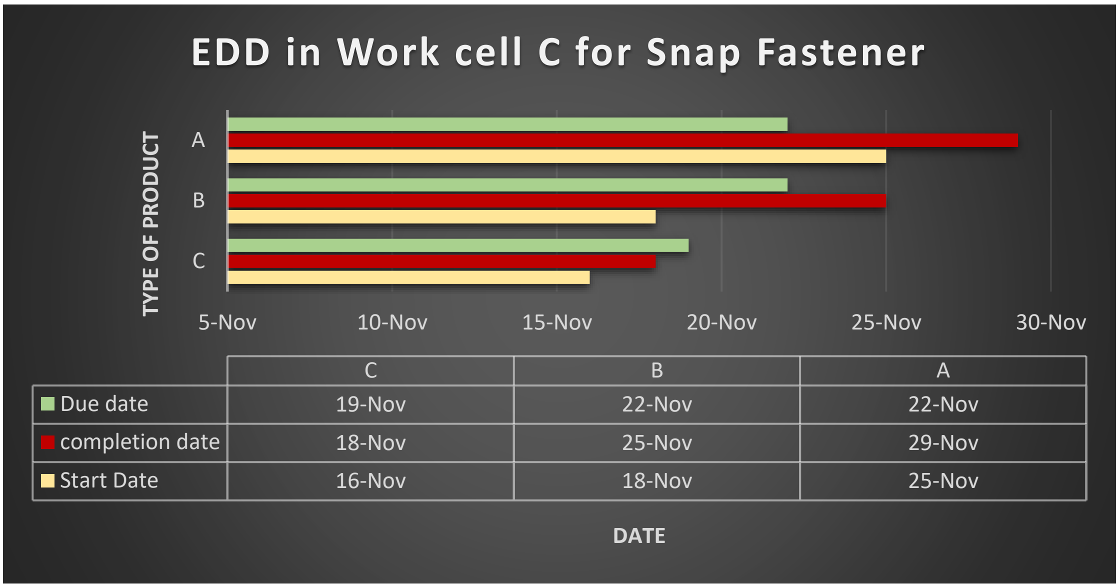

Figure 4.22: Dispatching rule EDD in workcell C for snap fastener

From the above result in Table 4.16 display in the table above show the sequence of product snap fastener based on its due date. Product snap fastener C has early due date which is on 19 November compared to the other two products. There are three workers assigned in this work cell and they completed the first product before the due date which is early one day. Product snap fastener (B) and (A) has the same due date, so the product that will done their packaging process in second place is snap fastener type B. This is due to the reason that the product has a higher quantity which means its completion date is nearly to the due date. In order to reduce number of lateness the product must be done first before snap fastener type A. Based on Figure 4.22 there are two number of job delay in this work cell.

Work cell D

- One number of workers = 4

Table 4.17: Sequence of operation using approach EDD in Work cell C

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
S	840	16/11	16/11	2	16/11	0	16/11	1	-

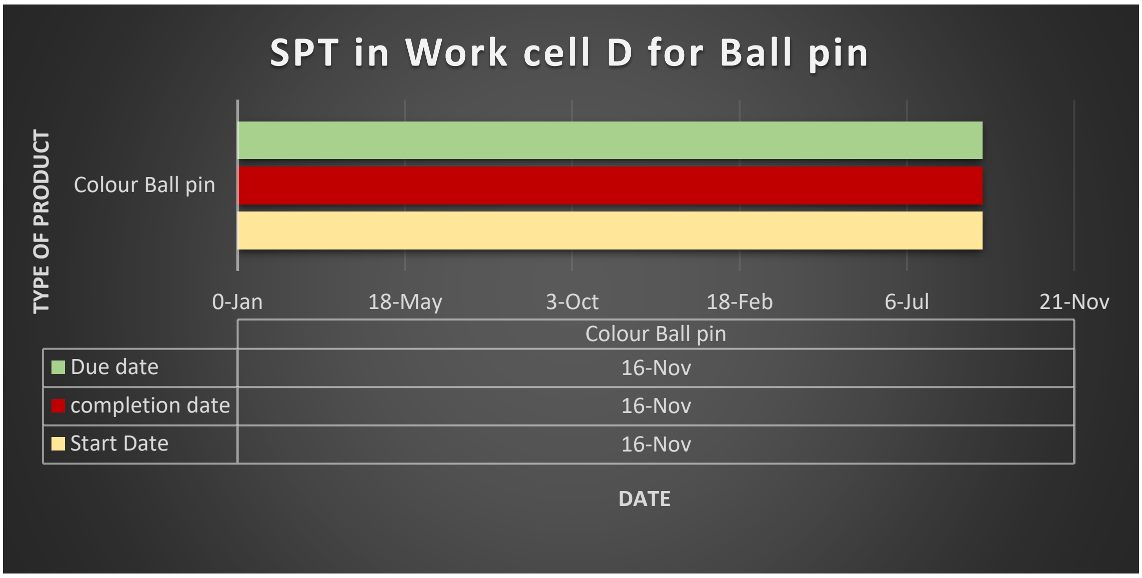

Figure 4.23: Dispatching rule EDD in workcell D for ball pin

Table 4.17 shows the results of the simulation of the packaging process for the ball pin product. On November 16, the product will arrive. The ball pin packaging was done on November 16, so the deadline was met. Because the project is so important, the client will expect us to finish it by the deadline. Figure 4.23 shows bar graph shows that there are no job delays in this workcell.

Work cell E

- Number of workers = 4

Table 4.18: Sequence of operation using approach EDD in Work cell E

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
L	1440	16/11	16/11	0	16/11	0	18/11	2	-
M	1920	16/11	17/11	0	17/11	0	22/11	5	-
N	1920	16/11	17/11	1	18/11	1	22/11	5	-

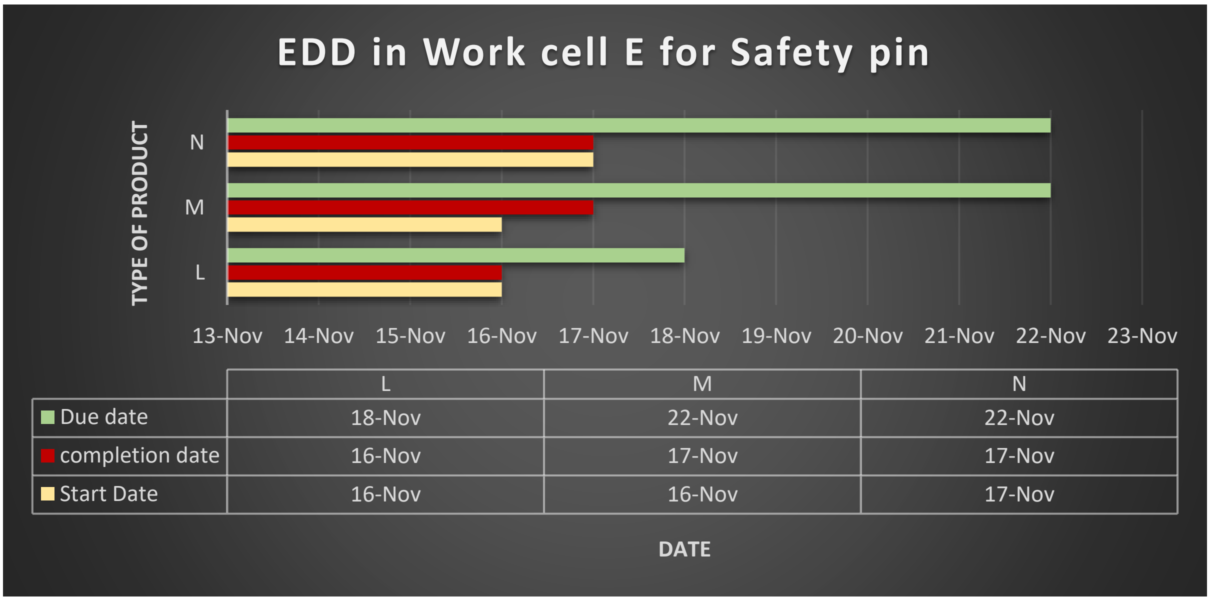

Figure 4.24: Dispatching rule EDD in workcell E for safety pin

From the above Table 4.18 shows that, the safety pin done their packaging process in work cell E. Safety pin (L) is top urgent product which mean the due date will be earlier than other. This type of product has a status of top urgent where it need to complete within their time. The sequence for each of the product will start from L,M and N. Based on Figure 4.24 the product manages to complete the packaging process within time without any number of job delay.

Work cell F

- Number of workers = 3

Table 4.19: Sequence of operation using approach EDD in Work cell F

Sequence	Quantity	Order arrived	Begin work	Processing Time(day)	Finish time	Flow Time	Due date	Early	Past
E	100	16/11	16/11	0	16/11	0	17/11	1	-
G	260	16/11	16/11	0	16/11	0	18/11	2	-
D	1200	16/11	17/11	5	22/11	5	22/11	-	-
F	800	16/11	22/11	2	24/11	7	22/11	-	2
H	800	16/11	24/11	2	26/11	9	22/11	-	4

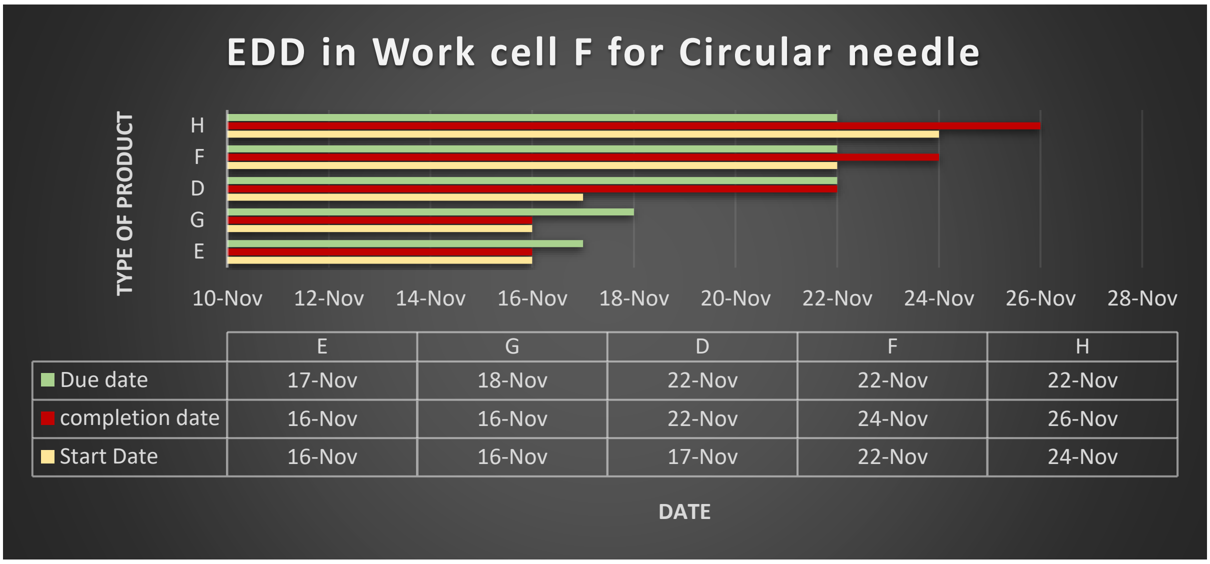

Figure 4.25: Dispatching rule EDD in workcell F for circular needle

According to the Table 4.19 above shows, circular needles are produced in five batches with varying quantities and due dates. There are two product of circular needle E and G that has status top urgent which means that the product will have early due date compared to other. The sequence of product is E,G,D,F and H that are arrange according to the due date. Product circular needle E,G and D completed its packaging process within time. There are two job delay in this work cell which is circular needle F and H. Circular needle (E) manage to complete the packaging process one day earlier and circular needle G completed with two days earlier.

The result above shows that in order to implement the dispatching rule of Earliest Due Date (EDD), it can cause five jobs to be delay according to this data. The total number of workers to complete the packaging process is 17 workers, however by using this dispatching rule EDD might result in higher lateness of product to be done within their timeframe.

4.2.4 Performance Measure of SPT, LPT and EDD

Table 4.20 below shows the performance measure for three types of dispatching rule SPT, LPT and EDD. The average of flow time, average days early and average past due has been calculated by using the formula as stated above. In order to find the suitable and effective rule, it must follow the benchmark below:

(a) Minimize the average number of jobs

(b) Minimize average flow time

(c) Minimize average number of lateness

(d) Maximize average days early

Table 4.20: Calculation of Performance measure for each of dispatching rule

Dispatching Rule	Workcell	Average flow time	Average days early	Average day past due/ average lateness
SPT	A	3	3	0
	B	4	1.33	0.67
	C	7	0.33	2.33
	D	0	0	0
	E	0.66	4	0
	F	3.4	1.2	1
	Total	**18.06**	**9.86**	**4**
LPT	A	3	3	0
	B	5.67	1	2
	C	10.33	0	5.33
	D	0	0	0
	E	1	3.67	0
	F	7.8	0.6	4.2
	Total	**27.8**	**8.27**	**11.53**
EDD	A	3	3	0
	B	5	0.33	0.67
	C	8	0.33	3.33
	D	0	0	0
	E	0.33	4	0
	F	4.2	0.6	1.2
	Total	**20.53**	**8.26**	**5.2**

Based on the result above in Table 4.20 SPT has resulted to follow the benchmark of finding the effective dispatching rule with average flow time of 18.06 days, average days early with 9.86 days and average lateness of 4 days.

4.2.5 Comparison between SPT, LPT and EDD

In order to overcome the production planning and scheduling problem in TF, this part will be discussed about the different in scheduling analysis of three dispatching rule of SPT. LPT and EDD based 3 element which is number of job delay, average flow time, average day past due and average day early in order to analyze the dispatching rule that give higher effectiveness. This analysis will evaluate the measures of effectiveness in criteria of the four elements according to the benchmark in all work cell to complete their packaging process with each number order for the packaging process in each work cell. All of order has been distributed accordingly to each work cell based on the number of workers available in each work cell.

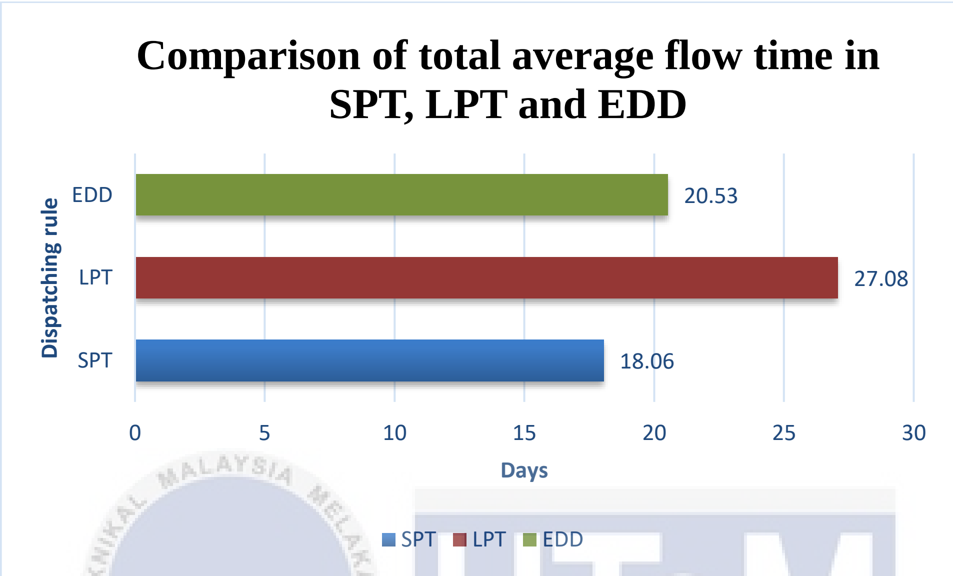

Figure 4.26: Comparison of total average flow time in SPT, LPT and EDD

From the graph in Figure 4.26 represented the comparison of total average flow time in SPT, LPT and EDD. As can see in the Figure above, SPT method is the method with less total flow time which is 18.06 days compared to the other two method which is LPT with 27.08 days and EDD with 20.53 days. According to the above results, it shows that SPT rule is the effective rule because SPT schedule provide a lower total average flow time. In general, SPT will push more jobs through system to completion quickly than with the others rules. Lower average flow time can result in better effectiveness of rules. Based on the previous research by Nazif and Hafizuddin (2012) related to the assessing the priority rules of scheduling application in job-shop manufacturing company has resulted in applying SPT as the new priority rules allows the jobs with the shortest processing time to be processed first and reduces the amount of work which awaits capacity at the end of the work schedule, thus increasing the capacity of the production and resulting in the highest percentage of lowest number average flow time.

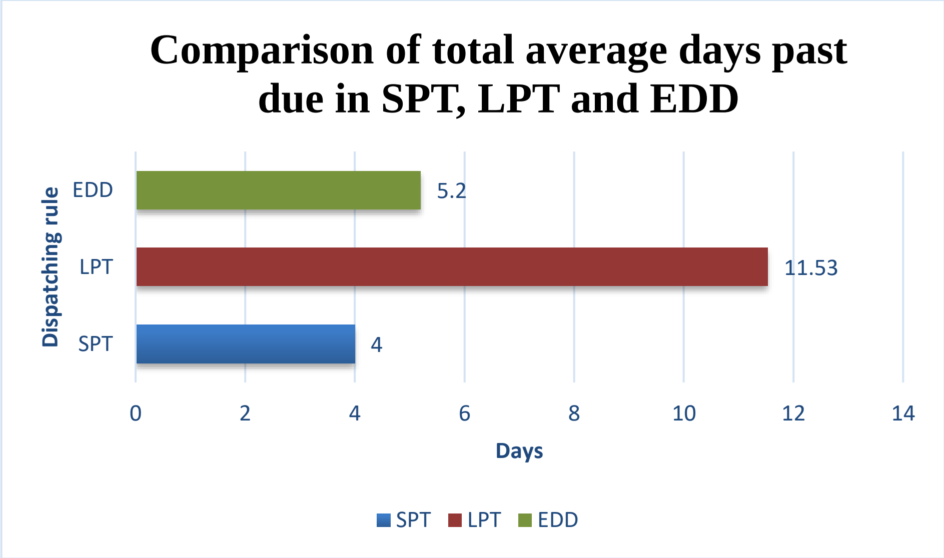

Figure 4.27: Comparison of total average past due in SPT, LPT and EDD

From Figure 4.27 display the average day past due for each dispatching rule. SPT sequencing rule has lowest average number of days past due or average lateness which is 4 days compared to LPT with 11.53 days and EDD with 5.2 days. Lower average past due will result in better customer service levels. This result shows that SPT in an effective sequencing rule and is supported by the previous research from Gozali (2019) in order to establish the most effective job scheduling arrangement is by minimizing mean tardiness as well as mean lateness job. According to the research the better proposed method that can minimize delay time is to conduct production scheduling using SPT method. It is the best solution for scheduling method and capable of producing the higher output by decreasing mean lateness job. As the production process uses flow shop method with heuristic methods, such as Earliest Due Date (EDD) method and Short Processing Time (SPT), it shows that SPT method provides the most optimum outcome, specifically by decreasing mean lateness job by 66.67%.

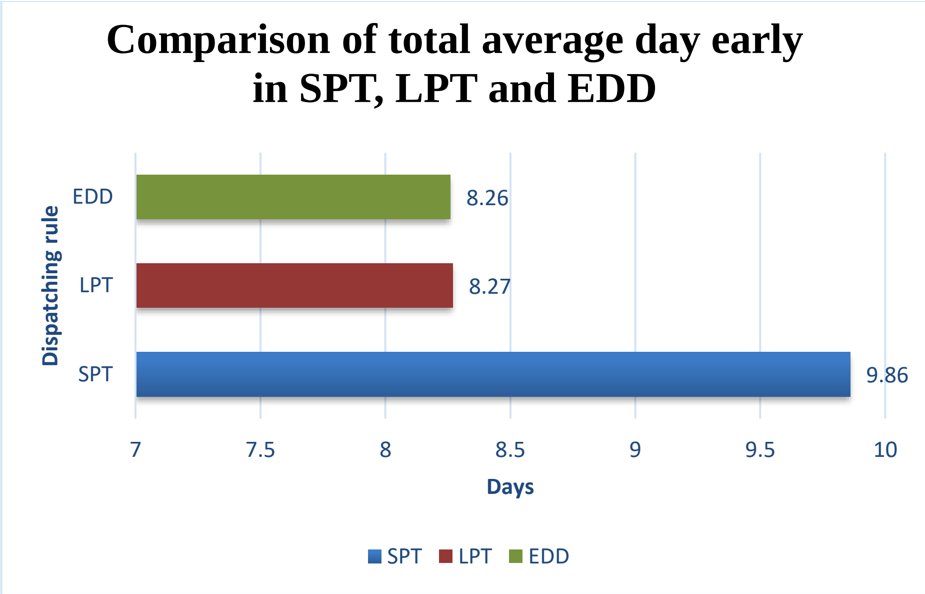

Figure 4.28: Comparison of total average day early in SPT, LPT and EDD

From Figure 4.28 depicted the comparison of total average day early in SPT, LPT and EDD. SPT sequencing rule has higher number of total average day early with 9.86 days compared to EDD and LPT. LPT has total average early day with 8.27 days whereas for EDD which is slightly lower to LPT with 8.26 days. In order the find the better effectiveness of rule, the higher number of average early days is the better effective of the rule. From the results above, it shows that SPT is an effective rule compared to LPT and EDD.

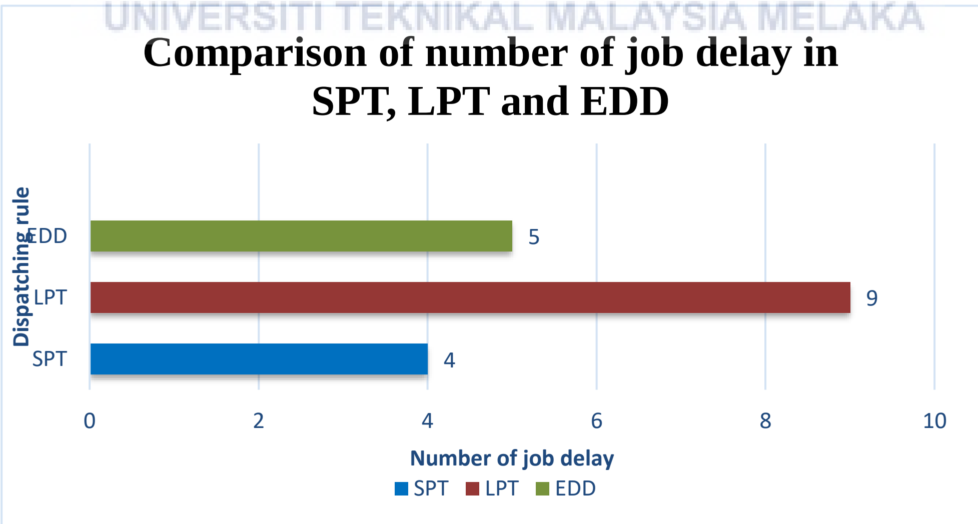

Figure 4.29: Comparison number of job delay in SPT, LPT and EDD.

SPT yields the lowest number of job delay with 4 jobs compared to LPT which is 9 jobs and it is slightly lower than EDD with 5 jobs. LPT is somehow not practicable in certain scenario, in a way that it will consume the longest time and causing the other job either with earliest due date or shortest processing time to delay its processing time and fail to fulfil customers demand within the agreed time period. Thus, LPT is just not a good choice of rule to be practiced in TF.

According to the above results of comparing each dispatching rule, it is completely obvious that the SPT rule is the effective rule because it has followed the benchmark to find the best rule. SPT yield has a minimum average flow time, minimum number of job delays, minimum average day lateness and maximum number of average days early compared to LPT rule and EDD rule. Therefore, it is strongly recommended for TF to implement this type of dispatching rule. The current packaging procedure at TF lacks a proper method for order sequencing which could result in late customer deliveries. This SPT job sequencing will be used as the order sequence for TF to provide good planning and scheduling of each product that must complete its packaging process including the number of work cells and workers required. Apart from that, the result of Gantt chart in simulation will help to identify the total completion time for each of product on each work cell. SPT also can help the planner to plan well the product that need to be done within that day and the number throughput per day in simulation can determine well the output that each operator has achieved.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In a conclusion, production planning and control are concerned with all of the actions that take place during the packaging process at (TF) UTeM. It includes estimating production, handling materials, developing production schedules and scheduling jobs for all activities. The Important aspect in a production planning and control system is to establish a production flow that is correctly coordinated so that there is no need to rush orders to meet deadlines owing to a disorganized plan. In order, to address the complete production planning complex challenges, a simulation model was developed to represent and analyze the operations. Tecnomatix Plant Simulation software used to constructs the system modelling of workcell for each of the product. In addition, it is used to visualize the makespan for each product in each workcell. This simulation-aided scheduling approach demonstrated its capability to assist planners. The results show that from the proposed method using SPT, LPT and EDD dispatching rule, the best dispatching rules is the SPT method. This project shows that SPT rule can minimize the average flow time, minimize the number of job delays, minimize number of lateness and maximize the number of average days early.

5.1.1 1st Objective achievement

The first objective for this study is to develop a simulation aid scheduling tool for TF packaging operation. This objective has been achieved by gathering all information needed and turned it into model of simulation. The layout of TF is used as the base of the model.

5.1.2 2nd Objective achievement

The second objective for this study is to identify the effectiveness of a proper planned of sequence operation by using dispatching rule. This objective has been achieved by utilizing three types of dispatching rule of SPT, LPT and EDD to find the better effectiveness of the schedule used. Based on the results has been achieved, SPT rules is the most suitable dispatching rule to be implemented in TF.

5.2 Recommendation for future work

After conducting this research, a few recommendations have been made in order to draw attention to the most important aspect of TF UTeM. The following are the key recommendations for this goal:

I. Suggestion to implement the genetic algorithm in the simulation to optimise the job scheduling.
II. Run the simulation by inserting all batch of product in the data table instead of batch per batch.

5.3 Limitations of study

During the process of completing this study, there were a few limitations that has been faced which are:

I. Difficult to collect data individually while the work cell is operating
II. Difficulties arise for first-time Tecnomatix software users.
III. There is a lack of information and instructions for using the Tecnomatix software for research purposes.

5.4 Project Sustainability

Recently, people have become interested in the idea of sustainability. It is important to remember that putting new ways of making things into practise successfully requires solutions that will last, and the key to the solution is by that is standardising it. This would not only save time, but it would also help to make industrial processes more sustainable and less harmful to people and the environment. Other than that, scheduling used is one of sustainable element in the production planning where it based on the makespan in the gantt chart.

5.5 Project Complexity

Complexity issues must be addressed in both the research source and the system, component, or process that determines critical regions and meets predefined criteria while accounting for engineering factors. A variety of factors are also considered.

I. Difficulties in using the simulation software and to figure out the problem arrived when there is an error in the simulation.
II. Difficulties in identifying the dispatching rule that suitable to be choose in this study according to many types of dispatching rule that are available.

5.6 Lifelong Learning

Lifelong learning talks about aspect as a type of self-directed learning that focuses on personal growth. Lifelong learning is also known as the development of human skills through a process that is always there to help and encourage people to get all the knowledge, values, and understanding they will need throughout their lives and be able to use what they have learned in all of their roles. In this study, the use of software technology is looked at in terms of lifelong learning, which has never been done before. The information learned is very useful for moving through the world of work.

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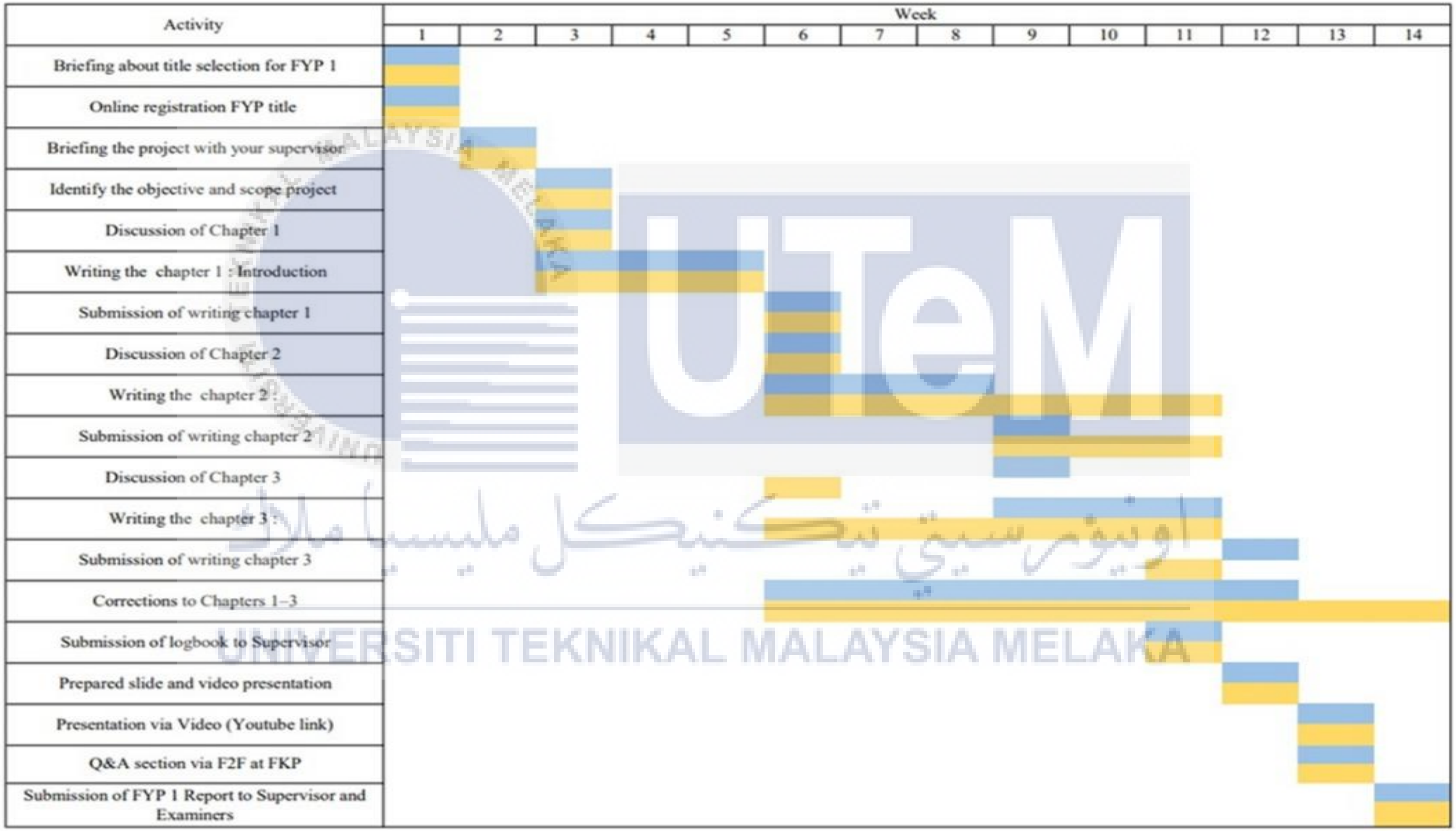
APPENDIX A

Activity	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Briefing about PSM 2 with Dr Shahir															
Overview of PSM 1															
Briefing the project with your supervisor															
Preparation of the needed and information															
Conduct the methodologies															
Propose the development of tool used															
Thesis writing for Chapter 4															
Thesis writing for Chapter 5															
Slide preparation															
Presentation															
Submission of PSM 2 Report															

APPENDIX B


Activity
Week
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Briefing about title selection for FYP 1
Online registration FYP title
Briefing the project with your supervisor
Identify the objective and scope project
Discussion of Chapter 1
Writing the chapter 1 : Introduction
Submission of writing chapter 1
Discussion of Chapter 2
Writing the chapter 2 :
Submission of writing chapter 2
Discussion of Chapter 3
Writing the chapter 3 :
Submission of writing chapter 3
Corrections to Chapters 1–3
Submission of logbook to Supervisor
Prepared slide and video presentation
Presentation via Video (Youtube link)
Q&A section via F2F at FKP
Submission of FYP 1 Report to Supervisor and Examiners