SIMULATION OF PREVENTIVE MAINTENANCE SCHEDULE IN REDUCING MACHINE STOPPAGE AND DOWNTIME

By:

MAK KAM SHENG

(Matrix no.: 125411)

Supervisor:

Dr. Hasnida Binti Ab Samat

June 2018

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfilment of requirement to graduate with honors degree in

BACHELOR OF ENGINEERING
(MANUFACTURING ENGINEERING WITH MANAGEMENT)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

DECLARATION

I hereby declare that this Final Year Project entitled "Simulation of Preventive Maintenance Schedule In Reducing Machine Stoppage And Downtime" was carried out for the degree of Manufacturing Engineering with Management under the guidance and supervision of Dr. Hasnida Binti Ab Samat, School of Mechanical Engineering at Universiti Sains Malaysia. The interpretations put forth are based on my reading and understanding of the original texts and they are not published anywhere in the form of books, monographs or articles. The other books, articles and websites, which I have made use of are acknowledged at the respective place in the text.

For the present thesis, which I am submitting to the University, no degree or diploma or distinction has been conferred on me before, either in this or in any other University.

Name: MAK KAM SHENG

Date :

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor, Dr Hasnida Binti Ab Samat for allowing me to undertake this work. I extremely thankful and indebted to her for sharing expertise, and sincere and valuable guidance and encouragement extended to me. Besides, she gave me many ideas to complete the simulation modelling with the patience.

I take this opportunity to express gratitude to all of my friends who helped me during my research. This work would not have been possible without the support from School of Mechanical Engineering because our school have the Surface Mounted Technology machine to make me more understand every machine.

Nobody has been more important to me in the pursuit of this course than the members of my family. I would like to thank my parents, whose love and guidance are with me whatever I pursue. Finally yet importantly, I have been extremely lucky to enter University Sains Malaysia (USM). Hence, I would like to thank University Sains Malaysia (USM) gave me such a nice place to complete my degree study.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

MTBF	Mean time between failures
MTTF	Mean time to failure
MTTR	Mean time to repair
PM	Preventive maintenance
PCB	Printed Circuit Board
SMT	Surface Mounted Technology

ABSTRAK

Dalam beberapa dekad yang lalu, terdapat aktiviti penyelidikan yang pelbagai dan signifikan mengenai penjadualan penyelenggaraan. Mesin biasanya mengalami kerosakan mempunyai banyak sebab seperti aktiviti penyelenggaraan pencegahan. Penyelenggaraan pencegahan ditakrifkan sebagai tindakan penyelenggaraan yang dijadualkan secara berjadual berdasarkan kadar kegagalan purata. Strategi penyelenggaraan pencegahan yang optimum dapat memberikan banyak faedah kepada organisasi dalam memperpanjang umur peralatan dan ketersediaan mesin. Beberapa kajian telah membincangkan isu-isu penyelenggaraan pencegahan. Sebagai contoh, penjadualan penyelenggaraan pencegahan yang betul boleh memaksimumkan kitaran hayat mesin dan penghasilan pengeluaran.

Dalam tesis ini, objektifnya adalah mengkaji ketersediaan mesin yang terjejas oleh penjadualan pencegahan pencegahan. Model ini dibina berdasarkan Teknologi Surface Mounted (SMT) dalam sistem pembuatan. SMT adalah barisan pengeluaran aliran berterusan kerana setiap mesin disambungkan sesama lain. Dalam kajian ini, model yang telah dibina terdiri daripada lima mesin yang berbeza iaitu pencetak skrin, dispenser gam, penembak cip, pilih dan tempat dan reflow oven. Perisian Witness Edisi Pembuatan 14 digunakan untuk simulasi sistem pengeluaran Teknologi Surface Mounted (SMT). Hal ini adalah untuk melaksanakan optimum penjadualan pencegahan pencegahan dengan menggunakan jadual penyelenggaraan yang berbeza dan tempoh penyelenggaraan pencegahan.

Hasil penyelidikan simulasi membandingkan ketersediaan mesin dengan penjadualan pencegahan pencegahan yang berbeza. Jumlah ketersediaan sistem dikira menggunakkan semua mesin SMT kerana SMT merupakan pengeluaran aliran berterusan. Penemuan projek ini menunjukkan bahawa pengoptimuman penyelenggaraan pencegahan perlu dilakukan setiap satu minggu dengan tempoh 30 minit PM.

ABSTRACT

In the past several decades, there have been diverse and significant research activities on maintenance scheduling. Machines are usually down periods due to plenty of reasons such as preventive maintenance activities. Preventive maintenance is defined as regularly scheduled maintenance actions based on the average failure rates. An optimize implemented preventive maintenance strategy can provide many benefits to an organization in terms of extending equipment life and machine availability. Few researches have addressed the issues of preventive maintenance. For instances, proper preventive maintenance scheduling can maximize the machine lifecycle and production throughputs.

In this thesis, the objective is to study the machine availability that affected by the preventive maintenance scheduling. The model was developed based on the Surface Mounted Technology (SMT) in manufacturing system. The SMT line is a continuous flow production line since every machine are connected in line. In this research, the model that has been build consists of five different machine which is screen printer, glue dispenser, chip shooter, pick and place and reflow oven. WITNESS 14 Manufacturing Performance Edition software was used to imitate the Surface Mounted Technology (SMT) production system. This is to carry out the optimisation of preventive maintenance scheduling by using different breakdown intervals and preventive maintenance duration.

Results of simulation study comparing the availability of machine with different preventive maintenance scheduling. The total system availability was calculated since the SMT line is continuous flow production. The findings of this project shown that the optimise preventive maintenance should be done every one week with 30 minutes PM duration.

CHAPTER 1

INTRODUCTION

Maintenance system is very useful in industry field. It helps a company to plan and schedule, material control and some preventive maintenances to get a good performance of the production line. Maintenance recover and improves equipment performance, and is an important part of a product life cycle [1]. From the information that get from the computer system, maintenance workers can do their own works effectively. For instance, worker can prepare the spare parts that needed in the maintenance time. Thus, they can save a lot of time when doing the maintenance.

Maintenance system help the company to meet plants-specific needs and more importantly is to meet production goals. In the same time, maintenance system also improve the equipment performance by reducing equipment and facility downtime. With the maintenance system, maintenance team will be work smarter through the powerful tools to standardize processes in an organization. The common use of mechanization and automation has reduced the number of production staff and has increased the capital employed in production equipment [2]. In addition, maintenance program will compile, list and analyse data of the company. For example, there will be a signal to the maintenance team when somethings happened. A design process is a very crucial to ensure proper and cost-effective maintenance system.

Meanwhile, simulation modelling is an important method of analysis, which is easily verified, communicated and understood. Computer simulation is used in industry to conducting the experiments on real system is impossible or impractical. Many costs and times can be save through computer simulation. This is because simulation is less expensive than building and testing hardware prototypes. According to simulation output, production process can be verify by conducting the additional experiment [3]. Simulation can be used to forecast the future behaviour of a system and investigate what you can do influence that future behaviour. Therefore, we can identify necessary changes to improve our system that we needed via simulation software.

There are some benefits of using simulation software such as risk-free environment, save money and time, visualization, insight into dynamics, increased accuracy and handle uncertainty. In real industry, we can reduce the risk of machine breakdown based on the simulation analysis. Therefore, we can solve the problem in the shorten time and provide some preventive maintenances. To supporting the production planning, suitable simulation tool development is needed to help the company achieve profit.

For this Final Year Project(FYP), a simulation software named WITNESS is used for analysis. Witness is a simulation tool for dynamic process simulation of manufacturing and business process in 2D or 3D models. Program witness helps decreasing the risk with enabling model the work environment and simulate consequences of different decisions. It can propose the right solution for a company with displaying in virtual reality environment and information change with present of witness simulation tool. Witness software Manufacturing Edition can help people by predicting and solving problems related to production bottlenecks, overly idle resources [4]. The major disadvantage of simulators is that they are not as flexible as simulation languages, since they do not allow full-blown programming as in simulation languages [5]. The use of simulation to check out and validate process automation systems, perform software acceptance tests and train operators provides numerous benefits to companies in the process industries.

1.1 Project Background

Manufacturing companies strive to attain manufacturing efficiency by removing process bottlenecks, improving productivity through job redesign, training, and other interventions. Minimising equipment downtime in manufacturing operations provides a range of benefits leading to maximised efficiency and higher profits. Machine stoppages and downtime is a major factor that hinders the attainment of manufacturing efficiency. It leads to hold-up of the manufacturing effect that disrupts the workflow. The cost for the machine downtime is very huge. This is because cost of labor rendered idle by unavailability of the machinery. Thus, company need to pay overtime for maintenance personnel. Company will delayed the shipments because of machine breakdown, hence the surcharges will be applied for the lateness.

It is crucial to have access to accurate and timely data to be able understand the extent of downtime and its roots causes. There are two types of downtime: planned downtime and unplanned downtime. Planned downtime is one thing but unplanned disruptions in the production can end up costing significant time and money. Company need to implement a regular maintenance schedule to prevent the machine stoppages and breakdown. In busy factories, regular maintenance will be easily neglected due to the high production. To prevent this, preventive maintenance scheduling must be a practise to personnel in the company. If company want a courier that has 24/7 availability, minimize downtime as much as possible is necessary.

Availability is a metric that combine the concepts of reliability and maintainability. Simulation method is used to estimate a system availability and associated measures. These include the number of failures and number of expected maintenance needed. A simulation model of the system could be developed that emulates the random failures and repair times of the components in the system, thus we can know what the suitable time for maintenance is. Simulation is the "imitation of the real world process or system overtime" which is sufficient enough demonstrate and illustrate the real industry using software with certain adequately accuracy [6].

To show to management the effects these proposed changes will have on system as whole, a simulation model need to be build using witness software. From the simulation, we are able to construct the maintenance schedule for the maintenance team to do their jobs in the right time. There are many simulation software available in the market now like SIMUL8 basic and Arena other than Witness. Witness can models real processes can be emulated already within the planning phase and used for experiments. Witness have some special features like modular structure and building block design and 3D visualisation.

1.2 Problem Statement

Downtime will ruin the throughput in production line. If machine or people are idle, then the products are not being made, this will certainly affects the business's bottom line. Therefore, minimizing manufacturing downtime makes money for a company. Profitability is the concern of a company, thus providing a regular equipment maintenance will reduce the probability of machine breakdown happen. Hence, simulation is needed to illustrate the condition to schedule the maintenance system based on the results of simulation.

1.3 Objective

1) To study the use of maintenance scheduling in reducing machine stoppage and downtime by using simulation.
2) To study the effectiveness by using simulation to generate the maintenance system
3) To know the optimize time and PM duration for doing the maintenance

1.4 Scope of Work

Machine breakdown and stoppage always happened in the industry if the maintenance scheduling did not arrange properly. Machine breakdown are always costly. For most manufacturers down time is the single largest source of lost production time. Focusing improvements effort on the constraint ensures optimal use of the resources and is the most direct route to improved productivity and profitability. Therefore, a manufacturer need good maintenance systems to prevent the machine breakdown and stoppage. Besides, there are many types of maintenance technique used in the industry. For this project, the scope of work focus on Preventive Maintenance(PM) scheduling as PM is the most common and basic maintenance technique. Through Witness simulation, we can generate out the best maintenance scheduling based on the results that get from the simulation. In this project, there are few options that used in the simulation which is 1 month 2 days PM, 2 weeks 1 day PM, 10 days half day PM, 1 week 30 minutes PM, twice a week 30 minutes PM and 1 day 15 minutes PM.

CHAPTER 2

LITERATURE REVIEW

To establish an e-intelligence maintenance system is crucial for manufacturing enterprise to reduce costs and increase profits in the global market. Some researchers have done some researches in conventional analytical modelling or maintenance optimization model to get a good maintenance schedule. Based on the content analyses of the reviewed articles, some relevant issues (themes) related to maintenance performance measures, measurement, and management emerged.

Maintenance program should be designed to reduce both maintenance and inventory related costs [7]. A simulation model is developed for the system operating with block replacement. A cost optimal solution is not guaranteed in terms of system downtime and work in process inventory.

In addition, maintenance plan need to make well in the prevention of losses due to breakdown within an enterprise [8]. To ensure the production run smoothly, a necessary maintenance schedule must be carried out. Implementation of maintenance management and lean techniques is to eliminate the losses due to breakdown and enhance productivity of an enterprise. Delay and halts production due to breakdowns during production only can be prevented by using the maintenance system that has planned. Maintenance costs has very big impact in total operating costs of enterprise. In order to reducing the costs of maintenance, good planning and scheduling is needed based on the simulation. As result of this study, researcher want to provide a good solution for prevent the production breakdown and most importantly is to reduce the operation costs.

Since the production line must run smoothly without breakdown, proper maintenance is essential for today’s production systems [9]. Inadequate maintenance will cause breakdown times, therefore the task of supplying spare parts must be on the right place at the right time. The performance improvements of integration of intelligent maintenance systems and supply chain can be evaluate by using the simulation model. Simulation results help the company reduce the cost by displayed a significant transportation and storage cost. There are two managerial research that is tactical planning and coordination methods to the spare parts supply and optimization of the planning and scheduling on the operation level. Simulation of integration concept is one of the way to improve the effectiveness and efficiency of maintenance services and activities.

Simulation application is a fundamental for enhancing production systems and reduction of bottleneck occurrences [10]. When doing the computer simulation during the production scheduling, there are variety of possibilities. We can verify the production process and conduct the simulation experiment according to the simulation output. When we change the simulation inputs, the simulation of outputs will be change automatically. Therefore, we can compared the original outputs of production plans easily. The efficient production means the machine must be fully utilised and prevent the idle time if possible in the production line. The utilization of simulation in supporting the planning has very big impact in maintenance scheduling. This is to optimize the production and identify the bottlenecks that can make impact on delaying to the customer. Therefore, the production planner can make some changes based on the simulation results. In addition, production planner will provide a good scheduling for production line because they know when the maintenance is needed.

Impact of preventive maintenance on the service level of degrading manufacturing systems will affected the completion time and delivery dates of customer orders [11]. Multi-stage manufacturing system made up of different machines, material handling and some other equipment. Therefore, effective maintenance planning is one of the method to achieve high productivity and breakdown prevention. Engineering tools should be used to support the complex manufacturing system to optimize the production in manufacturing company. Some considerations is needed when we want to plan our preventive maintenance such as productivity, customer demands and so on. Hence, preventive maintenance can help reduce the unplanned breakdown thus increasing the production level.

To keep the system in good condition and increase machine availability, maintenance management is an important policy in repairable system [12]. There are two famous type of maintenance system that is preventive maintenance (PM) and corrective maintenance (CM). These two methods is used to obtain the greatest availability. Apply periodic preventive maintenance to machine will minimize the cost rate and maximize the mean time between failures. The machine can run longer without breakdown or failure if periodic preventive maintenance was optimise. Optimal time to service the machine will increase the availability and reliability of machine. Therefore, the optimization time for preventive maintenance must be properly planned and scheduled. This is due to too much PM will also reduce the productivity of machine.

Preventive maintenance can help to maintain the production system in top operating conditions in order to minimize operating costs [13]. Failed preventive maintenance planning will have same failure before preventive maintenance that is called imperfect preventive maintenance. In this case, most probably the machine will need to undergo major repair if imperfect preventive maintenance planning has done. Hence, maintenance process requires excellent planning and scheduling on damaged productions systems. The preventive maintenance planning need to be discuss among team to get a good suggestion. The preventive maintenance can be modelling by some useful production software to get an optimum preventive maintenance time.

Moreover, introduction of failure possibility decreased the production lot size for a specific preventive maintenance age [14]. Maintenance optimization is one of the way to help the production planner achieve a better maintenance management. Reductions in quality costs can be done by performing the preventive maintenance. Therefore, the defects of product will eventually decreased. Preventive maintenance costs will increase the costs of the company if the frequency of schedule of preventive maintenance increased. The availability of the machine will decrease since most of the time is under maintenance. The inventory stock will more and more due to the machine idle.

Efficient operation of machine can be achieved from an optimal preventive maintenance strategy. There are many benefits for having an optimal preventive maintenance strategy. Optimal preventive maintenance is used to increase the availability of machine and reduced the production downtime. There are few optimal preventive maintenance schedule such as daily, once a week, once a month and once a year [15]. Traditional preventive maintenance was based on the concept of bathtub curve (Figure 2.1). The bathtub curve consists of three periods: an infant mortality period with a decreasing failure rate followed by a normal life period with a low, relatively constant failure rate and concluding with a wear-out period that exhibits an increasing failure rate. Therefore, PM must be schedule for the high failure rate. Further discussion on PM schedules and suggested methodology for this research will be provided in the next chapter.

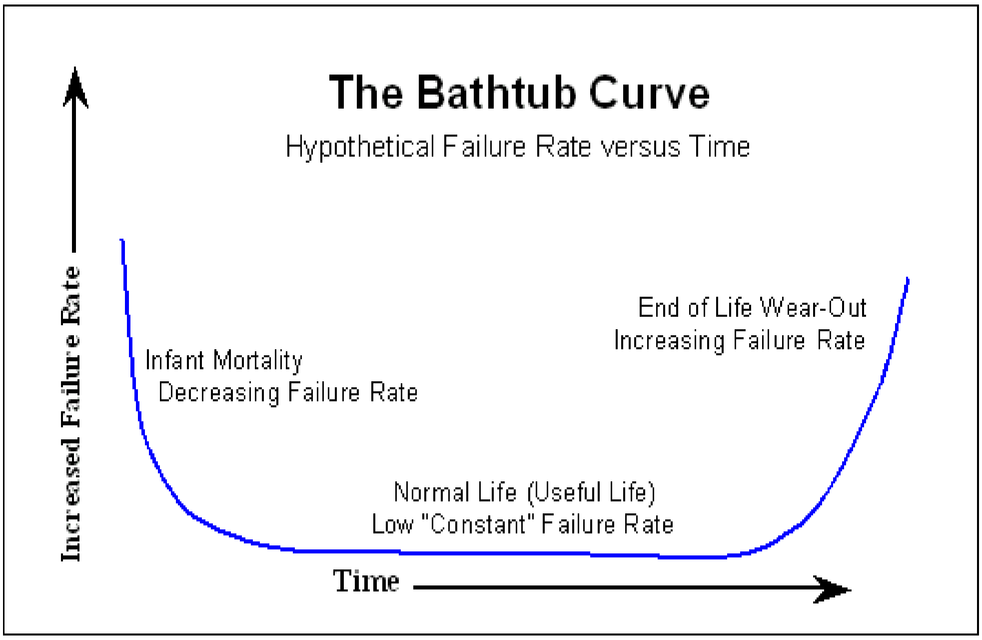


Figure 2.1 Bathtub curve

CHAPTER 3

METHODOLOGY

In majority of maintenance scheduling studies, the machines are assumed to be continuously available. However, the resources are subject to down periods because of plenty of planned resources such as preventive maintenance. In order to achieve the research objectives, a process flow has been done to make a model for the simulation. Hence, the research methodology can be drawned as shown in Figure 3.1.

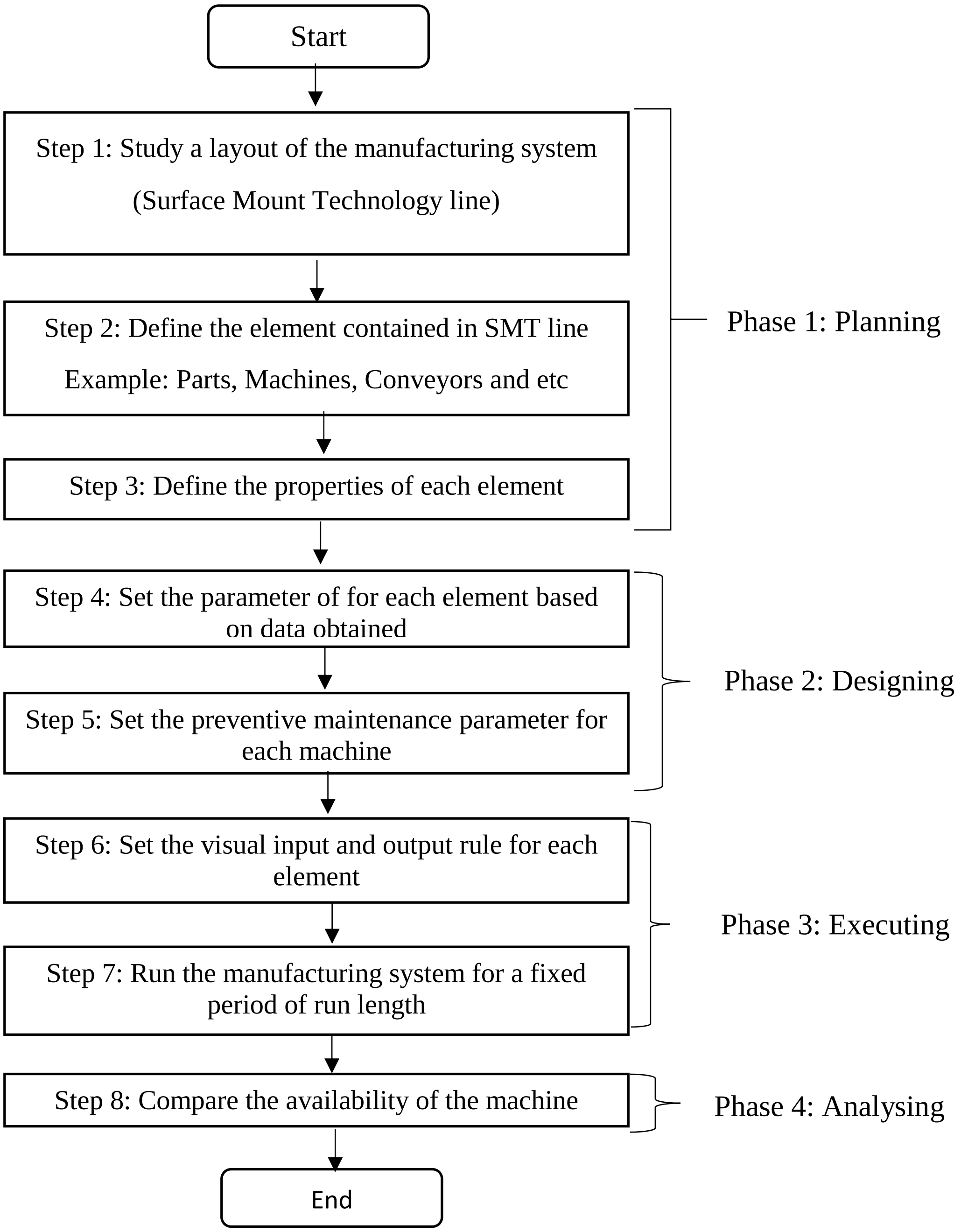


Figure 3.1 Flow Chart

Simulation has been widely used to study the availability and effectiveness of maintenance management systems. Interaction between maintenance policies and manufacturing systems have been considered in their researches. The software package used to simulate the model was Witness Simulation Educational Version Release 14 (Build 2124) by Lanner group. The benefits of using Witness software enables users to develop feature of model rapidly, analyse business environments to deliver improved process performance, optimized use of resources and conduct comprehensive experimentation, optimization & reporting framework.

3.1 Phase 1: Planning

3.1.1 Step 1: Study a layout of the manufacturing system (SMT line)

Surface Mount Technology (SMT) is an assembly process about complex circuitry fitting in small spaces. SMT is used to mount electronic components on the surface of printed circuit boards [16]. Components need to be directly mounted onto the printed circuit board rather than wired. Surface Mount Devices (SMDs) are devices that use surface mount technology.

In SMT line, there are five different machines that are connected to each other by conveyors. Since the process of SMT is continuous process, whole production line will stop when one of the machine breakdown. This will cause the other machines goes into idle state. Therefore, the availability of machine will be affected.

The simulation of model is referring to the Surface Mount Technology (SMT) line which located in Business Unit Innovation Centre, School of Mechanical Engineering, Universiti Sains Malaysia. Figure 3.2 and Figure 3.3 showed the processes in SMT line and layout of model in witness software.

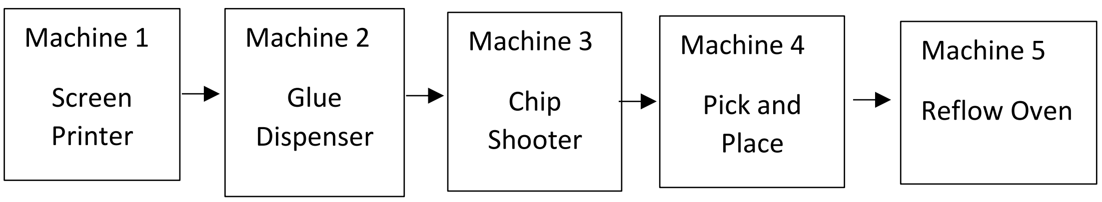


Figure 3.2 Processes in SMT line

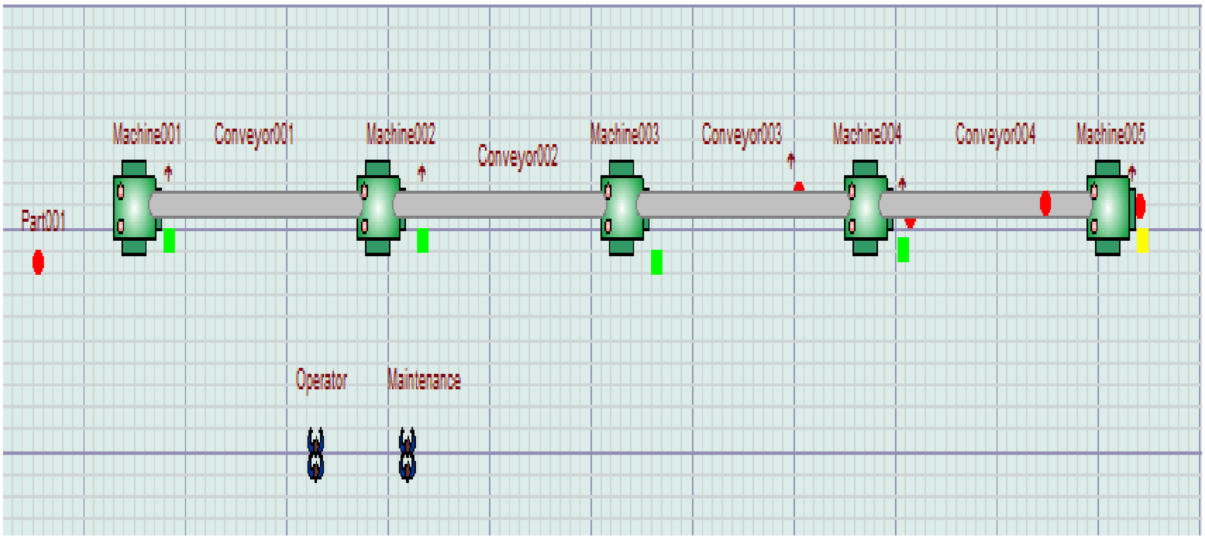


Figure 3.3 Layout of model in witness Software

Process Description of each machine

Machine 1: DEK 265 GSX Solder Paste Screen Printer

The PCB has entered the first machine as shown in Figure 3.4, which was solder paste Screen Printer. The aim of this process is to deposit the correct amount onto each of the pads to be soldered. The most common method of applying solder paste to a PCB using a stencil printer is squeegee blade printing. To print the perfect component placement, alignment of solder paste, amount of solder paste and replacement of squeegee must be considered carefully [17]. This is because solder paste printing process is a very critical step in the surface mount manufacturing process. Figure 3.4 shown the machine DEK 265 GSX Solder Paste Screen Printer.

Figure 3.4 DEK 265 GSX Solder Paste Screen Printer

Machine 2: Fuji GL V-5000 Glue Dispenser

The PCB moved into the second machine which is Fuji GL V-5000 Glue Dispenser after the conveyor belt. During an adhesive process, deposition of glue onto PCB solder mask in a appropriate position without losing any feeder capacity or placement performance. The dispensing system must transfer uniform and precise adhesive height and dot shape at different volumes onto the PCB in order to make perfect adhesive dots [18]. Figure 3.5 shown the machine Fuji GL V-5000 Glue Dispenser.

Figure 3.5 Fuji GL V-5000 Glue Dispenser

Machine 3: Fuji CP-65 Chip Shooter

Machine 3 was a chip shooter machine. This machine consists of three primary mechanisms that are turret head, moving table and feeder carriage. Time required to mount all the components on a PCB was affected by placement sequence of the components and arrangement of the feeders in the carriage [19]. Therefore, the placement sequence of components determined by longest movement time. Figure 3.6 shown the machine Fuji CP-65 Chip Shooter.

Figure 3.6 Fuji CP-65 Chip Shooter

Machine 4: Fuji QP-341 E-MM Pick and Place Machine

Function of Pick and place machine was similar to chip shooter machine. Pick and Place machine pick components consistently and holding the components during transport from feeder to PCB [20]. There were more than one pick and place machine in one SMT line. This is because the cycle time of machine can be reduce if all components put in separate machine. Figure 3.7 shown the machine Fuji QP-341 E-MM Pick and Place Machine.

Figure 3.7 Fuji QP-341 E-MM Pick and Place Machine

Machine 5: BTU-Paragon 150 Reflow Oven

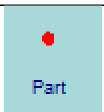
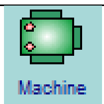
Last process in SMT was reflow oven. The function of reflow oven was heat the solder paste until liquidus (reflowed), then cooled until the solder hardens and creates permanent interconnection between the component leads and the PCB [21]. There were many zones in reflow oven, which was different temperature in all zones. Figure 3.8 shown the machine BTU-Paragon 150 Reflow Oven.

Figure 3.8 BTU-Paragon 150 Reflow Oven

3.1.2 Step 2: Define element contained in SMT line

There were three main components in SMT line that was machines, conveyors and parts. There were four elements shown in Table 3.1.Table 3.1 shown the type of elements used in the simulation.

Table 3.1 Type of elements

Designer Element	Characteristics
	Part represented the product produced that was Printed Circuit Board (PCB).
	In this research, there were total five machine used in SMT line that was DEK 265 GSX Solder Paste Screen Printer, Fuji GL V-5000 Glue Dispenser, Fuji CP-65 Chip Shooter, Fuji QP-341 E-MM Pick and Place Machine and BTU-Paragon 150 Reflow Oven.
	There were two types of labour, which were operator and maintenance team. Operator was in charge the minor issues such as feeder problem. Maintenance team were the person who in charge when performing preventive Maintenance (PM).
	Conveyors were used to connect all the machines together in SMT line. This was to transfer the part between each machine and made the process continuous.

3.1.3 Step 3: Define the properties of each element

In real manufacturing system, the properties of element depend on the field of manufacturing. For SMT production line, there was a straight line connect all the machines together made the process continuous flow. Most of the machine is single type machine since only one input move in and one output come out. The machine only can process one part once. Reflow oven contains multiple zones, which can be individually controlled for temperature. Therefore, when first PCB reaching the second zones of reflow oven, next PCB can enter the first zones. Hence, multiple station machine properties is used in the simulation. Table 3.2 shown the properties an dtype of each element.

Table 3.2 Properties and type of each element

Element	Properties	Description
Printed Circuit Board	Passive Type	The part was pulled from the first machine according to customer demand. Screen printer will pull NEXT batch of PCB if one batch of order has shipped.
Screen Printer Glue Dispenser Chip Shooter Pick and Place	Single type machine	PCB must come out first before the next PCB moved in to the machine
Reflow Oven	Multiple station machine	Multiple units inside the machine were possible since there have different temperature zones in reflow oven. Another PCB can enter before next unit come out.
Nutek Linking Conveyor	Type: Continuous Queuing Length:1m Speed:14m/min Maximum Capacity:4	The conveyor used was a continuous queuing type which can transfer the PCB continuously.

3.2 Designing

3.2.1 Step 4: Set the parameter of for each element based on data obtained

Data was the most important parameter that needed to ensure the simulation is running correctly. Some data was obtained from the previous studied and researched about the SMT line.

From the research, there have three categories of data shown in Table 3.3.

Table 3.3 Categories of Data Availability and Collectability.

Category	Data Type
Category 1	Available
Category 2	Not Available but collectable
Category 3	Not available and not collectable

There was no continuous data can be collected since the SMT line in Mechanical School USM was not yet running and still under research. There are two main ways of dealing with category C data. The first is to estimate the data and the second is to treat the data as an experimental factor rather than a fixed parameter. Therefore, first method was considered that is estimate the data. The data may be estimated from various sources such as journal, article and some internet information.

Secondary Data

In addition, manufacturing system in SMT line is very common nowadays. The process almost similar among all the SMT lines. From here, the data collection from analogous manufacturing company called secondary data can be used for the simulation. In this study, secondary data was available and can be a reference.

Subject Matter Expert

Since surface mount technology was widely used in manufacturing system. Therefore, there was also an effective way of obtaining the data from internet that shared by expert.

Machine Manual

Another way of obtaining data was from the machine manual provided by machine. The cycle time for Screen Printer, Glue Dispenser, Chip shooter, Pick and Place and Reflow Oven machine were obtained from the standard cycle time stated in machine manual.

Process Parameter

The cycle time data was obtained from many sources such as machine manual and analogous manufacturing company. Table 3.4 shown the process parameter for each machine.

Table 3.4 Process Parameter for each Machine

Machine	Cycle time (min)
Screen Printer	0.25
Glue Dispenser	0.25
Chip Shooter	0.24
Pick and Place	0.23
Reflow Oven	1.61

3.2.2 Step 5: Set the preventive maintenance parameter for each machine

There were many maintenance strategies in manufacturing system such as preventive maintenance, predictive maintenance, corrective maintenance and reliability-centred maintenance (RCM). In this research, preventive maintenance was focused. Preventive maintenance involves periodically taking assets offline and repairing machine at predetermined intervals. It was used for reducing unexpected failure of critical equipment and to promote better safety, health and working environment conditions for the workforce.

Timing of preventive maintenance (PM) should be optimized to reduce risks of failure or after PM. The machine availability depend on the frequency of breakdown and duration for done the preventive maintenance. Therefore, preventive maintenance scheduling was an important decision need made by maintenance team or engineer. Figure 3.9 shown the simulation model of maintenance strategies.

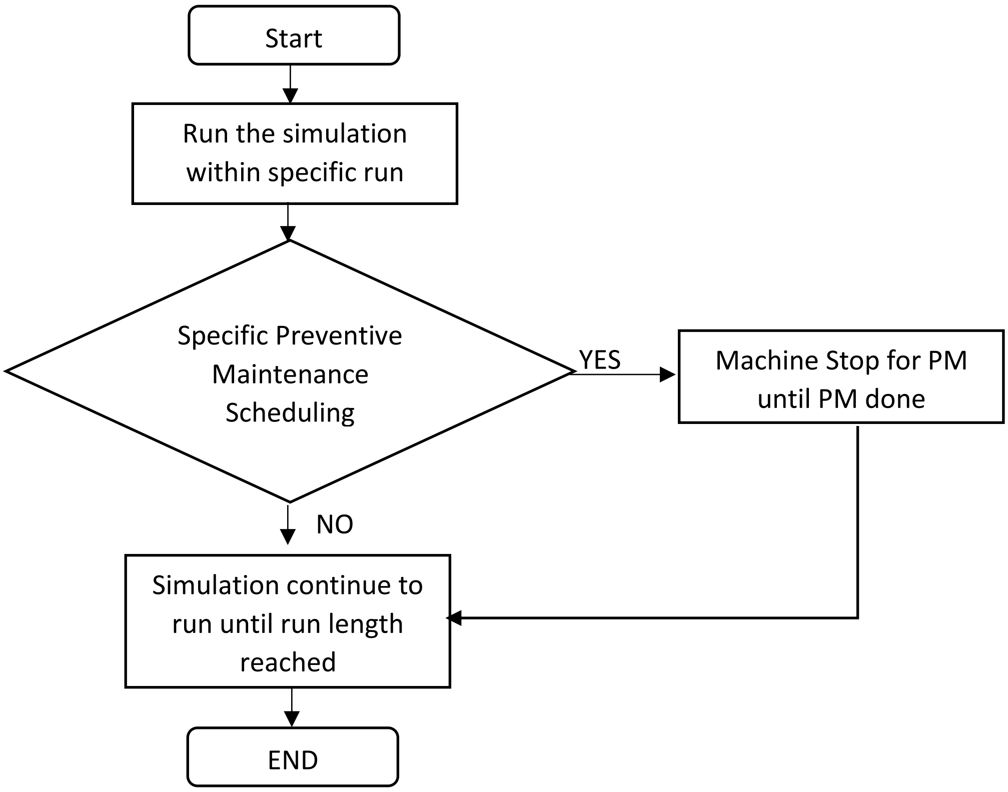


Figure 3.9 Simulation model of maintenance strategies

Breakdown Interval

Maintenance includes all activities that need to maintain the system in good condition. The Mean Time Between Failure (MTBF) estimate is necessary for designing a planned scheme for maintenance and support of systems in the manufacturing environment. MTBF can be useful in determining the frequency of preventive replacements. Mean time to repair (MTTR) is the average time required to troubleshoot and repair broken equipment and return it to normal operating condition. The understanding of terms used in the maintenance should be very clear in order to run the simulation accurately. Figure 3.10 shown the diagram of MTBF, MTTR,MTTF.

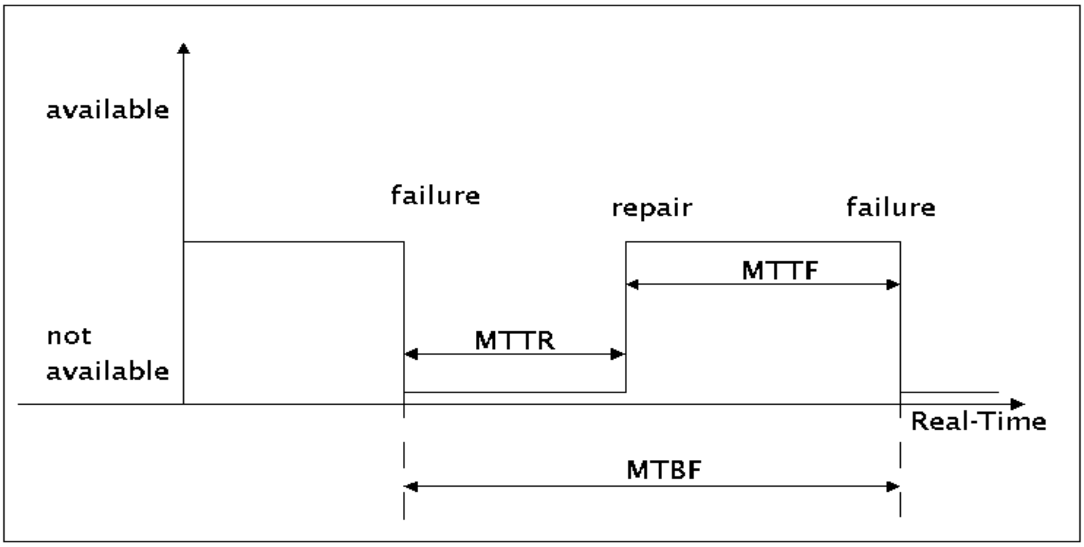


Figure 3.10 MTBF, MTTR, MTTF [22]

According to the traditional model machines encounter the most failures when they are new and when they are close to the end of their lifecycle [23]. Every machine has different lifecycles and different maintenance needs. Thus, preventive maintenance need to consider specifications of machine. For example, expected life cycle is one year, then preventive maintenance need to carry out before the lifecycle. On the other hand, the machine could be broken down. Figure 3.11 shown the bathtub curve.

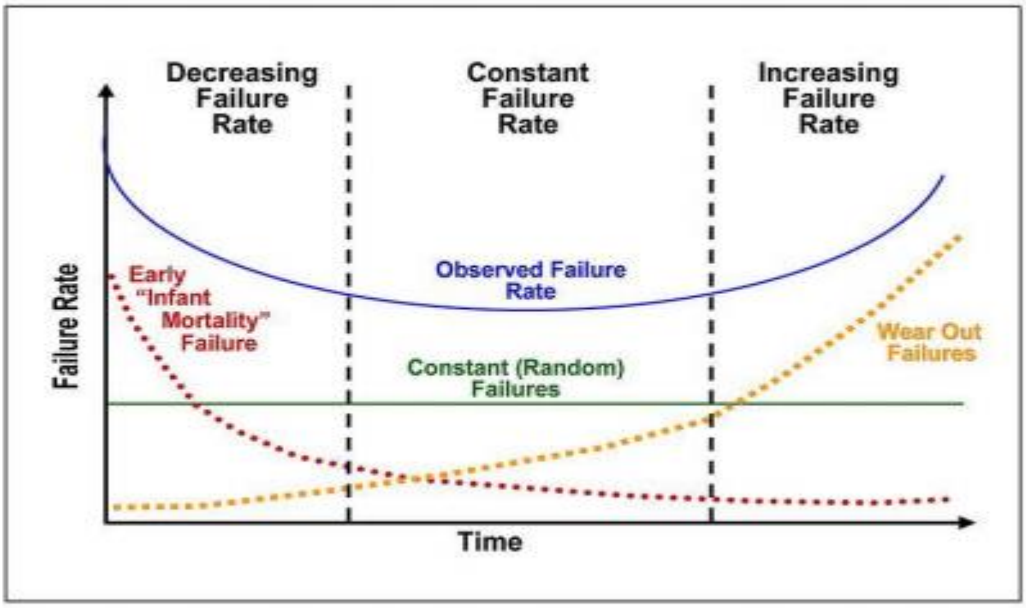


Figure 3.11 Bathtub curve

In witness simulation, MTBF and MTTR were used to set the maintenance parameter that represented the time between machine failure and repair time. Due to unavailable data, the breakdown time was estimated based on the journal paper [15]. For example, long breakdown needed for the machine that run for very long duration. When the machine run for a long time, the PM time will be higher since the tool wear is higher. Therefore, optimisation should be done to get the suitable PM time.

Table 3.5 summarised the breakdown interval and PM duration for every machine.

Table 3.5 Breakdown Interval and PM duration

Breakdown Interval (min)	PM duration (min)
1 month (43200)	2 days (2880)
2 weeks (20160)	1 day (1440)
10 days (14400)	Half day (720)
1 week (10080)	(30)
Twice a week (5040)	(30)
1 day (1440)	(15)

Availability

Availability deals with the duration of up-time for operations and is a measure of how often the system is alive and well. Hence, the run length in simulation was set as three months (129600 minutes). Since the SMT line production was continuous between 5 machines, availability of machine need to calculate the overall availability of machine.

Overall Availability= (Availability machine 1) x (Availability machine 2) x (Availability machine 3) x (Availability machine 4) x (Availability machine 5)

The purpose of this research is to reduce machine stoppage and downtime. Thus, the results was based on the machine downtime and machine availability. In theory, the availability of machine will decrease with the increase of machine stoppage.

3.3 Executing

3.3.1 Step 6: Set the visual input and output rule for each element

In simulation, all elements are connected by using the visual input and output rule due the continuous SMT line. The command for visual input rule was "PULL FROM" and the output rule was "PUSH TO". Another easier way was pressed the icon (Input rule) or  (output rule) to set the motion. For instances, Figure 3.12 shown the part was pull by the machine001 then machine001 push the part to conveyor001. The details of overall process also displayed in Figure 3.13.

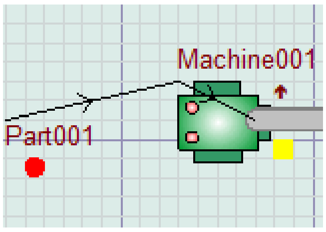


Figure 3.12 Example of visual input and output rule setting

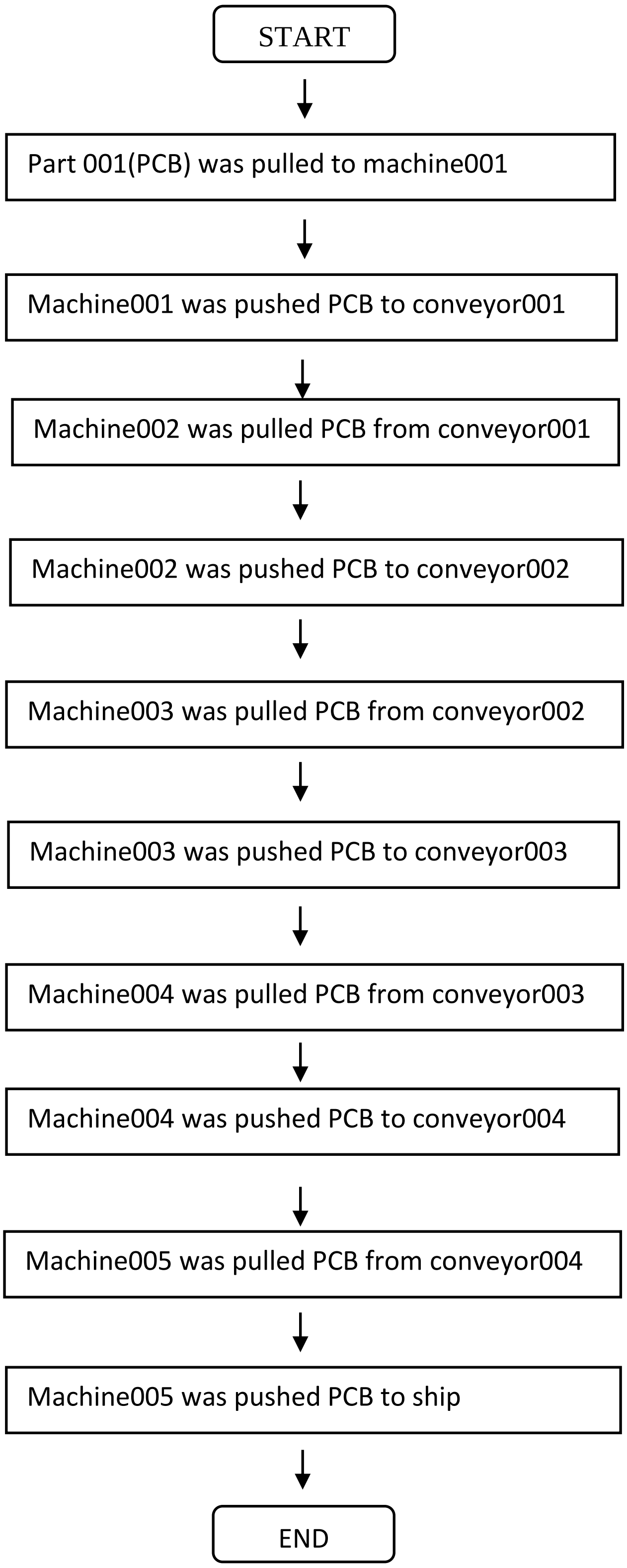


Figure 3.13 Visual input and output rule of overall process of SMT line

3.3.2 Step 7: Run the manufacturing system for a fixed period of run length

The run length of the simulation was set as three months (129600 minutes). Units in the simulation must double confirmed to prevent the incorrect results. The units that used in the simulation was shown in the Table 3.6.

Table 3.6 Units used in simulation

Measurements	Unit
Time	Minutes (min)
Length	Meter (m)
Speed	Meter per minutes (m/min)

3.4 Phase 4: Analysing

3.4.1 Step 8: Compare the availability of the machine

The results of machine availability can obtained from the simulation performance straight away. For whole SMT line, some calculations need to be done to get the results of SMT line availability. Comparison between same machine for different breakdown interval and PM duration must be analyse. For example, availability for machine001 in breakdown time 1440 minutes and 5040 minutes. After finished analysed the results, decisions should be made according to the results displayed in graph. The results of this FYP will be presented and discussed in Chapter 4.