A STUDY OF PRODUCTION LINE OPERATION IN ELECTRONIC MANUFACTURING INDUSTRY

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UNIVERSITY MALAYSIA PAHANG

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Report submitted in partial fulfillment of the requirements for the award of the Bachelor of Industrial Technology Management with Honors

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion this report is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Industrial Technology Management with Honor.

Signature :
Name of Supervisor :
Position :
Date :

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for the quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

Name :

ID Number :

Date :

DEDICATION

This thesis is dedicated to my mother, sister and friends who support me all the way during my study.

I would like to dedicate this thesis to my supervisor, Professor Razman bin Mat Tahar who give me a lots of advice and suggestion throughout my study.

Finally, I want to dedicate this study to PINHOE Technology Sdn. Bhd. as well.

ACKNOWLEDGEMENTS

I am thankful and would like to express my sincere gratitude to my supervisor, Professor Razman bin Mat Tahar in providing his germinal ideas, invaluable guidance, continuous encouragement and constant support in succeeding this study. Professor Razman has always impressed me with his professional in which relates to this study and his belief that a Bachelor Degree program is only a start of a life-long learning experience. I appreciate his advices during the time of my study. He advices me that this study's purpose is not only to fulfill the final year project but also for the future use which may relate to my career.

My sincere thanks also go to my seniors whose share their knowledge with me in developing simulation model, writing and conducting my study. In addition, I acknowledge my sincere indebtedness and gratitude to my mother, sister and lover for the love, dream and sacrifice throughout my life. It is hard to express out all my appreciation for their devotion, faith and support in my ability to succeed my goals. There are many obstacles I faced during this study, but I manage to keep this in until I manage to finish the study. This is because of the advices given by them.

ABSTRACT

In this study, it discusses about evaluating and improving production system in electronic manufacturing industry by using simulation method. The scope of this study is focusing on the operation system of Functional Test jigs production line. The time frame covered is one year it is in the year of 2014. This study is conducted by using ARENA simulation software to simulate and model the production line. It is a quantitative study in which the performance is measured by the value added time, waiting time and productivity for the entire system of the Functional Test jigs production line. Results generated from the simulation show that adding a new holes drilling/milling workstation would produce significant effect in reducing overall value added times and wait times and improving productivity.

Keywords: Electronic Manufacturing Industry, Simulation, Production Line, ARENA, Value Added Time, Waiting Time, Productivity

ABSTRAK

Kajian ini membincangkan tentang menilai dan memperbaiki sistem pengeluaran dalam industri pembuatan elektronik dengan menggunakan kaedah simulasi. Skop kajian ini memberi tumpuan pada sistem operasi untuk barisan pengeluaran kepada Ujian Fungsi jig. Tempoh masa yang diliputi adalah satu tahun iaitu pada tahun 2014. Kajian ini menggunakan perisian simulasi ARENA untuk menjalankan proses simulasi dan model barisan pengeluaran. Kajian ini merupakan kajian kuantitatif di mana prestasi adalah diukur oleh masa menambah nilai, masa menunggu, dan produktiviti bagi seluruh sistem untuk barisan pengeluaran kepada Ujian Fungsi jig. Keputusan yang dijana daripada simulasi menunjukkan menambah stesen menggerudi/mengilang lubang yang baru akan menghasilkan kesan yang ketara dalam mengurangkan keseluruhan masa menambah nilai dan masa menunggu dan meningkatkan produktiviti.

Kata Kunci: Industri Pembuatan Elektronik, Simulasi, Barisan Pengeluran, ARENA, Masa Menambah Nilai, Masa Menunggu, Produktiviti

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Current high technology manufacturing systems can be very complex such as those in the electronics, semiconductor, aerospace, and automotive industries. Simulation is one of the most generally used tools for the design and analysis of complex systems. There are several types of simulation. Simulation can be classified to static simulation model, dynamic simulation model, deterministic simulation model, stochastic simulation model, discrete simulation model, and continuous simulation model (Rossetti, 2010).

Among the simulation models stated above, the discrete-event simulation model is used in this study. Discrete-event simulation is one of the most commonly used methods for analyzing and understanding the dynamics characteristics of a complex manufacturing system (Negahban and Smith, 2014). In this study, the operation processes in electronic manufacturing industry will be simulated and performance of the current operation system will be evaluated. After that, proposed a best solution to improve the efficiency of the operation system by using simulation approach.

1.2 BACKGROUND OF STUDY

Production line refers to an organized arrangement in a plant in which a product being manufactured is passed through a set of operations. Nowadays, most of modern production lines operate with the combination of people and machine which known as semi-automated processes line. Each workstation in the production line consists of one or more machines, one or more operations, and a work-in-process buffer. Efficiency of a production line is crucial for an industry as it results in an improved production performance and effective utilization of available resources. This study is proposed to evaluate the behavior of current operation processes and to improve the efficiency of operation in the production line.

According to "Market Watch 2012", electronic manufacturing industry is the leading sector in Malaysia, contributing significantly to the country's manufacturing output (31%), exports (48.7%) and employment (33.7%). Transistor by transistor, the electronic industry is exactly change the world. In this study, PINHOE Technology Sdn. Bhd., a Penang electronic manufacturing plant is chosen as the study target because electronic is dominates almost any sector of the world by now. The market demands and increasingly competition condition have forced electronic manufacturing industries to improve the efficiency of the production process to increase productivity and reduce unwanted waste of production times and resources.

Effective evaluation of the actual world conditions is too complex, so alternative way should be used to evaluate the performance of such systems. Tüysüz and Kahraman (2009) proposed a simulation-based approach to model and to evaluate time critical, dynamic and complex system. Simulation is used before an existing system is changed or a new system condition built, to reduce the probability of specifications failures, to reduce bottlenecks in process, to avoid under or over-utilization of available resources and to improve system performance (Maria, 1997). System analyst may try out different production runs, new operational conditions, new equipment layouts, or different cycle times to observe the behavior of the system being modeled.

In today world, the most common test or inspection strategy is Manual Visual Inspection (MVI), In-Circuit Test (ICT) and Functional Test (FT). PINHOE Technology is a company that fabricates the ICT jigs and Functional Test jigs. In this study, production line of the Functional Test jigs is taken as the study target. PINHOE Technology manufactures the Functional Test jigs and delivers to the customers such as Sony, Yamaha, Sharp, Roxy and Panasonic.

Through observations and information given by Mr. Ng, director of the PINHOE Technology, production line of the Functional Test jigs separated to two different operation routes which are Printed Circuit Board (PCB) and Acrylite Board operation routes. PCB operation route consists of components/pins inserting, soldering and wiring workstations, whereas Acrylite Board operation route including squaring, holes drilling/milling and numbering workstations. There is two core machines work in operation processes which are squaring and drilling/milling machines. Design or layout of the machines, operators and equipment in production line can influence the productivity, work-in-process time, and efficiency of the whole manufacturing process. To remain competitive, a company must design manufacturing system that not only manufacture high quality products at low cost, but also allow for rapid reaction to customer requirements and market changes.

PINHOE Technology is a make-to-order manufacturing company. Customers will send the orders in Gerber file, which is a standard electronics industry file format used to transfer design information to produce for numerous types of PCB. With the make-to-order policy, manufacturing is based on the customer orders and each order can be different and unique. The manufacturing system design is vitally important and has to be flexible to react to changing production capacity requirements. Therefore, this study is proposed to measure the performance of current operation system and to improve the productivity and efficiency of the operation processes in production line.

1.3 STATEMENT OF THE PROBLEM

Through the information received, PINHOE Technology sometimes will received complaints from their customers due to late delivery or longer order lead time. For the manufacturing, lead time refers to a time span required to produce a product, including order preparation time, queue time, processing time, move time, inspection time, and put- away time. In business world, lead time minimization is preferred. Late delivery of products can result in bad customer experience and lost sales. Therefore, this study suggested using the simulation method to improve the efficiency of operation processes in production line to reduce the order lead time. Simulation modeling can let us take a look and provides insight at each part of the production line layout and performance measures of the operation processes. Moreover, we can realize the cause of delays in work processes, components, information or other processes by doing analysis from the outcomes reported by simulation software.

In addition, some manufacturing companies may face problems in the operation processes, for instance, work pieces produced do not meet quality standards that required rework which known as specifications failures. For example, PINHOE Technology sometimes faced with the problem of inconsistency drilled holes of the Acrylite Board and required to drill a new one. In more serious case, the Functional Test jig is rejected and returned by customer due to the quality specification problem which need remanufactured the whole jig. This can result in unwanted waste of production times and materials. Based on Mr. Ng, human error is the main factor of the problem arises as most of the processes in the Functional Test jigs production line are controlled by operators. Human error might because of fatigue, careless, lack of experience and so on.

Nowadays, industries have installed machineries to assist and ease workers. There are two machines used in the Functional Test jigs production line which are squaring and drilling/milling machines. Machine efficiency and operator utilization is the common factors affecting the efficiency of manufacturing process. For instance, machine breakdown will lead to inefficiency of production line operation. Therefore, preventive maintenance activity on machines needs additional attention by the management to keep the machines running smoothly through the overall operation processes. Inefficiency of industrial production line is confronting most of the industries today. In this study, the simulation approach will used to measure the performance of the current operation processes and improve the efficiency of the entire production process.

1.4 RESEARCH OBJECTIVES

The objectives of this study are:

i. To develop a model of the Functional Test jigs production line using simulation method.

ii. To measure the performance of current operation system.

iii. To purpose a best solution to improve the operation system by using What-if analysis and Scenarios analysis.

1.5 RESEARCH QUESTIONS

This study shall answers the following research questions:

i. How the model of Functional Test jigs production line?

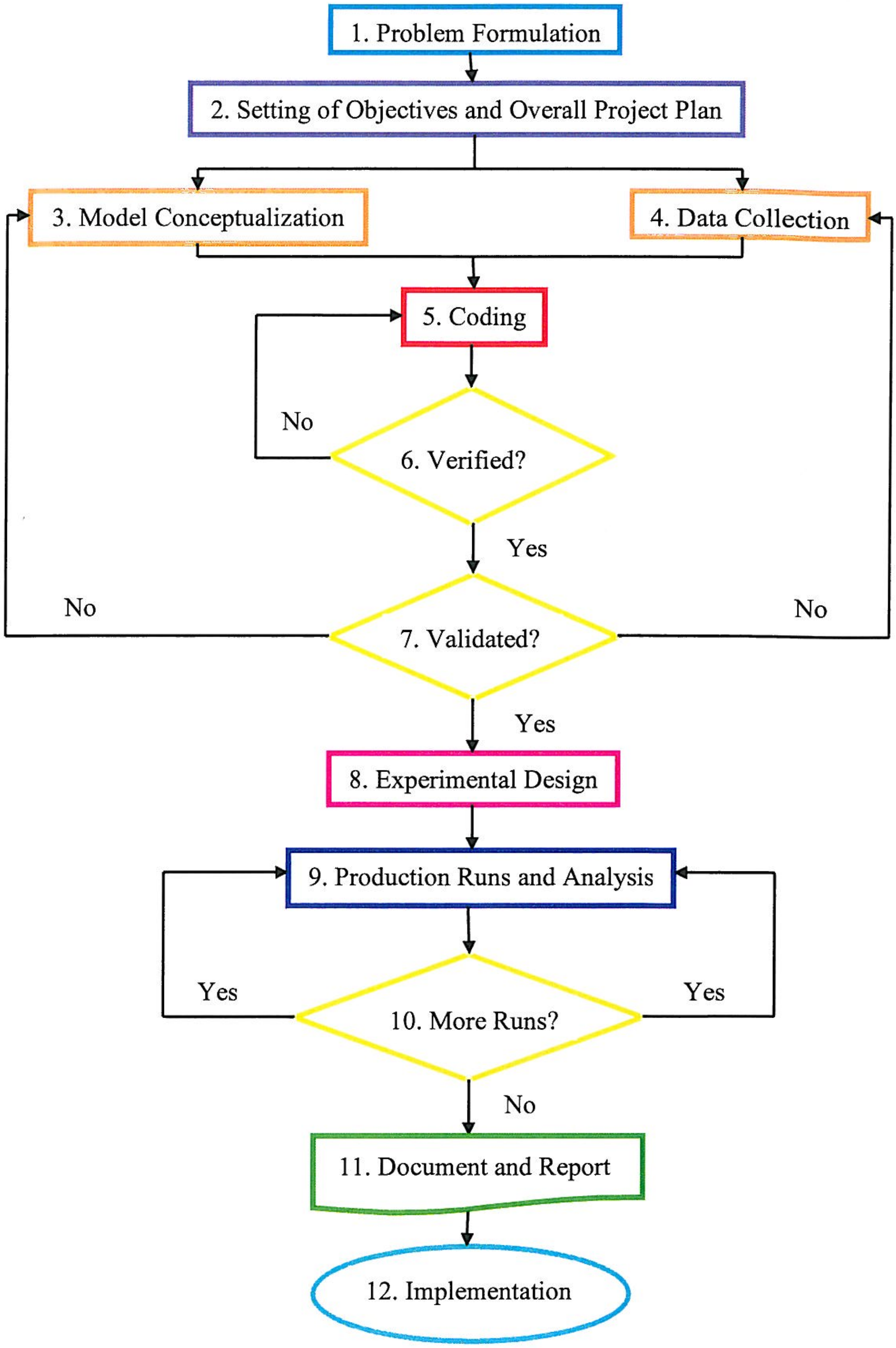
ii. What are the limitations in current operation of the Functional Test jigs production line?

iii. How to enhance the efficiency of the entire operation process?

1.6 METHOD OF ANALYSIS

Simulation is one of the most widely used quantitative methods which is flexible and can yield many helpful results. It can be used to perform What-if analysis. What-if analysis is a useful tool for improvement that determines how planned, tactical or operational changes affecting the processes. Through different conditions, system analyst will be able to carry out a true-to-life analysis of processes without operation risks.

In addition, simulation can also use to investigate the behavior of existing or proposed manufacturing systems, supply chains, communications systems or transportation system. System analysts can perform experiments on a model of the actual system faster, cheaper and safer using the simulation. General steps in a simulation study are shown as following:



1. **Problem Formulation:** The problem must be identified and clearly understood by the system analyst.

2. **Setting of Objectives and Overall Project Plan:** Prepared a project proposal which consists of unambiguous objectives. The overall project plan must include scenarios to be investigated and required data and time frame for the study.
3. **Model Conceptualization:** Develop and construct a model of the system. It is best to begin with draw a simple model and build toward greater complexity form. For instance, consider a model of manufacturing system, construct a basic model with arrivals, processes, and stations then add on operation capabilities and essential features afterward to enrich the model until a useful approximation resulted.
4. **Data Collection:** There is a constant interplay between the building of the model and the collection of the required data. After the project proposal is accepted, data can be collected from the particular company.
5. **Model Translation:** The theoretical model is coded into an operational model. The modeler must decide whether to program the model in simulation software such as ARENA, SUMUL8, AutoModel, and etc, or to use special-purpose simulation software.
6. **Verification:** The process of determining if the operational logic is correct.
7. **Validation:** The process of determining if the model represents the real system or problem accurately. Compared simulation results with the collected data from the real world system.
8. **Experimental Design:** For each system design that is simulated, decision need to be made regarding the initialization between replications, the length of replication, and the number of replications to be run.
9. **Production Runs and Analysis:** Model runs and their subsequent analysis are used to estimate performance measures for the system design that are being simulated.
10. **Repetition:** Based on the analysis of the runs that have been completed, the system analyst determines if any additional simulation scenarios and runs are needed.
11. **Documentation and Reporting:** Documentation and report is important for the system analyst to understand how the program operates. The analysis results must be reported briefly and clearly. This will enable the company to review

final simulation model formulation of the system, results of experiments and recommendation of the analyst.

12. **Implementation:** Report prepared provides information to the company for decision making. Director of the company can decide whether to run or not the plan at the actual situation.

1.7 SCOPE OF STUDY

This study focuses on electronic manufacturing plant in Penang, Malaysia. The study target is the operation system of the Functional Test jigs production line in PINHOE Technology. Efficiency of a production line will contribute profits whereas inefficiency of production line may cause loss. To complete this study, site visit and interview on-site are needed to be done in order to have more deep understanding about the real world situation and the production line to be simulated.

In this competitive world, many industries have forced to strive and to seek methods for improving their production process including design, layout and system. Simulation modeling will be used in this study to evaluate the performance measures of current operation system of the Functional Test jigs production line. Firstly, operation processes and layout of the machines or operators in the production line will be model out by using ARENA. Next, evaluate the performance of the current operation system through the simulation results. Then, recommend a best solution to improve the efficiency of the operation workflow. Finally, test the simulation results and compare it with the actual world system. The productivity, work-in-process time, utilization of machine, and manpower usage will be measured after modify the model. We can check the performance of existing or proposed manufacturing system by analyzing the results of the simulation model.

Therefore, the electronic manufacturing industry will be the context here, and this study will measure the performance of current operation processes and improve the efficiency of production line operation by using simulation modeling.

1.8 SIGNIFICANCE OF STUDY

The aim of this study is to develop a model and measure the performance of current production line operation of the Functional Test jigs manufacturing.

This study is purposely to enhance the efficiency of the production line. Each workstation in production line is critical to the overall operation processes. Simulation method can assist the industry in solving the troubles that faced at the production line. Besides that, manager will be able to organize and to handle the processes conveniently through the simulation model running. The industry will save the time and cost to find out the root cause when problems arise.

Furthermore, this study will show us how the modifications applied in the Functional Test jigs production line model affect the efficiency of entire process. Production line plays an important role in shortened the production time. The layout of a production line depends on the complexity of the manufacturing components, the production capacity, and so on (Subramaniam et al., 2008). The efficiency of a production line can give significant impact on the performance of whole operation process in the industry.

This study also enables low cost testing to infer how the real world systems of the operation processes at the electronic manufacturing plant might behave with computer software. By using ARENA, we can measure the performance of the company by testing with the collective data. The data included quantity of customer orders, processing time of each process and operators working schedule. Simulation model can aid the company to observe and to improve the efficiency of the operation processes without raise production cost.

In a nutshell, this study is proposed to help the company to speed up the manufacturing processes dramatically and reduce the processing time.

1.9 OPERATIONAL DEFINITION

Table 1.1 displays the operational definition of key terms in this study.

Table 1.1: Operational definition of key terms

Key Terms	Definition
Production line	The mechanical or manual operations set up in a factory where a product passing from one station to the next until the product is completed.
Simulation	The imitation of the operation of an actual world system or process on computer software.
Efficiency	The ability to carry out or produce something without wasting time, resources and materials.

1.10 CONCLUSION

To conclude, this study is purposely to examine how the model of the Functional Test jigs manufacturing processes, what the limitations present in current operation processes, and how to improve the efficiency of the production processes. Relevant literature will be reviewed and discussed in the next chapter to justify this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Nowadays, the customer demands and product specifications have change rapidly, so it is important for a manufacturing industry to accommodate the changes as fast as possible to maintain competitive in marketplace. The design of flexible manufacturing system is a critical issue and it can be very complex. The complexity of the manufacturing system is due to factors such as: different part types, many manufacturing steps, batch processing, and equipments which need high levels of preventive maintenance (Fowler and Rose, 2004). Performance measures of the manufacturing system are very difficult to estimate due to its complexity. Therefore, the simulation method will be used in this study. Simulation is a widely used modeling tool to analyze the extremely complex manufacturing processes.

2.2 PRODUCTION LINE

A production line is a "transfer line" that consists of a series of workstations laid out in which components or products are moved from one station to the next upon completion. Production lines are commonly used in high volume manufacturing. Usually, mass production system for products made of various components is organized into the production line. The production lines in industries can be classified into three types: automated production line, semi-automated production line, and manual production line (Subramaniam, et al., 2008). In today's world, semi-automated production line is used by most of industries in which new technologies are set up to assist and to ease operators in the production line. According to Liu (2010), the efficient production line reduces cycle time at mechanical assembly workstations and improves the throughput of production line.

Production line designs involve a variety of interconnected subjects such as tooling strategy, space strategy, material handling system, configuration of process flow, and flexibility desired for future production changes or capacity adjustment (Heilala, 1999). Industries plan and design the production line according to particular production requirements. In the production line, design problems are basically resource allocation problems (Altiok and Melamed, 2007). The problems consist of allocation of workload and buffer capacity for a given workstations with linked processing time. Zhou et al. (2009) present a simulation-based model for reconfiguring a piston production line to reduce work-in-process time and improve resource utilization. They test different scenarios and make recommendation based on the simulation results.

In a production line operation, the flow of components may be disrupted by machine failures, human errors, and variation in production time. In complex manufacturing systems, the spontaneous failures can have significant consequences for the upstream and downstream processes (Kr\"oning and Denkena, 2013). Quintero (2010) developed a simulation model in a Printed Circuit Board manufacturing operation to help in detection and elimination of quality defects. The efficiency of a production line can be enhanced by distributing buffers between machines (Demir et al., 2013). Buffering is defined as maintaining sufficient supplies to keep production process running smoothly. The implementation of buffering in manufacturing processes is tends to stabilize any fluctuations with supply and demand chains, production capabilities, and lead times. It can lead to production downtime if enough “buffer” inventories are unavailable to protect against upstream variability in the manufacturing processes (Melouk et al., 2013).

Production disturbance is one of the significant issues affecting the efficiency of production line operation. Disturbance is an unexpected change to production state that has negative impact on the goal (Saadat et al., 2008). When the disturbances arise, processing cannot be completed continuously and lead to waste of available production times and resources. Therefore, handling the disturbances is vitally importance for a more reliable and robust production line. According to Cao and Li (2014), there are typical operation disturbances as shown in table 1 that might occur in the production line.

Table 2.1: Typical disturbances in production line operation

Disruption	Impacts
Machine breakdown	Machine is unavailable for a period.
Absenteeism	If machine operator is unavailable temporarily, this considered as an idle machine. Whereas if the operator is unavailable for a long period of time, a substitute operator or overall rescheduling is required.
Delay in transportation	Failure to distribute the parts to the machine in time leads to increase in production time.
Variation in set up times	This will lead to changes in start/finish times of jobs.
Performance of machine variation	This may lead to changes in the production time and followed by changes in the complete time.
Arrival of a new order	A new job arrives and has to be inserted in the schedule immediately.
Rework	Some operations of job are required to be redone.
Rejection	The entire product has to be redone.

According to Altiok and Melamed (2007), the most commonly used performance measures of production line operation are throughput, average stocks level in buffer, probabilities of downtime, blocking probabilities at bottleneck workstations, machine and labor utilization and manufacturing lead time. Analysis production systems by using these measures can indicate better designs by identifying areas where loss of productivity is most risky. Development of more efficiency industrial production line can results in a better production yield and reduction of unwanted wastage.

2.3 PROCESS IMPROVEMENT

Nowadays, manufacturers worldwide are finding techniques to improve quality and productivity while decreasing operating cost. This led majority business organizations to adopt the Toyota Production System (TPS) or known as lean manufacturing (Liker, 2004). TPS is a well-known manufacturing methodology pioneered by Eiji Toyoda and Taiichi Ohno at Toyota Motor Company of Japan after World War II. TPS is designed as a set of methods or tools to improve constantly in the production system in order to optimize products quality, operate smoothly or efficiently, and minimize unnecessary waste. Waste was defined in TPS as activities that consume time, resource and space but do not added value. There are seven types of cardinal wastes or "muda" as it is called in Japanese aimed to be reduced:

- **Overproduction** – Produce larger quantities than the customer is required or produce parts earlier than what is needed
- **Waiting** – Time spent waiting for instruction, information, materials, or interruptions from operators/machines
- **Conveyance** – Part conveyance between the line and the parts rack
- **Inappropriate processing** – Longer lengths than necessary, greater volumes than necessary, or ineffective positioning
- **Unnecessary inventory** – Excessive inventory, too much floor space used to store parts, or parts accumulating dirt
- **Unnecessary / excess motion** – Parts are located in the wrong position (too high, too low or too far from the point of use)
- **Defects** – Rework or repairs needed for defective products

In addition, TPS was built based on two concepts which are Just-In-Time (JIT) and Jidoka. JIT and Jidoka are two main pillars of TPS as presented in Figure 2.1. JIT can be defined as manufacturing and transporting of only "what is needed, when it is needed, and in the amount needed". For the JIT, high quality products can be produced efficiently through the fully elimination of waste, inconsistencies, and unreasonable requirements in the production line. On the other hand, Jidoka refers to "automation with a human touch". The affected machine will be stopped automatically if equipment malfunctions, defective parts or late work is discovered. Jidoka helps prevent the passing of defects, recognize and correct problem areas using localization and isolation, and build quality during the manufacturing process. According to the basic philosophies of JIT and Jidoka, TPS can produce the products in high quality by the most efficient and quickest way, one at a time in order to fulfill and satisfy customer requirements.

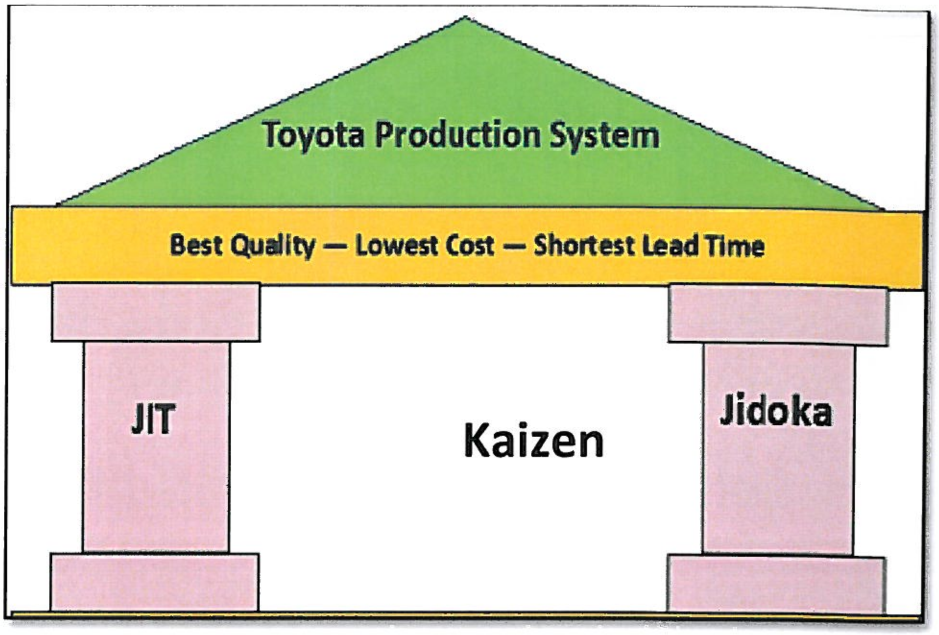


Figure 2.1: JIT, Jidoka and Kaizen of TPS

Furthermore, Kaizen is the heart of the TPS as shown in Figure 2.1. Kaizen refers to the Japanese term used for "continuous improvement". Kaizen means that every team member throughout the organization is continuously seeking for ways to enhance operations, and this process improvement is supported by people at all levels in the organization. Typically, Kaizen activities highlight manual work operations rather than equipment. In addition, Kaizen is not only based on improvements being built and applied by experts or management. Yet, it involves everyone in the company, depending on the broad skills, experience and knowledge of the people working directly in the production line.

2.4 SIMULATION

The complexity of manufacturing systems requires information and knowledge to be managed and presented digitally in a formal, standard and simplified way. The use of simulation modeling through the process from ideas to solutions can digitally and efficiently presented manufacturing systems (Nylund and Anderson, 2010). Simulation is a powerful modeling tool widely used for the purpose of planning, design, and control of complex manufacturing systems. Simulation can potentially provide significant insights into the behavior of the real system to find out what happened and why it happened. Simulation can be used to develop an existing manufacturing system, to design a new system, or to change the characteristics of existing requirements or capabilities. According to O'kane et al. (2000), there is a range of ways the manufacturing system could be modified such as:

- Added or removed machines
- Altered production process flow
- Labor levels, usage and skills
- Added or removed shifts
- Altered machines capabilities or set ups
- Altered batch quantities

Once an individual change was made to a particular modeling parameter, the consequence could be viewed on the overall system.

Beneficial simulation modeling applications in many practical actual worlds have proved its effectiveness in approaching a variety of problems in the manufacturing sector (Negahban and Smith, 2014). According to Fowler and Rose (2004), Simulation modeling has several strengths including:

- **Time compression** – The potential to simulate phenomena of system operation in a speed up time
- **Component integration** – The ability to integrate complex system components to study their interrelationships
- **Risk avoidance** – Supposed or potentially risky systems can be studied without the financial or physical risks that are encountered in constructing and studying a actual system
- **Physical scaling** – The ability to study much bigger and smaller versions of a system
- **Repeatability** – The capability to study same system in different environments or different systems in similar environments

- **Control** – All things in a simulated situation can be exactly monitored and controlled

By using simulation modeling, before a system is actually built and implemented, the pitfalls that may be involved in the start up of a new system or the alteration of an existing system can be avoided. Actual world systems are often too expensive to experiment with directly. Therefore, this is where simulation methods can be utilized. In addition, simulation also promotes a "try it and see" or "try and error" approach that motivates innovation and encourages thinking "outside the box".

While choosing a modeling approach, the analyst should consider the characteristics of the system and the nature of the problems to be tackled. In general, simulation models used in the area of manufacturing systems engineering can be categorized as: Stochastic or Deterministic, Static or Dynamic, Continuous or Discrete (Rossetti, 2010). A stochastic model exhibits random effects and yield different outputs, whereas a deterministic model does not affected by randomness and yields fixed outputs. A static model refers to a simulation of a system at one specific time, while a dynamic model refers to a simulation representing a system evolving over time. Discrete-event model refers to the state of the system changes at discrete point in time, and continuous model refers to the state of the system changes continuously over time. Figure 1 briefly illustrates the general simulation classifications.

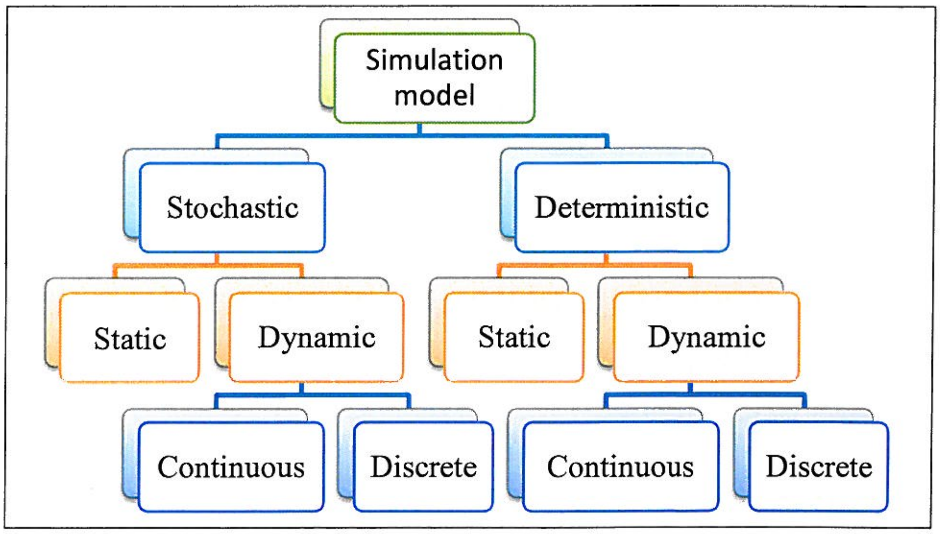


Figure 2.2: General types of simulation

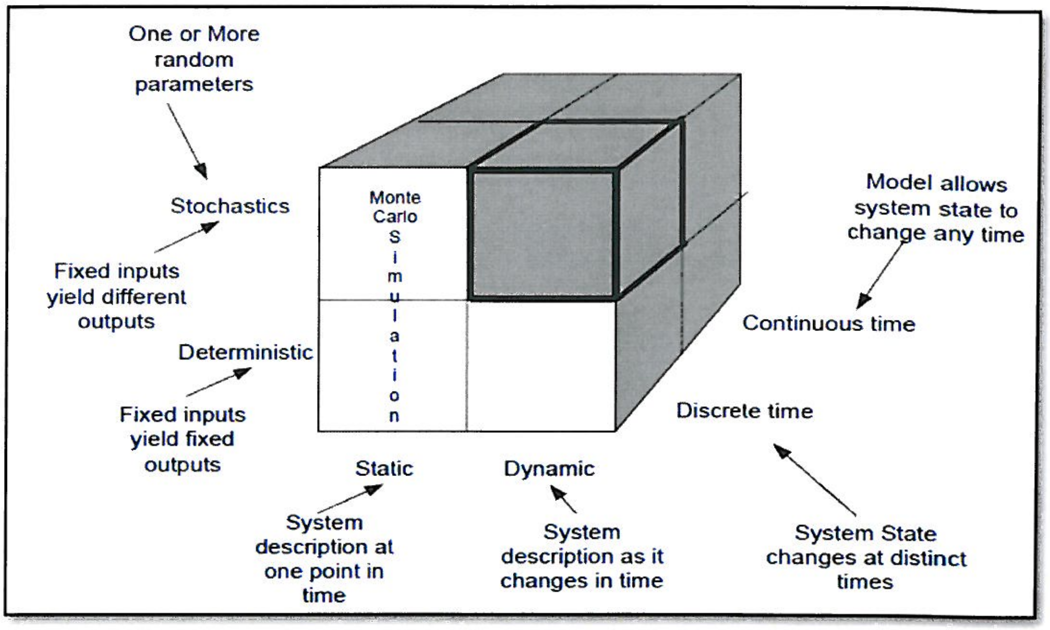


Figure 2.3: Classification of different types of model

Sources: Rossetti 2010

The discrete-event simulation model will be used in this study. In discrete-event model, the occurrence of an event drives the model. The discrete-event simulation is much simpler to implement and can be used in a wide variety of situations. The discrete changes normally arise from the application of digital regulatory control, equipment breakdown, or consequences of planned operational alteration. The discrete changes can significantly affect the overall process behavior.

Most of the simulation studies today are implemented using a simulation package. In this study, ARENA is chosen as a simulation tool to develop the model of electronic manufacturing processes. ARENA is a Microsoft Windows based application package for simulation modeling and analysis. ARENA is one of the general purpose discrete event simulation modeling tools that developed by Rockwell Automation in 2000. ARENA product family consists of ARENA Basic Edition for basic process modeling and performance enhancement and ARENA Professional Edition for developing more complex simulation models. According to Garrido (2009), ARENA simulation models consist of two types of modules which are:

- **Logic modules**: Also known as flowchart modules, it performs logical functions of a simulation model and control the logic of how entities flow through the system. The general logic modules are: Create, Process, Decide, Dispose, Batch, Separate, Assign, and Record.
- **Data modules**: Define the characteristics of process elements such as entities, specify and execute experimental conditions of simulation models such as number of replications and run length. The common data modules are: Resource, Queue, Variable, Schedule and Set.

ARENA uses an entity-based, flowcharting methodology for modeling dynamics manufacturing processes. ARENA product family supports both comprehensively analyses of a specific functional area such as manufacturing, logistics and customer service and across the supply chain. ARENA is easier to communicate the complex processes to others compared with alternative simulation tools. ARENA helps to reach the research objectives with simulation analysis and process optimization for more effective system operation.

The application of simulation in manufacturing design and operation is anticipated to grow and evolve continuously in the future (Negahban and Smith, 2014). Simulation provides an efficient technique to exhibit events that are happening in the production system. It is possible to find out the root causes of problems arise and prevent unwanted events from happening in the future. Simulation helps managers in managing their business, machinery, manpower, processing time and resources conveniently. For a complex manufacturing system, it is very hard to analyze the performance measures using the mathematical techniques, therefore the simulation techniques are the better alternatives for evaluating the complex systems to save effort and time (El-Tamimi et al., 2012).

2.5 APPLICATION OF SIMULATION MODELING IN MANUFACTURING INDUSTRY

In general, simulation has been used in a wide range of fields including but not limited to supply chain, marketing, healthcare, and military. Particularly, simulation modeling plays an important role to evaluate the design and operational performance of manufacturing systems. As an effective tool for analyzing complex actual system, simulation has been successfully implemented in many studies related to manufacturing system design and operation. Simulation enables analysts to evaluate alternatives of system configurations and operating tactics to support decision making in the manufacturing environment. Industries recognized the importance of ICT to improve efficiency, flexibility and sustainability of manufacturing systems and their integration within dynamic business processes (Ad-hoc Industrial Advisory Group, 2010).

Facilities design is one of the significant factors affecting the efficiency of manufacturing operations. An effective facility layout helps reduce manufacturing costs and improve performance of the system. Discrete event simulation is a highly flexible tool which allows analysts to evaluate the current layout and point out potential areas for enhancement by evaluating various layout alternatives. Vasudevan et al. (2010) proposed the adoption of simulation together with bottleneck analysis, measurement of work and facility layout design analysis to improve operational performance and profitability of steel-mill manufacturing. Jithavech and Krishnan (2010) developed an efficient facility layout design under uncertainty product demand by simulation method. They estimated the impact of stochastic demand in terms of risk and show how simulation method can significantly lessen the risk related to the layout.

Routing flexibility is a key contributor to the flexibility of a manufacturing system. Joseph and Sridharan (2011) evaluated the routing flexibility of a manufacturing system with agile part arrivals. Discrete event simulation is an appropriate tool to evaluate the routing flexibility of a typical manufacturing system configuration. Bilge et al. (2008) illustrated full routing flexibility which includes alternative operation sequences and alternative operation machines for manufacturing the identical part. They proposed new methods for dynamic part routing and test them under volatile system configuration through simulation experiments.

In addition, simulation has also been used for studying make-to-order manufacturing systems. Tunali et al. (2011) introduced an approach which merges simulation and mathematical modeling to schedule due date in a make-to-order manufacturing context. They utilized the simulation to evaluate production lines consolidation in a produce-to-order manufacturing industry. Ebadian et al. (2009) validated the performance of a hierarchical production planning structure for make-to-order industry through simulation experiments. Ehrenberg and Zimmermann (2012) proposed a simulation-based scheduling method for make-to-order manufacturing systems and evaluate its application in a special-purpose glass manufacturing industry. They used mixed integer programming to create schedules while its input parameters and constraints are iteratively updated by simulation modeling.

For certain cases, when production lines are consolidated or reconfigured, a number of changes are required to the operation and transportation parameters. Internal transportation of components and products in manufacturing atmosphere is a significant factor that influences work-in-process time, quality, and productivity. The factors that affect the internal transportation include shipping mode, lot size and waiting times (Aqlan et al., 2014). Tang and Gong (2009) conducted a study of coordinating production scheduling and shipment. They proposed an optimization of the total processing costs and overall completion time taking into account a batch machine scheduling problem that merged transportation before processing. Sancak and Salman (2011) presented an optimization of ordering and shipping decisions aimed at fulfilling the requirements in production planning and control with minimum transportation and inventory holding costs.

The disturbances occur in production line can cause machines to be idle and lower the throughput of the line. In order to minimize the impact of these disturbances, buffers are used between the machines. Amiri and Mohtashami (2012) introduced a simulation-based approach for buffer allocation in production lines. Staley and Kim (2012) conducted simulation experiments on buffer allocation in closed serial production lines consisting of various workstations and the results show that optimal buffer allocation within system are less sensitive to bottleneck severity. However, there is limited buffer space allocation due to highly inventory holding costs. Azzi et al.

(2012) compared the classical methodology to build mixed assembly systems with a proposed simulation-based method which aims at minimizing both lead and overload times and decrease required buffer capacity.

Besides its capability for production planning, Simulation also provided manufacturing decision maker a tool in considering long term production planning and short term scheduling simultaneously. Ruiz et al. (2011) proposed an agent-based simulation model for decision making in a manufacturing context and described its applicability in a metal-mechanic manufacturing real-world case study. Negahban and Smith (2014) developed an agent-support simulation tool to anticipate the future demand of new products and adjusting the production volume. By using simulation, they are capable of evaluating the performance of various output level management methods under different levels of production quantity flexibility and market changes.

On the other hand, simulation can be integrated with optimization to study the sequencing and determine the optimal batch size for manufacturing and inventory systems. A simulation model with a prioritized stochastic batch arrival method for a remanufacturing system to optimize production planning and control policies was developed by Li et al. (2009). Tolio and Urgo (2013) presented a method which combines simulation and optimization modeling to reconfigure flexible production line. The method applied in an actual world case study of an automotive manufacturing industry and with an objective to minimize the equipment cost.

Roux et al. (2013) conducted a study on the optimization of multi-component preventive maintenance problems. They proposed an easy to understand simulation modeling tool to facilitate the optimization of production and preventive maintenance. Sharda and Bury (2010) developed a discrete-event simulation model to recognize the effect of various failures on the overall production productivity in a chemical plant. The simulation model aids to understand key equipment parts which contribute to greatest production loss if failed. Ramirez-Hernandez and Fernandez (2010) illustrated the applicability of a simulation-support approach to optimize preventive maintenance scheduling decisions in semiconductor manufacturing systems. The results of simulation experiments show a significant cycle time reduction.

In many current research institutes, integration of environmental and sustainability aspect to simulations is one of the on-going development efforts. Generally, manufacturing processes are power intensive and electricity generated from fossil fuels which is a key carbon emissions contributor (Branker et al., 2011). Ball et al. (2009) developed a simulation model to integrate materials, energy, and waste process flows to create zero carbon emissions manufacturing facility. Fang et al. (2011) presented a new simulation-based scheduling approach to reduce energy consumption and carbon footstep in manufacturing industry.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this chapter, the research methodology which is the tools and techniques used to carry out the investigation in this study will be introduced. Selecting an appropriate and effective research method will leads to the success of the research. This chapter including process description, data collection method, and ARENA software used to develop and evaluate the simulation model of the operation processes in electronic manufacturing plant.

3.2 PROCESS DESCRIPTION

Figure 3.1 shows the operation processes to manufacture the Functional Test jigs. A functional test jig consists of many components which including Printed Circuit Board (PCB) (as shown in Figure 3.2) and Acrylite Board (as shown in Figure 3.3). There are three basic varieties of PCBs such as single-sided, double-sided and multi-layered PCBs. PINHOE Technology fabricates the single-sided PCB themselves and purchases the double-sided and multi-layered PCBs from the supplier for production purpose.

The production line of the Functional Test jigs manufacturing is splits into two vary separate operation routes which are PCB and Acrylite Board operation routes as presented in Figure 3.1. These two operation routes can run parallel and perform concurrently. The PCB will pass through components/pins inserting, soldering, and wiring processes. Whereas the Acrylite Board will go through squaring, holes drilling/milling, and numbering workstations. When these two entities were released from the operation processes respectively, they will be conveyed to assembling station. After assembled, final quality control checking will be conducted. After that, the Functional Test jig is completed and ready for shipment.

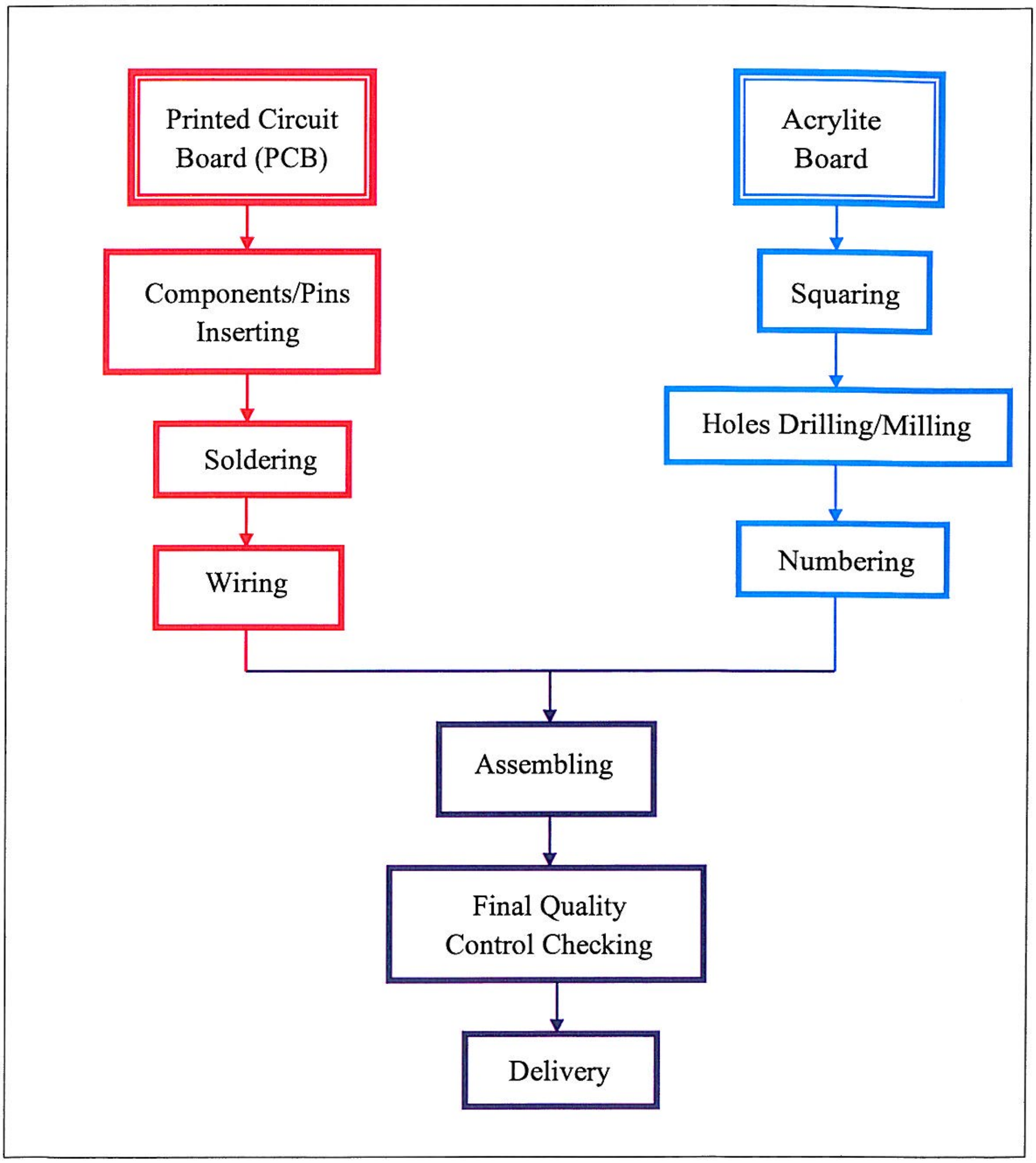


Figure 3.1: Operation processes of the Functional Test jig production line

3.3 METHOD OF DATA COLLECTION

In this study, the data collection methods including interview, observation, on-site collection, get historical data from the company and acquire information from electronic sources.

Through the interview, the data I gained from the company director are number of workers, number of workstations, types of machines used, and operation process flow. In addition, I gained the data such as layout of production line and arrangement of operators and machines in each workstation through the observation. Some data such as work-in-process times of each workstation are measured using a stopwatch. All of these data are recorded for future use in developing the model.

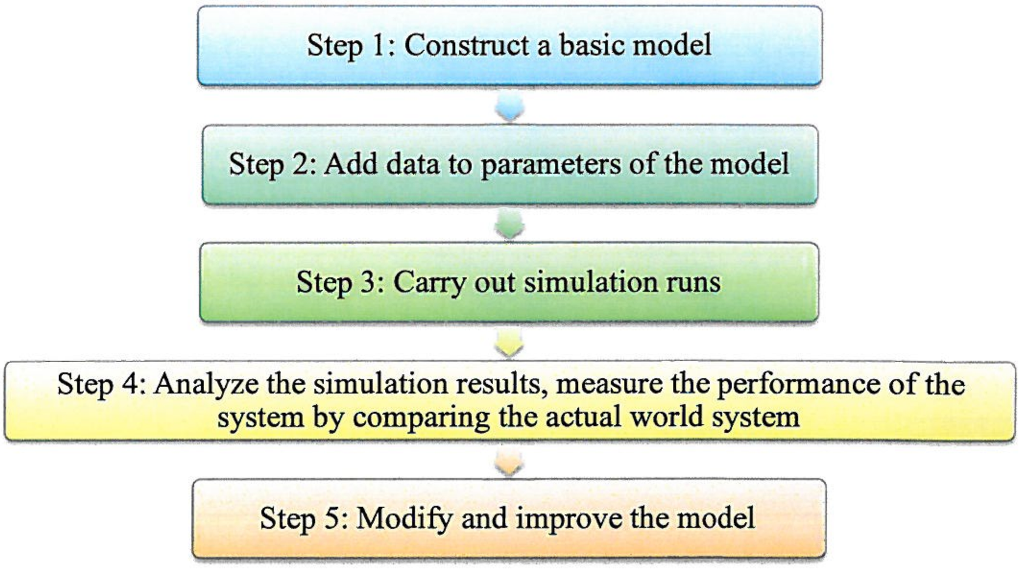
The historical data gained from the company are collected for accomplish the simulation modeling. The data collected from the company are in form of files, documents, and records. The records that required from the company are quantity of customer orders and operators working schedule.

On the other hand, I also acquired some information and additional knowledge from the internet. Information from the internet can become references to guide me in doing my report and analysis. For instance, mathematical calculation model and analysis methods retrieved from the electronic sources can be referred and learned in doing this study.

3.4 MODELING WITH ARENA

Modeling is the process of creating a model. It represents the building and running of some system of interest. A model is much simpler than the system it represents. A model should not be so complex and difficult to understand and experiment with it. A model must approximate alike to the real system and integrate most of its significant behaviors. Modeling enables the system analyst to expect the effects of changes to the system. A good model is a judicious tradeoff between realism and simplicity with support of appropriate simulation software. Simulation software I will apply in this study is ARENA. In this study, the Functional Test jigs production line operation system will be modeled and simulated by using ARENA.

ARENA is automation software developed by Systems Modeling and acquire by Rockwell Automation. It built by using SIMAN processor and simulation language. ARENA is a powerful simulation modeling software tool that allows the analyst to create a simulation model and run experiments on the model. It can produce numerous reports as the results of simulation runs. The steps to construct a simulation model and perform simulation run with ARENA are show as follow:



Step 1: Construct a basic model

- ARENA offers a model window flowchart view for creating a model. The analyst can select and move the flowchart module shapes into the ARENA window and connects them to illustrate process flow of the model.

Step 2: Add data to parameters of the model

- The actual data collected from the company such as quantity of customer orders, processing times and operators working schedule will add to the model.

Step 3: Carry out simulation runs

- Simulation run can be performed and results can be observed.

Step 4: Analyze the simulation results, measure the performance of the system by comparing the actual world system

- Performance of the operation process can be measured and the sources of problems can also be detected through the simulation runs. It is required to use mathematical calculation in analyzing the results.

Step 5: Modify and improve the model

- The model can be enhanced by making changes to the model according to the analyst's needs. Problems detected from the performance evaluation in step 4 can eliminate by redesign and retest the new and more effective model.

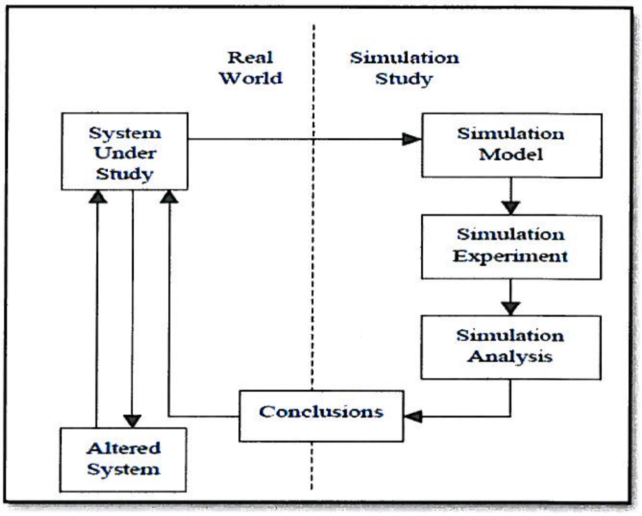


Figure 3.2: Simulation study schematic

Sources: Maria 1997

` Figure 3.5 shows a schematic of a simulation study. Simulation imitates operation of actual system and the simulation results can be used to do comparison.

In the basic process template panel, there are several types of flowchart modules such as Create, Dispose, Process, Decide, Batch, Separate, Assign and Record. Figure 4 shows a simple workstation displays in the ARENA Window which included Create, Process and Dispose modules.

- **Create module**: Generate arrivals of entities such as people, jobs and demands. Define characteristics of entity arrivals such as time between arrivals, entity types, batch size and so on.
- **Process module**: Process entities through necessary operations which includes a resource, its queue and processing time.
- **Dispose module**: Entities leaving the system and the entities is disposed and discarded.

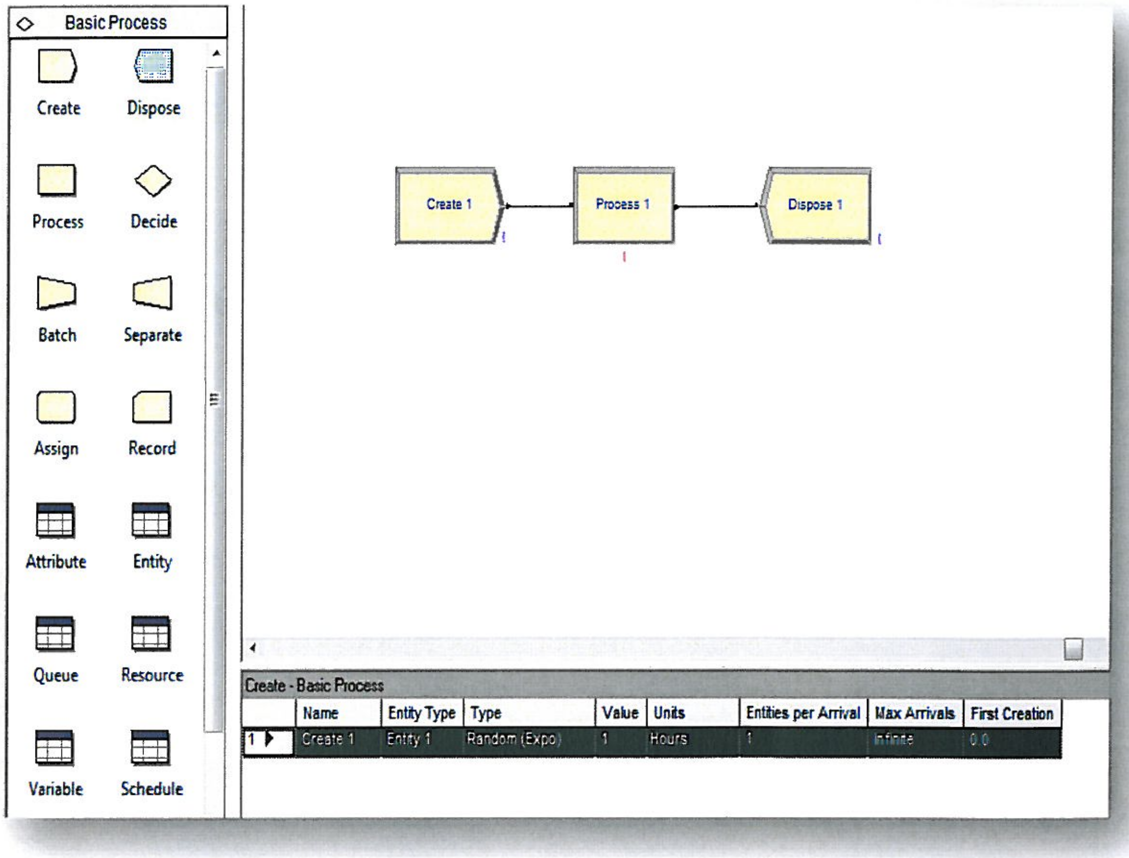


Figure 3.3: A simple workstation displays in the ARENA Window

CHAPTER 4

DATA ANALYSIS (RESULTS AND DISCUSSION)

4.1 INTRODUCTION

This study is purposed to evaluate and improve the performance of Functional Test jigs production line operation in an electronic manufacturing plant. This chapter consists of an analysis of all data collected from the electronic manufacturing plant and a summary of the simulation results. In this chapter, the findings and analysis displayed are supported by a key instrument that is simulation software called ARENA. ARENA is considered very important and indispensable in this study. The basic model of the current Functional Test jigs production line is developed by using ARENA in this chapter.

After evaluated the performance of current operation system, some experiments will be conducted to improve and optimize the system performance. Modifications will be made to the original model such as added machine or process, altered the workflow of operation or changed the operators working schedule plan to improve efficiency of the system and resources utilization. Once a single change was made to a specific modeling parameter, the results or consequences could be viewed on the overall system. Therefore, the results obtained from experiments will be analyzed and discussed when every single change made to the model.

4.2 INPUT ANALYSIS

PINHOE Technology Sdn. Bhd., an electronic manufacturing company which located at Penang, Malaysia was chosen in this study. The company fabricates two types of test jig which are ICT jig and Functional Test jig. Functional Test jigs production line is selected as target of study for this thesis. The production line of the Functional Test jigs is splits into two separate operation routes which are PCB and Acrylite Board operations. PCB operation processes included components/pins inserting, soldering and wiring, whereas Acrylite Board operation processes included squaring, holes drilling/milling and numbering. There are only two machines used in entire production line, which are squaring machine and drilling/milling machine.

There are some collective data which conducted in this study such as layout of the production line, quantity of customer orders, operators working schedule, and processing time in each workstation. The data was obtained from observation, company historical records, and on-site collection. Before creating the model, all related factors must be taken into account to optimize the system. All elements in the operation system will be evaluated and analyzed using ARENA.

In addition, ARENA also provides a standard built-in data analysis tool which known as Input Analyzer, whose major objective is to fit distributions to a given sample. There are a wide range of distributions which are Exponential, Normal, Triangular, Uniform, Erlang, Beta, Gamma, Log-normal, Weibull and Poisson. The Input Analyzer is accessible from the Tools menu in the ARENA home screen. With the Input Analyzer, the particular class of distributions and numerical estimates of the associated parameters that provide the best fit can be specified and determined. Specifying of distribution and model parameter is important in modeling as the parameters applied to the model might influence the model output. In this study, expression with the lowest square error shown in the Input Analyzer will be selected to apply in the model in order to get a precise result.

As mentioned before, PINHOE Technology is a make-to-order electronic manufacturing company in which the manufacturing is based on the customer orders and the quantity of the orders can be different and varying from time to time. PINHOE Technology operates 5 days in a week. Table 4.1 shows the collected data of customer orders of Functional Test jig for 2 weeks or 10 working days.

Table 4.1: Customer orders of Functional Test jig

Day	Quantity of Customer Order
1	2
2	1
3	0
4	1
5	3
6	1
7	1
8	2
9	3
10	2
Total	**16**

Calculation:

$$\text{Average of Inter-arrival Time} = \frac{\text{Sum of the Inter-arrival Time}}{\text{Quantity of Customer Order}} \qquad \textbf{(Eq. 4.1)}$$

$$= \frac{10 \text{ days x } 8 \text{ hours}}{16 \text{ orders}}$$

$$= 5 \text{ hours}$$

Inter-arrival time is the time between arrivals which is a significant resource to create entity. Create module is the entry point for entities. For this study, the entity is customer orders and the most appropriate distribution for inter-arrival time is Exponential. The Value is used as the mean of the exponential distribution. Based on the calculation, the mean or average time of each order arrive to the entry point is 5 hours. There are only 1 order distributed for each repeating run of the model and amount of orders allocated for each replication is infinite. In the simulation model, entities, the customer orders will flow through the system and dispose when they leave the system. Therefore, create module for the Functional Test jig production line model was filled as following:

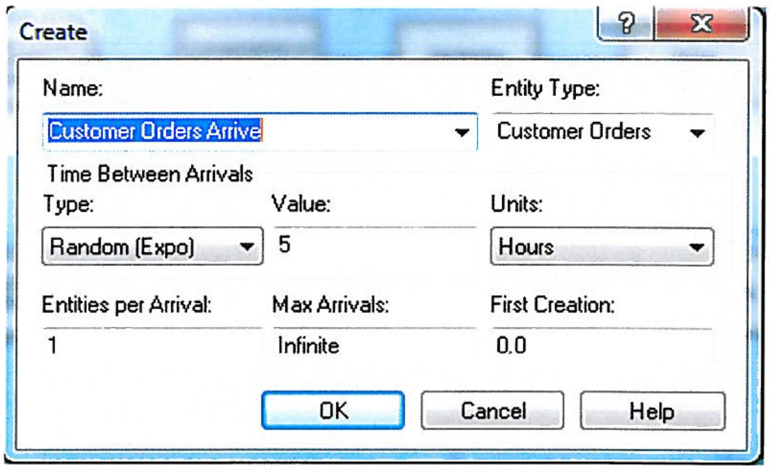


Figure 4.1: Create module in the model

After the customer order released from the entry point, it will separates into two operation routes which is PCB and Acrylite Board operation. PCB will pass through components/pins inserting, soldering and wiring workstations, whereas Acrylite Board operation will undergo squaring, holes drilling/milling and numbering processes. Each workstation or process has different processing time. The data of processing time in each process is collected and analyzed. After key in the collected data of processing time in a notepad and fitting distributions via the ARENA Input Analyzer tool, the result will automatically presents a particular distribution of data that has the smallest square error value. Smallest square error implies the data is precise and fit to the distribution.

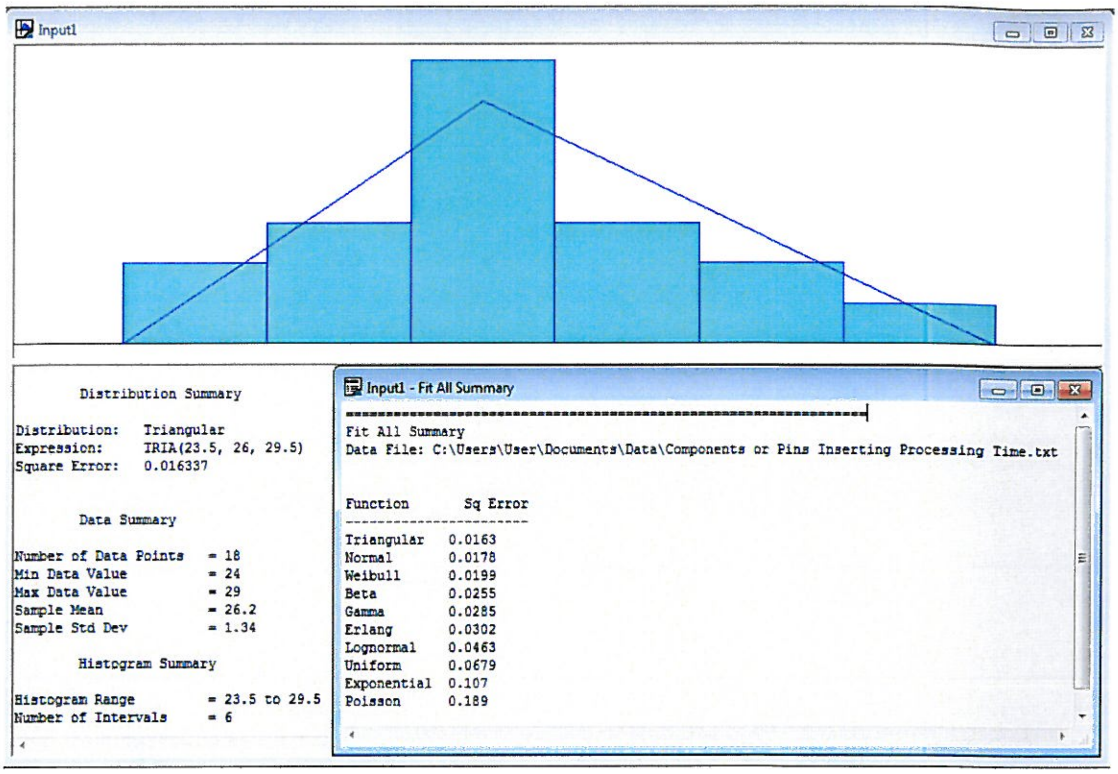


Figure 4.2: Distribution of processing time of the pins/components inserting process

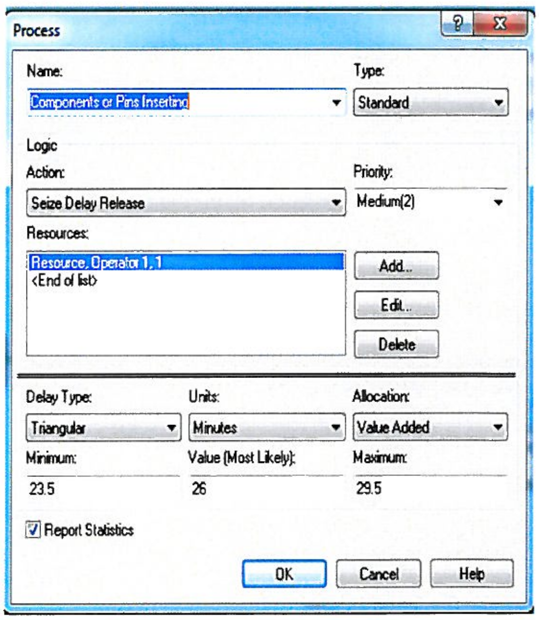


Figure 4.3: Components/pins inserting process module

Pins/components inserting process is the first process of PCB operation. Input Analyzer shows the data distribution of the pins/components inserting process in Figure

4.2. Based on the distribution summary, square error of triangular distribution is the least with value of 0.016337. Therefore, triangular distribution with expression TRIA(23.5, 26, 29.5) will be apply to delay type for the pins/components inserting process.

The module of pins/components inserting process is shown in Figure 4.3. Based on Figure 4.3, Seize Delay Release is selected for logic action. Seize Delay Release indicates that a resources will be allocate, delay by time and then will be release. Resource in pins/components inserting process is operator 1. There are three parameters in the pins/components inserting process module: the minimum possible value, the most likely value, and the maximum possible value of processing time needed. The numerical estimates of the three parameters are filled in with the time units, minutes according to the result shown in the Input Analyzer.

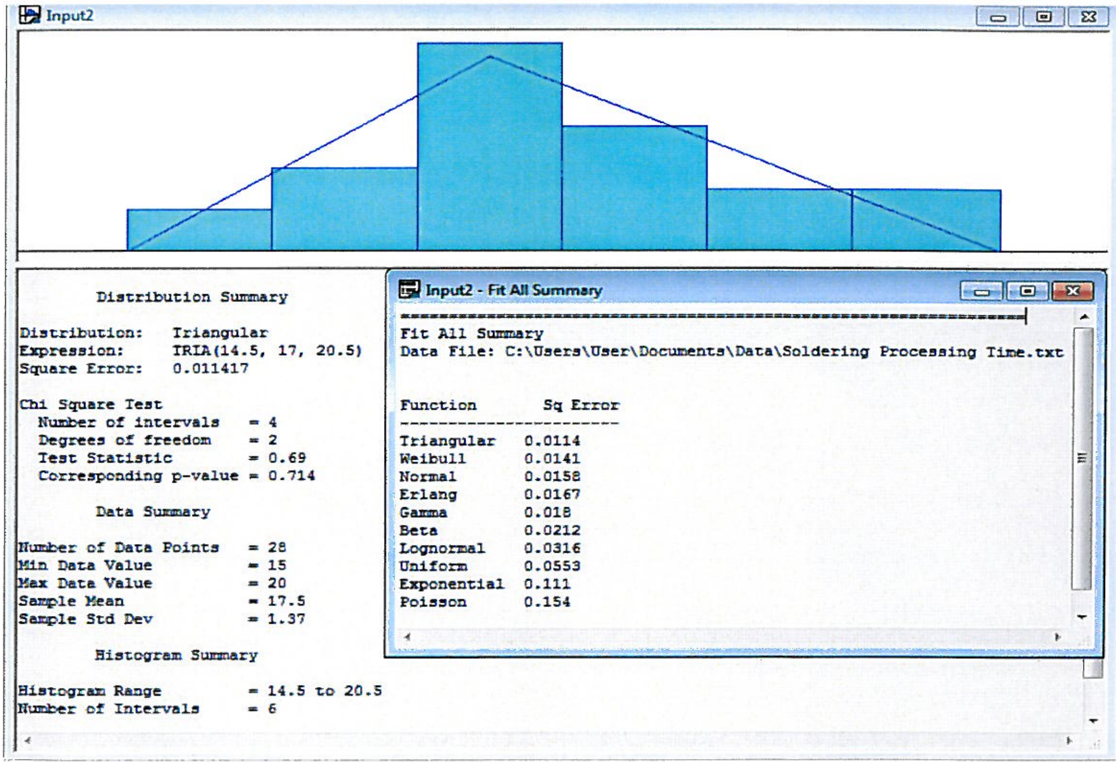


Figure 4.4: Distribution of processing time of the soldering process

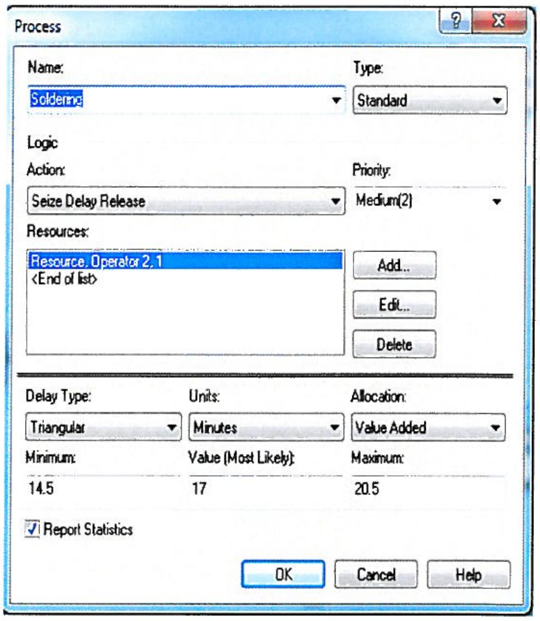


Figure 4.5 Soldering process module

Soldering is the second workstation of PCB operation after the pins/components inserting process. Figure 4.4 indicates the data distribution of the soldering process. According to the distribution summary, triangular distribution has the smallest square error which is 0.011417. Therefore, triangular distribution with expression TRIA(14.5, 17, 20.5) will be chosen as delay type for the soldering process. The module of the soldering process is shown in Figure 4.5. For the soldering process, the logic action is also Seize Delay Release as the PCB seizes the resource, then releases the resource after processing. On the other hand, operator 2 is assigned as resource of the soldering process.

The third workstation of PCB operation after soldering process is wiring. The data distribution of the wiring process which reported by Input Analyzer is shown in Figure 4.6. The distribution summary exhibits triangular distribution has the minimum square error with value of 0.000998. So, triangular distribution with expression TRIA(22, 23.2, 26) will be selected as delay type for the wiring process. Process module for the wiring process is presented in Figure 4.7. The Seize Delay Release logic action is picked again for the wiring process, whereas operator 3 is allocated as resource of the wiring process.

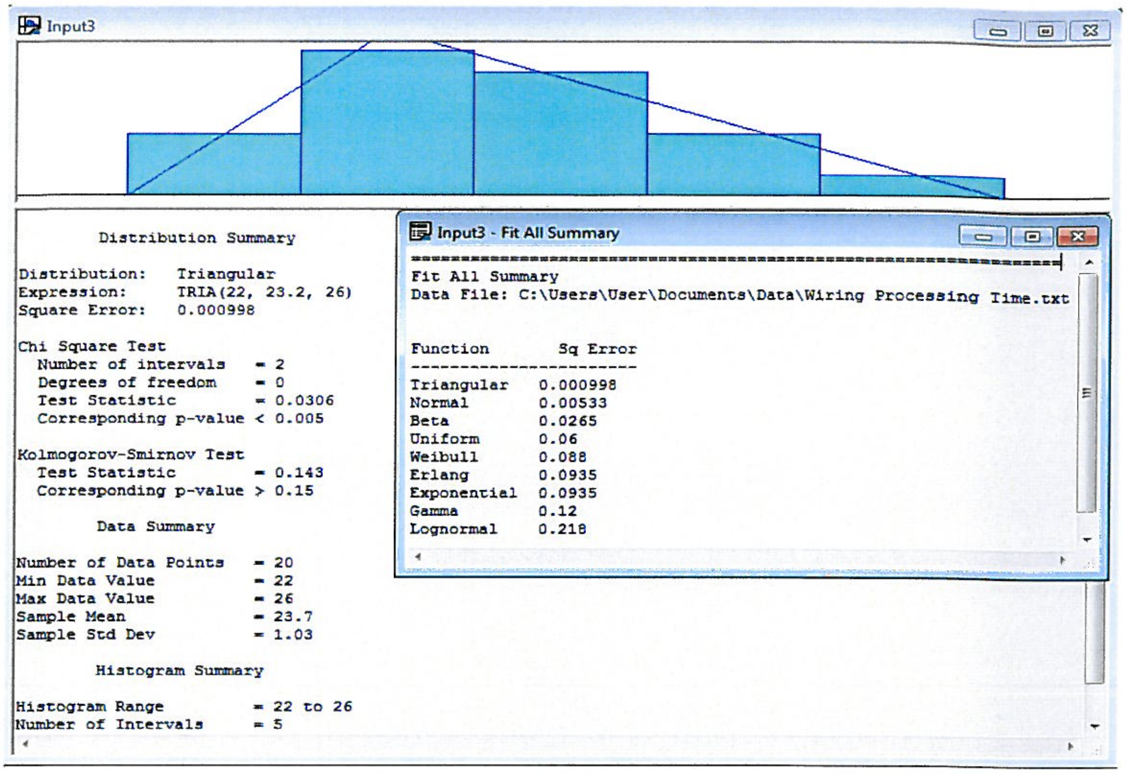


Figure 4.6: Distribution of processing time of the wiring process

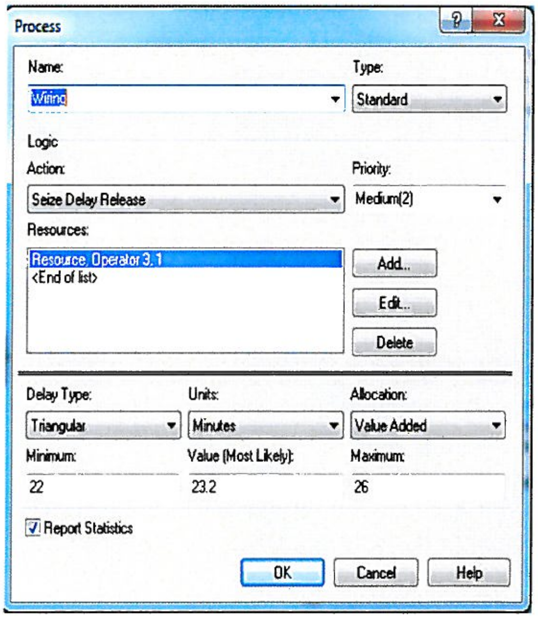


Figure 4.7: Wiring process module

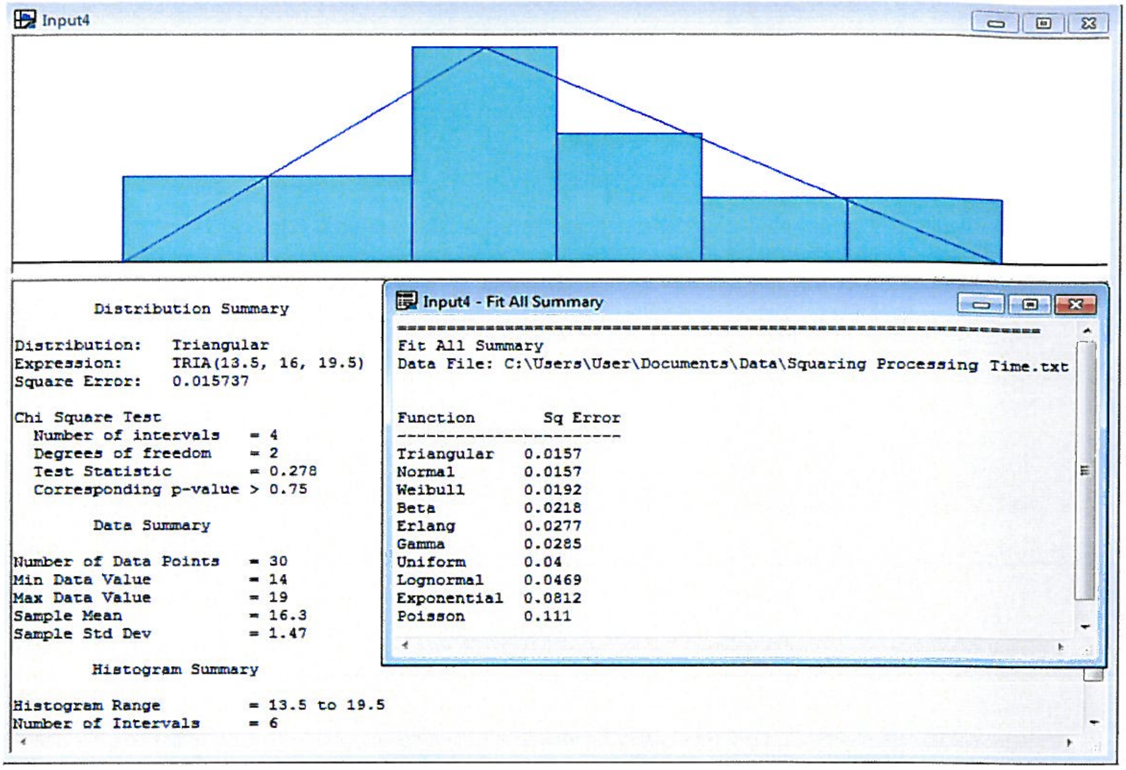


Figure 4.8: Distribution of processing time of the squaring process

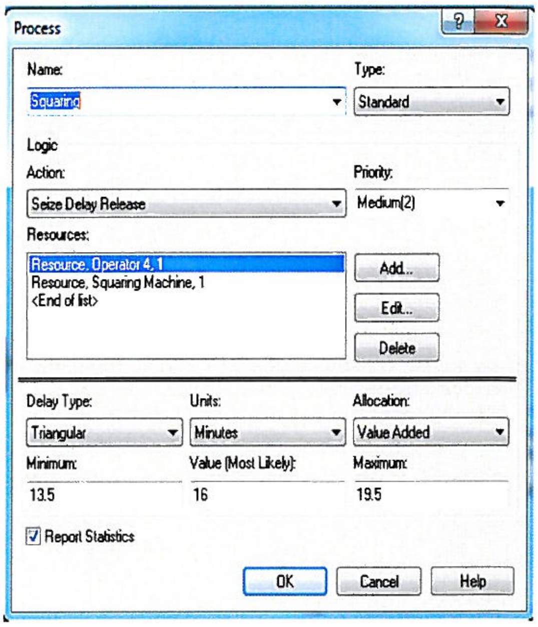


Figure 4.9: Squaring process module

For Acrylite Board operation, the first process or workstation that Acrylite Board will be undergone is squaring. Through Input Analyzer, data distribution of the squaring process is shown in Figure 4.8. According to the distribution summary, square error of triangular distribution is the lowest which is 0.015737. Hence, triangular distribution with expression TRIA(13.5, 16, 19.5) will be chosen and apply as delay type for the squaring process.

The process module for the squaring process was filled as shown in Figure 4.9. Based on Figure 4.9, Seize Delay Release also had been chosen for logic action as the Acrylite Board grabs the resource, processing or delaying by time, then releases to next process. There are two resources assigned for the squaring process which are operator 4 and squaring machine.

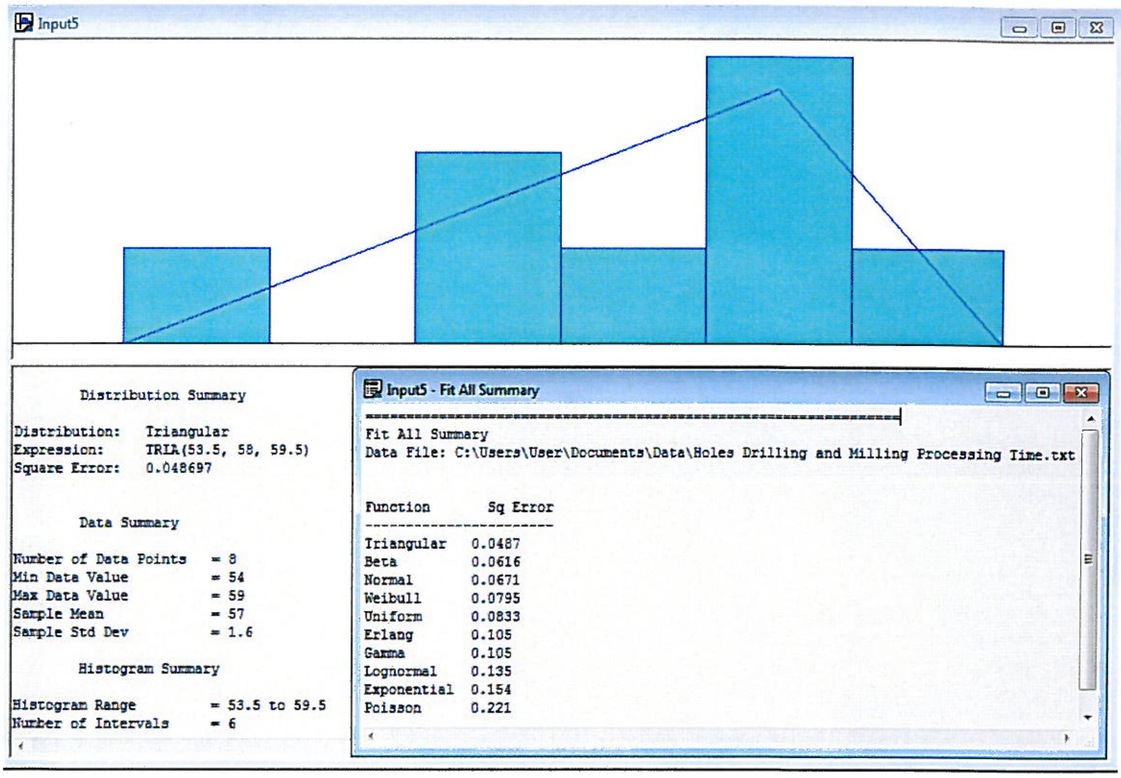


Figure 4.10: Distribution of processing time of the holes drilling/milling process

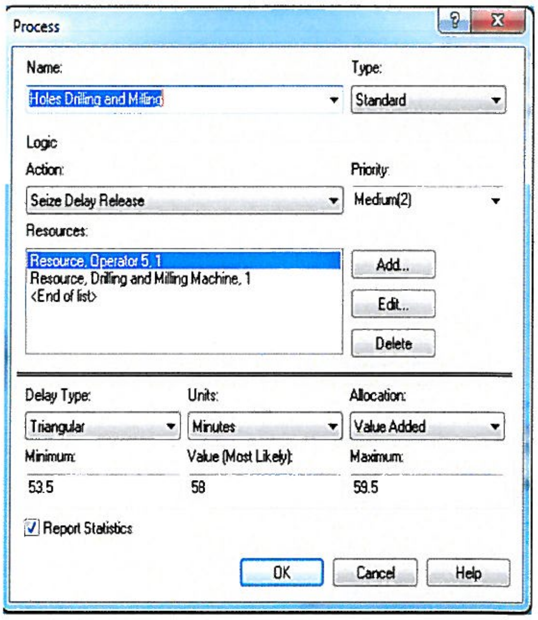


Figure 4.11: Holes drilling/milling process module

The second workstation of Arcylite Board operation is holes drilling/milling. Input Analyzer displays the data distribution of the holes drilling/milling process in Figure 4.10. The distribution summary shows triangular distribution has the minimum square error with value of 0.048697. Therefore, triangular distribution with expression TRIA(53.5, 58, 59.5) will be selected as delay type for the holes drilling and milling process. The holes drilling/milling process module is presented in Figure 4.11. The Seize Delay Release logic action also had been used in the holes drilling/milling process module. Operator 5 and drilling/milling machine are assigned as resources for this process.

Numbering is the third process of Acrylite Board operation. Figure 4.12 exhibits the data distribution of the numbering process reported by Input Analyzer. Based on the distribution summary, triangular distribution has the least square error which is 0.0114. Thus, expression TRIA(33.5, 35.8, 40.5) of triangular function will be copy and apply as delay type in the numbering process module as shown in Figure 4.13. Based on Figure 4.13, the logic action for the numbering process is also Seize Delay Release and resource allocated is operator 6.

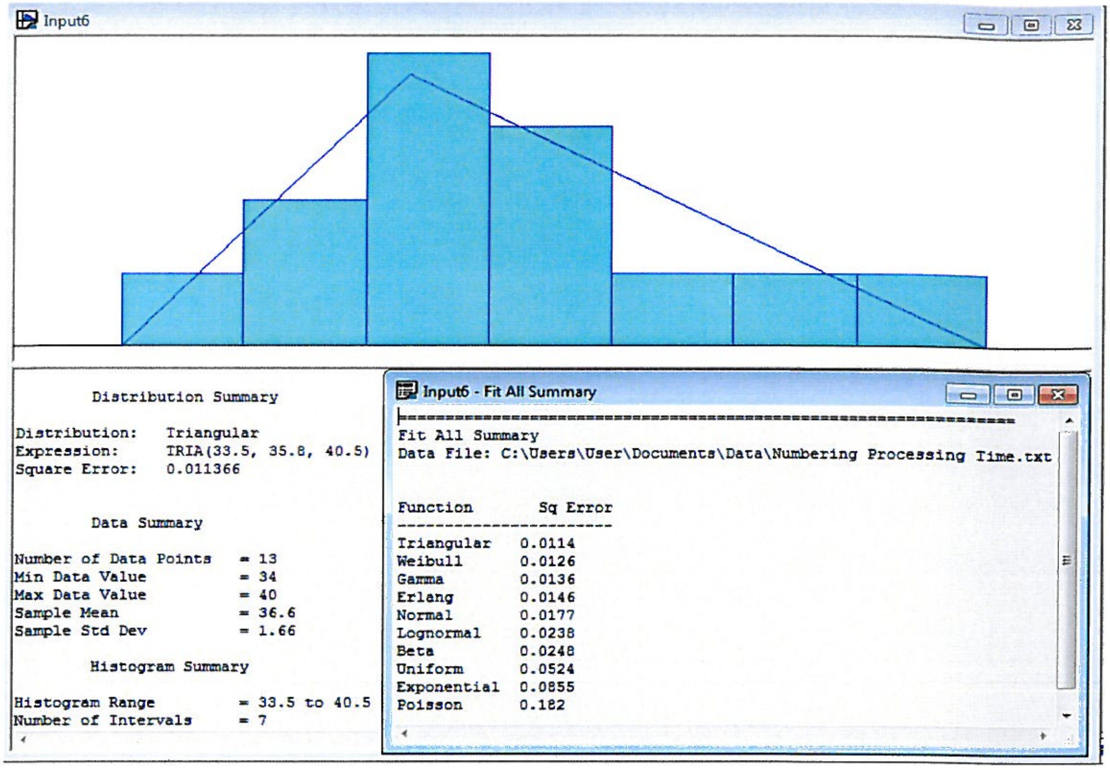


Figure 4.12: Distribution of processing time of the numbering process

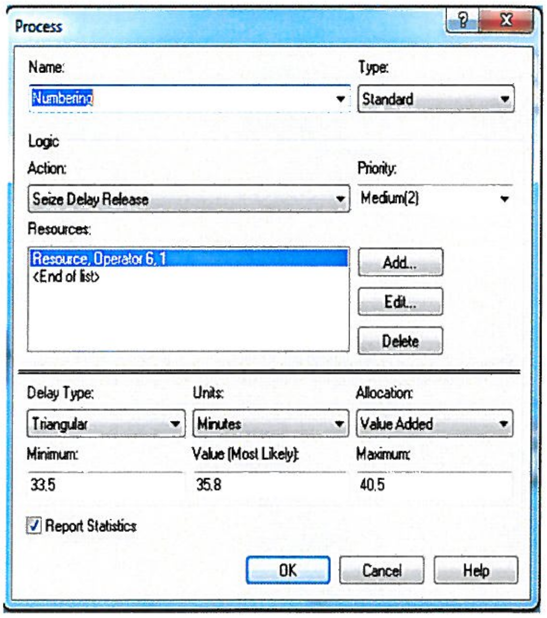


Figure 4.13: Numbering process module

In addition, decide module is used in the model of Functional Test jigs production line as shown in Figure 4.14. There are two exit points associated with this module type. Entities that meet the true condition will exit from right side of the module, while entities that meet the false condition will exit from the bottom of the module. In this model, 2-way by Chance will be selected as the type of the decide module.

According to the information given by the director of PINHOE Technology, the percentage of facing the problem of inconsistency or fail drilled holes of the Acrylite Boards is approximately 4%. So, the percent true is filled with 96% by the condition "if drilled holes are consistent". In the model, the decide module is laid after the holes drilling/milling process, Arcylite Boards that meet the true condition will exit from the true and proceed to the numbering process. Whereas Arcylite Boards that meet the false condition will exit from the false and will be disposed.

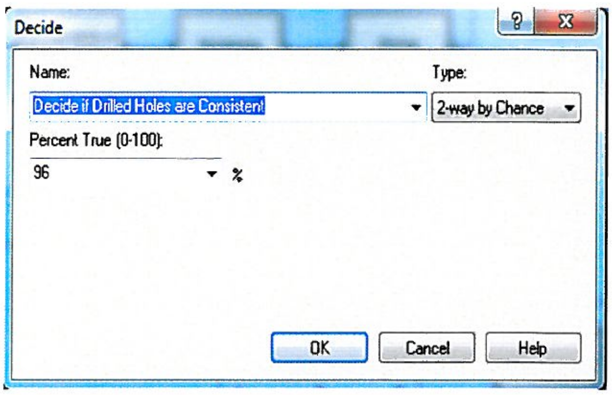
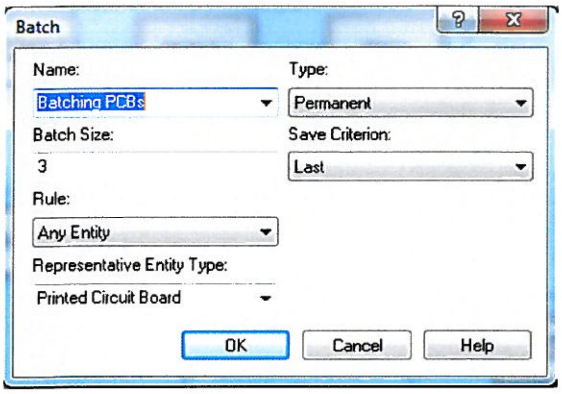


Figure 4.14: Decide module in the model

Moreover, Figure 4.15 shows the batch modules used in the model to group a number of PCBs and Arcylite Boards. When using the batch module, the entities arriving are places in a queue until the required number of entities has accumulated. Once the entities are accumulated, a single new representative entity leaves the module. In the model, the batch size of PCB and Arcylite Board is 3 and 2 respectively. On the other hand, batches of entities can be permanently or temporarily grouped. The permanent is selected as the type of the both batch modules as the specified numbers of PCB or Arcylite Board are batched into a single entity permanently. The new entity retains the properties of the last entity to be added to the batch and can't be separated back to its original members.



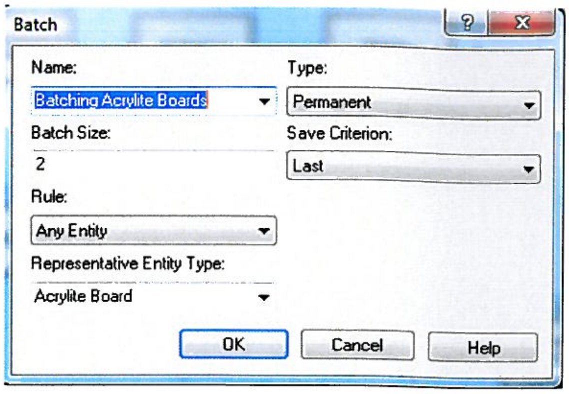


Figure 4.15: Batch modules in the model

Figure 4.16 presents the match module used in the model after the batch module. The match module brings together a specified number of entities waiting in different queues. After batch module is used to form the permanent single representative entity of the PCB and Arcylite Board, the match module is then applied to match the representative entities created by the both batch modules.

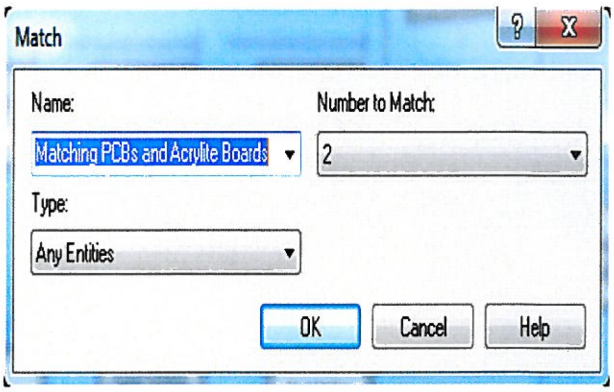


Figure 4.16: Matching module in the model

4.3 MODEL DEVELOPMENT

In this study, ARENA simulation software is used to develop the model of the Functional Test jigs production line in the electronic manufacturing company. Data and statistics information collected from the company are taken and entered into the ARENA menus. Figure 4.17 shows the entire production line of Functional Test jigs which was modeled starting from the customer orders arrive and ending via the ready for shipment. After running the model, the simulation result provided by ARENA are recorded and analyzed. For discrete event simulation model, resource utilization and queue of products are the significant issues to be concerned because they will influence the efficiency of the whole manufacturing process.

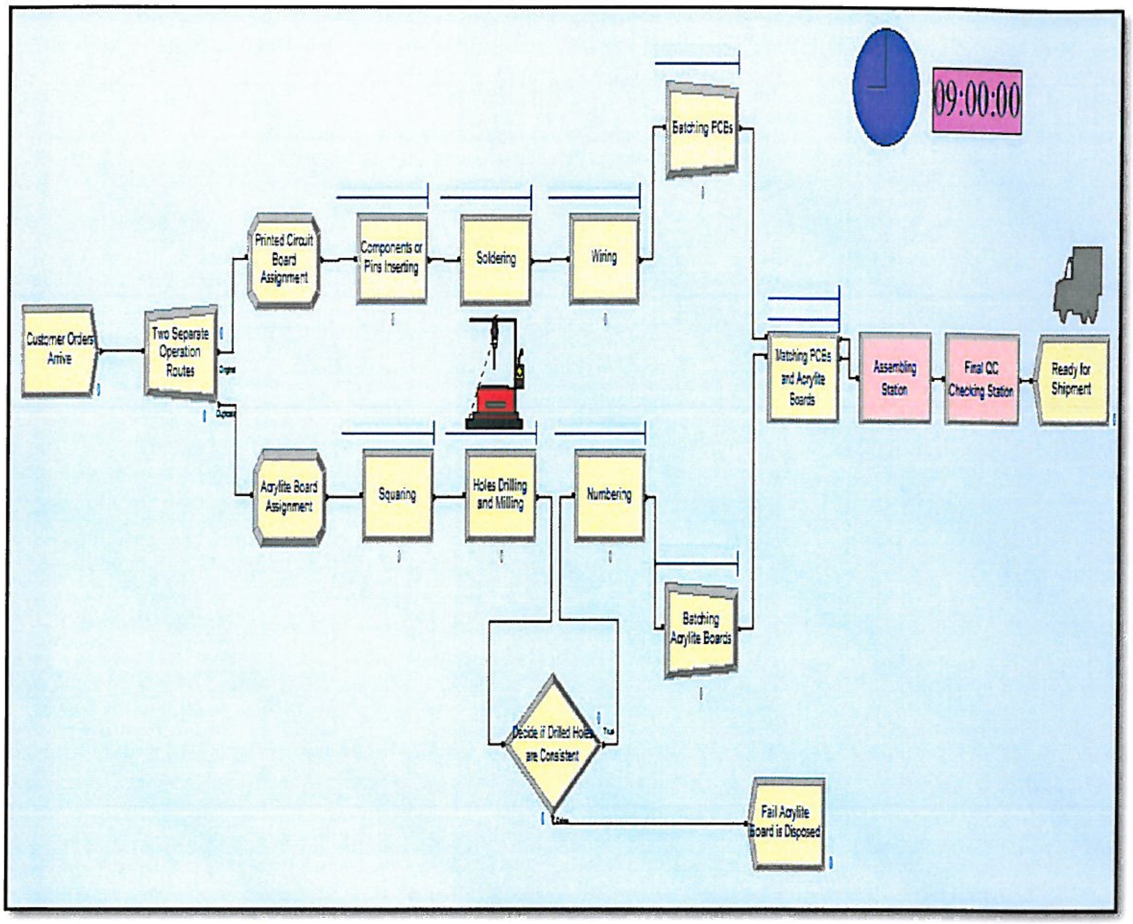


Figure 4.17: Model of Functional Test jigs production line

Figure 4.18 presents six main processes of the Functional Test Jigs production line. PCB operation needs to pass through components/pins inserting, soldering and wiring workstations. Whereas Acrylite Board operation needs to undergo three processes which are squaring, holes drilling/milling and numbering.

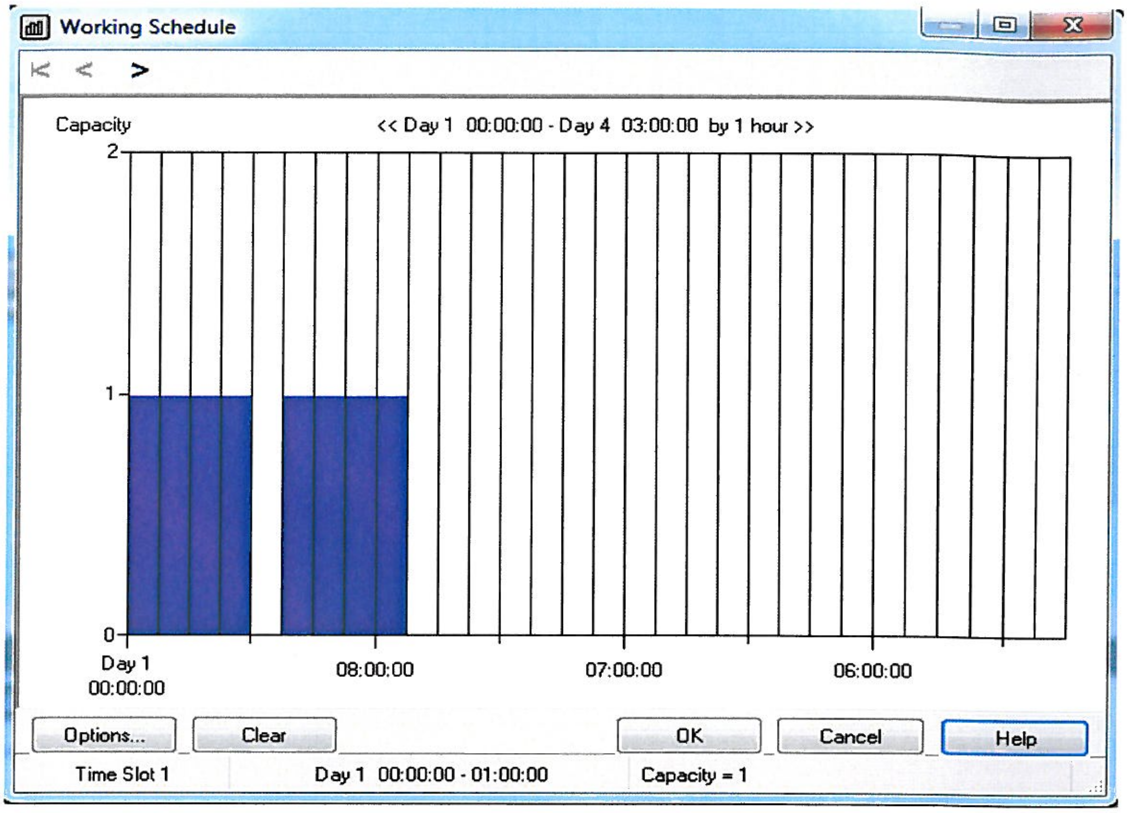
Based on Figure 4.18, all processes are using the same logic action which is Seize Delay Release. Squaring and holes drilling and milling processes have two rows of resources as there are using the machines and operators simultaneously. In addition, delay type for those six processes is the same which is triangular distribution and the value of the three parameters are filled in according to the result displayed by Input Analyzer. The collective data of service times in each process is very important to find out the specific class of distribution and the parameters value.

Process - Basic Process

	Name	Type	Action	Priority	Resources	Delay Type	Units	Allocation	Minimum	Value	Maximum	Report Statistics
1	Components or Pins Inserting	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	23.5	26	29.5	☑
2	Soldering	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	14.5	17	20.5	☑
3	Wiring	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	22	23.2	26	☑
4	Squaring	Standard	Seize Delay Release	Medium(2)	2 rows	Triangular	Minutes	Value Added	13.5	16	19.5	☑
5	Holes Drilling and Milling	Standard	Seize Delay Release	Medium(2)	2 rows	Triangular	Minutes	Value Added	53.5	58	59.5	☑
6	Numbering	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	33.5	35.8	40.5	☑

Figure 4.18: Basic processes of the Functional Test jigs production line

According to working schedule provided by PINHOE Technology, six operators are allocated to handle different workstations in the Functional Test jigs production line. The operation time of the company is start from 9.00 am to 6.00 pm. So, operation hour for each day is 9 hours and one hour break time is given to operators from 1.00 to 2.00 pm. Each workstation consists of only one operator. Thus, the capacity of operator in every process is 1. Figure 4.19 shows a module of operators working schedule for the Functional Test Jig production line model.

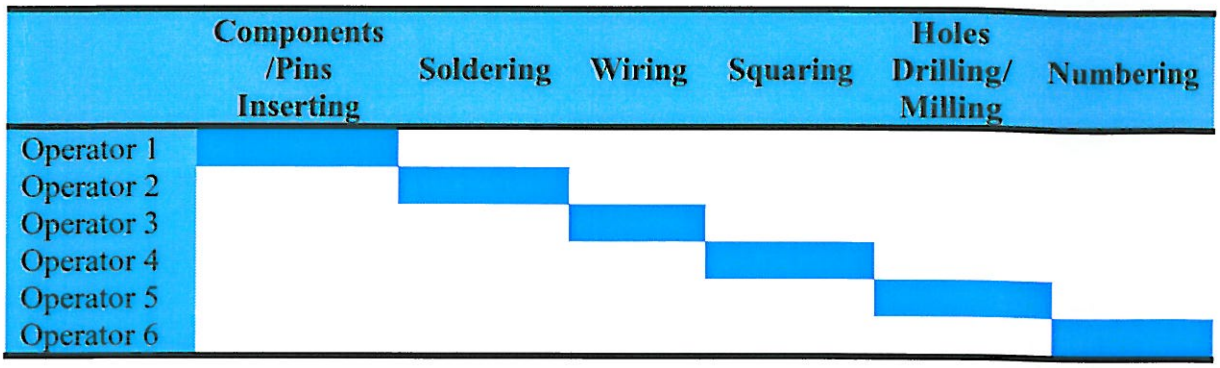


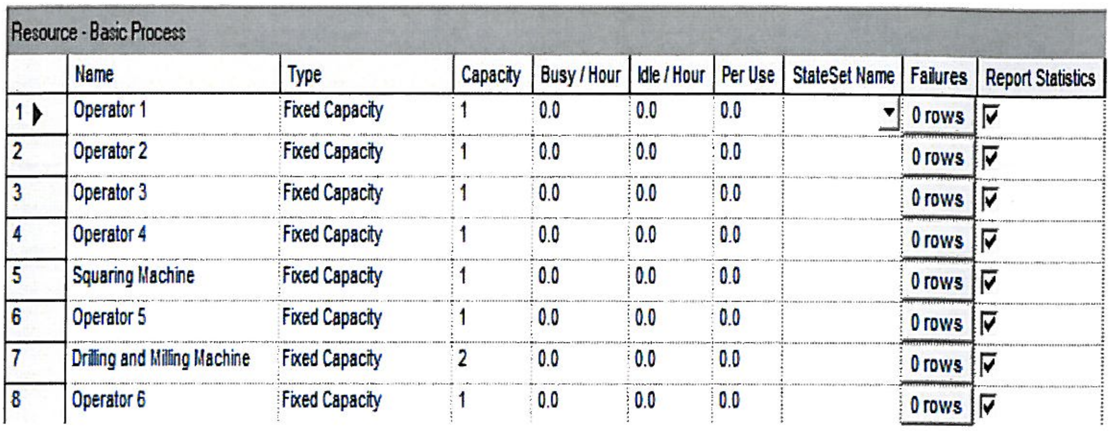
Schedule - Basic Process					
	Name	Type	Time Units	Scale Factor	Durations
1	Working Schedule	Capacity	Hours	1.0	3 rows

Figure 4.19: Operators working schedule module

As mentioned before, there are six operators work in the Functional Test Jigs production line. Table 4.2 exhibits the operators working schedule plan in which each operator is assigned to one particular workstation. On the other hand, two machines are used in the production line which are squaring and drilling/milling machines. Therefore, there are eight resources exist in the model of Functional Test Jig production line as shown in Figure 4.20. The resource of drilling/milling machine shows the capacity of 2 as there are two machines available to be used in the holes milling/drilling process.

Table 4.2: Operators working schedule plan




Resource - Basic Process

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics
1	Operator 1	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
2	Operator 2	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
3	Operator 3	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
4	Operator 4	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
5	Squaring Machine	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
6	Operator 5	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
7	Drilling and Milling Machine	Fixed Capacity	2	0.0	0.0	0.0		0 rows	☑
8	Operator 6	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑

Figure 4.20: Resources module in the model

Run setup menu is used to organize the run conditions of the simulation model. Before starting a simulation run, the replication parameters of the run setup menu must be specified such as the number of replications, replication length and base time units. For the Functional Test Jigs production line model, the number of replications is 10 with the base time units, minutes. Operation hour per day is 9 hours. Every replication begin with time 0 and finish when the process done in 8 hours. After the simulation runs, 10 statistical reports will be obtainable. The replication parameters of the run setup menu were filled as shown in Figure 4.21.

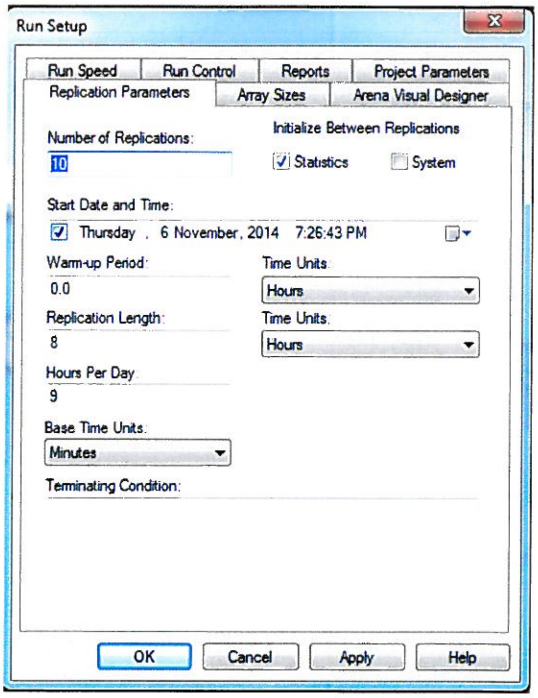


Figure 4.21: Run setup menu in ARENA

4.4 DATA VERIFICATION AND VALIDATION

During the development of a simulation model, verification and validation are carried out in order to produce an accurate and credible model. Verification is known as creating a model correct whereas validation is concerned with creating a correct model. Verification is the process of ensuring a model behaves as its intended purpose or application. On the other hand, validation is to make sure the model developed is no significant variation compared to the actual system.

Ten replications were done for the Functional Test jig production line model to ensure the simulation result reported is truly and precisely. ARENA was provided the statistical result for each replication. Basically, the tenth replication is the final result and will be selected for doing analysis. According to Figure 4.21, initialized statistics is ticked for initialize between replications but not initialized system as the statistics are cleared at the beginning of each replication, but the model status accumulated for each replication.

Through validation, the output statistics will be compared to the company records. It can be easily observed whether the model built is valid when compared to the data collected from company. From the ARENA simulation result, the output of the system is only one unit of the Functional Test jig. According to Mr. Ng, the daily production of Functional Test jigs is also one unit. There is no difference between actual output and simulation output. Thus, the model can be concluded as valid.

Moreover, the input data and simulation model can be verified and validated by check if the computer codes contain any programming errors or known as "bugs". ARENA window displayed as shown in Figure 4.22 when the Functional Test jigs production line model had been checked, so this means the model built does not consists of any errors and can be proceed to the results analysis.

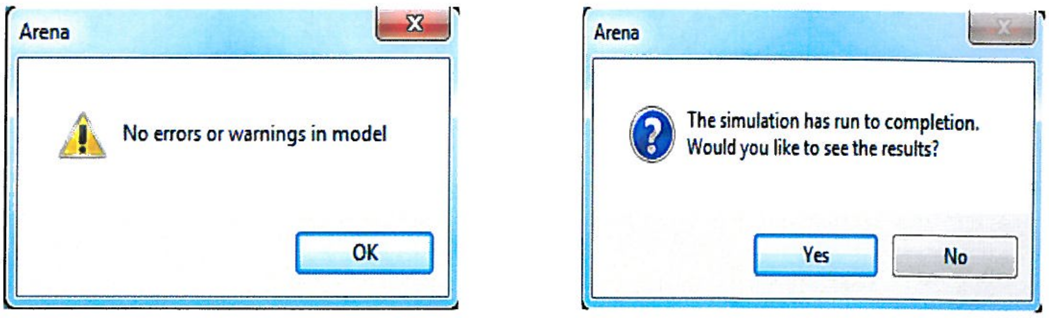


Figure 4.22: Verification and validation of the simulation model

4.5 SIMULATION RESULT ANALYSIS

As stated before, a discrete event simulation is used to model the Functional Test jigs production line in this study. Discrete event is takes place from time to time meanwhile human being control the processes. Therefore, there is potential queue or waiting time occurred at components/pins inserting, soldering, wiring, squaring, holes drilling/milling and numbering processes since those processes are handled by operators.

This study is intended to measure the efficiency of the overall system, to determine the resource utilization and to improve the performance of the system. Therefore, the important factors such as value added time, waiting time, total time, resource utilization, and simulation output summary must be assessed and analyzed. The simulation results are briefly presented as following:

Table 4.3: Average value added time (minutes) per entity

Process	Average	Minimum Average	Maximum Average
Components/Pins Inserting	24.4091	0.00	28.5878
Soldering	15.4220	0.00	18.5389
Wiring	21.3142	0.00	24.8309
Squaring	15.1686	0.00	18.2924
Holes Drilling/Milling	51.7792	0.00	59.2771
Numbering	32.8835	0.00	37.8301

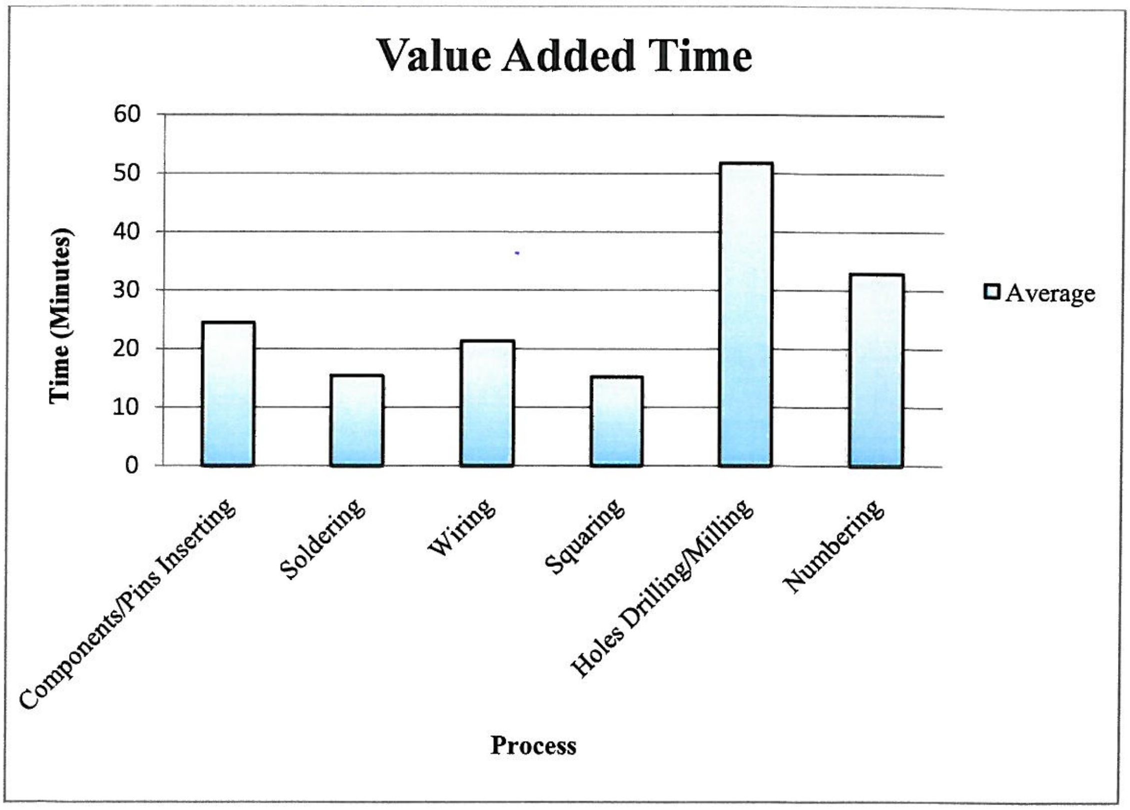


Figure 4.23: Average value added time per entity

Table 4.4: Average accumulated value added time (minutes) per entity

Process	Average	Minimum Average	Half-Width	Maximum Average
Components/Pins Inserting	48.4118	0.00	19.61	81.4275

Soldering	30.8336	0.00	12.60	53.9279
Wiring	42.7926	0.00	17.80	74.4926
Squaring	30.4698	0.00	12.87	52.3333
Holes Drilling/Milling	103.42	0.00	37.47	171.29
Numbering	66.5310	0.00	33.47	150.75

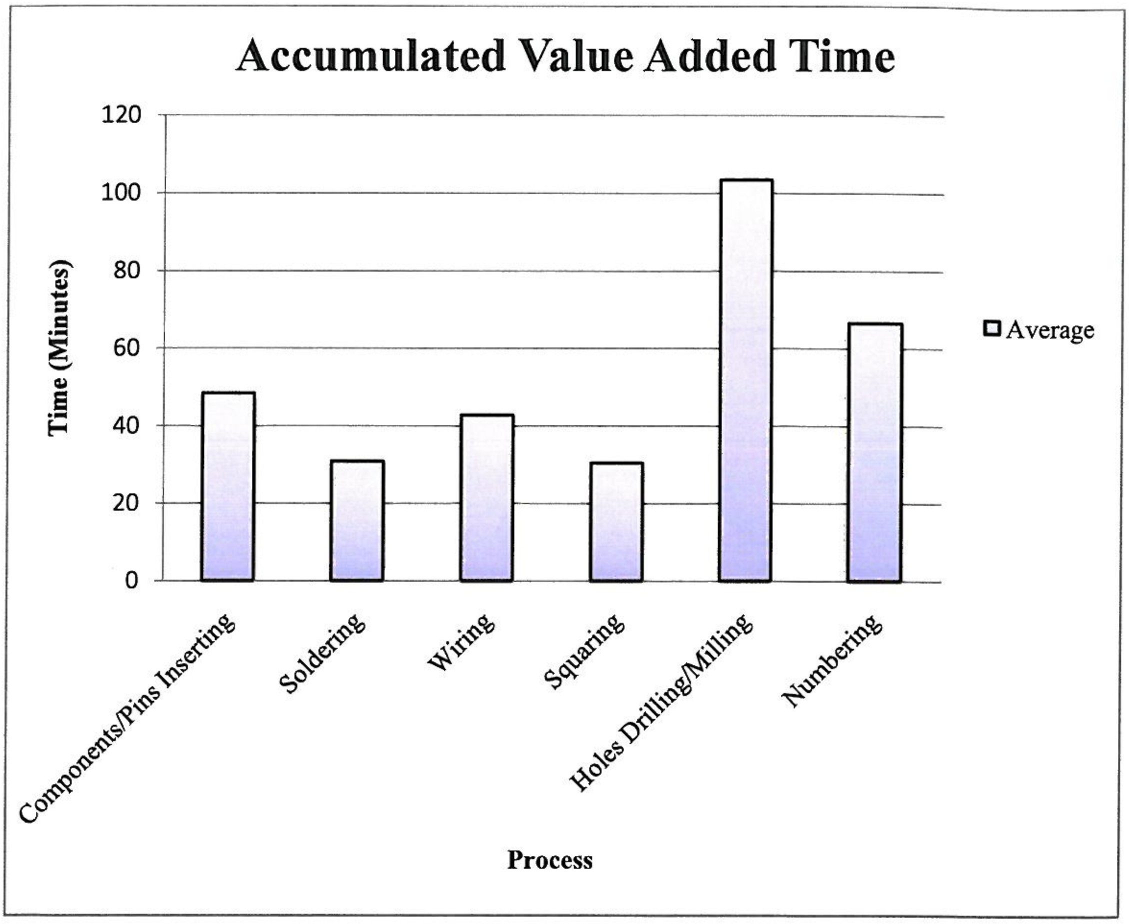


Figure 4.24: Average accumulated value added time per entity

Table 4.5: Average total time (minutes) per entity

Process	Average	Minimum Average	Maximum Average
Components/Pins Inserting	24.8425	0.00	30.9425
Soldering	15.4220	0.00	18.5389
Wiring	21.3142	0.00	24.8309
Squaring	15.2748	0.00	18.5071
Holes Drilling/Milling	56.3092	0.00	78.8223
Numbering	32.8835	0.00	37.8301

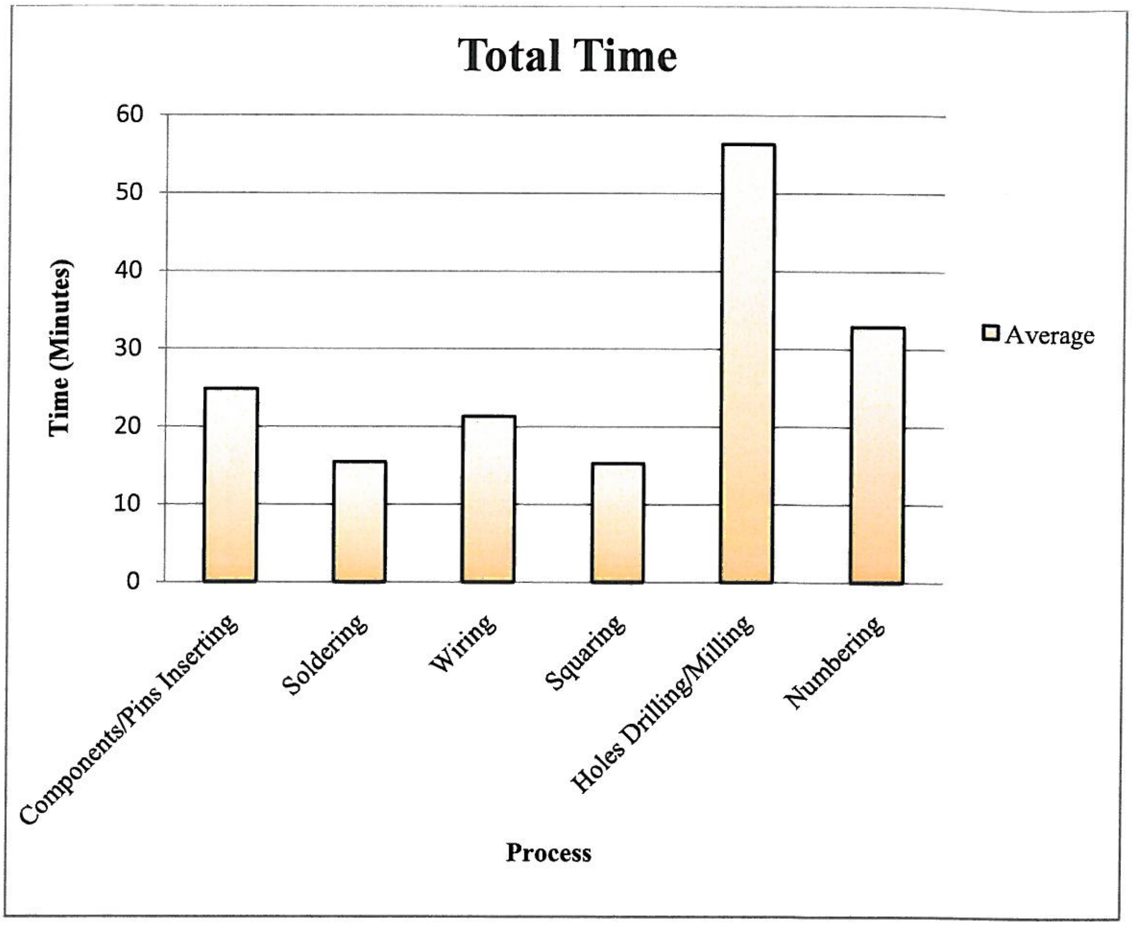


Figure 4.25: Average total time per entity

Bar charts displayed above are representing the simulation results collected from ARENA. Based on the table and figure shown above, the results of the value added per entity and total time per entity are almost the same. Value is added to the entity while processing PCB or Acrylite Board. The holes drilling/milling process took the longest time to process Acrylite Board followed by the numbering process. Processing time of the soldering process and the wiring process are nearly similar. Six processes in the Functional Test jigs production line are all operated and controlled by operators. Therefore, the job performance of the operators will influence the performance of entire operation system. Sometimes, operators will feel fatigue and low energy because people are not robot and can't work as machine.

Table 4.6: Average wait time (minutes) per entity

Process	Average	Minimum Average	Maximum Average
Components/Pins Inserting	0.4333	0.00	4.3333
Soldering	0.00	0.00	0.00
Wiring	0.00	0.00	0.00
Squaring	0.1063	0.00	1.0627
Holes Drilling/Milling	4.5300	0.00	19.5452
Numbering	0.00	0.00	0.00

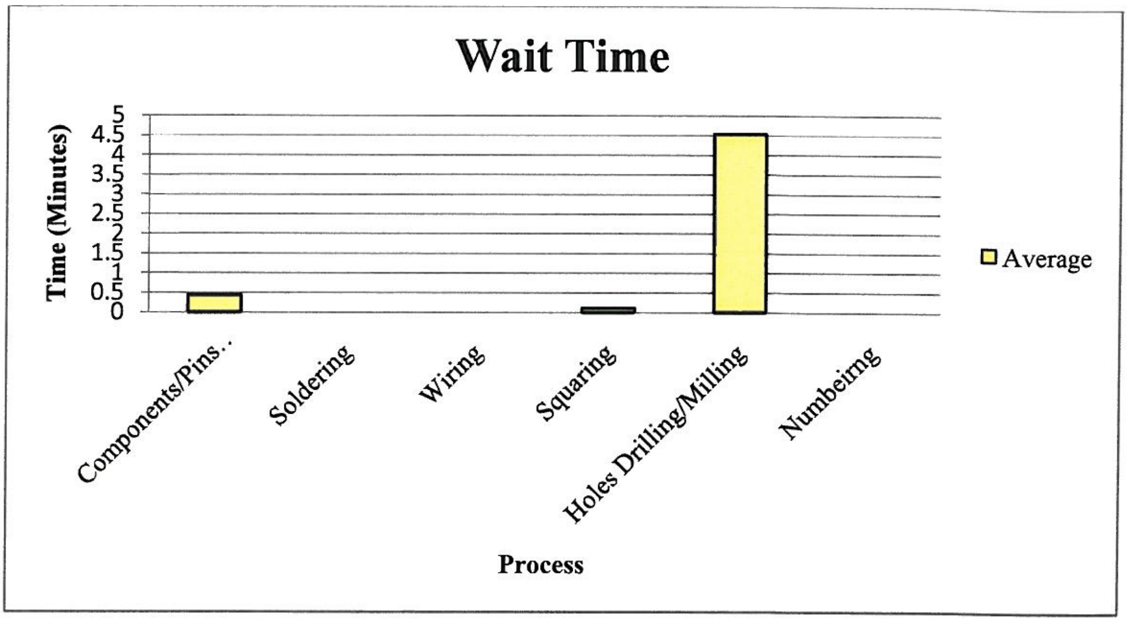


Figure 4.26: Average wait time per entity

Table 4.7: Average accumulated wait time (minutes) per entity

Process	Average	Minimum Average	Half-Width	Maximum Average
Components/Pins Inserting	1.3000	0.00	2.94	12.9999
Soldering	0.00	0.00	0.00	0.00
Wiring	0.00	0.00	0.00	0.00
Squaring	0.3188	0.00	0.72	3.1881
Holes Drilling/Milling	9.5820	0.00	9.89	39.0904
Numbering	0.00	0.00	0.00	0.00

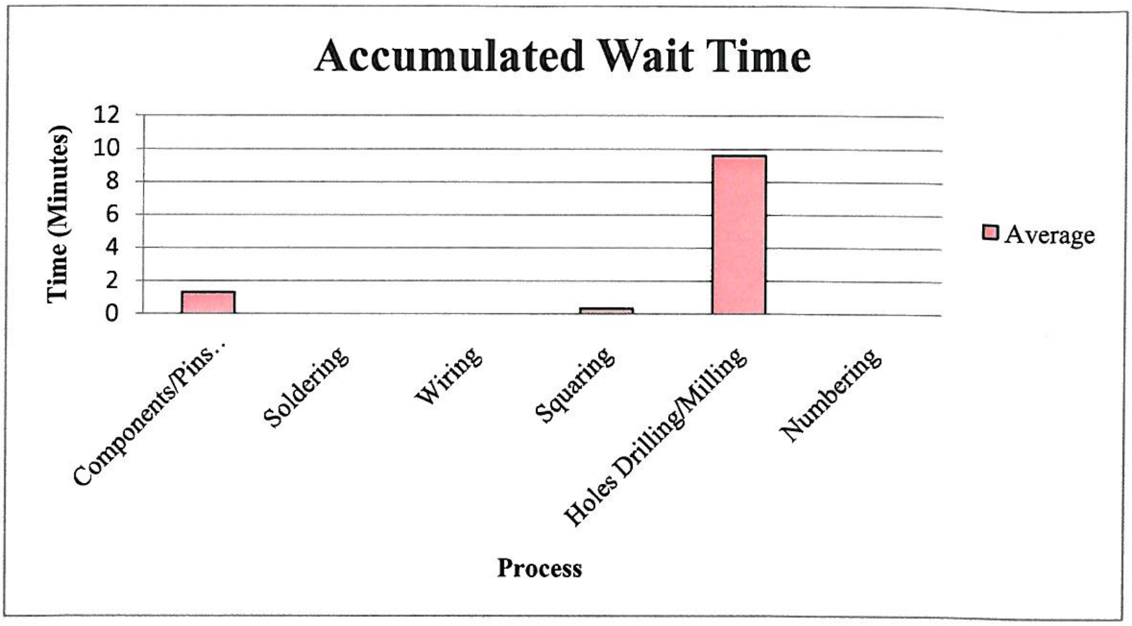


Figure 4.27: Average accumulated wait time per entity

Table 4.8: Average waiting time (minutes) per entity in queue

Queue	Average	Minimum Average	Maximum Average
Components/Pins Inserting. Queue	0.4333	0.00	4.3333
Soldering. Queue	0.00	0.00	0.00
Wiring. Queue	0.00	0.00	0.00
Squaring. Queue	0.1063	0.00	1.0627
Holes Drilling/Milling. Queue	3.8785	0.00	13.0301
Numbering. Queue	0.00	0.00	0.00
Batching PCBs. Queue	187.50	0.00	421.70
Batching Acrylite Boards. Queue	70.6075	0.00	293.34
Matching PCBs and Acrylite Boards. Queue	531.97	0.00	1407.86

Generally, wait time is the time that the entity waiting to proceed to the next workstation. Minimization of the waiting time in each station is preferred to make sure that overall process can flow smoothly and quickly. According to Table 4.6 and Figure 4.25, waiting time at the holes drilling/milling process is the highest which is 4.53 minutes. On the other hand, waiting time at the components/pins inserting and squaring processes is very little, which is only 0.4333 and 0.1063 minutes respectively. This means just small queue will happen at those two processes. Moreover, there are zero queues at the wiring, soldering and numbering processes since the waiting time for those three processes are zero.

Based on Table 4.8, waiting time in the queue of matching PCBs and Acrylite Boards is the highest which is 531.97 minutes followed by the waiting time in the queues of batching PCBs and batching Acrylite Boards which are 187.50 and 70.6075 minutes respectively. This is because the PCBs and Acrylite Boards are place in a queue until the required number is accumulated. After that, the PCBs and Acrylite Boards waiting in different queue are brought together. Therefore, queue time of matching PCBs and Acrylite Boards took the longest time.

Table 4.9: Percentage of resource utilization – Operator utilization

Operator	Average	Percentage	Minimum Average	Half-Width	Maximum Average
Operator 1	0.1019	10.19%	0.0102	0.04	0.1696
Operator 2	0.0642	6.42%	0.00	0.03	0.1123
Operator 3	0.0892	8.92%	0.00	0.04	0.1552
Operator 4	0.0645	6.45%	0.0102	0.03	0.1090
Operator 5	0.2155	21.55%	0.00	0.08	0.3569
Operator 6	0.1386	13.86%	0.0220	0.06	0.3108

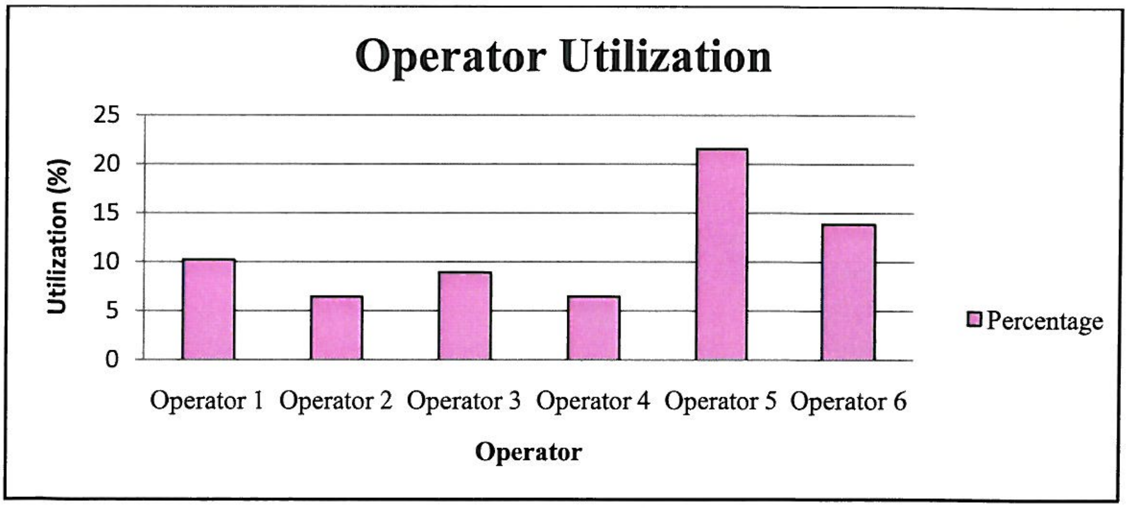


Figure 4.28: Percentage of operator utilization

Table 4.10: Percentage of resource utilization – Machine utilization

Machine	Average	Percentage	Minimum Average	Half-Width	Maximum Average
Squaring Machine	0.0645	6.45%	0.0102	0.03	0.1090
Drilling Milling Machine	0.1077	10.77%	0.00	0.04	0.1784

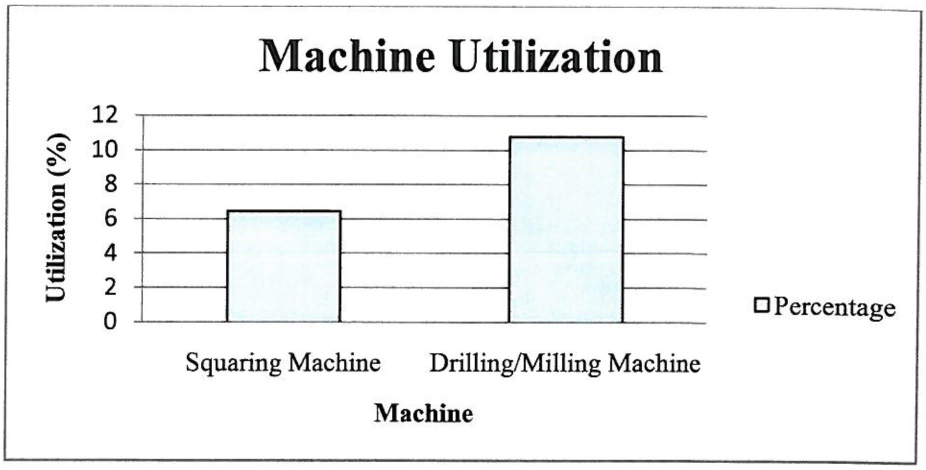


Figure 4.29: Percentage of machine utilization

In this study, one of the significant purposes is to evaluate and maximize the resource utilization. Inappropriate machine layout and weak operator assignment might lead to inefficiency of entire production line process. Utilization can be known as busy or working time of the resources. In the real world situation, it is not easy to fully utilize the resources.

Basically, 60% and above of operator utilization rate is considered good enough. According to Table 4.10 and Figure 4.25, most of the operators are low utilization. The percentage of utilization for operator 5 is the highest but only with the value of 21.55%, whereas rate of utilization of others operator are lower than 20%. It is believed that the low utilization of the operators is stemming from ineffective working schedule. Therefore, changes should be made on the operators working schedule to improve the capacity utilization and minimize the resource idle time.

In addition, machine is another resource for entity. There are only two machines used in the Functional Test jigs production line which are squaring and drilling/milling machines. Based on the Table 4.11 and Figure 4.26, those two machines have the low rates of utilization which are lower than 20%.

Table 4.11: Simulation output summary – Number in

Entity / Process	Average	Minimum Average	Half-Width	Maximum Average
PCB	2.5000	1.0000	0.91	4.0000
Acrylite Board	2.8000	1.0000	0.81	5.0000
Components/Pins Inserting	1.9000	1.0000	0.63	3.0000
Soldering	1.8000	0.00	0.74	3.0000
Wiring	1.8000	0.00	0.74	3.0000
Squaring	1.9000	1.0000	0.63	3.0000
Holes Drilling/Milling	1.8000	0.00	0.74	3.0000
Numbering	1.8000	0.00	0.66	3.0000

Table 4.12: Simulation output summary – Number out

Entity / Process	Average	Minimum Average	Half-Width	Maximum Average
PCB	2.4000	0.00	1.48	4.0000
Acrylite Board	1.8000	0.00	1.11	3.0000
Components/Pins Inserting	1.8000	0.00	0.74	3.0000
Soldering	1.8000	0.00	0.74	3.0000
Wiring	1.8000	0.00	0.74	3.0000
Squaring	1.8000	0.00	0.74	3.0000
Holes Drilling/Milling	1.8000	0.00	0.66	3.0000
Numbering	1.8000	0.00	0.88	4.0000

Table 4.13: Percentage of productivity of each process

Process	Average Number In	Average Number Out	Productivity (%)
Components/Pins Inserting	1.9000	1.8000	94.74
Soldering	1.8000	1.8000	100
Wiring	1.8000	1.8000	100
Squaring	1.9000	1.8000	94.74
Holes Drilling/Milling	1.8000	1.8000	100
Numbering	1.8000	1.8000	100

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} \qquad \textbf{(Eq. 4.2)}$$

Productivity can be defined as a measure of the efficiency of a person, machine, factory, system and so on. Table 4.14 shows the productivity of all processes are high. All of the processes have the percentage of productivity more than 90% and even some are 100%. Although the processes in Functional Test jigs production line have high productivity, but the improvement still can made on the others element to optimize and upgrade the operation system.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

There will be a series of discussion dealing with the model experimentation in this chapter. For this thesis, ARENA simulation software is used to develop the current Functional Test jigs production line model and aid in proposing a better and improved model. In this chapter, What-if analysis and Scenarios analysis will integrate with the simulation model to compare different situations or scenarios and their possible outcomes based on some altering conditions. The simulation results collected from ARENA are analyzed in previous chapter. The analyzed results are reviewed in this chapter to explore the solutions and provide some suggestions to enhance the operation system of Functional Test jigs production line in the electronic manufacturing plant by using Scenarios analysis.

5.2 RESULT DISCUSSION

The steps to model the real system of the Functional Test jigs production line in the electronic manufacturing company is shown in the previous chapter. Moreover, value added time, waiting time, total time, resource utilization, and simulation output summary was analyzed in chapter 4. In chapter 5, the simulation results will be discussed again in order to transmit clearer and unambiguous information to readers. Through the results discussion, problems of the system can be easier discovered.

Firstly, value added time in each workstation will be discussed. As analyzed in the prior chapter, holes drilling/milling workstation took the longest average time in processing an Acrylite Board. According to Mr. Ng, holes drilling/milling process has more workload contrast to other processes, therefore the value added time or total time of this process is longer relative to others. For instance, there are hundreds holes required to drill and mill on an Acrylite Board. Therefore, longer processing time of the holes drilling/milling process occasionally is because of fatigue or tiredness of operators.

In addition, waiting time at the holes drilling and milling process is also the highest based on what was examined in the previous chapter. However, there is little waiting time at others processes and even no waiting time or zero queues exist at the wiring, soldering, numbering processes. In addition, there is long wait time in the queues of batching PCBs, batching Acrylite Boards and Matching PCBs and Acrylite Boards.

On the other hand, there is ineffective resources utilization in the Functional Test jigs production line. Most of the operators in the production line are low utilization. From the Table 4.10 and Figure 4.28 in the chapter 4, it can be seen that operator 5 has the highest utilization rate, but only with the value of 21.55%. Moreover, percentage of utilization of others operator are all lower than 20%. It is assumed that the low utilization of the operators is because of the ineffective working schedule. Hence, some modifications should be applied to the operators working schedule to improve the capacity utilization and efficiency of the whole operation system. In addition, there is another resource exists in the production line which is machine. Based on the Table 4.11 and Figure 4.29 in the previous chapter, squaring machine and drilling/milling machine are performed with a low utilization speed during the production process run.

Lastly, the summary of simulation outputs will be discussed. According to the Table 4.14 in the chapter 4, the productivity rate of all processes involved in Functional Test jigs production line are high which are all with the value more than 90% and even some are 100%. Although these results indicated that productivity of overall system is good enough, but the system still can be optimized by using What-if analysis and Scenarios analysis.

5.3 MODEL EXPERIMENTATION BY USING WHAT-IF ANALYSIS AND SCENARIOS ANALYSIS

In simulation, What-if analysis and Scenarios analysis is very important in performing model experimentation. What-if analysis, or known as sensitivity analysis is a process of modifying one key parameter in the simulation model to observe how sensitive the model is to the modification in that variable. Scenarios analysis refers to the process of performing multiple sensitivity analyses at the same time. Different type of scenarios will be formed and the impacts of the scenarios to the outcomes will be examined through the changes on the current simulation model. The development of scenarios is according to the problems to be solved or projection to be improved and aid in decision analysis. For this study, 2 scenarios will be formed to discuss on the changes in term of the value added time, total time, wait time, resources utilization, and productivity.

5.3.1 *What-if* Altering the Delay Type of Squaring and Holes Drilling/Milling Process to Constant and Reducing the Parameter Value of Holes Drilling/Milling Process to 55 Minutes

Value added time, total time and waiting time at the holes drilling/milling process is obviously longer than others process by evaluating the statistical results of the simulation model. In addition, waiting time in the queues of batching PCBs, batching Acrylite Boards and matching PCBs and Acrylite Boards is quite high.

What-if shifting the delay type of squaring and holes drilling/milling process to constant and reducing the parameter value of holes drilling/milling process to 55 minutes in the process modules as presented in Figure 5.1? The value added time, total time and waiting time at the holes drilling/milling process and queue time in batching PCBs, batching Acrylite Boards and matching PCBs and Acrylite Boards will be reduced? After the modification, the new simulation model is run and the outcomes are compared with the current simulation model as shown in Table 5.1 and 5.2.

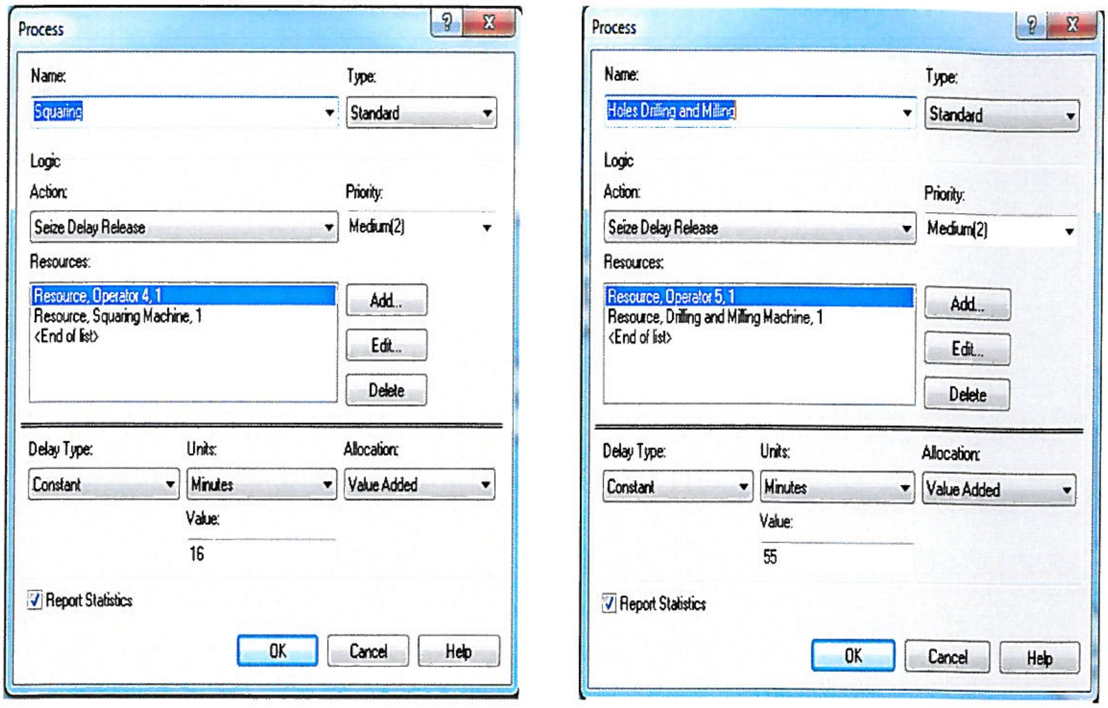


Figure 5.1: Altering the delay type and the value of parameter in the process modules

Table 5.1: Comparison of current and new model results for holes drilling/milling process

	Current Model	New Model
Value Added Time (Minutes)	51.7792	49.5000
Total Time (Minutes)	56.3092	51.7948
Waiting Time (Minutes)	4.5300	2.2948

Table 5.2: Comparison of waiting time (minutes) in queue for current and new model

	Current Model	New Model
Batching PCBs. Queue	187.50	147.94
Batching Acrylite Boards. Queue	70.6075	80.3079
Matching PCBs and Acrylite Boards. Queue	531.97	435.28

Table 5.1 shows value added time, total time and waiting time at the holes drilling/milling process have significant reduction in the new simulation model. Total time at the process is drops from 56.3092 to 51.7948 minutes with approximately 8%. On the other hand, there is also some improvement in waiting time of batching PCBs

queue and matching PCBs and Acrylite Boards queue. The waiting time of matching PCBs and Arcylite Boards queue has reduced from 531.97 to 435.28 minutes with 18.18%.

5.3.2 *What-if* Removing the Operators 2 and 6 and Replacing with the Operators 1 and 4 in the Soldering and Numbering Process Respectively

From the simulation results, majority of the operators in Functional Test jigs production line are low utilization. This implies resources allocation of the company is ineffective. What-if modifying the operators working schedule plan by removing the operators 2 and 6 and replacing with the operators 1 and 4 in the soldering and numbering process module respectively as shown in Figure 5.2? The capacity utilization in Functional Test jigs production line will be improved? The modified operators working schedule plan are presented in table 5.3. After the alteration, the simulation results of the current and new model are compared as shown in table 5.4 and 5.5.

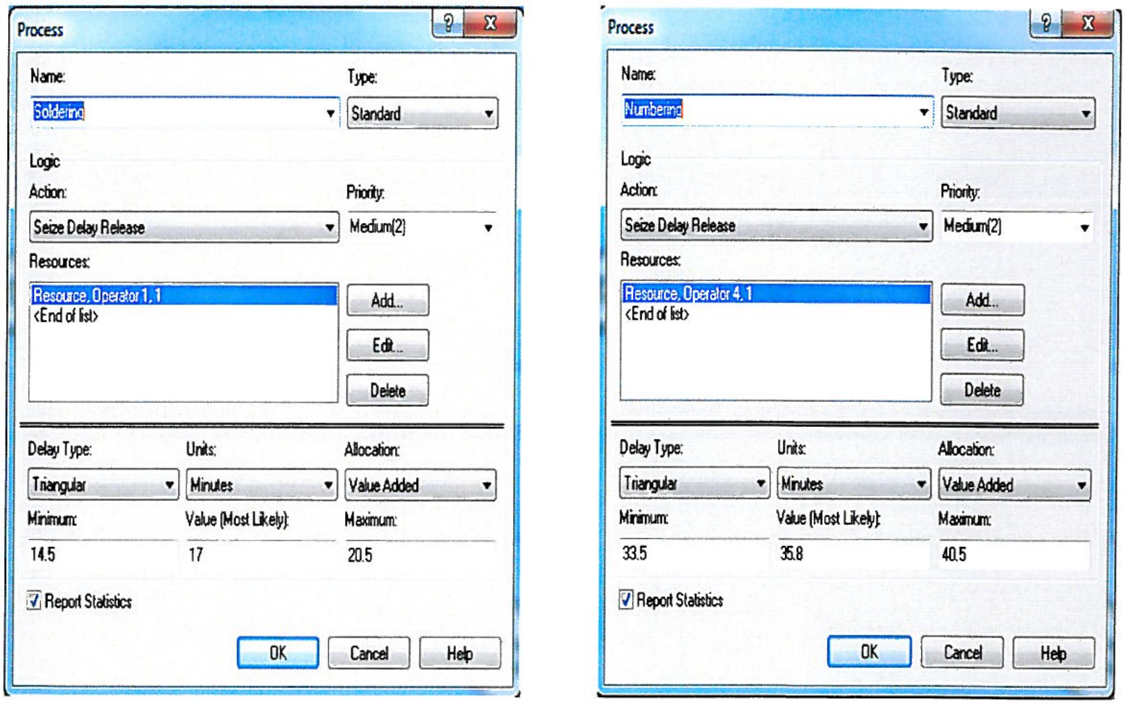


Figure 5.2: Removing and replacing resources in the process modules

Table 5.3: Modified Operators Working Schedule Plan

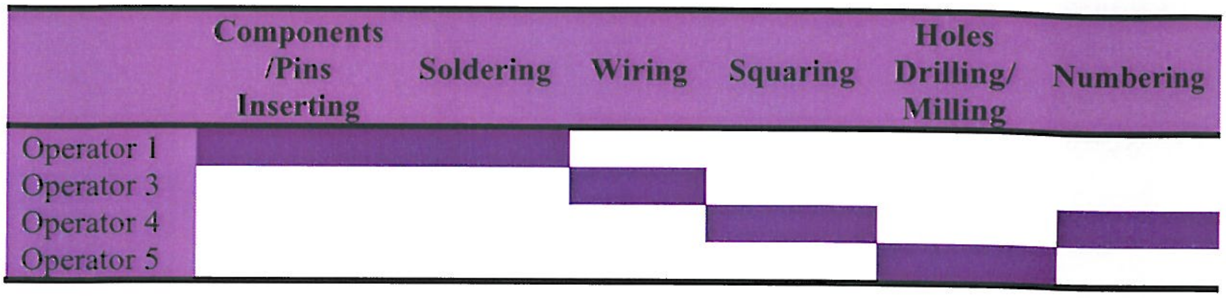


Table 5.4: Comparison of operator utilization for current and new model

	Current Model	**New Model**
Operator 1	10.19%	21.95%
Operator 2	6.42%	Removed
Operator 3	8.92%	12.02%
Operator 4	6.45%	26.56%
Operator 5	21.55%	28.63%
Operator 6	13.86%	Removed

Table 5.5: Comparison of machine utilization for current and new model

	Current Model	**New Model**
Squaring Machine	6.45%	8.35%
Drilling/Milling Machine	10.77%	14.31%

Based on Table 5.3, the percentages of utilization for all the operators are increased and more balancing after the operator 2 and 6 are removed. Both of the operators 1 and 4 are performed two different jobs in two different workstations. The utilization rate of operator 1 and operator 4 are increased to 21.95% and 26.56% respectively. On the other hand, the percentages of machines utilization also have slightly improved. The utilization rate of squaring machine is enhanced from 6.45% to 8.35%, whereas the percentage of drilling/milling machine utilization is increased from 10.77% to 14.31%.

5.3.3 *What-if* Adding One More Holes Drilling/Milling Workstation and Machine, and Assigning Operator 4 to be in Charge of the New Workstation

As what was mentioned before, the value added time, total time and waiting time at the holes drilling/milling process and queue time in batching PCBs, batching Acrylite Boards and matching PCBs and Acrylite Boards are somewhat high. In addition, most of the operators in Functional Test jigs production line are in low utilization. What-if adding one more holes drilling/milling workstation and machine, and assigning operator 4 to be in charge of the new workstation as displayed in Figure 5.3? In this case, the value added time, total time and waiting time of all processes in the production line and queue time in batching and matching will be enhanced? Moreover, resources utilization in the production line will be improved? The altered operators working schedule plan are shown in Table 5.6. After the change, the new simulation statistical results are shown and compared with the current model in Table 5.7, 5.8, 5.9, 5.10 and 5.11.

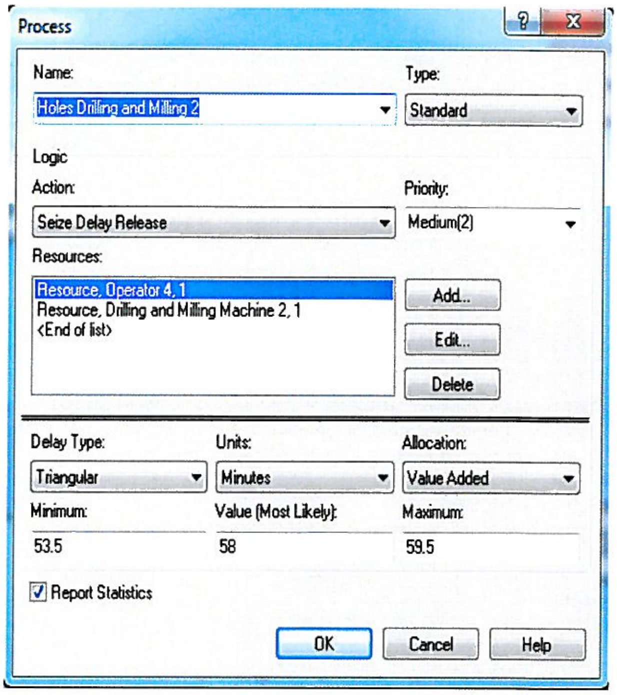


Figure 5.3: Adding new holes drilling/milling workstation and resources in the process module

Table 5.6: Altered Operators Working Schedule Plan

	Components /Pins Inserting	Soldering	Wiring	Squaring	Holes Drilling/ Milling	Holes Drilling/ Milling 2	Numbering
Operator 1							
Operator 2							
Operator 3							
Operator 4							
Operator 5							
Operator 6							

Table 5.7: Comparison of value added time for current and new model

	Value Added Time (Minutes)	
Process	**Current Model**	**New Model**
Components/Pins Inserting	24.4091	18.9088
Soldering	15.4220	11.9576
Wiring	21.3142	16.6444
Squaring	15.1686	11.6448
Holes Drilling/Milling	51.7792	22.9002
Holes Drilling/Milling 2	None	39.3872
Numbering	32.8835	29.1848

Table 5.8: Comparison of total time for current and new model

	Total Time (Minutes)	
Process	**Current Model**	**New Model**
Components/Pins Inserting	24.8425	19.2014
Soldering	15.4220	11.9576
Wiring	21.3142	16.6444
Squaring	15.2748	13.8357
Holes Drilling/Milling	56.3092	22.9002
Holes Drilling/Milling 2	None	39.8861
Numbering	32.8835	32.6441

Table 5.9: Comparison of waiting time for current and new model

	Waiting Time (Minutes)	
Process	**Current Model**	**New Model**
Components/Pins Inserting	0.4333	0.2927
Soldering	0.00	0.00
Wiring	0.00	0.00
Squaring	0.1063	2.1909
Holes Drilling/Milling	4.5300	0.00
Holes Drilling/Milling 2	None	0.4989
Numbering	0.00	3.4593

Table 5.10: Comparison of waiting time in queue for current and new model

	Waiting Time (Minutes)	
Queue	**Current Model**	**New Model**
Components/Pins Inserting. Queue	0.4333	0.2927
Soldering. Queue	0.00	0.00
Wiring. Queue	0.00	0.00
Squaring. Queue	0.1063	2.1909
Holes Drilling/Milling. Queue	3.8785	0.00
Holes Drilling/Miliing 2. Queue	None	0.4989
Numbering. Queue	0.00	1.0176
Batching PCBs. Queue	187.50	67.6176
Batching Acrylite Boards. Queue	70.6075	51.6042
Matching PCBs and Acrylite Boards. Queue	531.97	256.43

Table 5.11: Comparison of resources utilization rate for current and new model

	Utilization	
Resource	**Current Model**	**New Model**
Operator 1	10.19%	10.09%
Operator 2	6.42%	6.42%
Operator 3	8.92%	8.42%
Operator 4	6.45%	20.93%
Operator 5	21.55%	5.98%
Operator 6	13.86%	12.85%
Squaring Machine	6.45%	6.23%
Drilling/Milling Machine	10.77%	2.99%
Drilling/Milling Machine 2	None	14.70%

Table 5.7 presents the comparison of value added time for the current and new model. After added a new holes drilling/milling workstation, overall value added times

at the processes are reduced and become more balancing. On the other hand, overall total times at the processes are also decreased obviously as shown in Table 5.8. In addition, waiting time at the first holes drilling/milling workstation is shrinks from 4.53 to 0 minutes, whereas the waiting time at the new holes drilling/milling workstation is 0.4989 minutes. However, there is a bit increase of waiting times at other processes as exhibited in Table 5.9.

Table 5.10 shows that waiting times in queues of batching PCBs, batching Acrylite Boards, matching PCBs and Acrylite Boards are also have great reduction. Moreover, as shown in Table 5.11, the utilization rate of operator 4 is increased obviously from 6.45% to 20.93%, whereas the percentage of utilization of the new drilling/milling machine is 14.70%.

5.3.4 Scenario 1: Changing the Delay Type of Squaring and Holes Drilling/Milling Process to Constant and Reducing the Parameter Value of Holes Drilling/Milling Process to 55 Minutes & Removing the Operators 2 and 6 and Replacing with the Operators 1 and 4 in the Soldering and Numbering Process Respectively

Scenario 1 is the condition of changing the delay type of squaring and holes drilling/milling process to constant then reducing the parameter value of holes drilling/milling process to 55 minutes and removing the operators 2 and 6 and replacing with the operators 1 and 4 in the soldering and numbering process respectively. Ten replications are run to examine the final model and the outcomes will be compared with the current model. In Scenario 1, what will happen to the performance of the Functional Test jigs production line model? The answer can be found through the new simulation statistical results reported by ARENA as shown in the tables below. However, the feature of the final model is remained same with the previous model as the alterations only applied to parameters of modules.

Table 5.12: Comparison of value added time between current and final model

Process	Value Added Time (Minutes)	
	Current Model	Final Model
Components/Pins Inserting	24.4091	24.4448
Soldering	15.4220	15.6838
Wiring	21.3142	21.3926
Squaring	15.1686	14.4000
Holes Drilling/Milling	51.7792	49.5000
Numbering	32.8835	32.8708

Table 5.13: Comparison of total time between current and final model

Process	Total Time (Minutes)	
	Current Model	Final Model
Components/Pins Inserting	24.8425	25.3600
Soldering	15.4220	18.0253
Wiring	21.3142	21.7276
Squaring	15.2748	16.5770
Holes Drilling/Milling	56.3092	51.7948
Numbering	32.8835	32.8708

Table 5.14: Comparison of waiting time between current and final model

Process	Waiting Time (Minutes)	
	Current Model	Final Model
Components/Pins Inserting	0.4333	0.9152
Soldering	0.00	2.3415
Wiring	0.00	0.3350
Squaring	0.1063	2.1770
Holes Drilling/Milling	4.5300	2.2948
Numbering	0.00	0.00

Table 5.15: Comparison of waiting time in queue between current and final model

Queue	Waiting Time (Minutes)	
	Current Model	Final Model
Components/Pins Inserting. Queue	0.4333	0.9152
Soldering. Queue	0.00	2.3415
Wiring. Queue	0.00	0.3350
Squaring. Queue	0.1063	2.1770
Holes Drilling/Milling. Queue	3.8785	2.2948
Numbering. Queue	0.00	0.00

Batching PCBs. Queue	187.50	148.81
Batching Acrylite Boards. Queue	70.6075	90.8016
Matching PCBs and Acrylite Boards. Queue	531.97	387.98

Table 5.12 exhibits the comparison of value added time between the current and final model. The value added times at the squaring, holes drilling/milling and numbering processes are decreased. On the other hand, total time at the holes drilling/milling process has obvious reduction as presented in Table 5.13. In addition, waiting time at the holes drilling/milling process is also shrinks from 4.53 to 2.2948 minutes. Although waiting times at other processes have a bit increase, but overall waiting times are become more balancing with all the waiting times are not more than 3 minutes as displayed in Table 5.14. Table 5.15 shows the waiting times in queues of batching PCBs and matching PCBs and Acrylite Boards are also have significant reduction. The queue time in matching PCBs and Acrylite Boards are declined from 531.97 to 387.98 minutes.

Table 5.16: Comparison of resources utilization rate between current and final model

	Utilization	
Resource	**Current Model**	**Final Model**
Operator 1	10.19%	16.62%
Operator 2	6.42%	Removed
Operator 3	8.92%	8.90%
Operator 4	6.45%	18.21%
Operator 5	21.55%	20.63%
Operator 6	13.86%	Removed
Squaring Machine	6.45%	6.00%
Drilling/Milling Machine	10.77%	10.31%

As what was discussed in the result discussion section, most of the operators in Functional Test jigs production line are in low utilization. However, there are some modifications made to the current model and the comparison of operators and machines utilization rate between current and final model are presented in Table 5.16. In the final model, the operator 2 and operator 6 are removed and replacing with the operator 1 and 4 in the soldering and numbering processes, therefore the percentage of utilization of the operator 1 and 4 shows the obvious increment. The utilization rate of operator 1 is increased from 10.19% to 16.62%, whereas the utilization rate of operator 4 is raised from 6.45% to 18.21%.

Table 5.17: Comparison of productivity rate between current and final model

	Productivity	
Process	**Current Model**	**Final Model**
Components/Pins Inserting	94.74%	100%
Soldering	100%	100%
Wiring	100%	100%
Squaring	94.74%	100%
Holes Drilling/Milling	100%	100%
Numbering	100%	100%

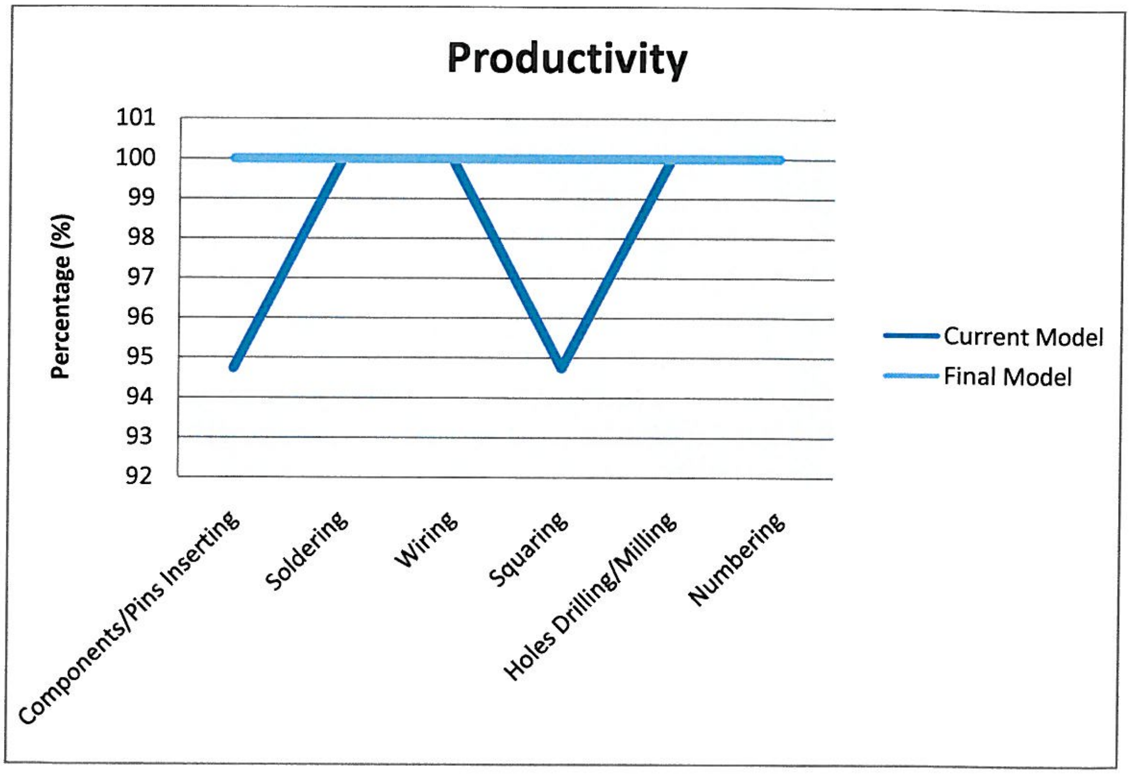


Figure 5.4: Comparison of productivity between current and final model

Table 5.17 and Figure 5.4 show the comparison of productivity rate between the current and final model. In the current model, all the processes in Functional Test jigs production line have high productivity. Yet, the productivity rates of all the processes in the final model are 100%. Therefore, the final model is succeeding to optimize overall productivity of the operation processes.

5.3.5 Scenario 2: Changing the Delay Type of Squaring and Holes Drilling/Milling Process to Constant and Reducing the Parameters Value of Holes Drilling/Milling Process to 55 Minutes & Adding One More Holes Drilling/Milling Workstation and Machine, and Assigning Operator 4 to be in Charge of the New Workstation

Scenario 2 is the condition of changing the delay type of squaring and holes drilling/milling process to constant then reducing the parameter value of holes drilling/milling process to 55 minutes and adding one more holes drilling/milling workstation and machine then assigning operator 4 to handle the new workstation. In Scenario 2, what will happen to the performance of the Functional Test jigs production line model? The answer can be found through the new outcomes provided by ARENA after the simulation runs as shown in the tables below. Moreover, the simulation results of Scenario 2 will be compared with the current model and Scenario 1. A new feature model is built and shown in Figure 5.5.

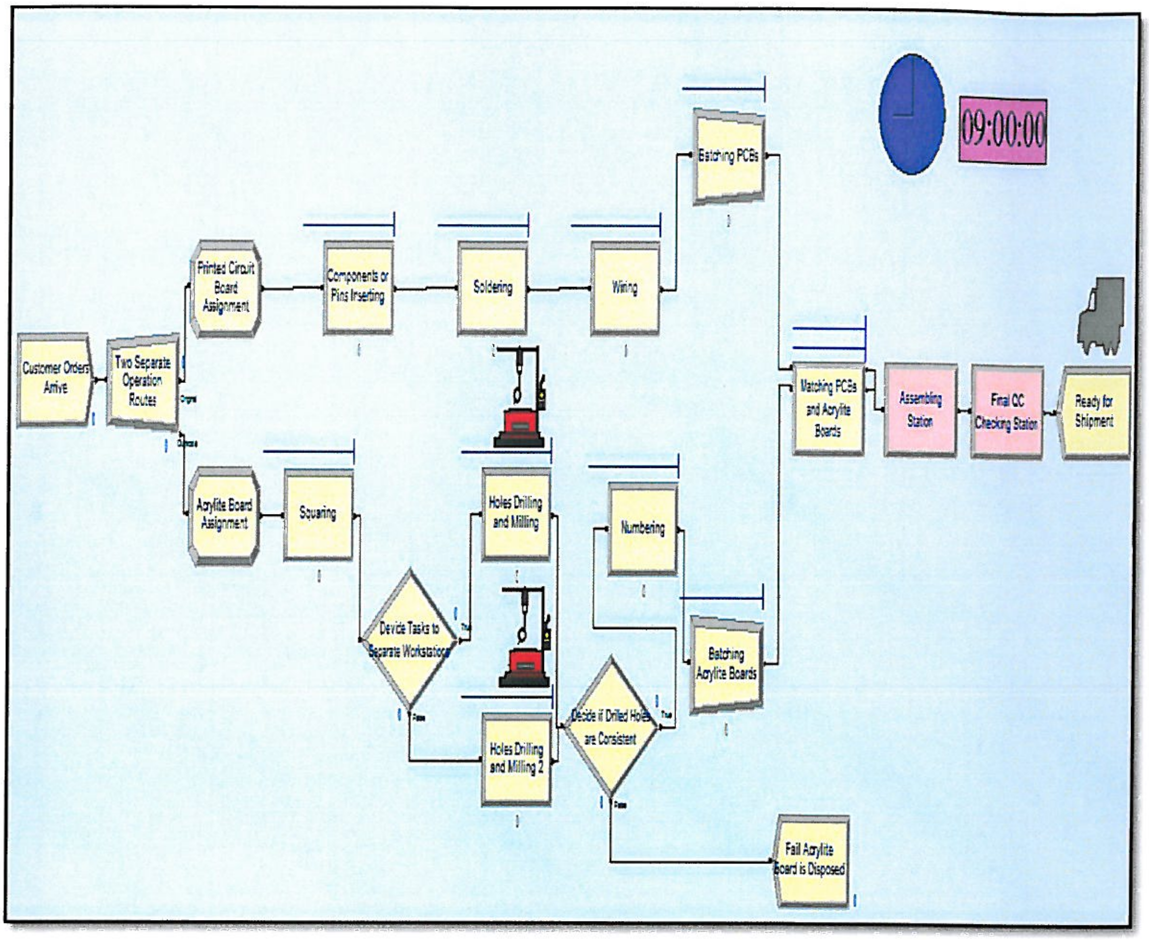


Figure 5.5: Final model (Scenario 2)

Table 5.18: Comparison of value added time

	Value Added Time (Minutes)		
Process	**Current Model**	**Scenario 1**	**Scenario 2**
Components/Pins Inserting	24.4091	24.4448	16.0960
Soldering	15.4220	15.6838	10.5080
Wiring	21.3142	21.3926	16.3763
Squaring	15.1686	14.4000	9.6000
Holes Drilling/Milling	51.7792	49.5000	16.5000
Holes Drilling/Milling 2	None	None	38.5000
Numbering	32.8835	32.8708	26.0829

Table 5.19: Comparison of total time

Process	Total Time (Minutes)		
	Current Model	**Scenario 1**	**Scenario 2**
Components/Pins Inserting	24.8425	25.3600	16.0960
Soldering	15.4220	18.0253	10.5080
Wiring	21.3142	21.7276	16.3763
Squaring	15.2748	16.5770	11.5384
Holes Drilling/Milling	56.3092	51.7948	16.5000
Holes Drilling/Milling 2	None	None	38.5000
Numbering	32.8835	32.8708	26.0829

Table 5.20: Comparison of waiting time

Process	Waiting Time (Minutes)		
	Current Model	**Scenario 1**	**Scenario 2**
Components/Pins Inserting	0.4333	0.9152	0.00
Soldering	0.00	2.3415	0.00
Wiring	0.00	0.3350	0.00
Squaring	0.1063	2.1770	1.9384
Holes Drilling/Milling	4.5300	2.2948	0.00
Holes Drilling/Milling 2	None	None	0.00
Numbering	0.00	0.00	0.00

Table 5.21: Comparison of waiting time in queue

Queue	Waiting Time (Minutes)		
	Current Model	**Scenario 1**	**Scenario 2**
Components/Pins Inserting. Queue	0.4333	0.9152	0.00
Soldering. Queue	0.00	2.3415	0.00
Wiring. Queue	0.00	0.3350	0.00
Squaring. Queue	0.1063	2.1770	1.9384
Holes Drilling/Milling. Queue	3.8785	2.2948	0.00
Holes Drilling/Milling 2. Queue	None	None	0.00
Numbering. Queue	0.00	0.00	0.00
Batching PCBs. Queue	187.50	148.81	172.38
Batching Acrylite Boards. Queue	70.6075	90.8016	50.6505
Matching PCBs and Acrylite Boards. Queue	531.97	387.98	269.62

Table 5.18 presents the comparison of value added time for the current model, Scenario 1 and Scenario 2. Statistical results show that overall value added times of the

Scenario 2 are the smallest. On the other hand, overall total times and waiting times of Scenario 2 are also the least as shown in Table 5.19 and 5.20 respectively. Table 5.21 displays the waiting times in queues of batching PCBs, batching Acrylite Boards, and matching PCBs and Acrylite Boards also have obvious reduction when compared with the current model. The queue time in matching PCBs and Acrylite Boards are shrinks from 531.97 to 269.62 minutes.

Table 5.22: Comparison of resources utilization rate

		Utilization	
Resource	**Current Model**	**Scenario 1**	**Scenario 2**
Operator 1	10.19%	16.62%	7.22%
Operator 2	6.42%	Removed	4.69%
Operator 3	8.92%	8.90%	6.35%
Operator 4	6.45%	18.21%	14.65%
Operator 5	21.55%	20.63%	4.58%
Operator 6	13.86%	Removed	9.35%
Squaring Machine	6.45%	6.00%	4.33%
Drilling/Milling Machine	10.77%	10.31%	2.29%
Drilling/Milling Machine 2	None	None	10.31%

As what was discussed before, there is low utilization of resources in the current Functional Test jigs production line. Therefore, some changes were made to the model and the comparison of resources utilization rate for current model, Scenario 1 and Scenario 2 are presented in Table 5.22. For the Scenario 2, new holes drilling/milling workstation and machine were added, and operator 4 was allocated to handle the new workstation. Therefore, operator 4 performed two different tasks in two separate workstations which are squaring and new holes drilling/milling stations. The percentage of utilization of the new drilling/milling machine and operator 4 shows the significant increment. However, there is reduction in utilization rate of other resources.

Table 5.23: Comparison of productivity rate

		Productivity	
Process	**Current Model**	**Scenario 1**	**Scenario 2**
Components/Pins Inserting	94.74%	100%	100%
Soldering	100%	100%	100%
Wiring	100%	100%	100%

Squaring	94.74%	100%	100%
Holes Drilling/Milling	100%	100%	100%
Holes Drilling/Milling 2	None	None	100%
Numbering	100%	100%	100%

Table 5.23 show the comparison of productivity rate for current model, Scenario 1 and Scenario 2. In the current model, the productivity rates of all operation processes in Functional Test jigs production line are good enough. However, the productivity rates of all the processes in the Scenarios 1 and 2 are 100%. According to overall results, Scenario 2 is the best solution to improve the current operation system.

5.4 RECOMMENDATION

In the Functional Test jigs production line, there are six main processes to processing the PCB and Acrylite Board which are components/pins inserting, soldering, wiring, squaring, holes drilling/milling, and numbering. Most of the processes are controlling by operators. There are only two machines used in the production line which are squaring and drilling/milling machines. Through analyzing on the Functional Test jigs production line using ARENA simulation software, there are some problems happened on the model such as lengthy waiting times in the queues and low utilization of operators. Yet, the productivity rate of all processes in the production line is good enough.

Firstly, I came with a proposition to choose constant as the delay type of squaring and holes drilling/milling process and the parameter value of holes drilling/milling process can be replaced with 55 minutes. To ensure the processing times at the squaring and holes drilling/milling workstations are constant, the company is suggested to allocate skilled and experienced operators to control the machines at those two processes. Skilled and experienced operators are more familiar with the machines and their jobs, so they are capable to operate the machine well. The processing time can be minimized and become more constant. On the other hand, skilled operators will decrease the failures or mistakes occurred in squaring or holes drilling/milling process. This will smooth the production system and avoid the unwanted waste of materials and times.

On the other hand, I recommended the PINHOE Technology to downsize the quantity of the employees in the company and modify the operators working schedule plan. In the soldering and numbering process, the operator 2 and operator 6 can be dismissed and replaced with the operator 1 and operator 4 respectively. In this case, operator 1 and operator 4 are performed two different duties in two different workstations. Operators 1 will in-charge the tasks at components/pins inserting and soldering process, whereas operator 4 will take over the works at squaring and numbering process. By this way, the utilization of operators was improved; the company will save costs in paying salaries to the operator 2 and 6 and the savings can be applied to others use.

In addition, I also suggested the PINHOE Technology to add a new holes drilling/milling workstation and machine, and assigned operator 4 to control the new workstation. In this case, operator 4 will handle two different tasks at two separate workstations which are squaring and new holes drilling/milling workstations. By this way, overall value added times and total times of operation processes in the production line were reduced obviously and utilization rates of operator 4 and new drilling/milling machine were also improved. In addition, the risks of entire production system stopped due to machine breakdown can also be reduced.

Nowadays, most of the companies are looking for ways to enhance their operation system. This study can assist companies to solve their difficulties in the production line. Simulation is a powerful technique to study the production system. It can be used to solve any complex industrial problems. Hence, this study is worth to carry out.

5.5 CONCLUSION

Efficiency of production line is very important for industries as it results in a superior production performance. In this study, a Functional Test jigs production line in an electronic manufacturing company is modeled by simulation and been discussed. Simulation is a very helpful method to solve the industrial troubles as it can imitate any manufacturing system in industries and allowing users to explore the root causes quickly and easily. In addition, users can also resolve their problems by carry out the model experimentation, a try and error manner to discover the greatest way.

After strived in learning ARENA simulation software and study on the operation processes in the study target plant for two semesters, I had achieved all of the objectives of this study. The model of Functional Test jigs production line in PINHOE Technology had been created by using ARENA, performance of the current operation system been evaluated and analyzed in the chapter 4 and lastly the current operation system been improved by using What-if analysis and Scenarios analysis. This study will be projected to the company director, Mr. Ng and he will decide whether to apply these alterations to his electronic manufacturing plant which called PINHOE Technology Sdn. Bhd.

For this study, I recommended the company to assign skilled and experienced operators to control the squaring and drilling/milling machines and added a new workstation for holes drilling/milling process as what was mentioned in Scenario 2 section. By this way, overall value added times, total times and waiting times in queues were reduced according to the simulation statistical results. On the other hand, these changes also contribute to the improvement of productivity of operation processes in the production line.

Studying the industries problems by using simulation is costing less since the experiments are carried out on the model in simulation software; there is no interrupting to any production process in the actual production line. Hence, simulation is very encouraged to learn and use in doing the industrial research.

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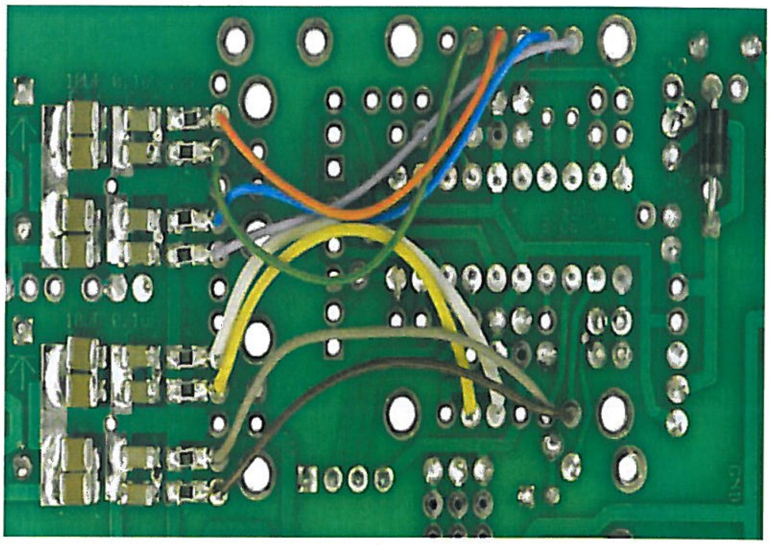
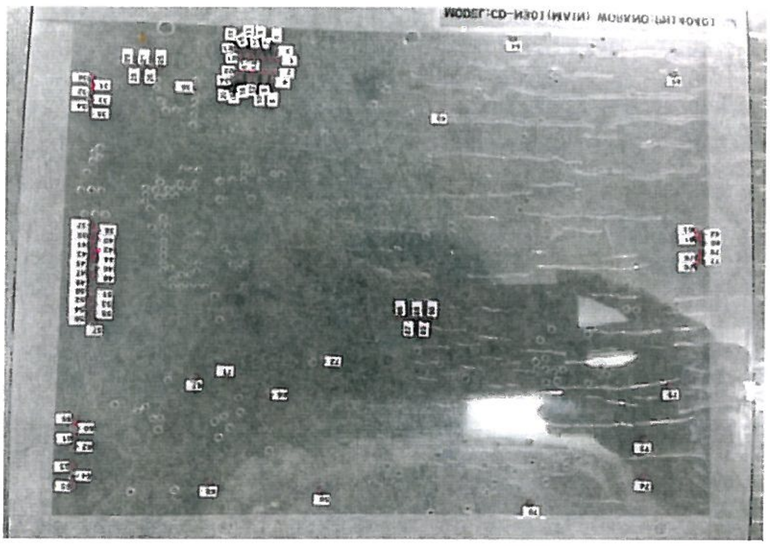
APPENDIX A

Images of Finished PCB, Acrylite Board and Functional Test Jig, Drilling/Milling Machine and Solder



Finished PCB



Finished Acrylite Board

APPENDIX A (Continued)

Finished Functional Test Jig

Drilling/Milling Machine

Solder

APPENDIX B

Gantt Charts of FYP 1 and FYP 2

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Preliminary Information Gathering	■													
Identify Problem		■												
Propose Research Title and Objectives			■											
Approval of Research Title and Objectives				■										
Start Doing Chapter 1				■	■									
Chapter 1 Complete					■									
Review Journals					■									
Start Doing Chapter 2						■	■							
Chapter 2 Complete							■							
Install Arena Software							■							
Start Doing Chapter 3								■	■					
Chapter 3 Complete									■					
Edit and Finalize FYP 1 Report										■	■			
Submit FYP 1 Report												■		
Prepare Presentation Slides												■	■	
FYP 1 Presentation														■

FYP 1 Gantt Chart

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Visit the Company	■													
Collect Data from the Company	■	■	■											
Develop the Simulation Model		■	■	■										
Start Doing Chapter 4					■	■	■							
Chapter 4 Complete							■							
Start Doing Chapter 5								■	■					
Chapter 5 Complete									■					
Edit and Finalize FYP 2 Report										■				
Submit FYP Full Report and Poster											■			
Prepare for Presentation												■	■	
FYP 2 Presentation													■	
Submit Corrected Report														■

FYP 2 Gantt Chart