

**MODELLING AND SIMULATION OF FLEXIBLE  
PRODUCTION LINE FOR  
COIL WINDING ASSEMBLY**

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MODELLING AND SIMULATION OF FLEXIBLE PRODUCTION LINE  
FOR COIL WINDING ASSEMBLY

HAZIMAH BINTI ABDUL RAHIM

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

Faculty of Manufacturing Engineering  
UNIVERSITI MALAYSIA PAHANG

JUNE 2015

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## **DEDICATION**

I dedicated this thesis for my late father and beloved mother,

**ABDUL RAHIM BIN ABDUL RAHMAN**

**HATIJAH BINTI AHMAD**



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## ABSTRACT

This thesis deals with modelling and simulation of flexible production line for coil winding assembly. Flexible production line is a production line capable to change any changes in different product simultaneously and continuously. The reason need of developing flexible production line is to have a high productivity, good quality and low cost and to ensure smoothness of the production line. The main problem at production line is the usage of the conveyer where it can make the space become crowded. The proposed method is by changing to cell manufacturing layout because it is way of lean manufacturing to guide company to implement less waste as possible for product variety to the customers. The objective of this project is to investigate current performance of coil winding assembly and to model and simulate flexible production line using Pro Model simulation software. In this case study, the framework of project will cover on research of cycle time, product mix, flexibility and efficient usage of space. A company has been selected is Vacuumschmelze(M) Sdn Bhd and simulation ProModel 7.0 Software Student Version was used to complete the case. The project is begin by identifying and evaluating the problem occur at the production line. The current condition of production line layout was modelled using simulation ProModel 7.0 Software Student Version. The simulation was run in 8 hours by following the working schedule at company. A total of 10 replication has been set for this project. From the result, the percentage show high utilization from the current performance. The percentage of operation is increase from 9.29% to 63.27%. From the result, it can be concluded that the changing of the new layout by changing the conveyer to the U-shape layout was the most significant factor in productivity enhancement of the production.

## ABSTRAK

Tesis ini membincangkan pemodelan dan simulasi barisan pengeluaran fleksibel untuk pemasangan gegelung penggulungan. Pengeluaran fleksibel ialah barisan pengeluaran yang mampu untuk mengubah perubahan dalam produk yang berbeza pada masa yang sama dan berterusan. Faktor keperluan membangunkan pengeluaran fleksibel adalah untuk mempunyai produktiviti yang tinggi, kualiti yang baik dan kos rendah dan memastikan kelancaran barisan pengeluaran. Dalam kajian kes ini, rangka kerja projek akan meliputi penyelidikan masa kitaran, pelbagai produk, fleksibiliti dan keberkesanan penggunaan ruang. Masalah utama di barisan pengeluaran adalah penggunaan konveyer di mana ia boleh membuat ruang menjadi sesak. Kaedah yang dicadangkan adalah dengan mengubah kepada sel susun atur pembuatan kerana ia adalah cara pengurusan (lean) untuk membimbing syarikat dalam melaksanakan sekurang yang mungkin untuk variasi produk kepada pelanggan. Objektif projek ini adalah untuk menyiasat keadaan semasa pemasangan gegelung penggulungan dan membuat pemodelan dan simulasi pengeluaran fleksibel menggunakan perisian ProModel. Berdasarkan tajuk projek, syarikat telah dipilih iaitu Vacuumschmelze (M) Sdn Bhd dan simulasi ProModel 7.0 Perisian Pelajar Versi telah digunakan untuk menyelesaikan kes itu. Projek ini bermula dengan mengenal pasti dan menilai masalah yang berlaku pada barisan pengeluaran. Keadaan semasa susun atur barisan pengeluaran telah dimodelkan menggunakan simulasi ProModel 7.0 Perisian Pelajar Version. Simulasi yang telah dijalankan selama 8 jam dengan mengikuti jadual kerja di syarikat. Sebanyak 10 replikasi telah ditetapkan untuk projek ini. Daripada keputusan itu, peratusan menunjukkan penggunaan tinggi daripada prestasi semasa. Peratusan operasi adalah peningkatan daripada 9.29% kepada 63.27%. Dari penilaian, dapat disimpulkan bahawa perubahan susun atur yang baru dengan menukar konveyer kepada susun atur bentuk U adalah faktor yang paling penting dalam meningkatkan produktiviti pengeluaran.

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**LIST OF ABBREVIATIONS**

FYP	Final Year Project
WIP	Work in Progress/Work in Process
MNC	Multi National Company

**LIST OF SYMBOLS**

$\bar{x}, \mu$	Mean
$\sigma$	Standard deviation
$\Sigma$	Sum/ Total
$hw$	Half-width

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 INTRODUCTION**

This chapter describes more on modeling and simulation of flexible production line for coil winding assembly and the importance of flexible production line in the industry. In addition, the background of company, project background, objective and scope of the study including in this section.

#### **1.2 BACKGROUND STUDY**

In this rapid development, the area of flexibility can be considered as the main issue for surviving today's demand which can be described as high productivity, shorter lead times, good quality, low cost and continuous evolution of the technological requirement of the product. The greater number variation of new models, fluctuation in the market demand refers as some problem need to face on the flexibility system. Even flexibility can be identify as a crucial strategic option which must consider as the competitiveness of a firm can be strongly affected by the burden of capital intensive investment in flexibility system. For that reason, there is the need of viewing flexibility system in the global image trying to consider both pros and cons related to the acquisition of flexibility.



### 1.3 PROBLEM STATEMENT

With the faster development of modern industry, the scale of the production became more expanding and it is proposed higher requirement for the process and production management system. Flexibility refer to ease physically rearrange the cell. It is necessary of production manufacturing system have to be flexible to adapt more faster to an increasing number and variety product and changing market volumes. The ideal condition is the flexible production line can be cater in term of volume fluctuation and product mix.

However, the concepts of classical assembly line are difficult to control utilization when producing part with different processing at same line. (Krajewaski *et al.*, 2010). This is support by the current condition at Vacuumschmelze (M) Sdn Bhd. The problem involve of conveyer usage. So that, it will give an impact to the spaces of the production line where can increase the work in progress (WIP) and bottleneck

In order to develop competitive organization, the production system must along with to be lean and flexible to achieve constant development. As the proposed solution to this project, cell manufacturing layout will be applied. This is supported by journal from Ogan & Azizoglu (2015), the need for higher productivity with greater flexibility has advocated the need for the U-shaped lines. The method approach in this case by using ProModel simulation software. According to the Villarreal & Alanis (2011), the uses of simulator such as ProModel, Witness and others have facilitated enormously the application of simulation to the design, improvement and validation of system in a wide area of knowledge.

## 1.4 OBJECTIVE

The objectives of this study are stated as below:

1. To investigate current performance of coil winding assembly.
2. To model and simulate the flexible production line using ProModel Software.

## 1.5 PROJECT SCOPE

The scope of project is mainly about on modeling and simulates the real production process. The research will be conducted in manufacturing company focused on Multinational Company (MNC) in Malaysia context. The project was conducted at Vacuumschmelze (M) Sdn Bhd. This company located at Lot 3465, Tanah Putih, 26600 Pekan Pahang. Basically, Vacuumschmelze is a leading global manufacturer of advanced material and related products. The early beginning of Vacuumschmelze (M) Sdn Bhd is transferring labor – intensive manufacturing processes to more cost effective countries. Since 1980's, VAC maintained the production facilities in Asia. Nowadays, VAC becomes well established in production network in Europe and Asia, which is optimized and best-suited for each product group. Generally, this company produced mixed model product at the production line. The variation of the model is depending on scheduling and demands from customer. The straight line layout was used and apply conveyer. The coil winding model was investigated in this project are 6161-X037 and 6161-X001 and ProModel 7.0 Student version was used in running the simulation



**Figure 1.1:** Vacuumschmelze (M) Sdn Bhd

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

This section presents on literature review of flexible production line in producing coil by using simulation study. The explanation was started by elaborate on the definition of flexible production system and flexible production line. Other than that, modeling and simulation using ProModel were described including the advantages and disadvantages.

#### **2.2 FLEXIBLE PRODUCTION SYSTEM**

In the fastest development of market framework, the demand from customer and more specific of product changes very fast, so it is crucial for a manufacturing system to carry on the changes as faster as possible to be able face the opposition in the market. From the effect of the shorter product life cycles and the arising of the product variety, the manufacturing industry faces biggest challenges in concerning the satisfaction of the customer demand. Due to the growing dynamic and variation in demand modern production systems have to be lean and flexible in order to strengthen the company's competitive position (Metternich, Böllhoff, Seifermann, & Beck, 2013). Flexible production system informs that the requirement from custom-made products is currently in main point. The expenditure of the ability must not design for the flexible and expandable manufacturing system to accomplish the efficient cost in large scale of production. From this it can able to exclude equal cycle times while support a smoothly running process. It can be achieve by an appropriate operations stepping onto specific

configuration of work stations and a control system which can monitor in good configurability of systems and distribution.

### **2.2.1 Production Line**

Production line is a series of arranged workstations where the product moves from one station to the next, and at each location a part of the total work is performed on it (Groover, 2010). The term production line is used to describe systems for discrete manufacturing and includes all of the equipment required for an independent segment of production on discrete objects. The examples include segments that assemble, package, fill, or test products as they move through the production line. There is often storage before and after production lines used to buffer material due to different rates of production. Major production lines are made up of work cells, which correspond to locations where specifically identified operations are performed on products.

Basically there are two main types of production line. The first type of production line is where every product is identical. While the second type of production line is the mixed-model production line. This type of production line applies to the situations where there is soft variety in the product made on the line (Rakiman & Bon, 2013). A production line layout can be considered to be a common and very efficient way to manufacture a product. Generally, the industry need or required flexibility in response and also a high quality standard which need to have led to the rapid development of automated flexible machines. These machines are able to perform in sequence of different operations which are commonly combined in automated flexible production line as a replacement for traditional manual or hard automation based on workstations.(Kalir & Arzi, 1998).

### **2.2.2 Flexibility**

Flexibility is defined as ‘capable of responding or conforming to changing or new situations’ based on Webster’s Dictionary. It also can be refer as to ease of physically rearranging the cell. The term flexibility also meets the meaning of the potential of producing variety of parts out of use of major retooling. The scope includes the converting process from making the old lines of output to new outputs. Besides that, the flexibility meets the ability to alternate part or multiple parts and transforms a production schedule. In the area of manufacturing system, there are several definitions for flexibility which includes; parts flexibility, volume flexibility and mix flexibility (Gerwin, 1982).

- i. Parts flexibility: Used to add parts and remove parts from the mix over time.
- ii. Volume flexibility: Ability to change the volume level and conduct shifts in volume of given part to ensure profits and minimal interruptions.
- iii. Mix flexibility: It can be process at any time that associates or combine various parts which are almost related to each other that belong to the same family

## **2.3 ASSEMBLY LINE**

The assembly line can be referring as manufacturing process where which interchangeable parts are added to a product in a sequential manner to create an end product. Normally the assembly line made can be classified as semi-automated system through which a product moves. At each station along the line some part of the production process takes place. The workers and machinery used to produce the item are stationary along the line and the product moves through the cycle, from start to finish. The traditional assembly line concepts struggle to maintain high utilization when producing components with high variances in processing times at the same line.(Greschke, Schönemann, Thiede, & Herrmann, 2014).

### **2.3.1 Mixed Model Assembly Line**

The mixed-model assembly lines are a manual production line capable of producing a variety of different product model simultaneously or continuously. Each workstation specializes in a certain set of assembly work elements, but the stations are sufficiently flexible that they can perform their respective task on different models. It can allow the simultaneous assembly of a set of products on a single assembly line. The vary models of products could be parts of a base product or constitute a special package of products, so inherently their assembly process is somehow similar and assembly models mostly differ in performance times. (Ramezani & Ezzatpanah, 2015).

## **2.4 PLANT LAYOUT**

Basically with the capital-intensive nature of manufacturing systems, plant layout is important to the smooth flow of product and movement of resources through the facility. A good layout results in a streamlined flow with minimal movement and thus minimizes material handling and storage costs. In deciding which layout to use will depend largely on the variety and lot size part produced that are produced. If the variety of parts is similar enough in processing requirement to allow grouping into part families, a cell layout is best.

### **2.4.1 Cell Manufacturing Approach**

Cell manufacturing can be refer as a way of lean manufacturing to guide company in implement as less waste as possible for product variety to the customers. The arrangement of equipment and workstation is arranged in sequence which can ensure the material flow with minimum transport or delay and component part going smoothness in their process. In this stage, recognize and understand the present condition to identify the process need to convert. Firstly is collecting the data of mixed model, production resources, process time, takt time and standard work combination worksheet. In this stage for mixed choose what are the process needs to be converted to a cell. It will make easier if the company produce few type of product in relatively large

volume. A large volume process will give more on advantage from the improvement and low variety will keep away on issues such as changeover. Normally the production resources need to be taken. It will involve gathering the information in production resources to analyze the mixed product such shift day, hours per shift; break time, work days/month, employee to the operation ratio, product volume in monthly which required from customer, approach for assigning work and finished goods inventory turns per months.

The processing time is necessary by examine the time elements which involve in production by doing the time observation. The first task will observe by measuring the cycle time for each machine operation in the process. The task will include writes the tasks for one complete machine cycle on the left side of a Time Observation Sheet. The example task will take in cycle is loading and unloading, opening and closing machine guards, and other human and machine actions. The time required for each task during cycles and finds the average of cycle time. The next process is identifying the sample of process lead time for the total process. Finally identify the value-added ratio. This can be refer as the time spent actually in machining or working on the product divided by the total process lead times.

Next, process capacity used to calculate the units operation can be produce in given time for example shift or day. From here, we can see the walking time each activity. The takt time is rate at which each product needs to be completed to meet daily customer requirements the need to be determine for the process. It can be done by divide the work time in daily by the required quantity daily. The units expressed in second or minutes per units. For the final step, prepare Standard Work Combination Sheet for each operation in the process. The sheet is a graphic display of the relationship between manual work time, machine work time, and walking time for each step in an operation.

$$\text{Takt time} = \frac{\text{Daily Work Time}}{\text{Daily Required Quantity}} \quad (1)$$

## 2.5 MODELLING AND SIMULATION

Generally, simulation, modeling and analysis of manufacturing systems to improve the performance have become increasingly important during the last few decades. Simulation has been used for decades as a tool to support decision making in manufacturing systems. It is far cheaper and faster to build a virtual system and experiment with different scenarios and decisions before actually implementing the system. Simulation has been widely used to support decisions in both manufacturing systems design and operation (Seleim, Azab, & AlGeddawy, 2012). Simulation is the imitation of a dynamic system using a computer model in order to evaluate and improve system performance. Modern computer aided simulation and modeling tools help to visualize, analyze and optimize complex production processes using computer animations within a reasonable amount of time and investment (Sandanayake, Oduoza, & Proverbs, 2008). In this project, the ProModel 7.0 student version was used to simulate the flexible production line. Basically, ProModel simulation software is a simulation and animation tool designed to quickly yet accurately model manufacturing systems of all types, particularly supply chains systems.

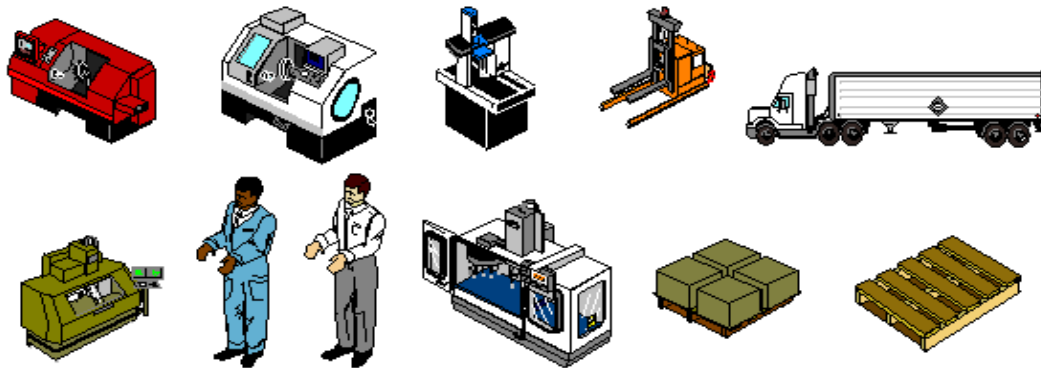
### 2.5.1 Building a Model

ProModel is a powerful, easy to use, commercial simulation package which designed to effectively model any discrete-event processing system. A model can be explained in ProModel using simple graphical tools; data entry tables, and fill in the blank dialog boxes. It consist of entities (the item being processed), locations (the place where processing occurs), resources (agents used to process and move entities and move traverse), and path (aisle and pathways along which entities and resources traverse). Dialogs are associated with each of these modeling elements for defining operational behavior such as entity arrivals and processing logic. Schedules, downtimes and other attributes can also be defined for entities, resources, and locations.

The elements of the system are defined graphically in ProModel (See figure 2.1). A graphic representing a location, for example, is placed on the layout to create a new location in the model. Some information can be input in this location such as name, capacity, etc. Default values are provided to help simplify this process. Defining objects



graphically provides a highly intuitive and visual approach to model building. The use of graphics is optional, and a model can even be defined without using any graphics.



**Figure 2.1:** Some element of ProModel graphic objects

In addition to graphic objects are provided by the modeling software, import capability is available to bring in graphic from other packages. It will include complete facility layouts created using CAD software such as AutoCAD.

### 2.5.2 Running the Simulation

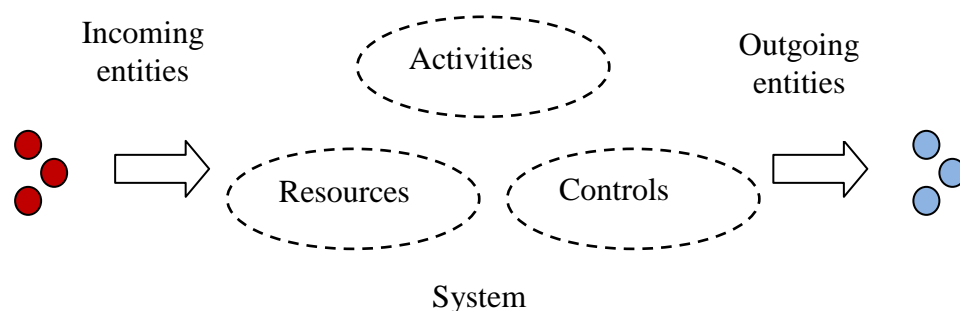
When running a model created in ProModel, the model database is translated or compiled to create the simulation database. The animation in ProModel is displayed concurrently with the simulation. Animation graphics are classified as either static or dynamic. Static graphic include walls, aisles, machines, screen text, and others. Static graphic provide the background against which the animation takes place. The background might be CAD layout imported into the model. The dynamic animation objects that move around on the background during the simulation include entities (parts, customers, etc.) and resources (man, fork trucks, etc.). Animation also includes dynamically updated counters, indicators, gauges, and graphs that display count, status, and statistical information.

### 2.5.3 Output Analysis

The output processor in ProModel provides both summary and detailed statistics on key performance measure. Simulation results are presented in the form of reports, plots, histogram, pie charts, etc. Output data analysis capabilities such as confidence interval estimation are provided for more precisely. The output from the multiple replications and multiple scenarios can be also showing multiple scenario output side-by-side make the result much easier to interpret. The summary report show totals, averages and other overall values of interest

### 2.5.4 System Elements

In simulation perspective, a system consists of entities, resources, activities, and controls as shown in Figure 2.2. By knowing this element, it can inform us on what, who, where, when, and how the entity is process.



**Figure 2.2:** System Elements

### 2.5.5 Entities

The term entities is refer to the items processed through the system such as a product, customer and documents. The different entities may have unique characteristics such as shape, condition, quality or cost. It can be subdivided into several types which are human or animate (e.g; customer), inanimate parts (e.g; parts), and intangible (e.g; call).

### **2.5.6 Resources**

Resources can be defined as activities performed. It will include facilities, equipment, and personnel for carrying out activities. It facilitates the entity processing, inadequate resources can constrain processing by limiting the rate at which processing can take place. Resources have characteristics such as capacity, speed, cycle time, and reliability. It can be subdivided into several types which are human or animate (e.g. operator), inanimate parts (e.g. tooling), and intangible (e.g. information).

### **2.5.7 Activities**

The activities are a job or tasks which performed in the system that are either directly or indirectly involved in processing of entities. The activities usually cover on time consuming and involve the use of resources. It can be classified as are human or animate (e.g. cutting), inanimate parts (e.g. forklift travel), and intangible (e.g. machine setups).

### **2.5.8 Controls**

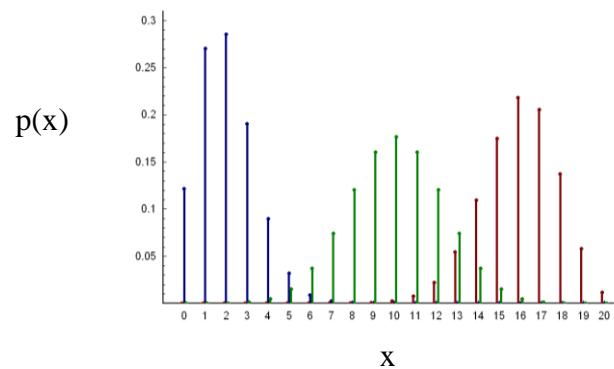
Control dictate how, when, and where activities are performed. Controls impose order on the system. At the highest level, controls consists of schedules, plans and policies. At the lowest level, controls, take the form of written procedures and machine control logic. At all levels, controls provide the information and decision logic for how the system should operate. The example of control is production plan, working schedules, control software and etc.

## **2.6 THEORETICAL DISTRIBUTION**

The theoretical distribution defined as a simple set of parameters usually defining dispersion and density. A normal distribution, for example, is defined by a mean value and standard deviation value. Theoretical distribution is either discrete or continuous. It is depending on whether finite set values within the range or an infinite continuum of possible values within a range can occur. The discrete distributions are seldom used in manufacturing and service system simulations because they can usually be defined by simple probability expression. (Harrel, 2012).

### 2.6.1 Binomial Distribution

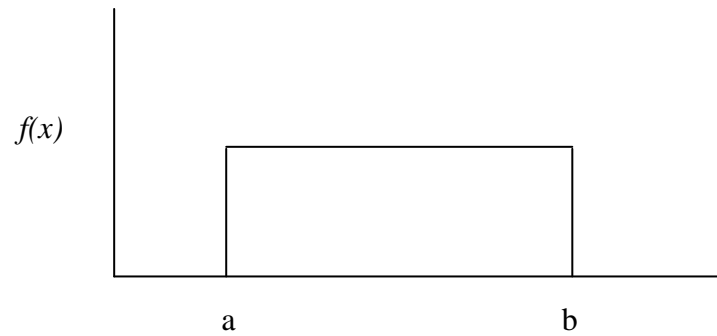
The binomial distribution is a discrete distribution that expresses the probability( $p$ ) that a particular condition or outcome can occur in  $n$  trials. A common application of the binomial distribution is to test for the number of items in a lot or the number of customers of a particular type in a group of defective items. The occurrence of the outcome of interest is a success or its non-occurrence is failure. The mean of the binomial distribution is given by  $np$ , where  $n$  is the number of trials and  $p$  is the probability of success on any given trial. The variance is given by  $np(1-p)$ . The figure 2.3 shows the probability mass function for the binomial distribution as below.



**Figure 2.3:** Probability mass function for binomial distribution

### 2.6.2 Uniform Distribution

A uniform distribution, which is also called a rectangular distribution, is used to describe a process in which the outcome is equally likely to fall between values of  $a$  and  $b$ . The uniform distribution is basically used in the early stage of simulation study. The reason is it is convenient and well-understood resource of random variation. Through uniform, the mean is  $(a+b)/2$ . While the variance is determined by  $(b-a)^2/12$ . In reality, it is extreme to find an activity time that is uniformly distributed because nearly all activity times have a central tendency or mode. Sometimes uniform distribution is used to represent a worst case test for variation when doing sensitivity. Figure 2.4 shows the probability density function for the uniform distribution.



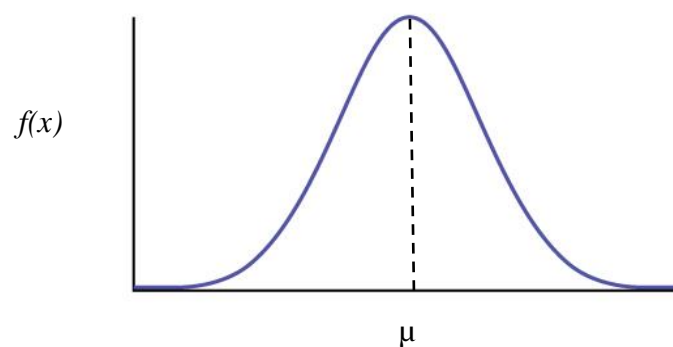
**Figure 2.4:** Probability density function for the uniform distribution.

### 2.6.3 Normal Distribution

The normal distribution explained on phenomena varies symmetrically above and below the mean (hence the bell- shape curve). While the normal distribution is often selected for defining activity times, in practice manual activity times are rarely ever normally distributed. They are nearly always skewed to the right (the ending tails of the distribution is longer than the beginning tail). This is because humans can sometimes take significantly longer than mean time, but usually not much less than the mean time. Some examples of the normal distribution are:

- Physical measurement-length, height, diameter, weight.
- Activities involving multiple tasks (e.g. loading a truck or filling a customer order).

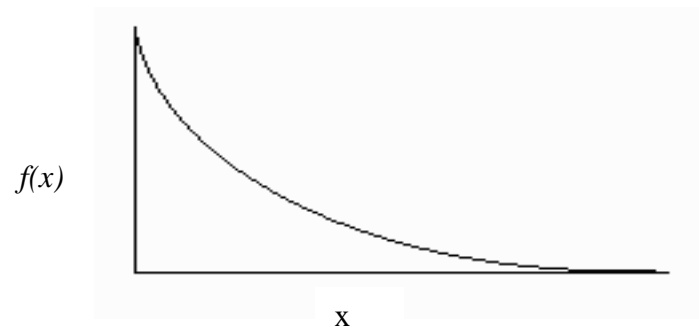
Generally, the mean of the normal distribution is designated by the Gree letter mu ( $\mu$ ). The variance is  $\sigma^2$  where  $\sigma$  (sigma) is the standard deviation. The probability density function for the normal distribution is shown in Figure 2.5.



**Figure 2.5 :** The probability density function for a normal distribution

### 2.6.4 Exponential Distribution

Exponential distribution also referred to the negative exponential. It also can be defines by single parameter, the mean ( $\mu$ ). This distribution is related to the Poisson distributions in that if an occurrence happens at a rate that is Poisson distributed, the time between occurrences is exponentially distributed. In other words, mean of the exponential distribution is the inverse of the Poisson rate. The exponential distribution is used frequently in simulation to show the event intervals. Some examples of the distributions is time between customer arrivals at a bank, duration of telephones conversations, time between arrivals of planes at a major airport, etc. The standard deviation is the same as the mean. Figure 2.6 show the probability density functions of the exponential distribution.



**Figure 2.6:** Probability density functions of the exponential distribution.

### 2.6.5 Fitting Theoretical Distributions to Data

Fitting theoretical distribution to data is basically an attempt to determine the underlying distribution from which the data were generated. Finding the best distribution that fits the sample data can be quite complicated and is not an exact science. The ProModel software consist Stat:: Fit where it can be access under the ProModel Tools Menu is available for automatically fitting distributions. The distribution fitting is largely trial-and-error process. There consist of three steps. Firstly, one or more distributions are selected as candidates for being good fits to the sample data. Then, estimates of the parameters for each distributions must be calculated and lastly goodness of fit tests are performed to ascertain how well each distribution fits the data.(Ghosh,2012).

## **2.7 MODEL VERIFICATION**

Model verification is the process of determining whether the simulation model correctly reflects the conceptual model. Verification is concerned with building the model right. It utilized in the comparison of the conceptual model to the computer representation that implements the conception. It involves the modeler more than the customer. During the verification process, the modeler tries to detect unintended errors in the model data and logic and remove them. In essence, verification is the process of debugging the model. A verified model is a bug- free model.

## **2.8 MODEL VALIDATION**

Model validation is the process of determining whether conceptual model correctly reflect the real system or determining whether the model is a meaningful and accurate representation of the real system. The validation is concerned with building the right model. The validations actually start with the data gathering stage of a simulation project before a model is even built. From here, the customer or stakeholder should become heavily involved in the validation process.

## **2.9 ADVANTAGE OF SIMULATION**

Among the advantage of simulation is possible to try alternatives without heavy machine investment, provides a solid ground wiser decisions, no disruption of ongoing on-line operation, experiments with time (lead/mean/cycle) possible, and the problems can be detected before they reach the shop-floor. In addition by using the simulation the new situation can be explored and good knowledge of the system can be gained.

The ProModel simulation software was used in this project. The benefit by using simulation is forthright and flexible. It also can be used to study the big and complex model which not easy to solve using mathematical models. Another point is the basic concept of simulation is easy to understand. According to the book manufacturing facilities design and material handling by Fred E.Meyer, he said that “simulation can

allows the study of the interactive effect of many components in a dynamic and stochastic environment, with the different advantage of providing the investigator with a clear visual effect". By comparing the mathematical model, simulation model is one of the simple to give understanding to the firms and buyer. Furthermore, it will allowed to the simulationist to do the try and error without give an effect to the actual system and also scale down the investment cost and time consumes to build new approach.

## **2.10 DISADVANTAGE OF SIMULATION**

As the limitation in using the simulation is it is hard to determine the level of details for simulation model, hard to find the right objective or unrealistic goals, a model is only an abstract simplified representation of reality. Other than that, the disadvantage of the simulation is scarcity of knowledge about simulation modelling, sometimes hard to analyze the result and the time –consuming high and also expensive software and hardware needed. Another limitation is by using the simulation which is quite costly and time taken in the buildup of complex model. Other than that, some simulation does not give favorable solutions to some problems and just develop the results according analysis of the model presented.

## **2.11 OTHER RESEARCHERS**

Basically some of journal have been review and from this can related to the project title which focuses on flexible production line. One of the journals explains on the approach to measure and evaluate volume and mix flexibility of a lean production system. Lean manufacturing systems strive for a reduction of throughput times by eliminating non-value-adding work. The time gaps between customer demand dates and production dates can be eliminate completely for every single order (Metternich, Böllhoff, Seifermann, & Beck, 2013).

Other than that, journal from Rakiman & Bon, 2013 is investigate on new production line in a metal stamping company which have problem and the researcher need to explore more on the better arrangement in production line to which focus on better concept of layout. The researcher attempt to get better layout or arrangement in production line where focus on inspection station allocation. When reducing the number of inspection station, the production time does not seem to decrease but increased. It



became contradict compare to the conventional thought where few stations means shorter time. The result show that it does not help when put few different layouts in allocating the inspection station in the hope of decreasing the production time presumably but the production increase when the inspection station is reduced.

Another researcher (Greschke.P *et.al*,2014) focus on elimination of equal cycle time while sustaining a fluently running process. The reseacher focus on specific allocation of several operation steps onto specifically arranged work stations and a control system that regulates appropriate distributions and ensure the dynamic configurability if the system. The result is high efficiency of each station was achieved without established a special sequence for every product or product variant.Hence the discrepancies between flexibility and efficiency is not only resolved but the demand for maximum capacity can neccesitate the application of more flexible systems.

In addition, another researcher is deal with mixed-model assembly line balancing and worker assignment problem where the worker assignment problem is deal with assigning worker to workstations by considering the abilities and cost of operating. The problem is mainly at the different product have different operating time and worker had different skill. So that, minimizing the cycle time is one of the key to solve. In addition, the minimizing of operating cost also took count in this paper. (Ramezani, *et.al*,2015)

Other than that, journal from Seleim, *et.al*,2015 refer on simulation method of changeable manufacturing. Simulation model and method used are reviewed and assess for their suitability to changeable manufacturing system. The need of having quick and efficient physical change in reality is important. The computer simulation classified an excellent tool for visualizing, understating, and analyzing the dynamics of manufacturing systems and assisting in the decision making process.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 INTRODUCTION**

This section basically focuses on methodology used in executing this project. The project begins by collecting data from Vacuumschmelze (M) Sdn Bhd. The observation is conducted based on two models which are 6161- X001 and model 6161- X037. Software simulation of Pro Model was used in form of trial and error on designing new layout. The layouts are designed and the data is recorded in the table.

#### **3.2 FRAMEWORK OF PROJECT**

The framework of project is starting with confirming the project title with supervisor. The project continues with the discussion with the assigned supervisor to detail out the project problem statement, objective, scopes of the project. Every two weeks meeting with supervisor will arrange. After that is seeking for the company to conduct this project evaluation. When doing this research in background of manufacturing company, application and permission letter was drafted and sent by email to the company including Johor and Pahang. Fortunately, Vacuumschmelze (M) Sdn Bhd gives good response from their general manager which allows doing the project where to improve the flexible production line by changing the layout. After the discussion is approved, the project is started immediately. The date and timing is arranged before going to Vacuumschmelze (M) Sdn Bhd to do the industrial visit.

The purpose is to understand the problem occur along the layout in one of the line in manufacturing toroid (See figure 3.0). During the visit, Mr Mohd Ariff bin Zakaria as general manager in Vacuumschmelze (M) Sdn Bhd give briefing on the background of company and product produce. As general manager, Mr Arif empowered Mr Faizal as the supervisor to explain more in the production line. Next, the visit is arranged by Mr Faizal to describe more on assembly production line of the toroid 6161-X001 and 6161-X037. There are several issues arise were highlighted by the supervisor in the production line and all the issue is take account for study purpose.

Then follow by study the issue or problems arise in production line. The proposed solution can be apply in this issue is by doing the simulation on the production layout to improve the production line. The main problem at the production line is the uses of long conveyer and this will cause large space used to the line. The company needs to put the automation machine from another plant to the plant to saving the space use. So the improvement propose is to changing the layout to the cell layout.

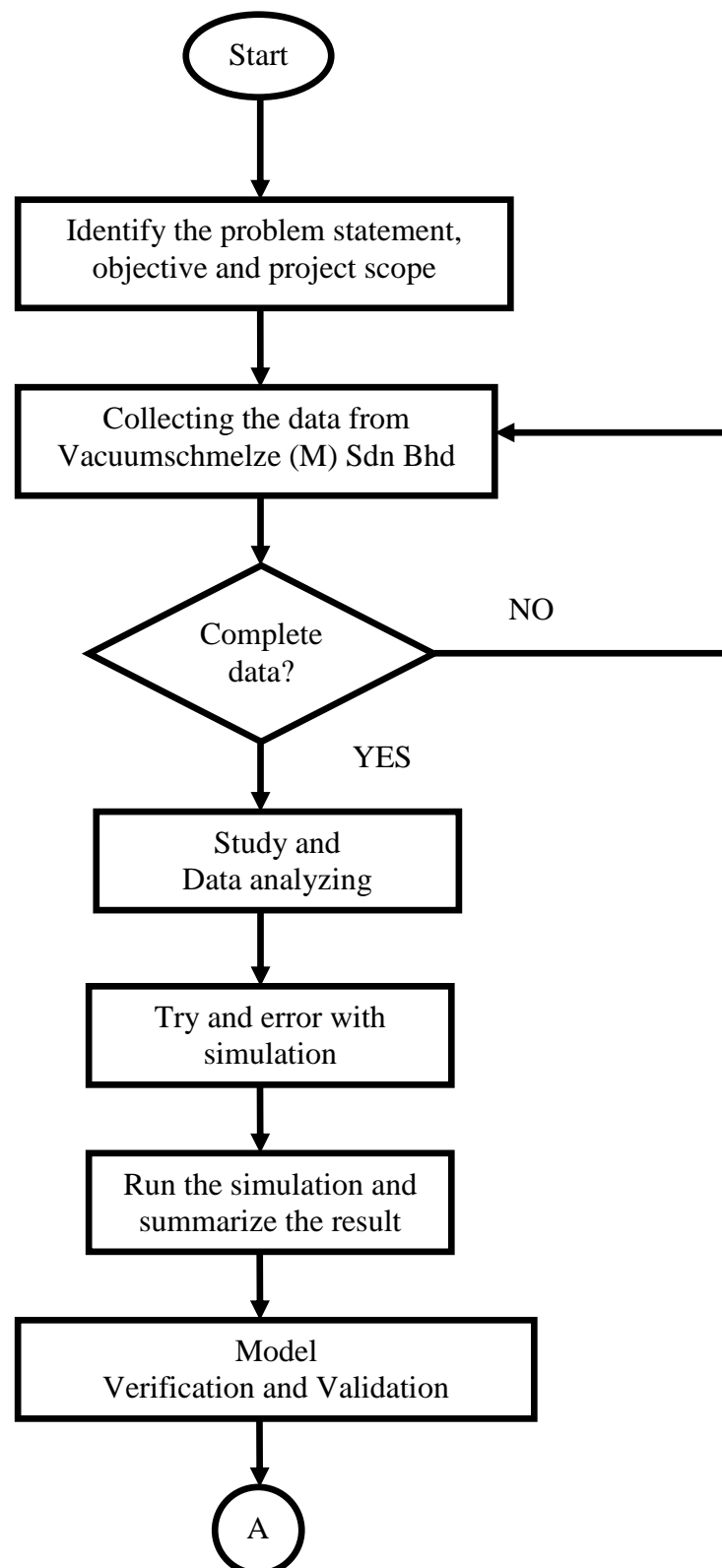
The next appointment is arranged to visit the company to get data collection for simulation. In order to build a simulation model, the data is required such as cycle time, waiting time and type of operation used. Then the project is continuing with the data analysis. About ten reading of cycle time and waiting time will be taken for each process at the workstation and the average will be calculated.

Continuing with simulation and modeling using ProModel Simulation software. The data such as cycle time will be input into the ProModel simulation software to run the simulation and it will verified by observe the animation simulated for correct behavior. Two alternatives layout were designed in order to improve productivity. The validation of the model is carried out by looking and observed at the animation. The following sequence is the output of toroid with the actual system is compared and generated the simulation result.

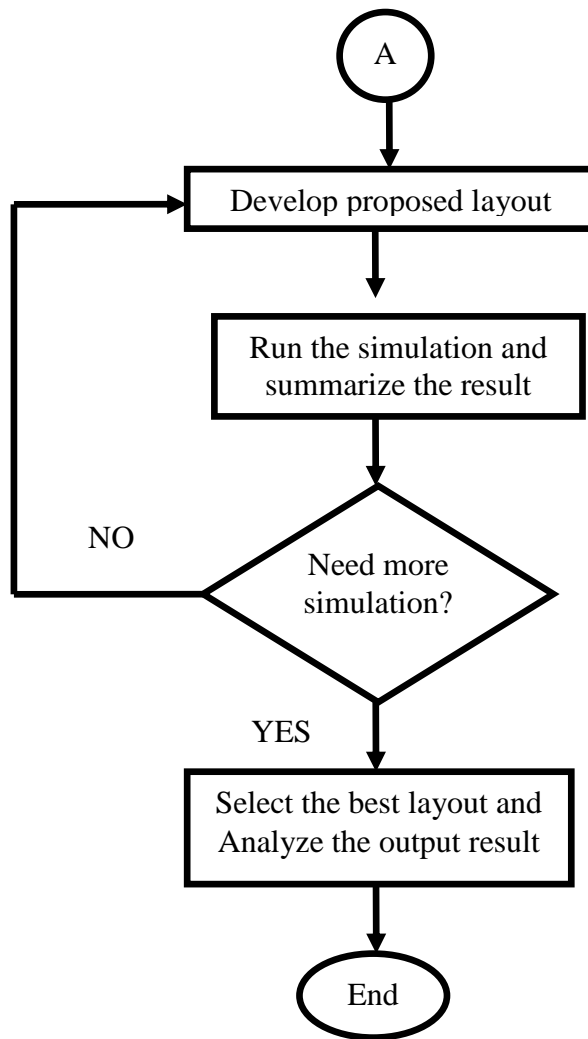
### **3.3 OVERVIEW FLOWCHART**

As an overview of flowchart of the research, the element need to consider in conducting the project is to determine the layout that suitable to use to reduce space usage in plant. The layout includes straight layout and cell layout or U-shape layout. The flowchart shown in Figure 3.1 and Figure 3.2 is the detail on how the methodology is conducted along the project research.

### 3.4 PROJECT FLOWCHART



**Figure 3.1:** Flowchart of project



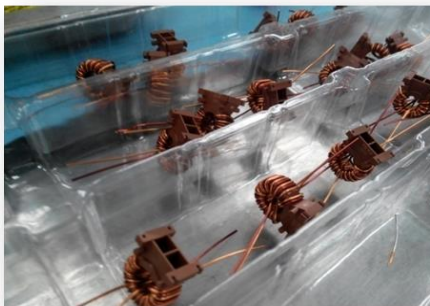
**Figure 3.2:** Flowchart of project (continued)

### 3.5 PROJECT RESEARCH

For this project, the model that will be used is 6161-X001 and 6161-X037 to analyze the data. The process need to be analyze is sole tape, winding N1 and N2, precut wire for first stage, strip wire insulation with mechanical stripper, pre-tinning wire, looping, precut and straighten wire using template precut, precut wire end for second time and tinning wire ends. The total waiting time is 34 second for the 10 workstations. Based on the collecting data, cycle time is collected by using 20 samples in 9 workstations, while the demand is depend on the model itself. The model is short run process because of the production will be finished in 2 or 3 days.



**Figure 3.3:** Model A 6161-X001



**Figure 3.4:** Model B 6161-X037

## **CHAPTER 4**

### **RESULT AND DISCUSSION**

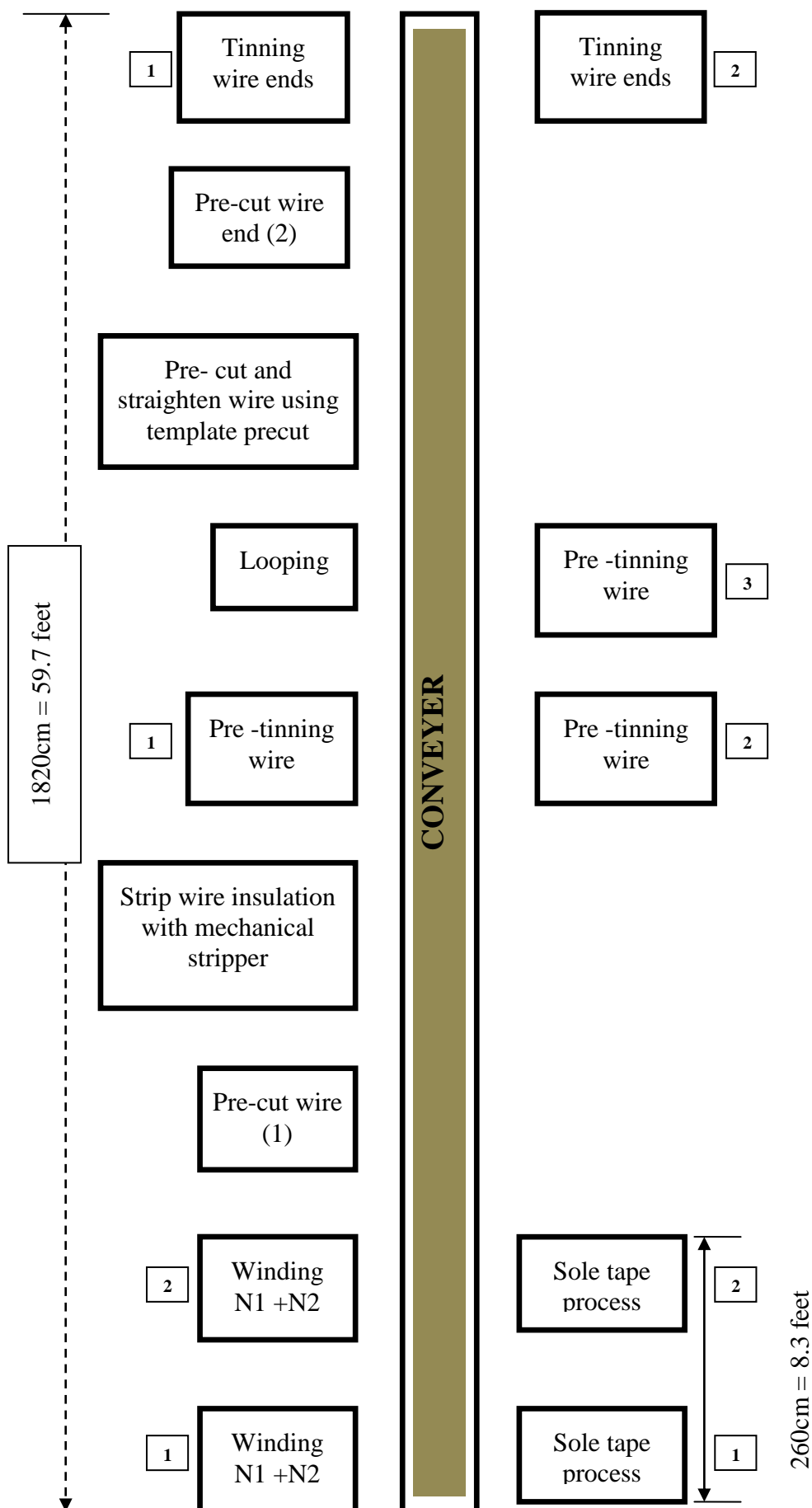
#### **4.1 INTRODUCTION**

This section discusses on result and analysis of model project 6161- X001 and model 6161-X037 using Minitab and building the model of layout using ProModel simulation software. In addition, the result and discussion on data were analyzed is included in this chapter. Then the model description, model assumption and model construction and determination of number of replication are explained

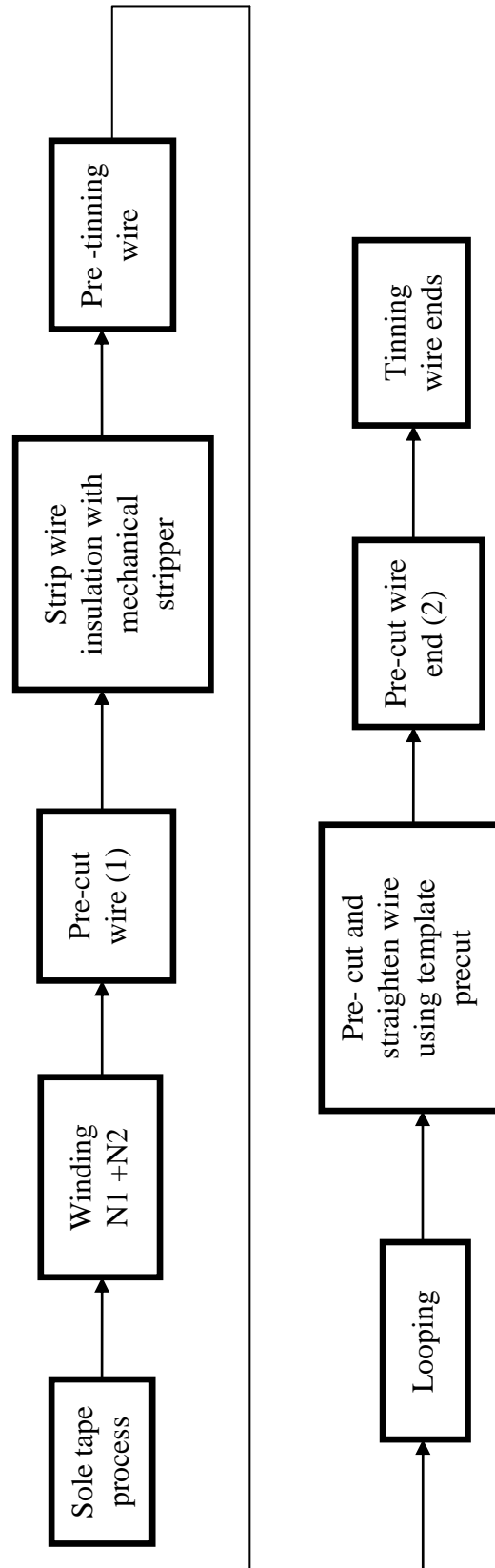
#### **4.2 TRANSFORM A CONCEPTUAL MODEL TO A SIMULATION MODEL**

Basically, the ideal conceptual model can be describes as formulation of one's mind which can figure out on how the system works using nodes and diagram and generate the output of the data gathering. The conceptual model is required to be transforming to a simulation model in order to develop a simulation model. The layout consists of nine processes in producing a toroid model project 6161- X001 and 6161-X037 as shown in Figure 4.1. The process flow shown Figure 4.2 need to be analyze in this project is sole tape, winding N1 and N2, precut wire for first stage, strip wire insulation with mechanical stripper, pre-tinning wire, looping, precut and straighten wire using template precut, precut wire end for second time and tinning wire ends. In this project running simulation, the process include until the tinning process only. The mechanical cleaning process and packaging is located at another work cell. So the two processes are excluded in this project simulation.





**Figure 4.1:** The layout and dimension of workstation at production line



**Figure 4.2:** Process flow diagram of toroid

### **4.3 PERFORMANCE MEASURE**

Based on this project, the performance measure is the parameter need to count in building the simulation. The parameter requires in this project is cycle time, waiting time, setup time, speed of conveyer, length of the conveyer and length of the production line.

- Speed 50sec/mtr

#### **4.3.1 Decision variables**

In this project consist of two types of variables which are control and uncontrolled variables. The control variables can be describes as the sequences of the processes and number of workers at production line. While the uncontrolled variable is things that cannot be control by human such as cycle times.

#### **4.3.2 Data analysis**

Through the simulation study, the next process after collecting the data is analyzing the data. The cycle time analysis data is done using Minitab. The MINITAB is an interactive software package for organizing, analyzing, and reporting statistical data. It can emphasize on providing the user with a wide range of basic and advanced functionality while maintaining the same high standards for ease of use. Feature include: descriptive statistics, regression analysis, analysis of variance and covariance, nonparametric tests, tabulation, time series analysis, exploratory data analysis, distributions, plots, and histogram. In this project, the Minitab was used only for variance. Besides that, the Stat :: Fit also used for analyzing user input data and fitting an appropriate analytical distribution.

**Table 4.1:** Current performance of Vacuumschmelze (M) Sdn Bhd cycle time for every workstation

No	Task	Cycle time (sec)
1	Wind core with hostaphan foil on circumference using winding vise with adapter type (A) NR.W6122-F101-01,one layer ½ Overlapped	120
2i	Put core in core stand. Hand winding N1(2LV) 28 turns 150 degree on core sector using winding vise with adapter type (B) W6166-F102-01 with help or crochet needle G5. It must be the maximum distance between wind beginning and end.	81
2ii	Hand winding N2 (P-Wire) 28 Turns 150 Degree on core sector opposite to N1 with help of crochet needle G5. It must be the max distance between wind beginning and end wire start and end is different with N1.	25
3	Cut the wire using precut jig and help with cutter midget diagonal cutting plier precut jig:W6161-B101-01	34
4	Strip wire insulation with mechanical stripper (P-wire)	40
5	Pre-tinning of wire ends	60
6	Loop wire around core. Stand pin and fix to appropriate grooves tightly. Using flat nose plier	10
7	Precut and straighten wire using the template precut and helping with cutter midget diagonal cutting plier.	20
8	Cut the wire ends using the chopper MC straight the pins using the flat nose plier W6161-R101-01 Cutting plate	40
9	Tinning of wire ends	120

### 4.3.3 Working hours

There is some data need to be included in the running simulation which is working time. The companies operate 8 hours per day and 5 day per week. Below is working hour at Vacuumschmelze (M) Sdn Bhd.

**Table 4.2:** Working hour

<b>Type</b>	<b>Time</b>
<b>Working hour (Monday-Friday)</b>	8.00a.m – 6.00p.m
<b>Break time</b>	10.00a.m – 10.20a.m 1.00p.m – 2.00p.m 4.00p.m-4.15p.m
<b>*Friday</b>	10.00a.m – 10.20a.m 12.30p.m – 2.00p.m 4.00p.m-4.15p.m

### 4.3.4 Setup Time

In this project, the setup machine covers only two machines which are on pre –tinning wire and precut. The setup time at tinning workstation only can be stop on Friday after working hours. In addition, the rework always can occur because not properly when installing the part. The assembly reject about 0.53% is taken into account due to almost the processes are human oriented. The waiting is shown in Figure 4.3.

1. Pre-Tinning wire = 30minute
2. Precut wire end = 29 second

4.3.5 Waiting Time

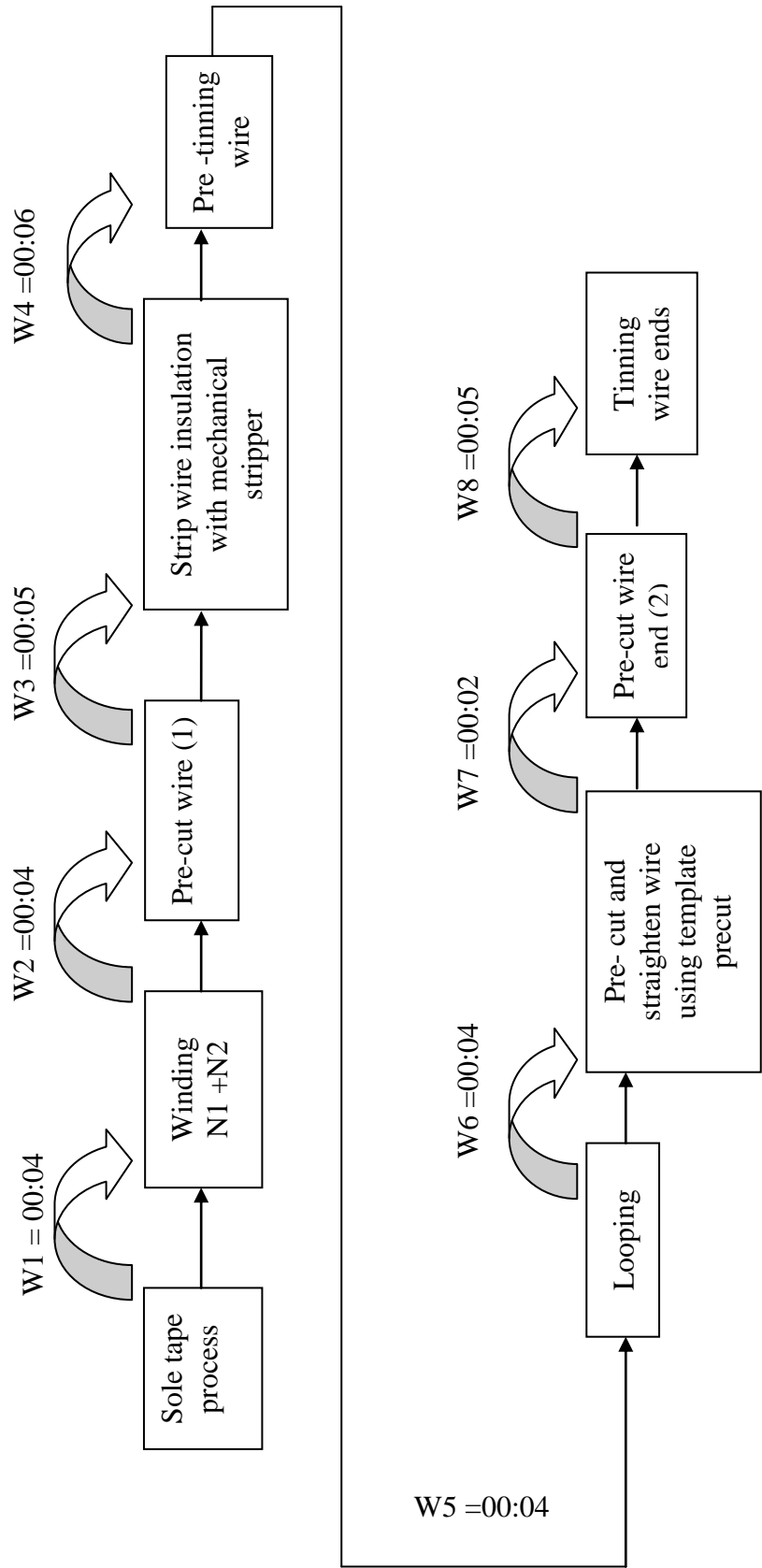





Figure 4.3: Waiting time of toroid

#### 4.4 DATA DOCUMENTATION AND COLLECTION

**Table 4.3:** Collecting data

Process	Task
<p>1) Sole tape</p> 	<p>The process will start by sole tape the wind core with hostaphan foil on circumference using winding vise with adapter type (A) NR.W6122-F101-01, one layer ½ Overlapped</p>
<p>2) Winding N1 + N2</p> 	<p>The next process is winding process. Put core in core stand. Hand winding N1(2LV) and N2 (P-Wire) 28 turns 150 degree on core sector using winding vise with adapter type (B) W6166-F102-01 with help or crochet needle G5. It must be the maximum distance between wind beginning and end.</p>
<p>3) Pre- cut wire for first stage</p> 	<p>Cut the wire using precut jig and help with cutter midget diagonal cutting plier precut jig:W6161-B101-01</p>

## 4) Strip wire insulation



Strip wire insulation with mechanical stripper (P-wire).

## 5) Pre -tinning wire



The pre-tinning wire will be done by tinning the wire in second. The leg of wire need to dye one by one to ensure the tinning will covered completely.

## 6) Looping



Loop wire around core. Stand pin and fix to appropriate grooves tightly. Using flat nose plier.



## 7) Pre-cut and straighten wire



The next process is pre-cut and straightens the wire. Precut and straighten wire using the template precut and helping with cutter midget diagonal cutting plier.

## 8) Pre-cut wire end for second time



Cut the wire ends using the chopper MC straight the pins using the flat nose plier W6161-R101-01 Cutting plate.

## 9) Tinning wire ends



Finally is tinning wire end. The process same like before. This is the last tinning which is the pre-finishing process and follow with mechanical cleaning process.

#### 4.5 DETERMINATION OF CONFIDENCE INTERVAL

The interval estimates is constructed by using mean,  $\bar{x}$  and standard deviation,  $s$ . The method used to determine the confidence interval estimation. Through this it will provide information about how far off the point estimate  $\bar{x}$  might be from the true mean,  $\mu$ . While a confidence level estimation can be defined as range within which we can have a certain level of confidence that true mean falls. Confidence intervals are constructed at a confidence level 95%. The interval is symmetric about  $\bar{x}$ , and the distance that each endpoint is from  $\bar{x}$  is called the half-width ( $hw$ ). A confidence interval, then, is expressed as the probability  $P$  that the unknown true mean,  $\mu$  lies within interval  $\bar{x} \pm hw$ . The probability  $P$  is called confidence level.

##### Model A : 6161-X001

##### WORKSTATION 1: Wind core with hostaphan foil

Given:

$P = \text{confidence level} = 0.95$

$\alpha = \text{significance level} = 1 - P = 1 - 0.95 = 0.05$

$n = \text{sample size} = 20$

$\bar{x} = 122$

$s = 1.92$

From student's table ( $t_{19,0.025}$ ) = 2.093

$hw$

$$= \frac{(t_{n-1, \alpha})s}{\sqrt{n}}$$

$$= \frac{(t_{19, 0.025})1.92}{\sqrt{20}}$$

$$= 0.89$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 122 - 0.89 = 121.11$

Upper limit =  $\bar{x} + hw = 122 + 0.89 = 122.89$

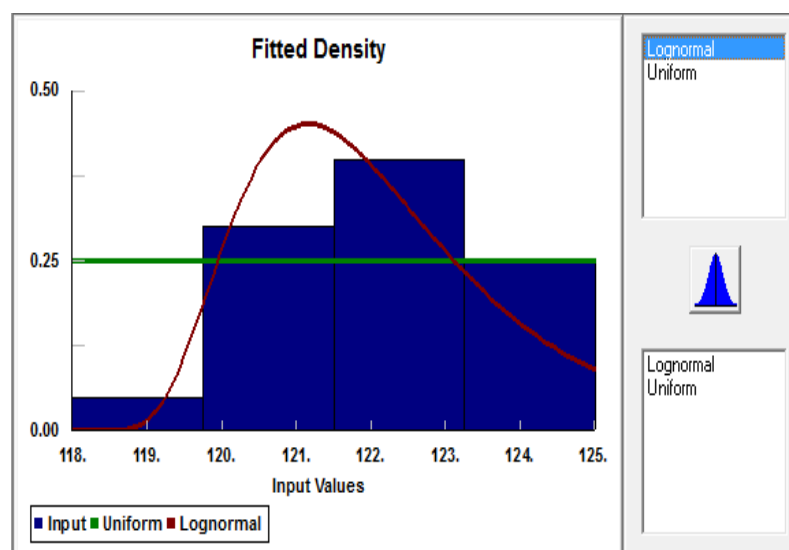
\*We confident that 95% operation times of winding process are between 121.11s and 122.89s with average 122s.

Document1: Automatic Fitting		
Auto::Fit of Distributions		
distribution	rank	acceptance
Lognormal[118, 1.35, 0.443]	100	do not reject
Uniform[118, 125]	52.6	do not reject

**Figure 4.4** : Various continuous distribution fitted to the input data for workstation 1

Document1: Descriptive Stat...	
descriptive statistics	
data points	20
minimum	118.
maximum	125.
mean	122.
median	122.
mode	120.
standard deviation	1.91943
variance	3.68421
coefficient of variation	1.5733
skewness	-0.198472
kurtosis	-0.814696

**Figure 4.5** : Descriptive statistics for the input data for workstation 1



**Figure 4.6:** Comparison between actual data and fitted uniform distribution for workstation 1

## WORKSTATION 2 :Handwinding N1 and N2

Given:

$P = \text{confidence level} = 0.95$

$\alpha = \text{significance level} = 1 - P = 1 - 0.95 = 0.05$

$n = \text{sample size} = 20$

$\bar{x} = 81$

$s = 1.68$

From student's table  $(t_{19,0.025}) = 2.093$

$hw$

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})1.68}{\sqrt{20}}$$

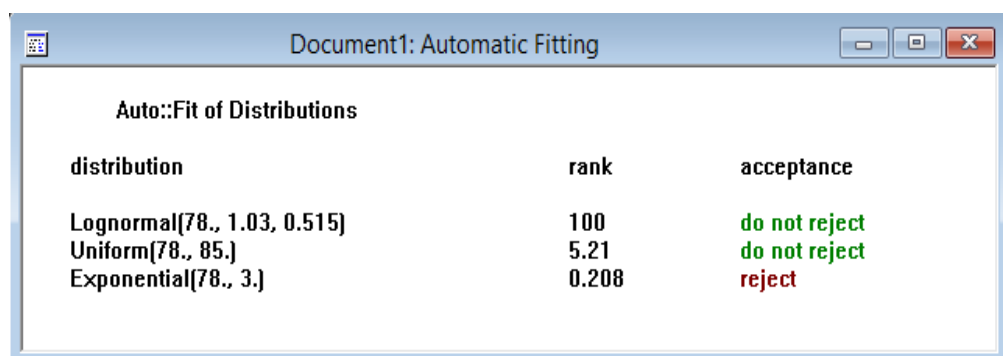
$$= 0.79$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit  $= \bar{x} - hw = 81 - 0.79 = 80.21$

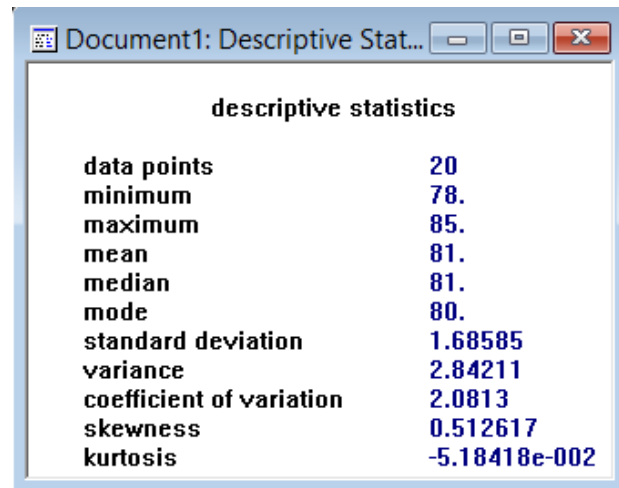
Upper limit  $= \bar{x} + hw = 81 + 0.79 = 81.79$

\*We confident that 95% operation times of winding process are between 80.21s and 81.79s with average 81.79s.

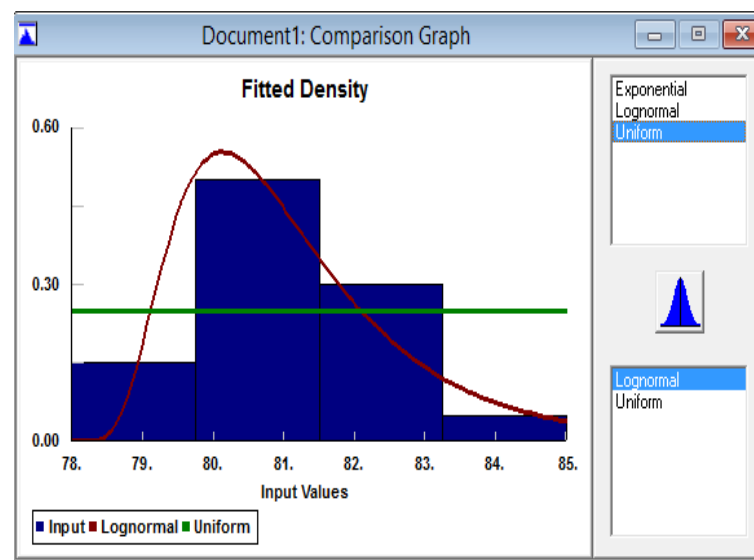


distribution	rank	acceptance
Lognormal(78., 1.03, 0.515)	100	do not reject
Uniform(78., 85.)	5.21	do not reject
Exponential(78., 3.)	0.208	reject

**Figure 4.7 :** Various continuous distribution fitted to the input data for workstation 2



**Figure 4.8** : Descriptive statistics for the input data for workstation 2



**Figure 4.9:** Comparison between actual data and fitted uniform distribution for workstation 2

**WORKSTATION 3 : Cut wire using pre cut jig**

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 27

s = 1.12

From student's table ( $t_{19,0.025}$ ) = 2.093

hw

$$= \frac{(t_{n-1, \alpha/2}) s}{\sqrt{n}}$$

$$= \frac{(t_{19, 0.025}) 1.12}{\sqrt{20}}$$

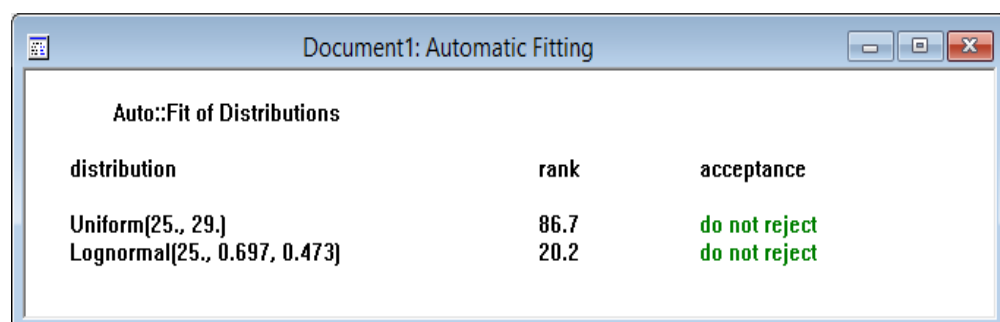
$$= 0.52$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 27 - 0.52 = 26.48$

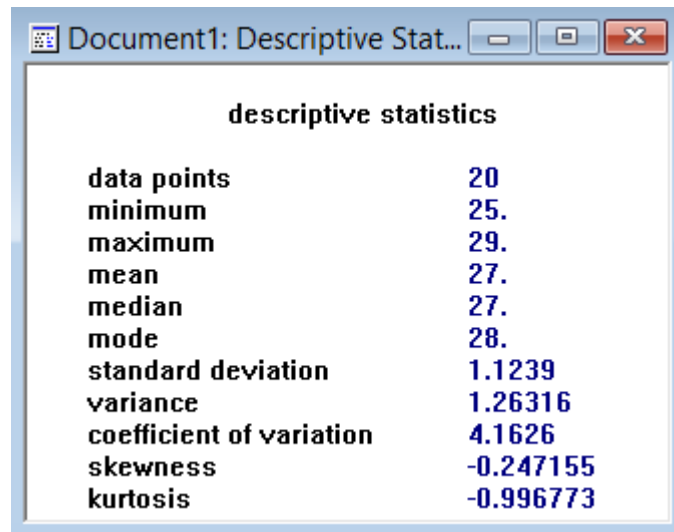
Upper limit =  $\bar{x} + hw = 27 + 0.52 = 27.52$

\*We confident that 95% operation times of winding process are between 26.48s and 27.52s with average 27s.

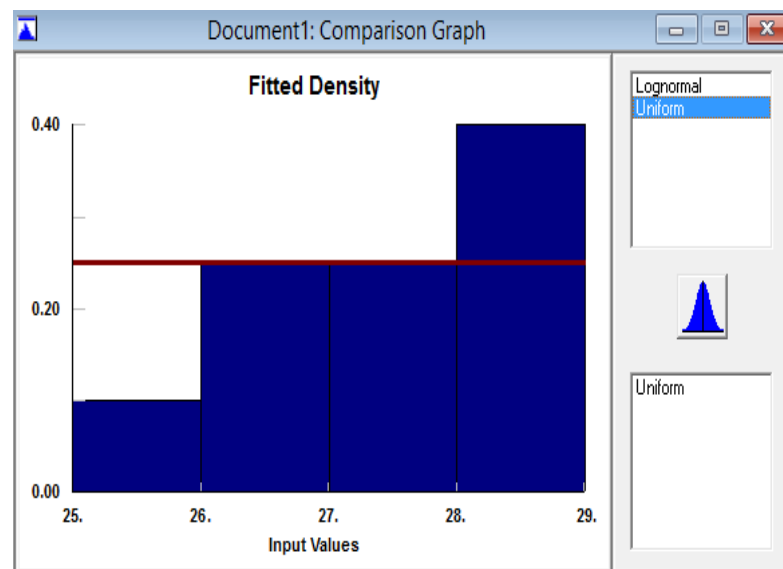


distribution	rank	acceptance
Uniform(25., 29.)	86.7	do not reject
Lognormal(25., 0.697, 0.473)	20.2	do not reject

**Figure 4.10:** Various continuous distribution fitted to the input data for workstation 3



**Figure 4.11** : Descriptive statistics for the input data for workstation 3



**Figure 4.12:** Comparison between actual data and fitted uniform distribution for workstation 3

#### WORKSTATION 4: Strip wire insulation with mechanical stripper

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 35

s = 0.86

From student's table ( $t_{19,0.025}$ ) = 2.093

$$hw = \frac{(t_{n-1,\alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})0.86}{\sqrt{20}}$$

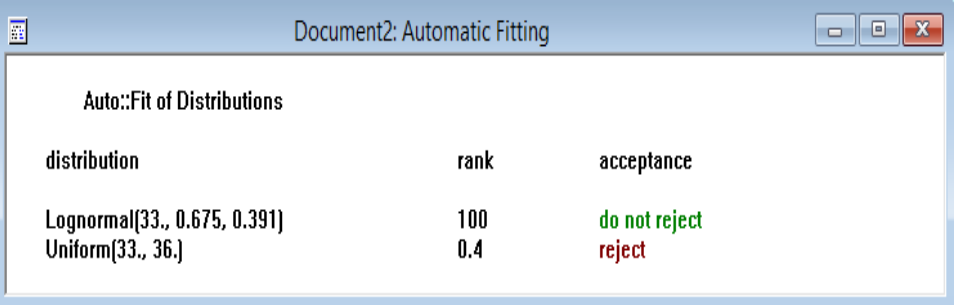
$$= 0.40$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 35 - 0.40 = 34.60$

Upper limit =  $\bar{x} + hw = 35 + 0.40 = 35.4$

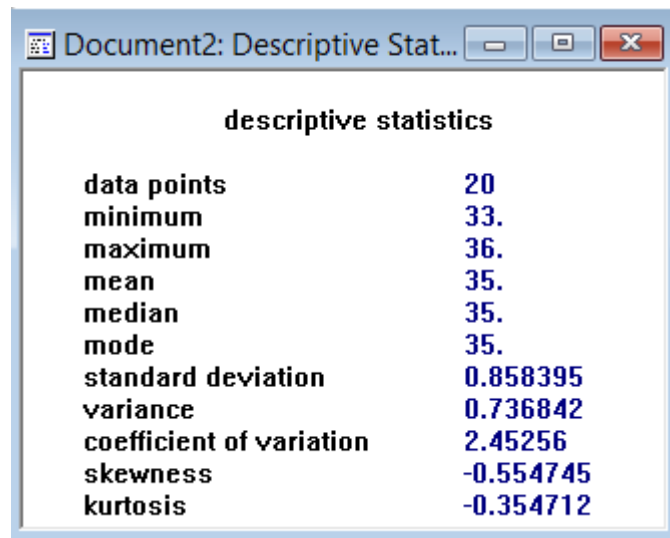
\*We confident that 95% operation times of winding process are between 34.60s and 35.40s with average 35s.



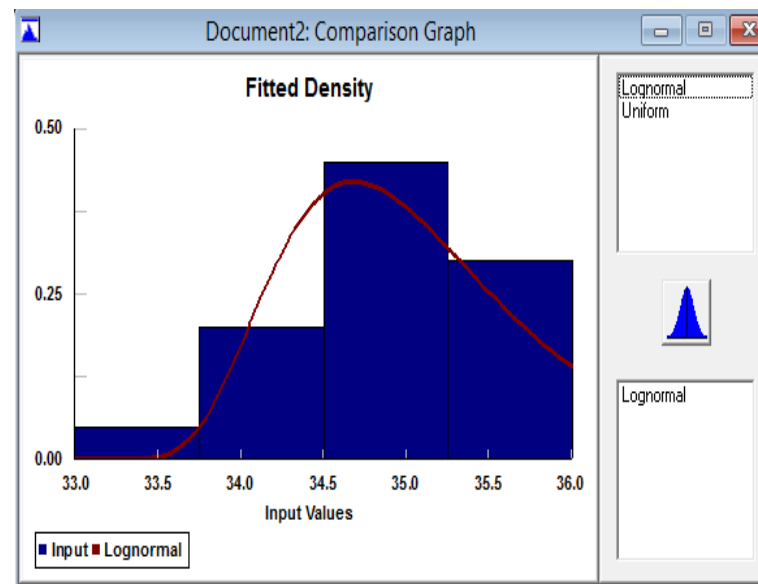
distribution	rank	acceptance
Lognormal[33., 0.675, 0.391]	100	do not reject
Uniform[33., 36.]	0.4	reject

**Figure 4.13:** Various continuous distribution fitted to the input data for workstation 4





**Figure 4.14** : Descriptive statistics for the input data for workstation 4



**Figure 4.15:** Comparison between actual data and fitted uniform distribution for workstation 4

**WORKSTATION 5:Pre-tinning wire ends**

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 42

s = 1.02

From student's table ( $t_{19,0.025}$ ) = 2.093

hw

$$= \frac{(t_{n-1,\alpha})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})1.02}{\sqrt{20}}$$

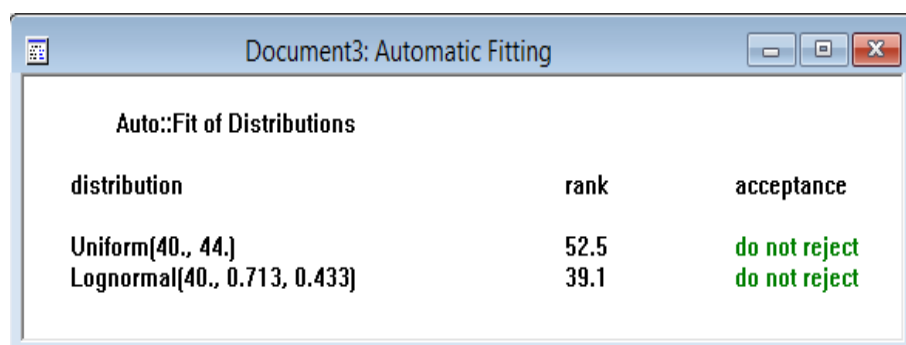
$$= 0.48$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x}$  - hw = 42 - 0.48 = 41.52

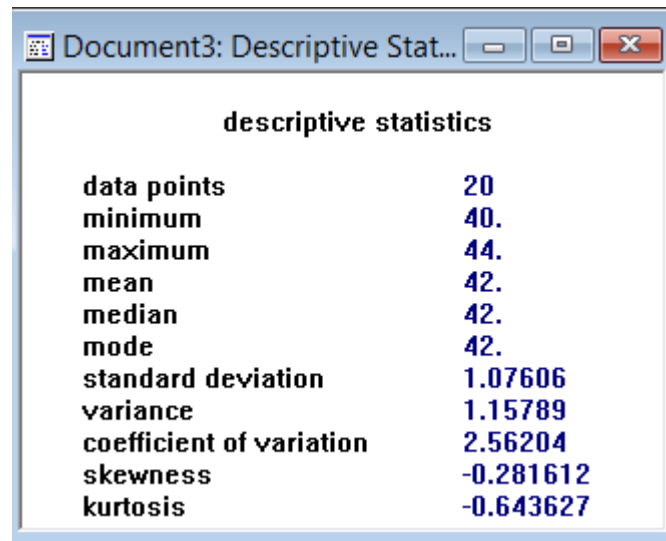
Upper limit =  $\bar{x}$  + hw = 42 + 0.48 = 42.48

\*We confident that 95% operation times of winding process are between 41.52s and 42.48s with average 42s.

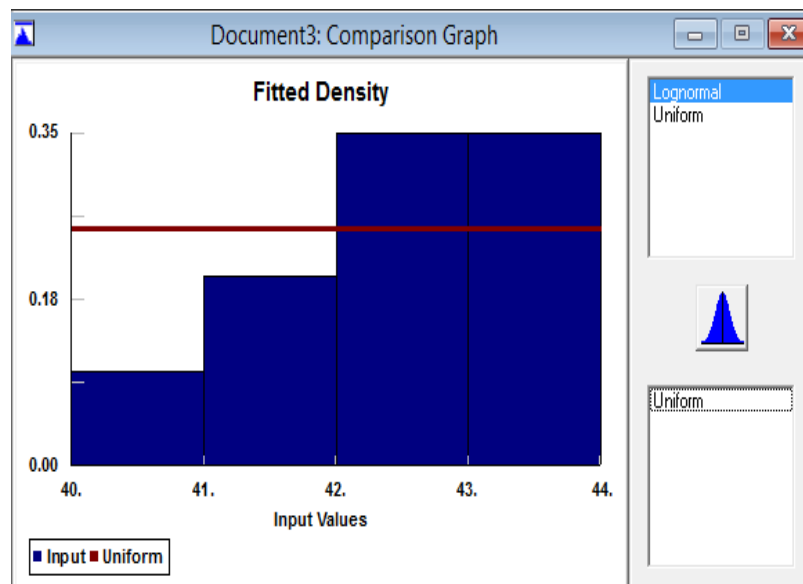


Auto::Fit of Distributions		
distribution	rank	acceptance
Uniform(40., 44.)	52.5	do not reject
Lognormal(40., 0.713, 0.433)	39.1	do not reject

**Figure 4.16:** Various continuous distribution fitted to the input data for workstation 5



**Figure 4.17:** Descriptive statistics for the input data for workstation 5



**Figure 4.18:** Comparison between actual data and fitted uniform distribution for workstation 5

**WORKSTATION 6: Loop wire around core**

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 61

s = 1.62

From student's table ( $t_{19,0.025}$ ) = 2.093

hw

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19, 0.025})1.62}{\sqrt{20}}$$

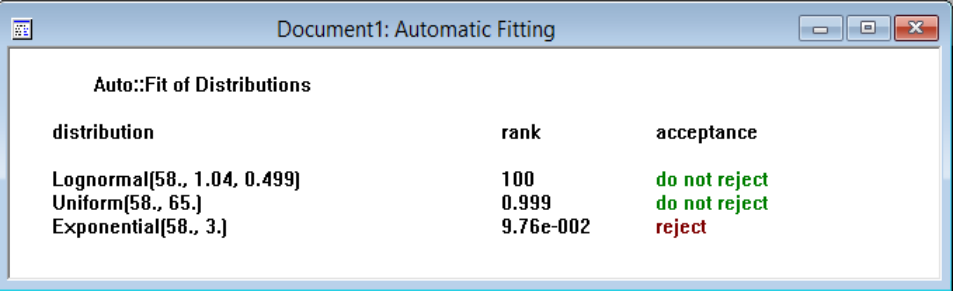
$$= 0.79$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 61 - 0.79 = 60.21$

Upper limit =  $\bar{x} + hw = 61 + 0.79 = 61.79$

\*We confident that 95% operation times of winding process are between 60.21s and 61.79s with average 61s.



The screenshot shows a window titled 'Document1: Automatic Fitting'. Inside, there is a section titled 'Auto::Fit of Distributions' which contains a table with three columns: 'distribution', 'rank', and 'acceptance'.

distribution	rank	acceptance
Lognormal[58., 1.04, 0.499]	100	do not reject
Uniform[58., 65.]	0.999	do not reject
Exponential[58., 3.]	9.76e-002	reject

**Figure 4.19:** Various continuous distribution fitted to the input data for workstation 6

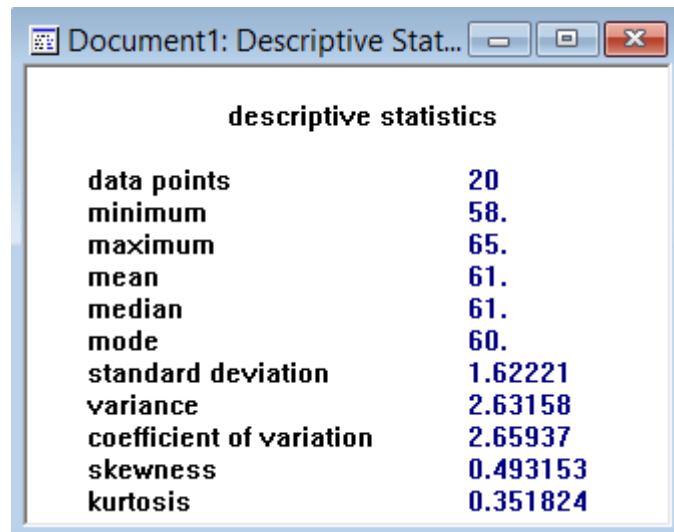


Figure 4.20: Descriptive statistics for the input data for workstation 6

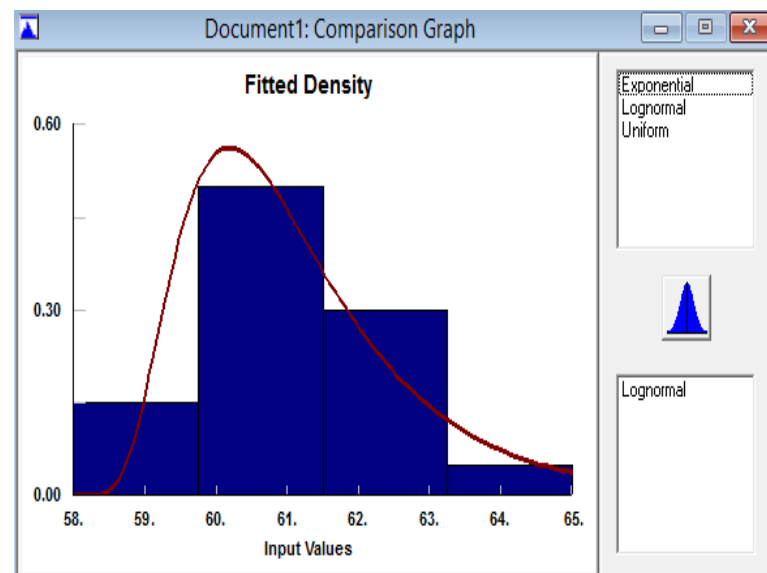


Figure 4.21: Comparison between actual data and fitted uniform distribution for workstation 6

**WORKSTATION 7: Precut and straighten wire using the template precut**

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 13

s = 1.89

From student's table ( $t_{19,0.025}$ ) = 2.093

hw

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})1.89}{\sqrt{20}}$$

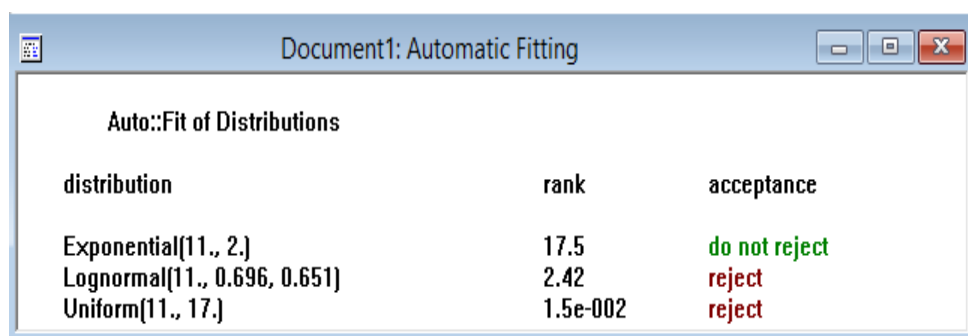
$$= 0.88$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 13 - 0.88 = 12.12$

Upper limit =  $\bar{x} + hw = 13 + 0.88 = 13.88$

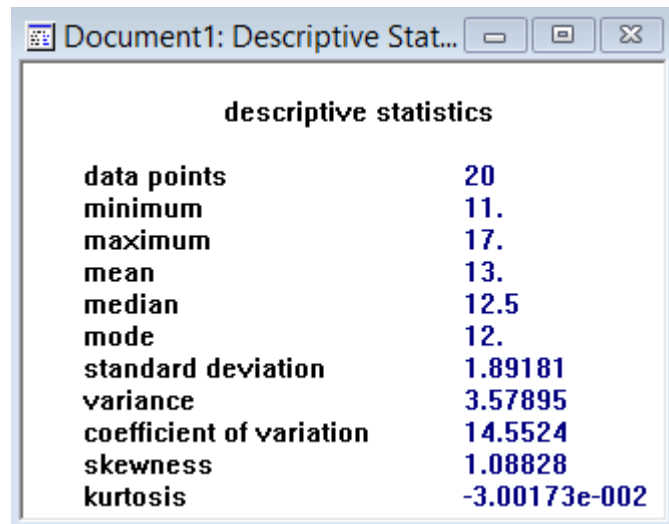
\*We confident that 95% operation times of winding process are between 12.21s and 12.88s with average 13s.



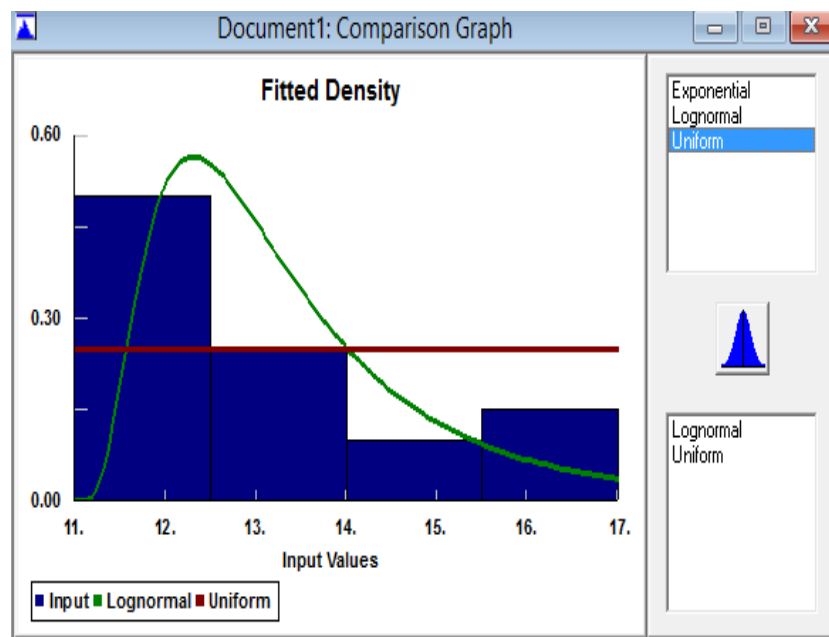
The screenshot shows a software window titled 'Document1: Automatic Fitting'. Inside, there is a section 'Auto::Fit of Distributions' containing a table with three columns: 'distribution', 'rank', and 'acceptance'. The table lists three distributions: Exponential(11., 2.), Lognormal(11., 0.696, 0.651), and Uniform(11., 17.). The 'rank' values are 17.5, 2.42, and 1.5e-002 respectively. The 'acceptance' column shows 'do not reject' in green for the Exponential distribution and 'reject' in red for the Lognormal and Uniform distributions.

distribution	rank	acceptance
Exponential(11., 2.)	17.5	do not reject
Lognormal(11., 0.696, 0.651)	2.42	reject
Uniform(11., 17.)	1.5e-002	reject

**Figure 4.22:** Various continuous distribution fitted to the input data for workstation 7



**Figure 4.23:** Descriptive statistics for the input data for workstation 7



**Figure 4.24:** Comparison between actual data and fitted uniform distribution for workstation 7

**WORKSTATION 8: Cut the wire end**

Given:

$P = \text{confidence level} = 0.95$

$\alpha = \text{significance level} = 1 - P = 1 - 0.95 = 0.05$

$n = \text{sample size} = 20$

$\bar{x} = 24.45$

$s = 2.28$

From student's table ( $t_{19,0.025}$ ) = 2.093

$hw$

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})2.28}{\sqrt{20}}$$

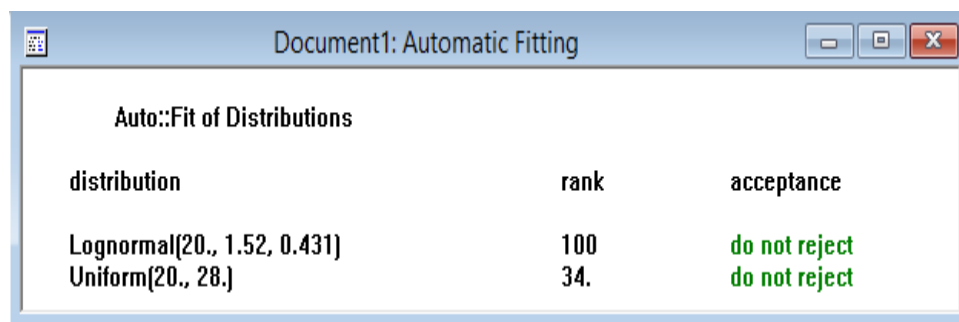
$$= 1.07$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 24.45 - 1.07 = 23.38$

Upper limit =  $\bar{x} + hw = 24.45 + 1.07 = 25.52$

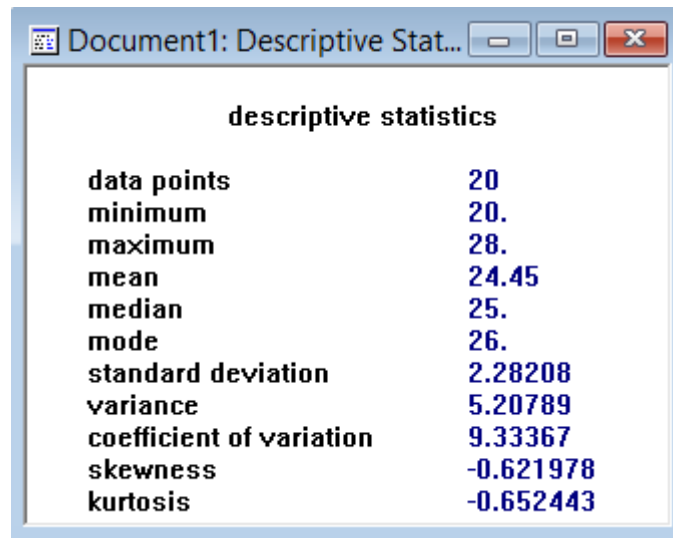
\*We confident that 95% operation times of winding process are between 23.38s and 25.52s with average 24.45s.



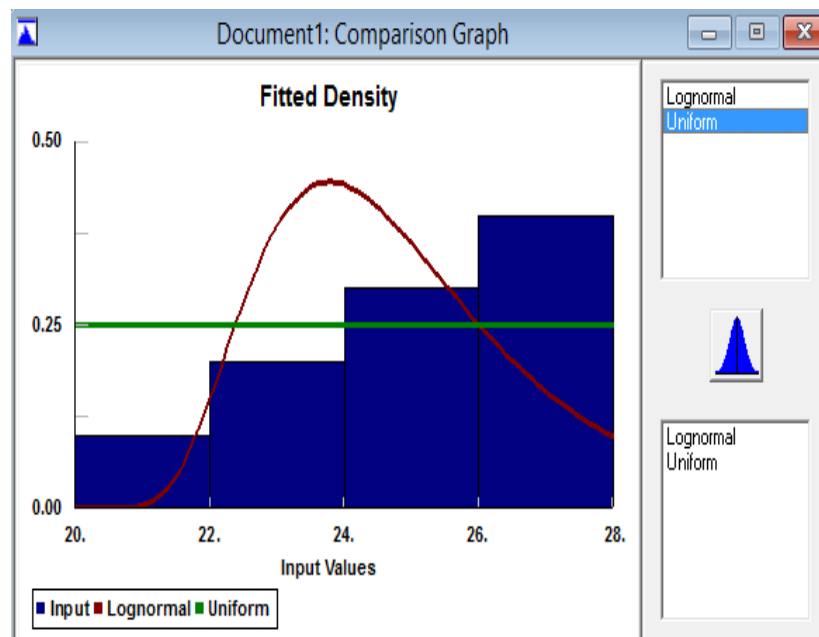
distribution	rank	acceptance
Lognormal[20., 1.52, 0.431]	100	do not reject
Uniform[20., 28.]	34.	do not reject

**Figure 4.25:** Various continuous distribution fitted to the input data for workstation 8





**Figure 4.26:** Descriptive statistics for the input data for workstation 8



**Figure 4.27:** Comparison between actual data and fitted uniform distribution for workstation 8

**WORKSTATION 9: Tinning wire ends**

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 43

s = 2.08

From student's table ( $t_{19,0.025}$ ) = 2.093

hw

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19, 0.025})2.08}{\sqrt{20}}$$

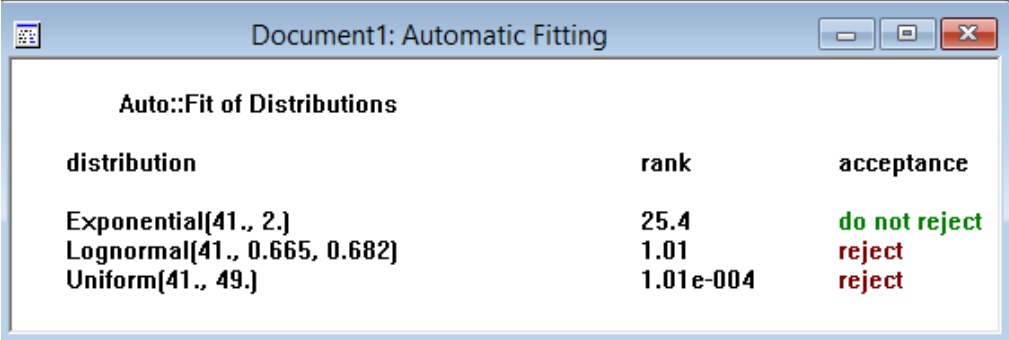
$$= 0.97$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x}$  - hw = 43 - 0.97 = 42.03

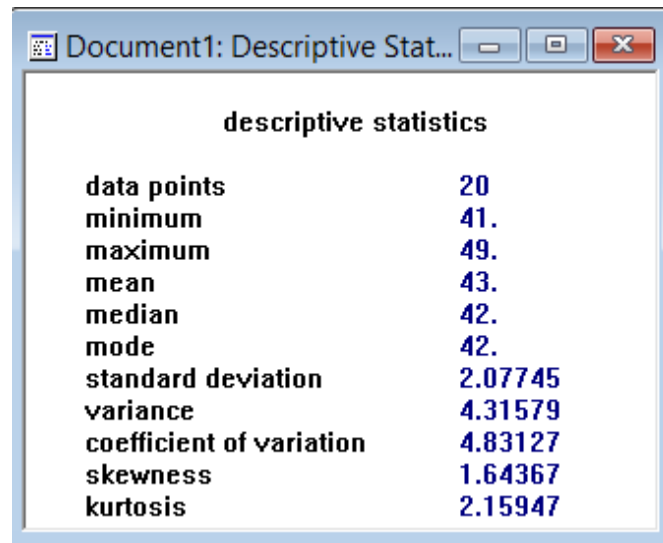
Upper limit =  $\bar{x}$  + hw = 43 + 0.97 = 43.97

\*We confident that 95% operation times of winding process are between 42.03s and 43.97s with average 43s.

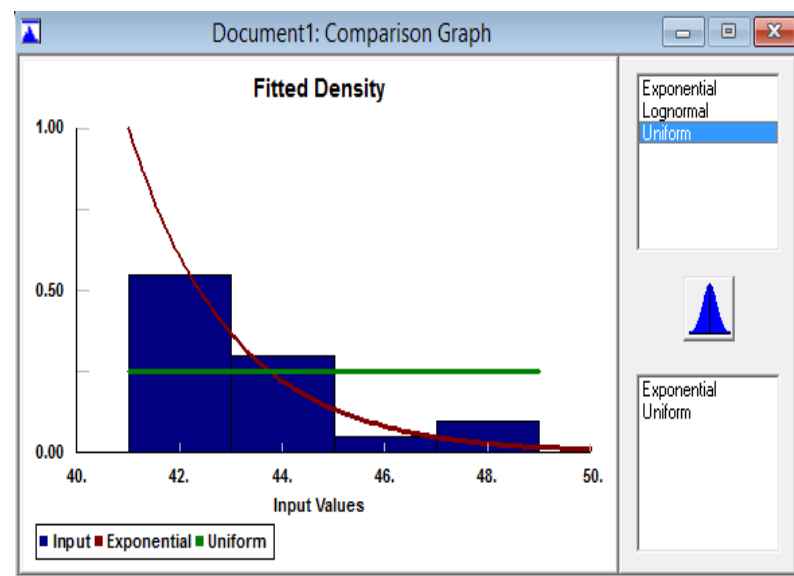


distribution	rank	acceptance
Exponential[41., 2.]	25.4	do not reject
Lognormal[41., 0.665, 0.682]	1.01	reject
Uniform[41., 49.]	1.01e-004	reject

**Figure 4.28:** Various continuous distribution fitted to the input data  
for workstation 9



**Figure 4.29:** Descriptive statistics for the input data for workstation 9



**Figure 4.30:** Comparison between actual data and fitted uniform distribution for workstation 9

**MODEL B: 6161-X037****WORKSTATION 1: Wind core with hostaphan foil**

Given:

$P$  = confidence level = 0.95

$\alpha$  = significance level =  $1 - P = 1 - 0.95 = 0.05$

$n$  = sample size = 20

$\bar{x} = 121$

$s = 2.29$

From student's table ( $t_{19,0.025}$ ) = 2.093

$hw$

$$= \frac{(t_{n-1, \alpha})s}{n}$$

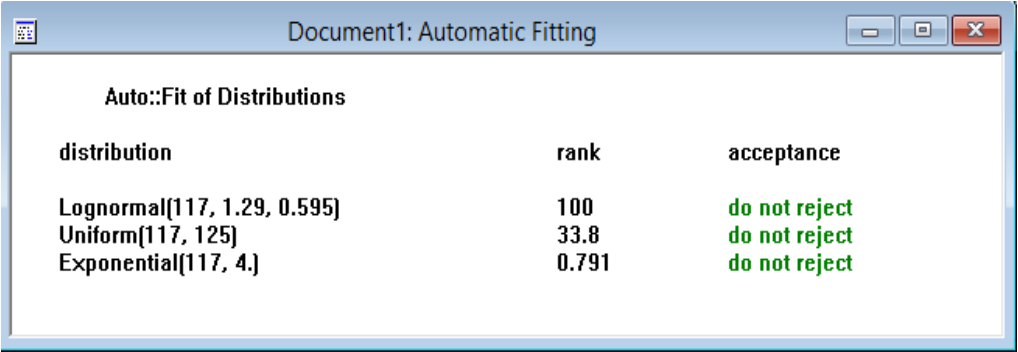
$$= \frac{(t_{19, 0.025})1.92}{\sqrt{20}}$$

= 1.07

Lower limit =  $\bar{x} - hw = 121 - 1.07 = 119.93$

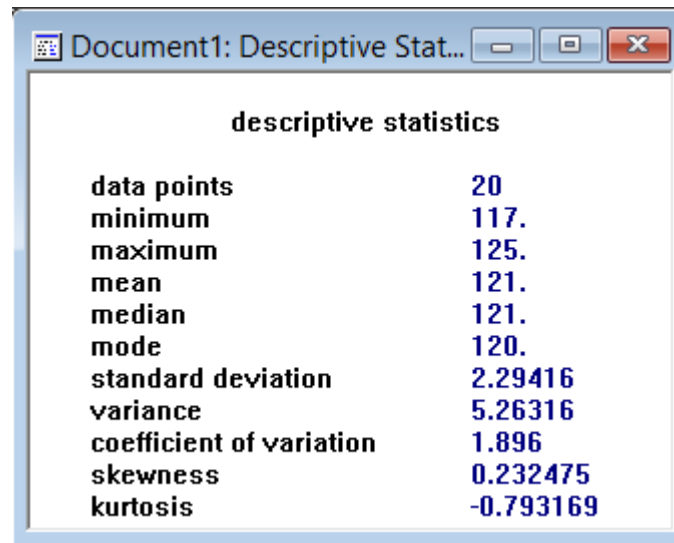
Upper limit =  $\bar{x} + hw = 121 + 1.07 = 122.07$

\*We confident that 95% operation times of winding process are between 119.93s and 122.07s with average 121s.

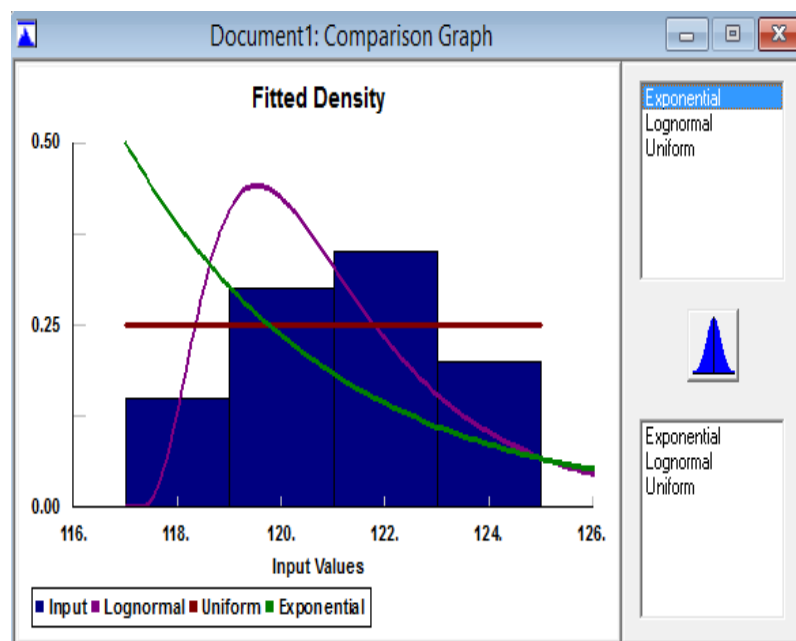


distribution	rank	acceptance
Lognormal[117, 1.29, 0.595]	100	do not reject
Uniform[117, 125]	33.8	do not reject
Exponential[117, 4.]	0.791	do not reject

**Figure 4.31:** Various continuous distributions fitted to the input data for Workstation 1



**Figure 4.32:** Descriptive statistics for the input data for workstation 1



**Figure 4.33:** Comparison between actual data and fitted uniform distribution for workstation 1

## WORKSTATION 2 :Handwinding N1 and N2

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1- P=1- 0.95= 0.05

n = sample size =20

$\bar{x}$  = 80

s =1.78

From student's table ( $t_{19,0.025}$ ) =2.093

hw

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})1.78}{\sqrt{20}}$$

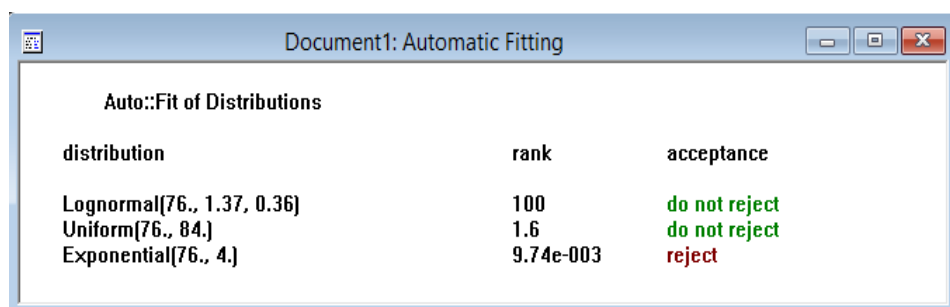
= 0.83

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x}$  -hw = 80-0.83 =79.17

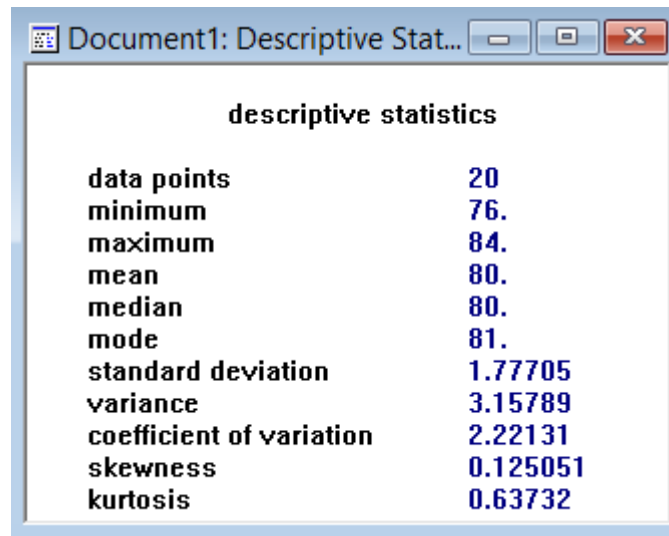
Upper limit =  $\bar{x}$  +hw =80+ 0.83 =80.83

\*We confident that 95% operation times of winding process are between 79.17s and 80.83s with average 80s.

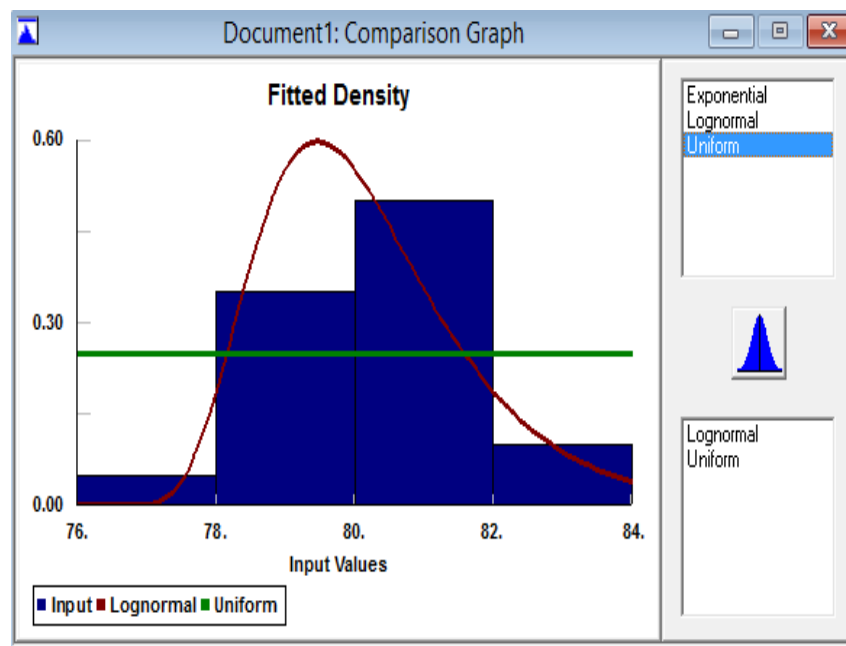


distribution	rank	acceptance
Lognormal[76., 1.37, 0.36]	100	do not reject
Uniform[76., 84.]	1.6	do not reject
Exponential[76., 4.]	9.74e-003	reject

**Figure 4.34** :Various continuous distribution fitted to the input data for workstation 2



**Figure 4.35** : Descriptive statistics for the input data for workstation 2



**Figure 4.36**: Comparison between actual data and fitted uniform distribution for workstation 2

**WORKSTATION 3 : Cut wire using pre cut jig**

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 85

s = 2.40

From student's table ( $t_{19,0.025}$ ) = 2.093

hw

$$= \frac{(t_{n-1, \alpha})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})2.40}{\sqrt{20}}$$

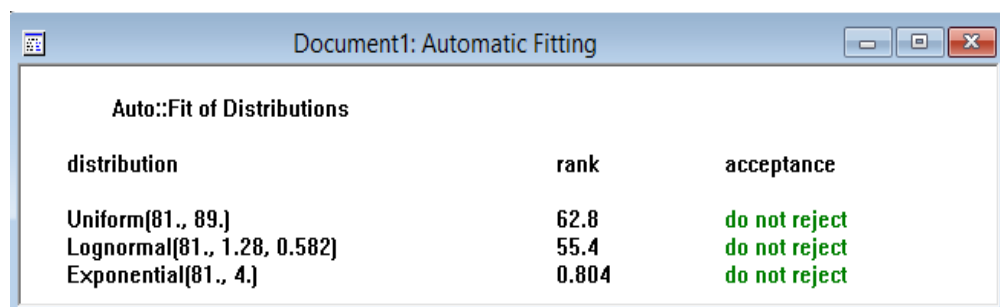
$$= 1.12$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x}$  - hw = 85 - 1.12 = 83.88

Upper limit =  $\bar{x}$  + hw = 85 + 1.12 = 86.12

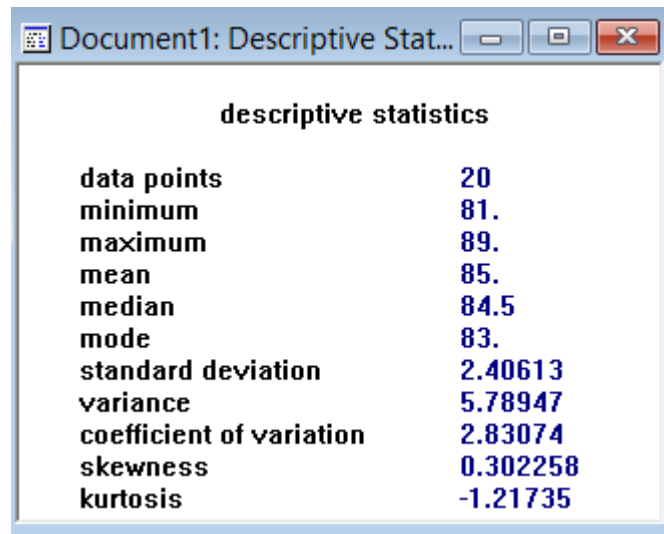
\*We confident that 95% operation times of winding process are between 83.88s and 86.12s with average 85s.



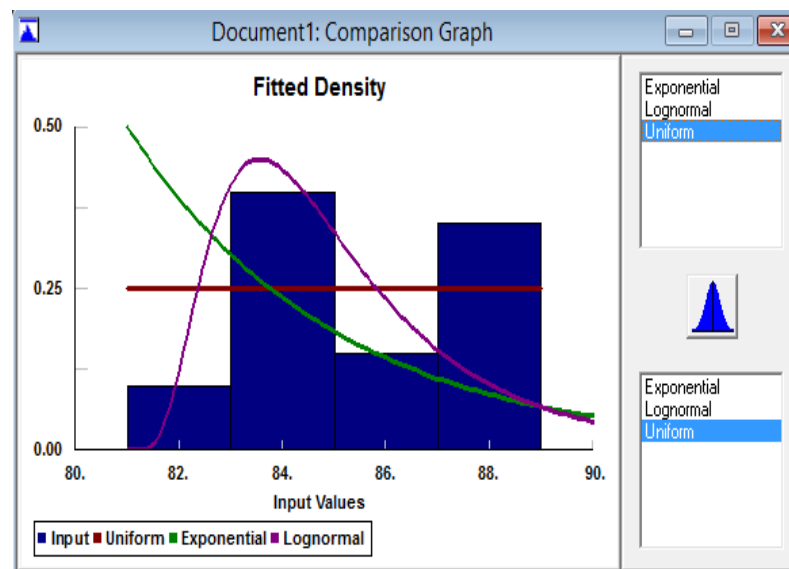
distribution	rank	acceptance
Uniform(81., 89.)	62.8	do not reject
Lognormal(81., 1.28, 0.582)	55.4	do not reject
Exponential(81., 4.)	0.804	do not reject

**Figure 4.37:** Various continuous distribution fitted to the input data  
for workstation 3





**Figure 4.38:** Descriptive statistics for the input data for workstation 3



**Figure 4.39:** Comparison between actual data and fitted uniform distribution for workstation 3

**WORKSTATION 4: Strip wire insulation with mechanical stripper**

Given:

P = confidence level = 0.95

$\alpha$  = significance level = 1 - P = 1 - 0.95 = 0.05

n = sample size = 20

$\bar{x}$  = 28

s = 1.56

From student's table ( $t_{19,0.025}$ ) = 2.093

$$hw = \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})1.56}{\sqrt{20}}$$

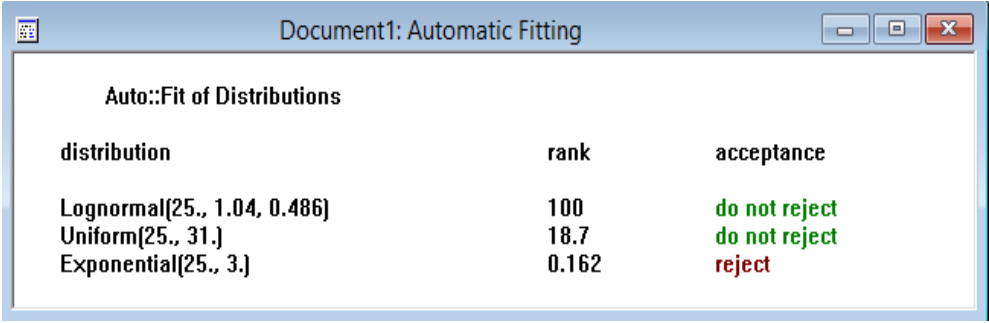
$$= 0.73$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 28 - 0.73 = 27.27$

Upper limit =  $\bar{x} + hw = 28 + 0.73 = 28.73$

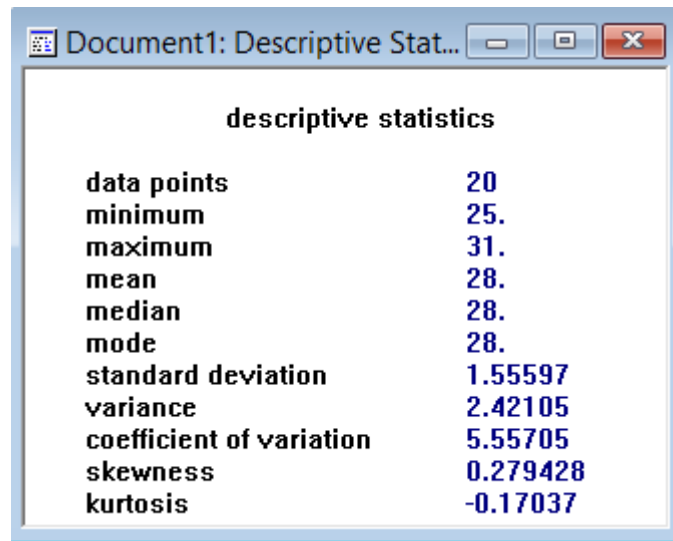
\*We confident that 95% operation times of winding process are between 27.27 and 28.73 with average 28s.



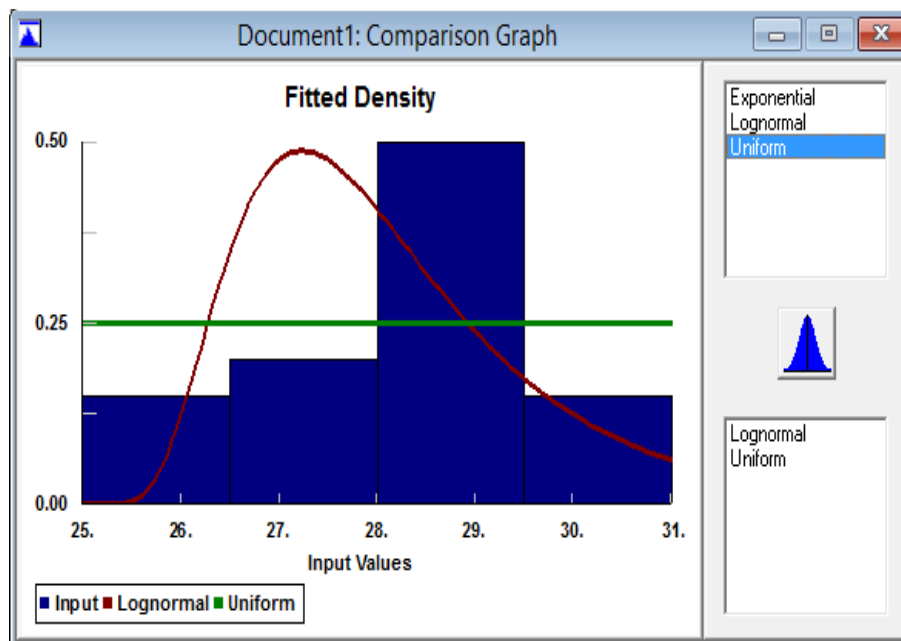
The screenshot shows a window titled 'Document1: Automatic Fitting'. Inside, there is a table titled 'Auto::Fit of Distributions'. The table has three columns: 'distribution', 'rank', and 'acceptance'. It lists three distributions: Lognormal[25., 1.04, 0.486] with rank 100 and acceptance 'do not reject'; Uniform[25., 31.] with rank 18.7 and acceptance 'do not reject'; and Exponential[25., 3.] with rank 0.162 and acceptance 'reject'.

distribution	rank	acceptance
Lognormal[25., 1.04, 0.486]	100	do not reject
Uniform[25., 31.]	18.7	do not reject
Exponential[25., 3.]	0.162	reject

**Figure 4.40:** Various continuous distribution fitted to the input data  
for workstation 4



**Figure 4.41:** Descriptive statistics for the input data for workstation 4



**Figure 4.42:** Comparison between actual data and fitted uniform distribution for workstation 4

### WORKSTATION 5: Pre-tinning wire ends

Given:

$P = \text{confidence level} = 0.95$

$\alpha = \text{significance level} = 1 - P = 1 - 0.95 = 0.05$

$n = \text{sample size} = 20$

$\bar{x} = 36$

$s = 1.89$

From student's table  $(t_{19,0.025}) = 2.093$

$hw$

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})1.89}{\sqrt{20}}$$

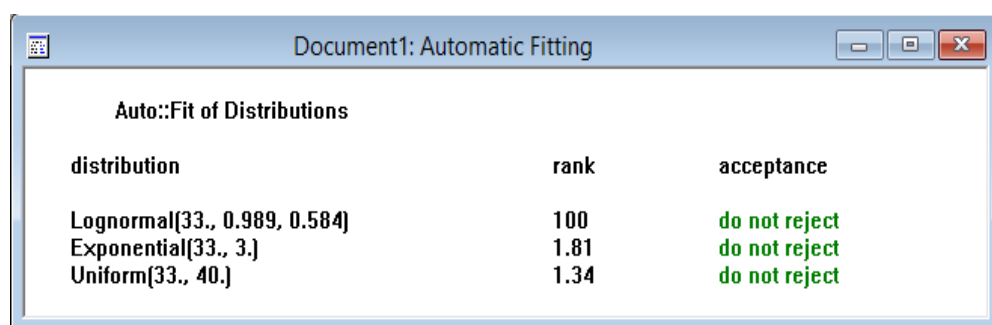
$$= 0.88$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit  $= \bar{x} - hw = 36 - 0.88 = 35.12$

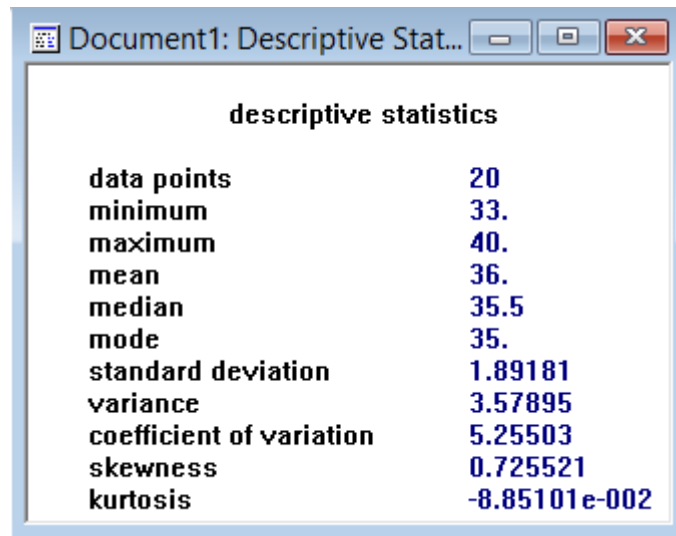
Upper limit  $= \bar{x} + hw = 36 + 0.88 = 36.88$

\*We confident that 95% operation times of winding process are between 35.12s and 36.88s with average 36s.

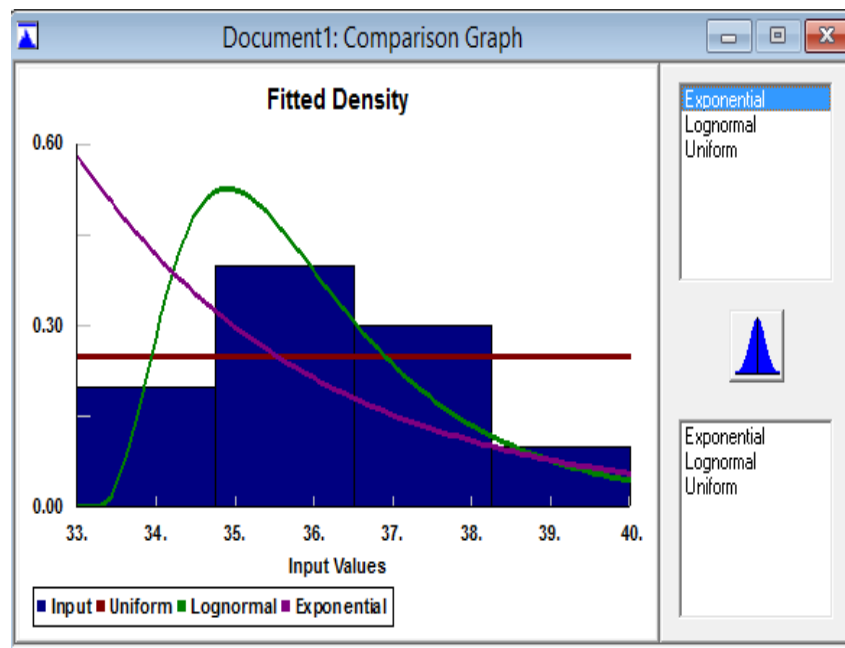


distribution	rank	acceptance
Lognormal[33., 0.989, 0.584]	100	do not reject
Exponential[33., 3.]	1.81	do not reject
Uniform[33., 40.]	1.34	do not reject

**Figure 4.43:** Various continuous distribution fitted to the input data  
for workstation 5



**Figure 4.44:** Descriptive statistics for the input data for workstation 5



**Figure 4.45:** Comparison between actual data and fitted uniform distribution for workstation 5

**WORKSTATION 6: Loop wire around core**

Given:

$P$  = confidence level = 0.95

$\alpha$  = significance level =  $1 - P = 1 - 0.95 = 0.05$

$n$  = sample size = 20

$\bar{x} = 51$

$s = 3.32$

From student's table ( $t_{19,0.025}$ ) = 2.093

$hw$

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})3.32}{\sqrt{20}}$$

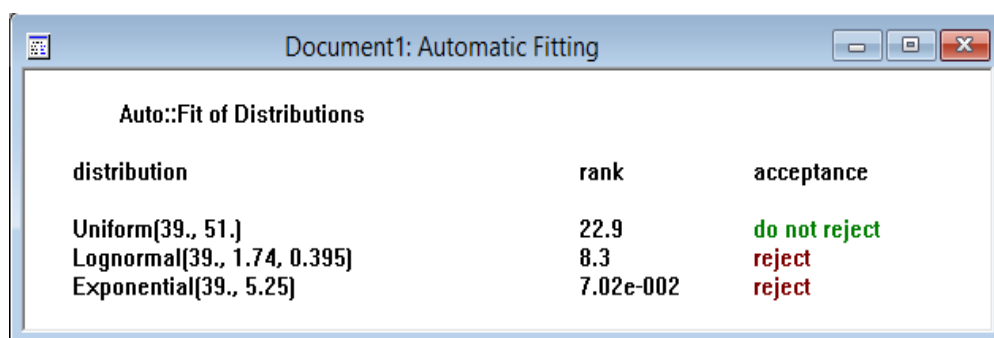
$$= 1.55$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 51 - 1.55 = 49.45$

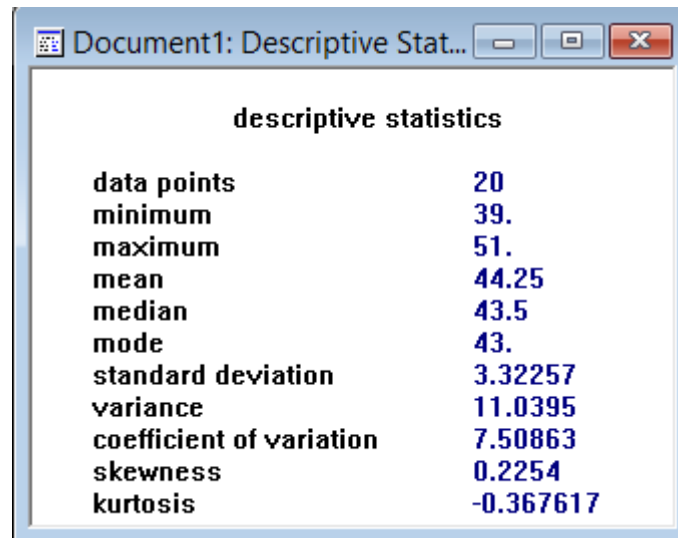
Upper limit =  $\bar{x} + hw = 51 + 1.55 = 52.55$

\*We confident that 95% operation times of winding process are between 49.45s and 52.55s with average 51s.

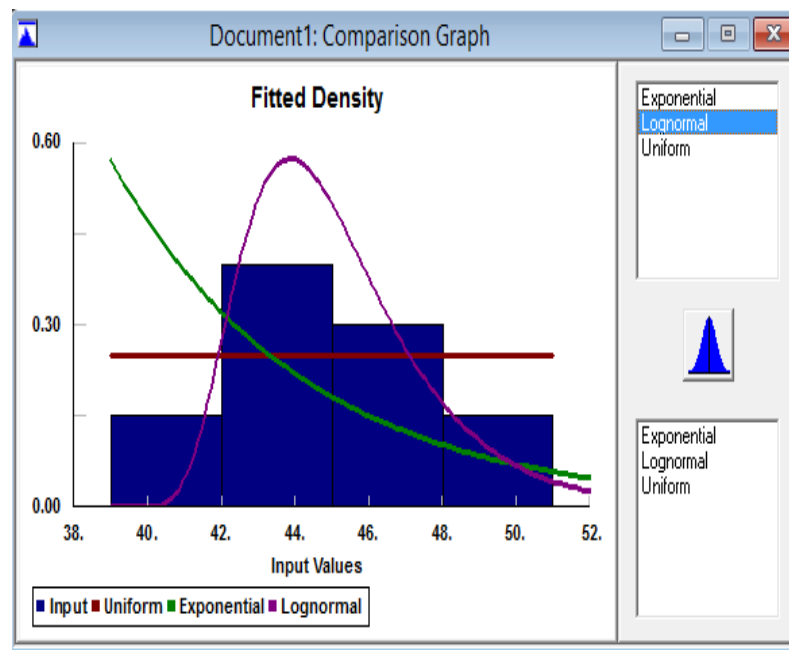


distribution	rank	acceptance
Uniform[39., 51.]	22.9	do not reject
Lognormal[39., 1.74, 0.395]	8.3	reject
Exponential[39., 5.25]	7.02e-002	reject

**Figure 4.46:** Various continuous distribution fitted to the input data for workstation 6



**Figure 4.47:** Descriptive statistics for the input data for workstation 6



**Figure 4.48:** Comparison between actual data and fitted uniform distribution for workstation 6

### WORKSTATION 7: Precut and straighten wire using the template precut

Given:

$P$  = confidence level = 0.95

$\alpha$  = significance level =  $1 - P = 1 - 0.95 = 0.05$

$n$  = sample size = 20

$\bar{x} = 66$

$s = 2.96$

From student's table ( $t_{19,0.025}$ ) = 2.093

$hw$

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})1.89}{\sqrt{20}}$$

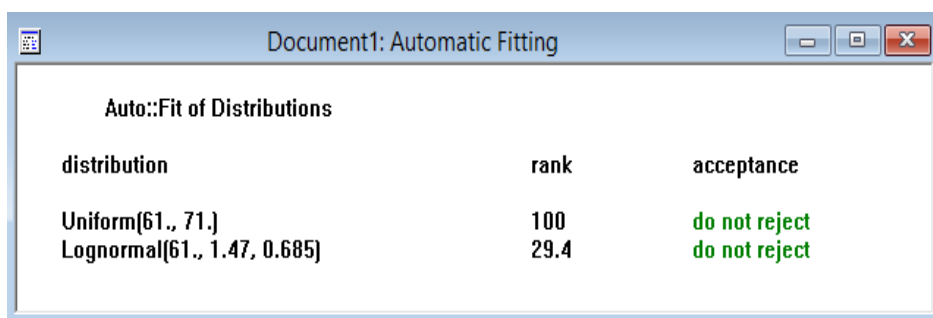
$$= 1.39$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 66 - 1.39 = 64.61$

Upper limit =  $\bar{x} + hw = 66 + 1.39 = 67.39$

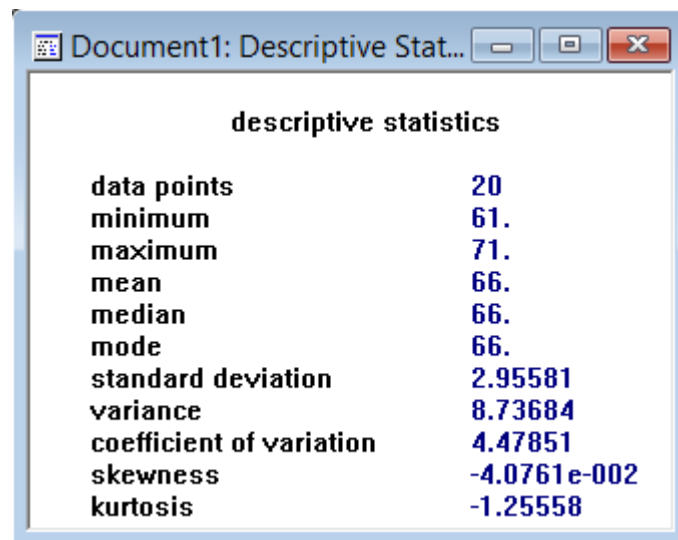
\*We confident that 95% operation times of winding process are between 64.61s and 67.39s with average 66s.



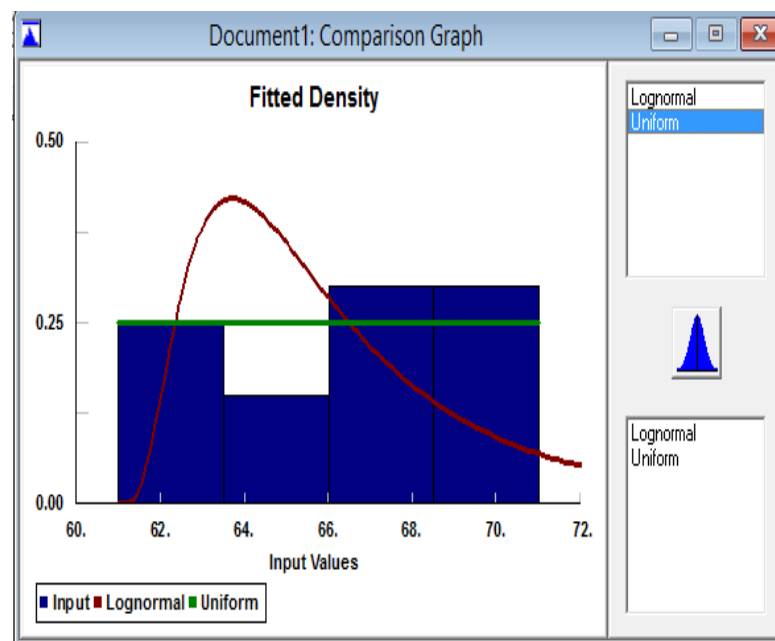
distribution	rank	acceptance
Uniform[61., 71.]	100	do not reject
Lognormal[61., 1.47, 0.685]	29.4	do not reject

**Figure 4.49:** Various continuous distribution fitted to the input data for workstation 7





**Figure 4.50:** Descriptive statistics for the input data for workstation 7



**Figure 4.51:** Comparison between actual data and fitted uniform distribution for workstation 7

**WORKSTATION 8: Cut the wire end**

Given:

$P$  = confidence level = 0.95

$\alpha$  = significance level =  $1 - P = 1 - 0.95 = 0.05$

$n$  = sample size = 20

$\bar{x} = 13$

$s = 1.56$

From student's table ( $t_{19,0.025}$ ) = 2.093

$hw$

$$= \frac{(t_{n-1, \alpha})s}{\sqrt{n}}$$

$$= \frac{(t_{19, 0.025})1.56}{\sqrt{20}}$$

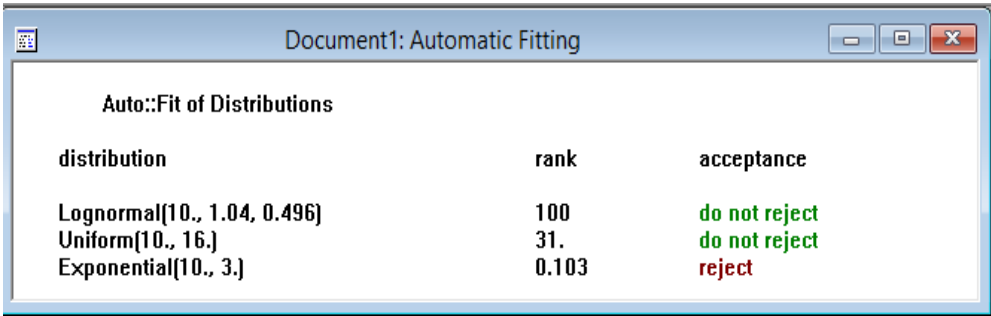
= 0.73

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 13 - 0.73 = 12.27$

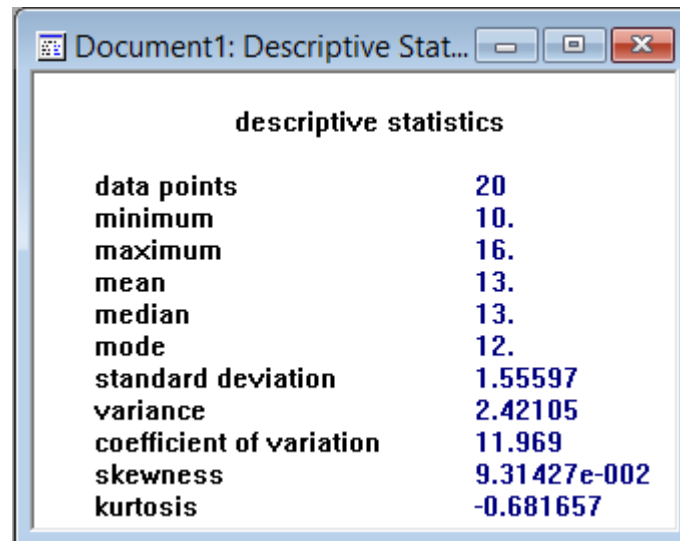
Upper limit =  $\bar{x} + hw = 13 + 0.73 = 13.73$

\*We confident that 95% operation times of winding process are between 12.27s and 13.73s with average 13s.

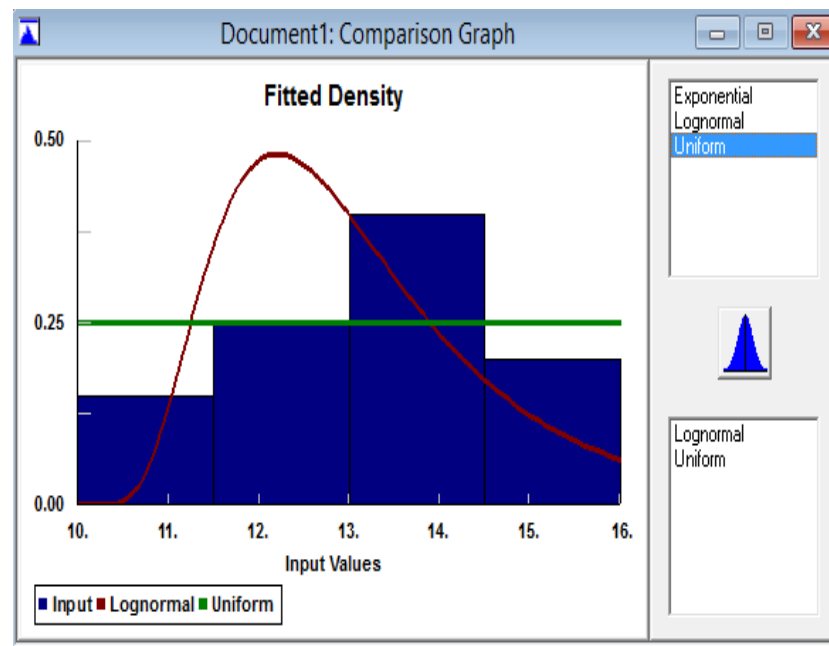


distribution	rank	acceptance
Lognormal(10., 1.04, 0.496)	100	do not reject
Uniform(10., 16.)	31.	do not reject
Exponential(10., 3.)	0.103	reject

**Figure 4.52:** Various continuous distribution fitted to the input data for workstation 8



**Figure 4.53:** Descriptive statistics for the input data for workstation 8



**Figure 4.54:** Comparison between actual data and fitted uniform distribution for workstation 8

**WORKSTATION 9: Tinning wire ends**

Given:

$P = \text{confidence level} = 0.95$

$\alpha = \text{significance level} = 1 - P = 1 - 0.95 = 0.05$

$n = \text{sample size} = 20$

$\bar{x} = 23.5$

$s = 2.01$

From student's table ( $t_{19,0.025}$ ) = 2.093

$hw$

$$= \frac{(t_{n-1, \alpha/2})s}{\sqrt{n}}$$

$$= \frac{(t_{19,0.025})2.01}{\sqrt{20}}$$

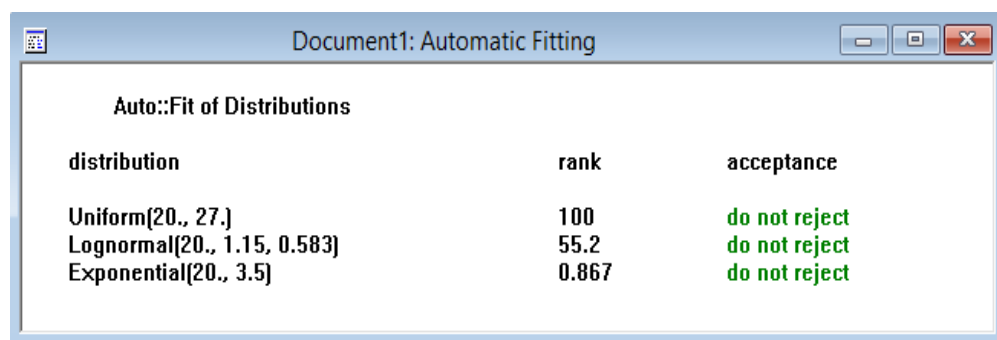
$$= 0.94$$

The lower and upper limits of 95% percent confidence interval are calculated as follows:

Lower limit =  $\bar{x} - hw = 23.5 - 0.94 = 22.56$

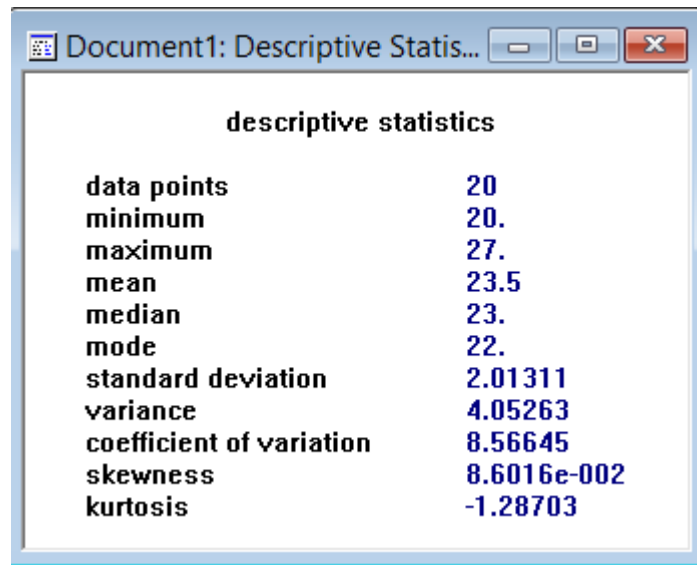
Upper limit =  $\bar{x} + hw = 23.5 + 0.94 = 24.44$

\*We confident that 95% operation times of winding process are between 22.56s and 24.44s with average 23.5s.

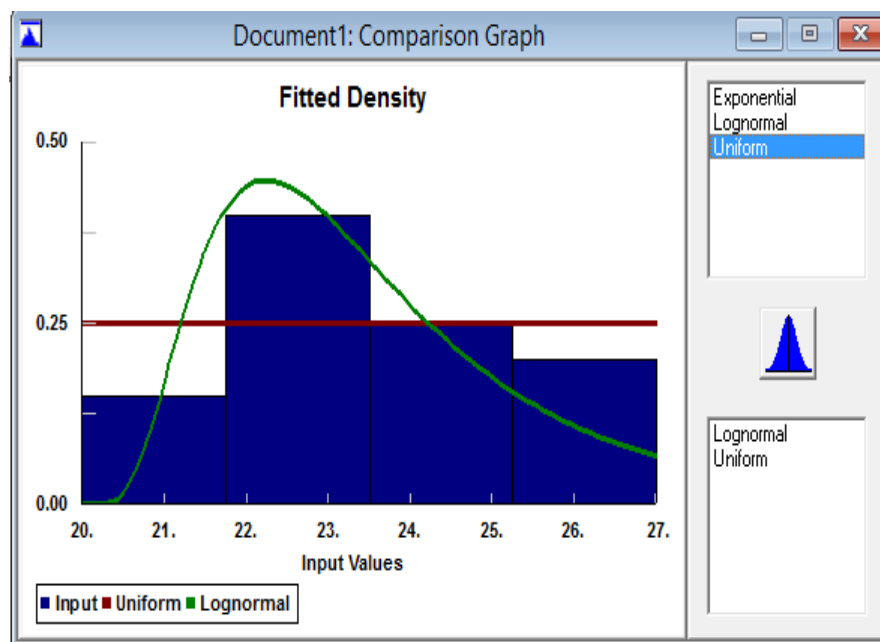


distribution	rank	acceptance
Uniform[20., 27.]	100	do not reject
Lognormal[20., 1.15, 0.583]	55.2	do not reject
Exponential[20., 3.5]	0.867	do not reject

**Figure 4.55:** Various continuous distribution fitted to the input data for workstation 9



**Figure 4.56:** Descriptive statistics for the input data for workstation 9



**Figure 4.57:** Comparison between actual data and fitted uniform distribution for workstation 9

**Table 4.4:** Comparison between mean and standard deviation two models

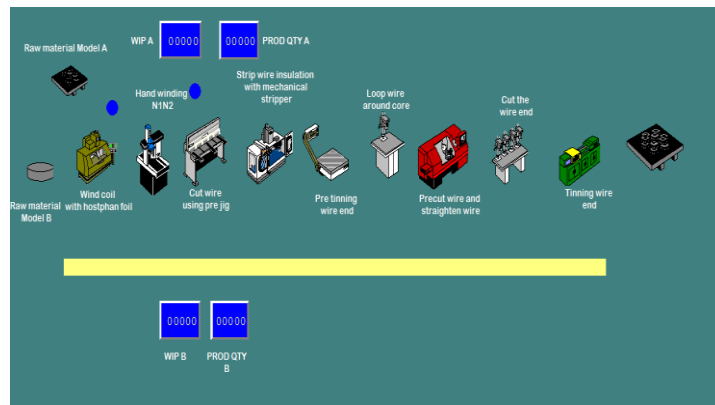
<b>Workstation</b>	<b>Model A</b> <b>6161-X001</b>			
	<b>Min</b>	<b>Mean</b>	<b>Max</b>	<b>SD</b>
W1	118	122	125	1.92
W2	78	81	85	1.68585
W3	25	27	29	1.1239
W4	33	35	36	0.858395
W5	40	42	44	1.07606
W6	58	61	65	1.62221
W7	11	13	17	1.89191
W8	20	24.45	28	2.28208
W9	41	43	49	2.07745

<b>Workstation</b>	<b>Model B</b> <b>6161-X037</b>			
	<b>Min</b>	<b>Mean</b>	<b>Max</b>	<b>SD</b>
W1	117	121	125	2.29416
W2	76	80	84	1.77705
W3	81	85	89	2.40613
W4	25	28	31	1.55597
W5	33	36	40	1.89181
W6	39	44.25	51	3.32257
W7	61	66	71	2.95581
W8	10	13	16	1.55597
W9	20	23.5	27	2.01311

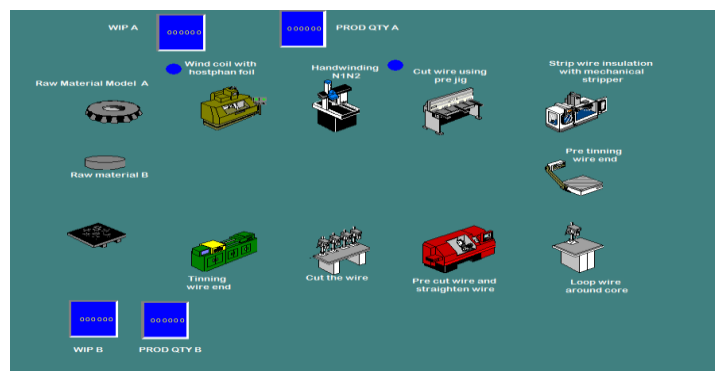
#### 4.6 CONDUCTING SIMULATION STUDY

Once a suitable application has been selected and appropriate tools are chosen, the simulation study can begin. Simulation is much more than building and running a model of the process. The successful simulation project is well planned and coordinated. The simulation is conducted in several steps. Firstly, define objective and plan the study which need to define the purpose of the simulation project and what the scope will be. A project plan needs to be developed to determine the resources, time, and budget requirement for carrying out the project. Follow by collecting and analyze the system data. In this stage try to identify, gather, and analyze the data defining the system to be modeled. The next is follow by building the model which develops a simulation model of the system. Validate the model which is debugging the model and make sure it is a credible representation of the real system. The experiment is conducted by running the simulation for each of the scenarios to be evaluated and analyze the results. Finally, presenting the result and make recommendation so that an informed decision can be made.

The Pro Model 7.0 student version was used to run the simulation for straight layout and cellular layout in U-shape. Before that, ensure the simulation run by identify objective and plan the study and focus on the aim and scope for the simulation project. The next is tried to develop the resources and time requirement for run the simulation. Besides that, the data such as entities, arrival, processing, waiting time, need to declare or to input first before doing the simulation. Basically the running simulation used to compare between the standard time from company and the observation cycle time that have done at the Vacuumschmelze (M) Sdn Bhd. The Figure 4.58 as below shows the allocation every processing in the company by using conveyer. These layouts refer to the straight layout. The process runs unit by unit. Every part will be transfer to the conveyer and pick up to the next operator in the next work station. From here, a problem will be occurred which is the operator a bit chaotic while taking the part at conveyer. As the proposed solution, cell manufacturing in U-shape layout is applied in this case study. The arrangement of the workstations is shown in Figure 4.59 as below.

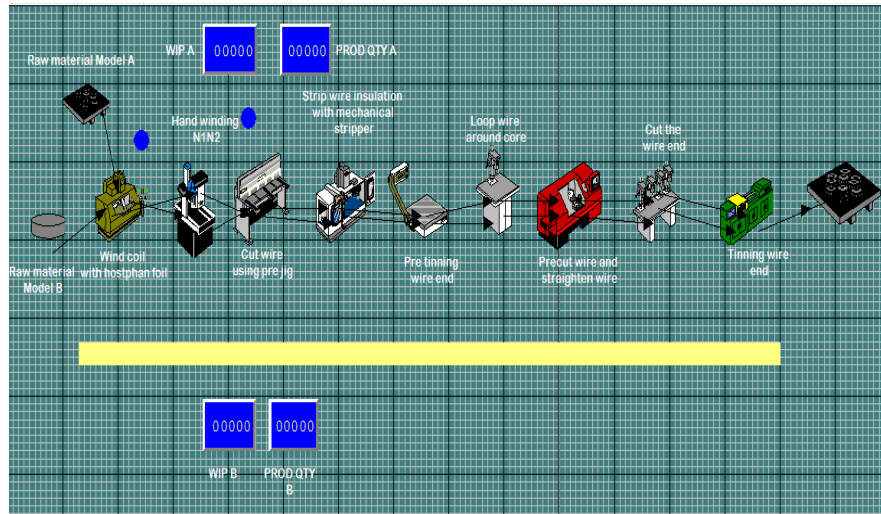


**Figure 4.58:** Layout conveyor using ProModel Simulation Software

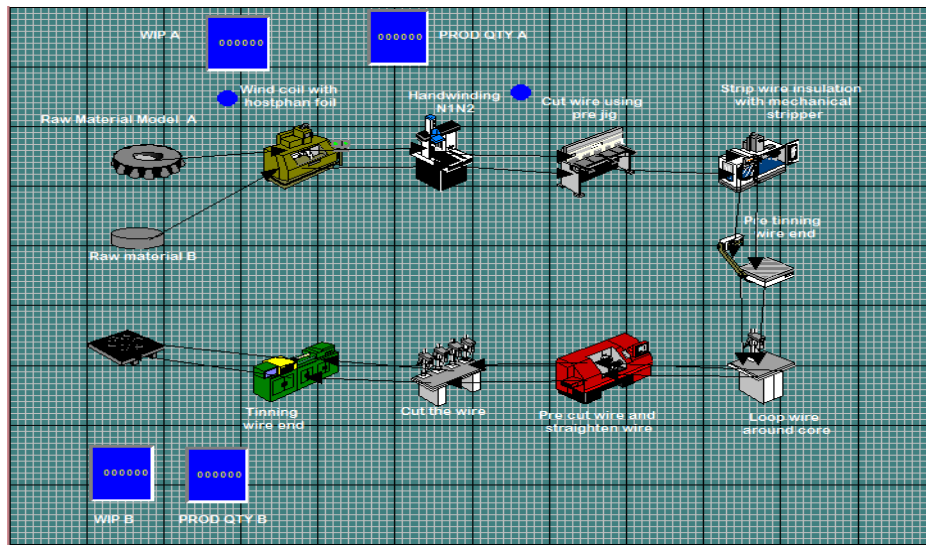


**Figure 4.59:** U-Shape Layout using ProModel Simulation Software





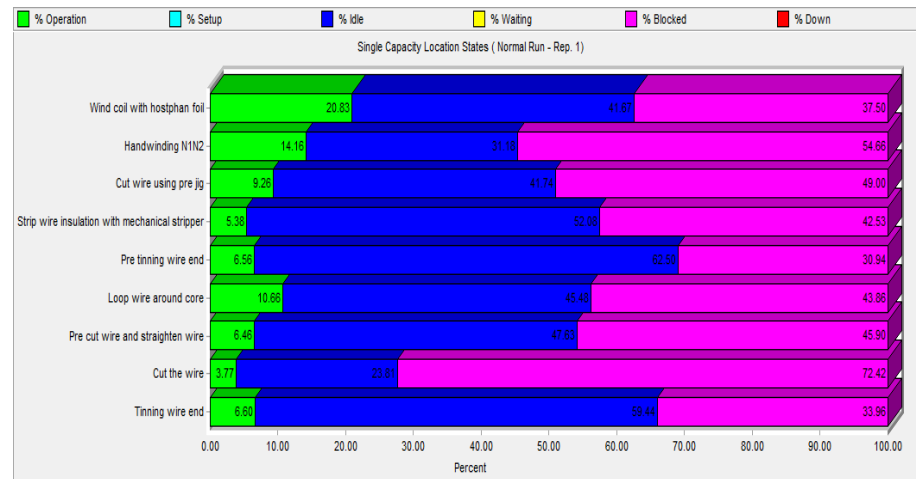
**Figure 4.60:** Processing route straight layout



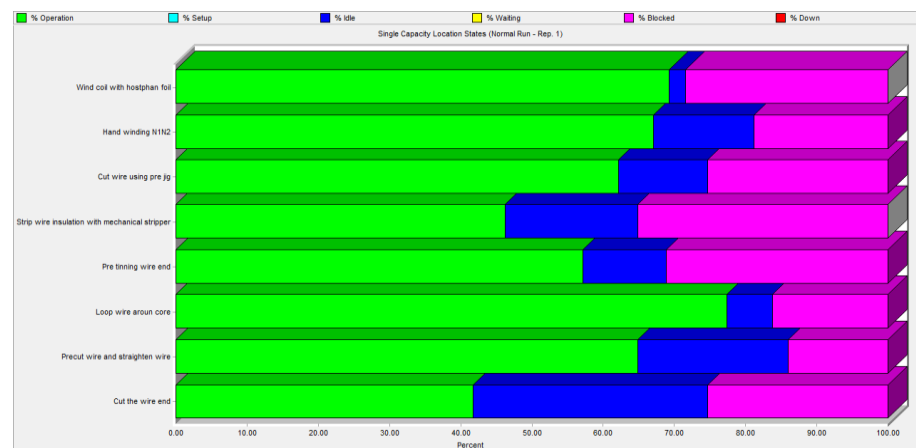
**Figure 4.61:** Processing route at U shape layout

## 4.7 DISCUSSION

### 4.7.1 Percentage Overall Result



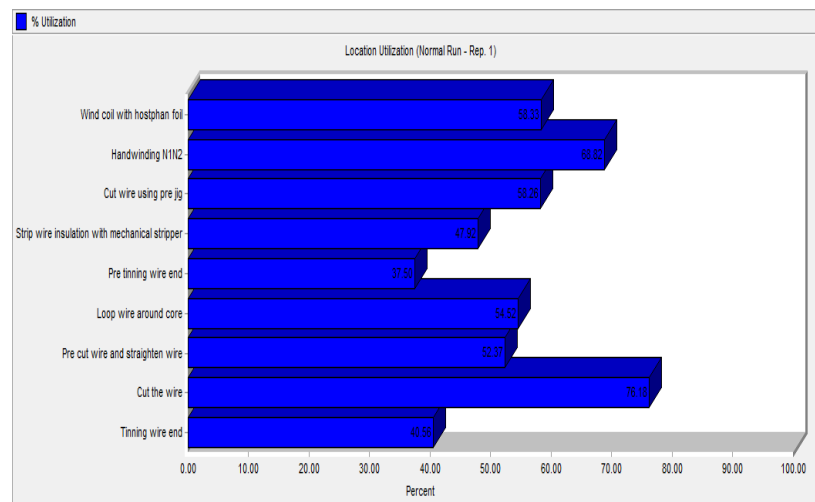
**Figure 4.62:** Single capacity location state at straight layout



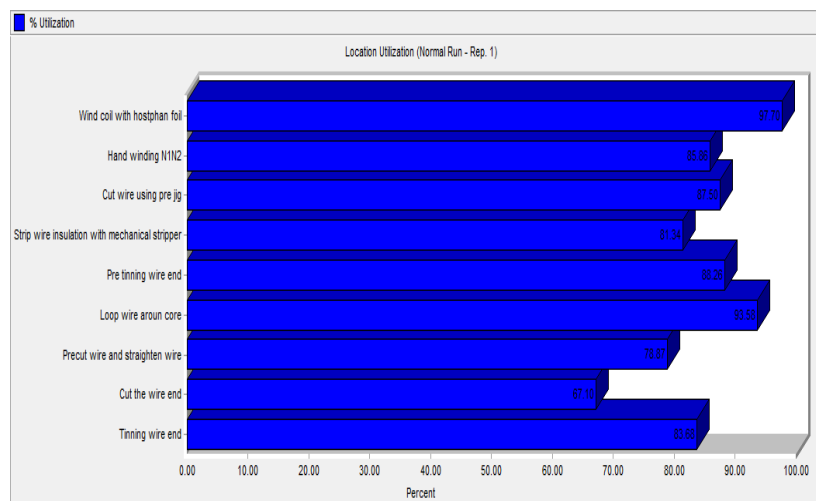
**Figure 4.63:** Single capacity location state at cellular layout

From figure 4.62 and 4.63 ,the chart show on straight layout and cellular layout overall percentage doing the simulation. These complete percentage result consist of percentage of operation, idle and blocked in this line. By comparing these two result, the operation is slow at the straight layout. Each workstation must need to give attention to overcome the problem and once of the method in enhancement the productiivity by implementing cellular layout. The factor related to the low operation percentage focussed on cycle time. The operation from 9.29% increase to 54.22%. When changing into the cellular layout, the routing process become short. So that the cycle time processing become low.

### 4.7.2 Percentage of Utilization



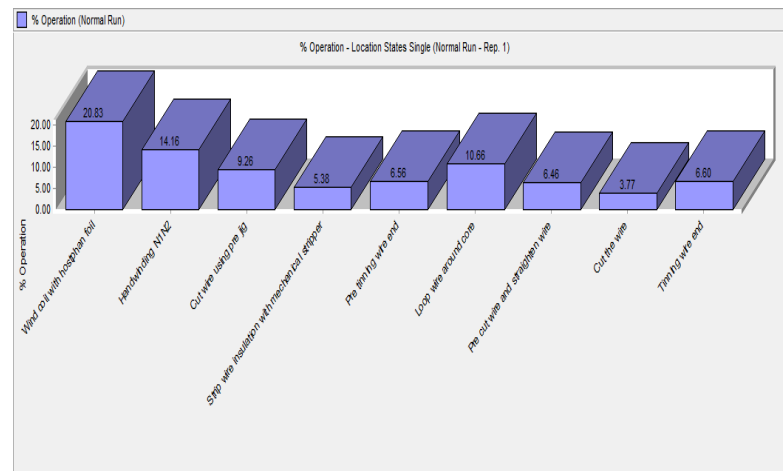
**Figure 4.64 :** Utilization in straight layout



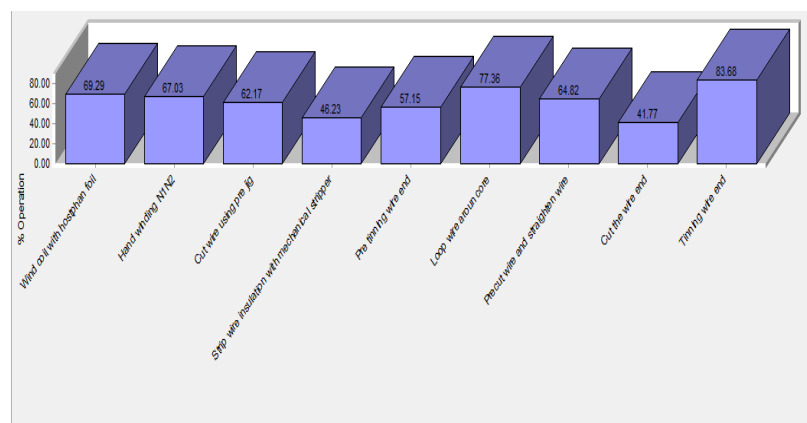
**Figure 4.65 :** Utilization in cellular layout

The term utilization refer to the processes were using in effectively. In this section will describe more on simulation results are presented in the form of pie charts to present the output of percentage of utilization. According to graph, there are two workstations where approximate to the 100% percentage which is workstation 1(wind coil with hostaphan foil) and looping wire around core. By refer to the proposed layout, workstation 1 and workstation 6 shown highest percentage utilization which are 97.70% and 93.58% compared to other workstation.

### 4.7.3 Percentage of Operation



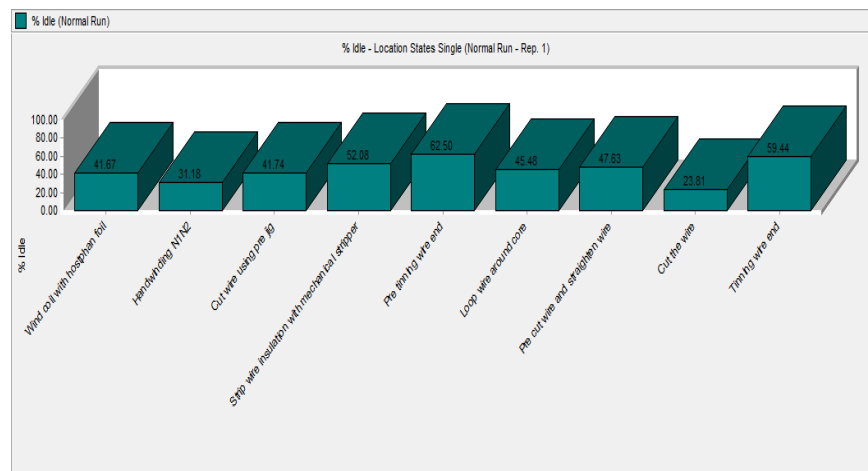
**Figure 4.66:**Percentage operation in straight layout



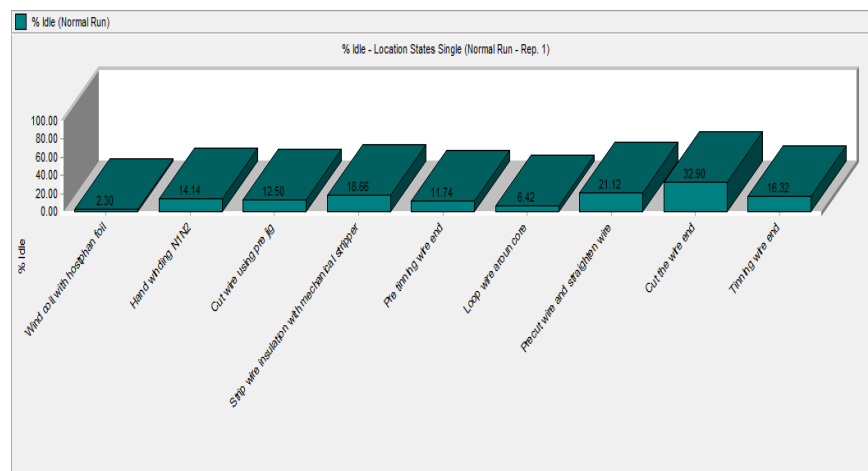
**Figure 4.67:** Percentage operation in cellular layout

From the figure 4.66 and 4.67, the overall percentage of operation increase from 9.29% to 63.27%. Figure 4.63, the percentage of operation at straight layout is lower than the percentage operation for cellular layout. Based on proposed layout, workstations 6 and 9 which is looping wire around core and tinning wire show highest percentage of operation. The factor that effecting on high percentage of some workstation is the time taken. The time taken in the workstation longer compares other process.

#### 4.7.4 Percentage of Idle time



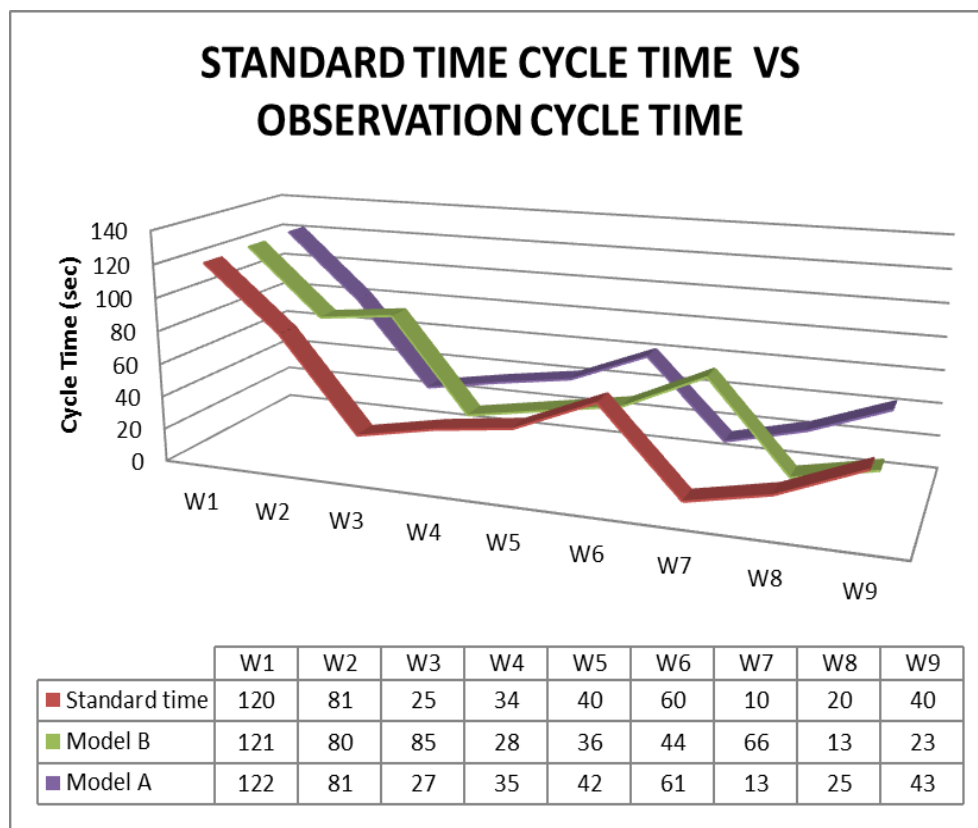
**Figure 4.68:** Percentage of idle time in straight layout



**Figure 4.69:** Percentage of idle time in cellular layout

In engineering term, idle time refer to the non-productive time of employees, machines or both where the company still paid to the worker due to work stoppage without any cause. According to the straight layout shown in figure 4.38, the percentage of idle time is high. The highest percentage detected at workstation pre tinning wire and tinning wire end. The percentage occur at this both workstation is 62.50% and 59.44%. From observation, the idle time has high percentage at pre tinning wire end because of need to wait the longer time in previous workstation which are stripping wire. Other than that, it is related to the cutting wire. There need to use jig. So that, operator need to change the template of jig depends on the model.

#### 4.7.5 Comparison between Standard Time and Cycle Time



**Figure 4.70:** Standard time against observation cycle time

By referring to the figure 4.70, the graph showed on the standard time cycle time against observation cycle time. The observation is done by collecting the data from Vacuumschmelze (M) Sdn Bhd. After analyzing the data observation, the cycle time increase compare to the standard time generated from company. This is because of the non-added activities done by operator such as rest while doing their task at the workstation. The worker sometimes talks to each other while doing their work. This will effect on increasing of the cycle time.

Other than that, the level of skilled worker and unskilled worker is one of the factors of the increasing of cycle time. This is related to the experience workers and new workers. The new workers need more time in settle their work. From observation, the workstation involve of increasing cycle time is hand winding and precutting. From

observation, the primary cause of bottlenecks in a production system is the discrepancy in the production rates among stations

In addition, when cycle time higher it effect on bottleneck and work in progress. A bottleneck is defined as a work center that limits the production rate of the entire production system because demand exceeds the capacity of the bottleneck either for some time or permanently. By having a bottleneck stations may lead to two major problems in a production process. First, if the capacity of the production system is not sufficient to satisfy customers demand, the company may lose sales and customer goodwill. Secondly, if excess inventory accumulates in front of bottleneck stations, additional inventory carrying costs are incurred. It is known that controlling bottleneck stations smoothed the flow of materials in a production system, which improves customer satisfaction and reduces costs (Glock & Jaber, 2013).

By refer to the simulation result; the increasing of percentage on overall workstation is because of the short run production. Other than that, the efficiency of industrial production lines is crucial as it results in an improved production and utilization of available resources. Some aspect of factors contribute to production line efficiency are manpower utilization and machine efficiency. (Subramaniam et al., 2008). By comparing overall percentage, the highest changes percentage occurred at workstation 5 which is 50.76% (pre tinning wire end). The increasing of percentage utilization is because of existing two work cell where there is two operator doing the same work at the same. The higher the percentage of utilization it make better and more economical for the overall processes.

In workstation 4 which is stripping wire insulation normally used longer time because of the process need to try and error. The observation in cycle time in workstation 4 also high because the processes a bit complicated compares to other. By implementing the cellular layout, the time taken was reduced and this is one of the idea to reduce idle time.

## **CHAPTER 5**

### **CONCLUSION AND RECOMMENDATION**

#### **5.1 INTRODUCTION**

In this chapter, it describe on conclusion of finding for this study and summarization of all progress including discussion of the result. Besides that, some recommendations are listed to further study to enhance the knowledge.

#### **5.2 CONCLUSION**

As a conclusion, in term of surviving a competitive industry a rapid and effective strategy to ameliorate the production line must be developed. It is vital in order to satisfy the demand of customer with any changes with unexpected reordering volume or part requirement has been made.

Based on the single state location, evaluation on the current production line layout for the company is carried out and major problems are identified. These problems include of overall percentage result such as utilization, operation and idle time. The overall percentage in this result showed the increment from 9.29% to 54.22 %. From result the idle time and blocking will reduce by increment of operation.

The percentage of utilization shows increment for each station except cutting pin process. The percentage on current state is 76.18% decrease to the 67.10%.The highest utilization showed at workstation 1 (wind hostaphan foil) and 6 (looping process) which are 97.70% and 93.58% after implement cell manufacturing layout.



In the percentage of operation, the percentage normally increases from every process. High percentage of workstation can be related to the time taken. The time taken in every process is longer comparing other process. The idle percentage become lower from is 62.50% and 59.44%. This factor related to the high productivity where the implement of cell manufacturing layout give benefit to the company.

Based on the analyze result, it can be concluded that the changing of the new layout by changing the conveyer to the U-shape layout was the most significant factor in productivity enhancement of the production. It was supported by the fact of travelling of conveyer and also the space need by using conveyer itself. Using the straight layout and apply the conveyer, it will involve more spaces needed to run the production. Based on objective, the current performance of coil winding assembly was investigated and new proposed layout has been designed. By implementing this method, productivity is increased. This is proved by the analysis of the result and objective is achieved.

### **5.3 RECOMMENDATION FOR THE FUTURE RESEARCH**

As for the recommendation, the study on analysis of spaces can be considered to further improve the production floor and add value to the company. The study on space analysis can be including distance of assembly line, ergonomic, etc. The production line can also be improved by apply another tool in lean manufacturing such as Value Stream Mapping. The value stream mapping process is one of the continuous improvement toolkits which can assist to identify the better way on how to improve the production flow in term of facility. Once the root cause is identifying, the idea of the improvement process can be done.

From the simulation, the output data show some problem occur at the production line in producing the both model. The problems occur during assembly the product is some operator have low skilled. This make the production become slow because of the high WIP and some workstation become bottleneck. As a recommendation, company need to provide enough training to the operator.

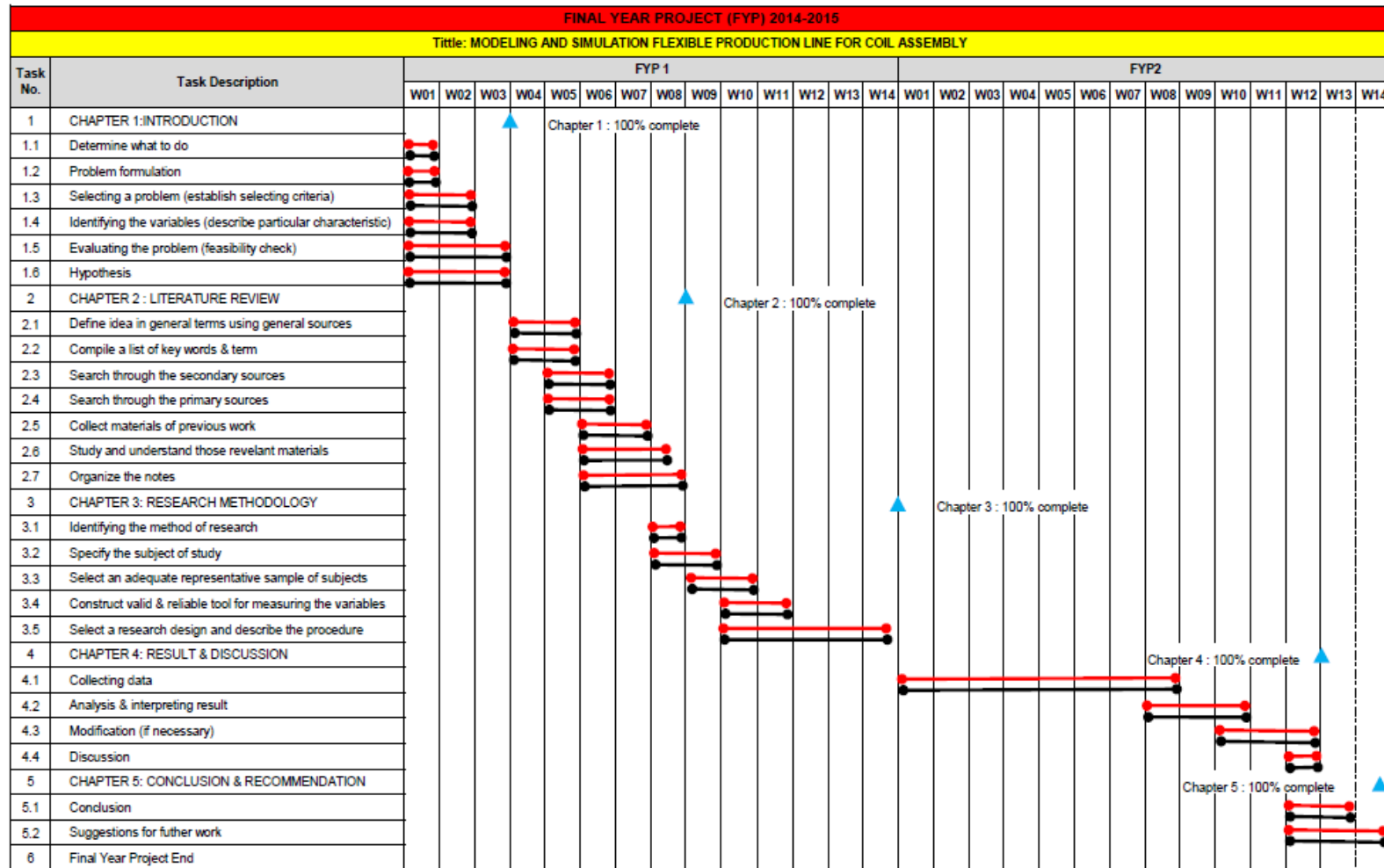
Other than that, by using conveyer it will make longer time to worker to take the product because the product runs unit by unit. The more cells need to develop which mean develop 2 or 3 cell in one workstation. So that, the cycle time will be reduced. In addition, these related to the process layout can be design to the floor plan which the purpose to improve the efficiency by arranging to its function. The productivity can be increased and lead time can be reduced.

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## APPENDIX A1

### GANTT CHART



**APPENDIX B1**  
**CYCLE TIME MODEL A: 6161-X001**

<b>Current State</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>18</b>	<b>19</b>	<b>20</b>
<b>W1</b>	120	122	124	120	118	122	122	120	120	125	121	120	122	125	124	123	122	124	123	123
<b>W2</b>	81	80	80	78	83	79	82	80	85	83	81	80	79	81	82	81	80	82	80	83
<b>W3</b>	27	28	26	28	28	27	26	29	28	26	28	28	27	26	28	25	27	26	25	27
<b>W4</b>	35	34	36	35	36	34	35	36	35	36	35	35	36	34	34	33	35	35	35	36
<b>W5</b>	40	41	40	43	42	42	41	43	42	42	43	44	42	43	41	42	42	43	43	41
<b>W6</b>	60	58	61	59	61	63	65	62	60	61	59	60	62	62	60	62	60	61	63	61
<b>W7</b>	11	17	13	11	12	12	12	13	12	11	16	12	11	14	12	15	17	13	13	13
<b>W8</b>	26	24	28	27	25	25	26	24	22	26	22	20	20	26	27	26	25	23	22	25
<b>W9</b>	44	47	42	43	42	42	43	41	44	42	41	45	43	41	42	49	41	42	42	44

## APPENDIX B2

### CYCLE TIME MODEL B: 6161-X037

Current State	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<b>W1</b>	122	120	121	120	118	120	125	119	125	122	124	120	117	121	124	122	118	122	119	121
<b>W2</b>	81	80	81	79	80	79	81	84	79	78	78	81	83	76	80	79	81	79	80	81
<b>W3</b>	82	85	84	87	89	83	85	84	87	85	83	83	83	88	89	83	81	84	87	88
<b>W4</b>	28	27	27	28	29	28	30	29	31	25	27	28	26	28	31	26	29	27	28	28
<b>W5</b>	38	35	33	36	35	37	34	37	35	34	37	35	37	35	34	37	40	36	40	35
<b>W6</b>	45	39	43	45	47	42	46	51	50	48	43	39	43	43	47	39	44	43	43	45
<b>W7</b>	69	64	70	65	66	68	69	71	61	63	66	69	62	62	63	64	66	67	66	69
<b>W8</b>	13	10	12	15	13	11	16	12	12	13	15	13	14	12	11	15	14	13	14	12
<b>W9</b>	20	25	21	22	23	22	22	21	23	25	26	27	25	26	25	24	22	23	26	22



**APPENDIX C1**  
**CRITICAL VALUE FOR STUDENT'S T DISTRIBUTION AND STANDARD**  
**NORMAL DISTRIBUTION**

df\p	0.40	0.25	0.10	0.05	0.025	0.01	0.005	0.0005
1	0.324920	1.000000	3.077684	6.313752	12.70620	31.82052	63.65674	636.6192
2	0.288675	0.816497	1.885618	2.919986	4.30265	6.96456	9.92484	31.5991
3	0.276671	0.764892	1.637744	2.353363	3.18245	4.54070	5.84091	12.9240
4	0.270722	0.740697	1.533206	2.131847	2.77645	3.74695	4.60409	8.6103
5	0.267181	0.726687	1.475884	2.015048	2.57058	3.36493	4.03214	6.8688
6	0.264835	0.717558	1.439756	1.943180	2.44691	3.14267	3.70743	5.9588
7	0.263167	0.711142	1.414924	1.894579	2.36462	2.99795	3.49948	5.4079
8	0.261921	0.706387	1.396815	1.859548	2.30600	2.89646	3.35539	5.0413
9	0.260955	0.702722	1.383029	1.833113	2.26216	2.82144	3.24984	4.7809
10	0.260185	0.699812	1.372184	1.812461	2.22814	2.76377	3.16927	4.5869
11	0.259556	0.697445	1.363430	1.795885	2.20099	2.71808	3.10581	4.4370
12	0.259033	0.695483	1.356217	1.782288	2.17881	2.68100	3.05454	4.3178
13	0.258591	0.693829	1.350171	1.770933	2.16037	2.65031	3.01228	4.2208
14	0.258213	0.692417	1.345030	1.761310	2.14479	2.62449	2.97684	4.1405
15	0.257885	0.691197	1.340606	1.753050	2.13145	2.60248	2.94671	4.0728
16	0.257599	0.690132	1.336757	1.745884	2.11991	2.58349	2.92078	4.0150
17	0.257347	0.689195	1.333379	1.739607	2.10982	2.56693	2.89823	3.9651
18	0.257123	0.688364	1.330391	1.734064	2.10092	2.55238	2.87844	3.9216
19	0.256923	0.687621	1.327728	1.729133	2.09302	2.53948	2.86093	3.8834
20	0.256743	0.686954	1.325341	1.724718	2.08596	2.52798	2.84534	3.8495
21	0.256580	0.686352	1.323188	1.720743	2.07961	2.51765	2.83136	3.8193
22	0.256432	0.685805	1.321237	1.717144	2.07387	2.50832	2.81876	3.7921
23	0.256297	0.685306	1.319460	1.713872	2.06866	2.49987	2.80734	3.7676
24	0.256173	0.684850	1.317836	1.710882	2.06390	2.49216	2.79694	3.7454
25	0.256060	0.684430	1.316345	1.708141	2.05954	2.48511	2.78744	3.7251
inf	0.253347	0.674490	1.281552	1.644854	1.95996	2.32635	2.57583	3.2905