A STUDY OF SIMULATION MODELING IN DOOR FRAME PRODUCTION

WONG ENG HOW

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SUPERVISOR'S DECLARATION

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

Signature :
Name of Supervisor :
Position :
Date :

STUDENT'S DECLARATION

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

Signature :

Name :

ID Number :

Date :

DEDICATION

This thesis is dedicated to my parents, brothers and friends who support me all the way during my study. Their encouragements are supportive and I had insisted to work on my study until complete.

I would like to dedicate this thesis to my supervisor, Dr. Cheng Jack Kie who give me a lots of advice and suggestion throughout my study.

Finally, I want to dedicate this study to door frame factory located at Johor as well.

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

ABSTRACT

This study discusses about assessing and enhancing the production line in door frame industries by using simulation method. The scope of this study is focusing on the production processes of a Door Frame Factory. The time frame covered is one year which is in year 2015. Simulation is a planning tool, implemented in the processes which required by the factory to meet the changing demands of the products. Modeling door frame production will be developed using Arena simulation software to test run and make comparison with the real world system. It is a quantitative study which the performance of the processes is measured by average wait time, machine utilization and operator utilization for the entire system of door frame production. The results obtained from the simulation software will act as an attempt to simulate the "What-If Analysis" scenarios to forecast the performance of real world system without developing costly implementation.

Keywords: Simulation, ARENA software, Wait Time, Machine Utilization, Operator Utilization, Productivity, Door Frame Production Line

ABSTRAK

Kajian ini membincangkan tentang menilai dan meningkatkan pretasi sistem pengeluaran dalam industri pembuatan bingkai pintu dengan menggunakan kaedah simulasi. Skop kajian ini memberi tumpuan pada sistem operasi untuk barisan pengeluaran kepada pembuatan bingkai pintu. Tempoh masa yang diliputi adalah satu tahun iaitu pada tahun 2015. Kajian ini menggunakan perisian simulasi ARENA untuk menjalankan proses simulasi dan model barisan pengeluaran. Perisian simulasi adalah alat perancangan untuk melaksanakan proses yang diperlukan oleh kilang untuk memenuhi permintaan kuantiti yang sentiasa berubah-ubah bagi pelanggan yang membeli produk. Pengeluaran bingkai akan dimodelkan dalam perisian simulasi untuk membuat kajian dan perbandingan dengan barisan pengeluaran dalam sistem realiti di kilang sebenar. Kajian ini merupakan kajian kuantitatif di mana prestasi adalah diukur dengan purata masa menunggu, peratusan penggunaan mesin dan peratusan penggunaan pekerja untuk seluruh sistem pengeluaran bingkai pintu. Keputusan yang diperolehi daripada perisian simulasi akan bertindak sebagai satu percubaan untuk meniru "analisis apa-jika" senario untuk meramal prestasi sistem dunia sebenar tanpa menggunakan banyak wang. Perisian simulasi dapat mengesan kesesakan dalam proses berkenaan dan juga bilangan pengeluaran dapat diketahui. Peningkatan prestasi dan produktivit pada proses tersebut dapat dilaksanakan dengan simulasi.

Kata Kunci: Simulasi, Barisan Pengeluran, ARENA, Masa Menunggu, Penggunaan mesin, Penggunaan Pekerja, Produktiviti, Industri Pembuatan Bingkai Pintu

TABLE OF CONTENTS

CHAPTER 3 METHODOLOGY

CHAPTER 4 DATA ANALYSIS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Manufacturing industry is the most fast-growing industry nowadays in the world as well as in Malaysia. According to the Department of Statistics Malaysia (2015), the growth index of industrial production in manufacturing ranked the top with 7.8%, mining (6.9%) and electricity (3.0%). Since so many competitors in the market, many manufacturers need to maximize the utilization of the machine and also the worker performance in order to compete in the market. Simulation is one of the most common used tools to analyze complex production system. The Oxford English Dictionary explain the term "simulation" as the skill of mimic the behaviour of system by means of analogous model, situation, or apparatus, in order to collect information more conveniently or to train personnel.

This research aims to build a pragmatic tool that called simulation model to eliminate the unnecessary running time and improve the efficiency in the production systems. Simulation model can act as the planner for the production system to move and follow the model that being built. It normally applied in the manufacturing industries as well as service industries like bank and hospital. By using simulation and refer to case study and also advanced templates, we can somehow figure out many solution. There is a variety of simulation models. Simulation is categorized as static simulation model, dynamic simulation model, deterministic simulation model, stochastic simulation model, continuous simulation model and discrete simulation model (Hailu *et al*., 2015)

Discrete-event simulation (DES) will be used in this research. It is suitable use to analyze the complex system in the manufacturing system which got a lot of changes in the process time for every workstation (Deng, X *et al.*, 2015). In this research, simulation is applied inside the workstation; the process time for each workstation can be measured and evaluated. Then, simulation modelling will be proposed to make improvements on the process running time to increase the efficiency of the production system. Simulation has been broadly used since it can save money by using what-if analysis aside from building the real model.

1.2 BACKGROUND OF STUDY

Over the last few years, factories especially in the manufacturing industries have progressively focused on productivity and efficiency. This is a win-win strategy which may benefit between the factories and customers. Customer can buy the product at the cheaper price and factories can generate more profits by producing more units at once time. Due to the rapid growth population, getting more market demand for door frame as the number of housing areas keep increasing. But, company sometime cannot fulfill the requirements of customer order. Moreover, many homogenous company compete in the market. Customer normally will go for shorter lead times and fast delivery company. Company tries to make some improvements to enhance the production by buying the semi-conducted product to further process until finished product, adding new production line to assuage the inefficiency supply. All the existing method seems cause high cost and does not work out. Moreover, in the production line, there are three types of operating methods, automated, partially automated and manually. The partially automated is the most preferred in the industry. Every workstation consists of operator with the machine. The number of machine and process may be more than one. So, it is hard to assess the performance of the operator and machine. Therefore, it is recommended to use simulation to predict the problem.

Simulation is an indispensible pragmatic tool to solve many real-world problems (Banks, J., 1998). Simulation is a tool that can construct a model of current system or proposed system in order to figure out what is the factors affect the system or forecast the system future behaviour. Our aim is to replace the existing method with simulation to solute the problem more efficiency. The correction can be done by eliminate the defects, speed up the machine runtime and fully utilization of the machine. With this, big amount of products can be produce at once time, reduce the mechanical stresses and in more high quality. Discrete-event simulation will be aimed in inspecting the bottlenecks, the queue size and allocation and machine breakdown interval.

According to observation and information given by the Production Executive, Mr. Alex She, the criterion that attained are the production line of door frame production consists of four different paths which are hinges for spot-weld, lockset installation, frame forming, spreader bar, all the parts from every path will be assembled, touch up and packing (Figure 3.2). The workstation design and layout of the machine and operator may affect the productivity, processing time and production cost (Saptari et *al.*, 2011) are all the data that is very crucial in the Arena software. Production lines are very complex. The company must design the best production line with little time and produce quality product at lowest cost. Moreover, need to follow the market trend like changing from time to time according to customer needs.

The door frame company is a manufacturing company. Customers need to fill in the Purchase Order (PO) Form online or fill in manually and faxing to the company. Company is using the MTO (Make To Order) Policy which upon received the order from customers, then only the production line start to produce the relevant stock. It is because the door frame available in profiles and sizes. The operators need to set up the machine following customer order. So that, the production system needs to be have high flexibility to change according to the production capacity requirements. Hence, this research aims to evaluate the performance of the current production system and make improvements to increase the efficiency and productivity of the system.

1.3 STATEMENT OF THE PROBLEM

In this research, the company faced problems like receiving complaints for late delivery and defect return back by the customer. In the factories normally the machine is set up by the operator, the door framing plant faces problem like operators speed up the machines in order to produce more units. But, it causes a big issue because the mould of the machine become uncontrollable and cause lots of defects. So the machine had to stop to find out the reason. In that case, the operational cost will be higher and longer lead time. But in the manufacturing industries, lead time is the most unacceptable reason since customer not prefers waiting time and will go for JIT (Just-in-time), they will go to buy competitors door frame as substitute. Company lacks of productivity and reliability may let customers lost confident and reject to buy from them.

Therefore, investigation has to carry out in the processing time. Simulation modelling is the most suitable to be applied in this research. The analyst can look into more details each part of the machines layout and processing time performance. It also allows the analyst to figure out the sources the problems which caused by fault. But the company lack of expertise in simulation. So that, identification of the door frame processing whether is appropriate to mimic a system is pretty paramount, if verify, then only we can proceed to build the simulation model.

After this, do adjustments in the process, so that the machines will be move smoothly for whole process. It is tough to evaluate the process as many processing formats, coupled with continual changing. Ineffective planning may cause time-consuming and cost wasting. Figure out which of workstation that cause the problem and do adjustment to put back to the suitable path.

Quantity demanded for door frame is not stable; it is depends on the customer order. So, the price of the door frame has interrelation with the quantity demanded in the market, no matter the market is in equilibrium. Hence, the quantity demanded for door frame will change according to the market price. In that case, the manufacturing plant must remain productivity in order to fulfill customer's demand and avoid stock out. The productivity of the production line depends on the running time of the machine. But the most critical problem is the welding department which uses the longest time to weld all the four parts together. Sometime, if spot-weld by inexperience operator, the frames may be not fit together firmly, therefore reject by the customer. To solute this problem, enhancement can be done through the process by using what if analysis. We can add in machine, speed up the running time in each station and so on. We can set up different scenario according to our preference. The system may analysis out what will happen if do adjustment on some workstation in the production line. We may adjust and change scenario until generate out the most optimum solution.

1.4 OBJECTIVES OF THE RESEARCH

The objectives of this study are:

I. To model the production system using simulation.
II. To assess the performance of the production line.
III. To propose a better strategy to enhance the performance of the production line.

1.5 RESEARCH QUESTIONS

This study will provide answers the following questions:

I. What is the most suitable model for the door frame production?
II. What are the problems incurred in the production line?
III. How to enhance the efficiency of the entire operation process?

1.6 METHOD OF ANALYSIS

Simulation is one of the most popular quantitative tools that broadly use by the researcher. It is high flexibility and can predict and investigate the previous behavior of the production line or propose future production systems like plant expansion; the tools can generate many useful results. Moreover, it can abstract the model of the real system in faster, cheaper and safer. Many industries include mining, healthcare, manufacturing, logistics and education already using the simulation software to construct their own modal, so it is paramount tool to remain competitive in the marketplace.

Steps in a simulation study:

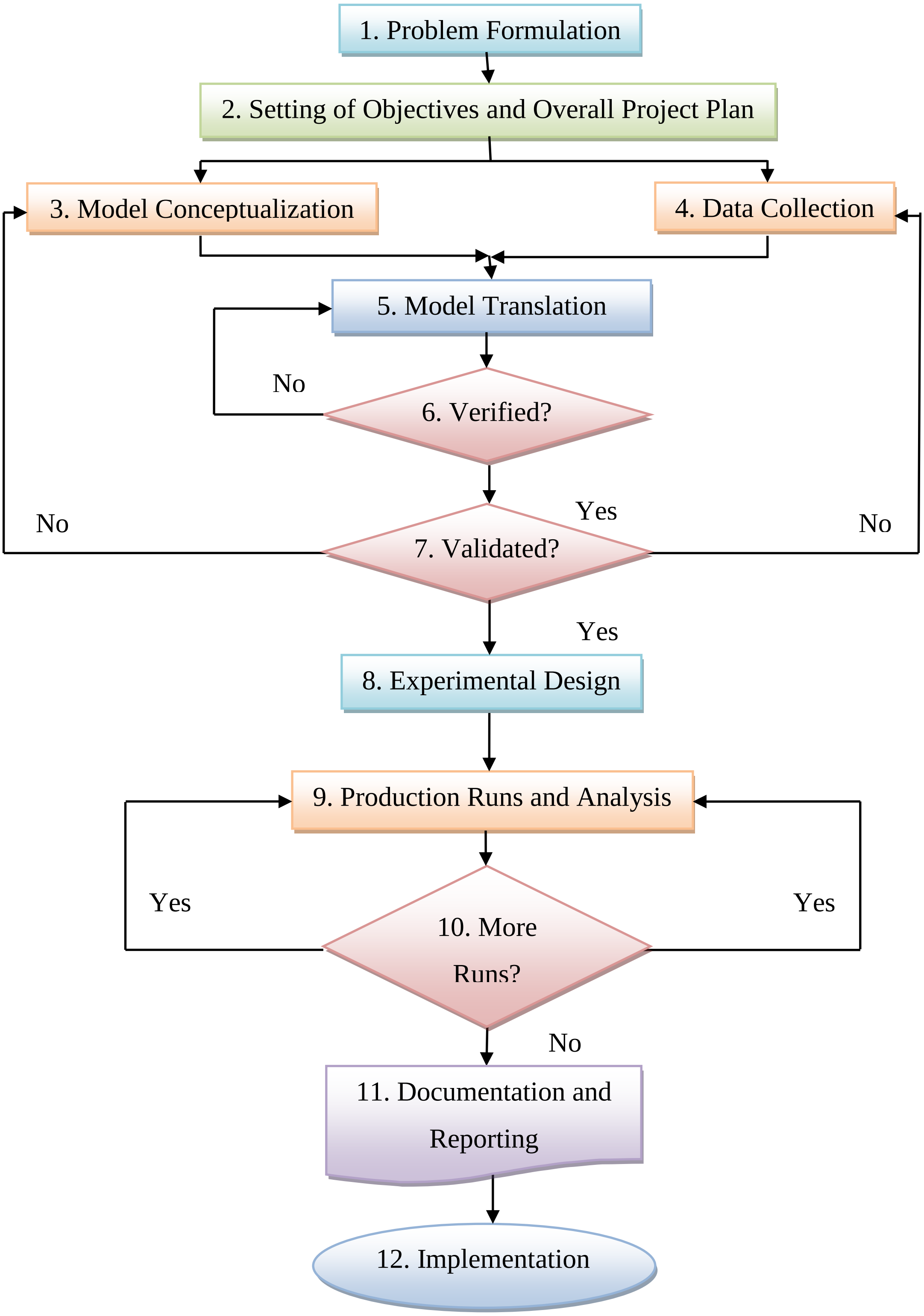

Figure 1.1: Steps in a simulation study "Discrete-event system simulation" (Banks et al., 2000)

1. **Problem Formulation**

   The problem must be determined. The analyst must have good understandings regarding the problem.

2. **Setting of Objectives and Overall Project Plan**

   Build up the explicit objectives for the project proposal. The project plan must included scenarios that can be investigated with the necessary relevant data like the machine run time, operators working hours and others. It is the combination of hardware, software and brainware.

3. **Model Conceptualization**

   Start to build the model. The model built is the abstraction the real system. The model built start with a simple model and keeps improving progressively until become a complex model. For instance, built a simple model in the process the raw materials arrivals → processing → welding → delivery. But after this, create more complex system by add in the more machines or open more production lines to fasten the process. Run continually until the most optimum result being generate.

4. **Data Collection**

   There is a continually close relationship between the building of model and the collection of necessary data. After the company accepts the proposal, data can be collect through the company.

5. **Model translation**

   The conceptual model is coded into an operational model.

6. **Verified**

   The system will be verified if the correct parameters being key in and the operation run smoothly.

7. **Validated**

   It is the process to determine whether the model building is an abstraction of the real system, the results generate from the simulation same as the data that collected from real world system.

8. **Experimental Design**

The substitutes that use to stimulate need to be confirm. The time of initialized, the length of the simulation runs and number of runs in the well-organized manner.

9. Production Runs and Analysis

It is used to estimate the performance of the system stimulate base on different types of scenarios that being built.

10. **More runs**

After the analysis of the runs being evaluate and complete, check whether any scenarios that needs more run.

11. **Documentation and Reporting**

Documentation is very crucial for the analyst to figure out the process of simulation modeling. All the result of analysis will be will be report clearly and shortly. This may allow the company to review final the simulation formulation in the final results. So that, company can does analyze on all the alternative systems and results from to experiments and choose the best model.

12. **Implementation**

Make the report with analysis to submit to the company to make decision. The manager will choose to run the best simulate model depends on the analysis.

1.7 SCOPE OF STUDY

This research focuses on door framing manufacturing factory in Johor, Malaysia. The door framing process from the raw materials to end product need to gone through a series of process. A productivity production line may generate profits; in conversely, a non productivity production line may let the company faces loss.

Nowadays, the business market is getting more challenging due to the increasing numbers of competitors in the market. Moreover, manufacturing is the most fast-growing sector in Malaysia. Company need to struggle in order to find out the most suitable ways to improve their productivity. The layout and design of the workplace and production line need to do improvements in order to have good performance (John and Jenson, 2013). First, the layout of the machines and production line need to construct model using Arena. After that, figure out the problems through the simulation modelling and try to model many scenarios and changing the parameters in order to design out the most high productivity model. Finally, compare the results with the real system. We need to adjust the model with highest machine utilization, worker utilization, shorter processing time, then only the most perfect model for productivity. The performance of the existing and proposed production line can be evaluated with simulation modeling results and what-if analysis.

Finally, the manufacturing industry will be the context here, and this study will access the current performance of the processing line and improve the production of the production line become more productivity by using simulation modeling and what-if analysis.

1.8 SIGNIFICANCE OF STUDY

The main aim of this research is to use ARENA to construct a model and access the performance of the door frame production line in the manufacturing plant. The findings of this research may help the production line become more efficiency. Thus, the manufacturing company may gain good public image and become more competitive.

Simulation software can help to solve the bottlenecks that appear in the production line. By running the simulation model, manager can predict the problem and control the process. The management level can make comparison between the assumption design of model with the real world model, the modelling system may generate the data and results analysis, we can make decision whether to change the operation design and not. Manufacturing plant may cut down the cost and time by figuring out the reason that cause the production line runs inconsistently. Moreover, if we did not do the simulation modelling in the computer and apply it in the real world machine, it may cause damage and we need to hire an expert to solute this problem; it may be very costly and wasting time.

In addition, this research will show the changes and improvements that implement into the door framing production line to ensure the system runs more faster and efficient. The design of the production line got interrelationship with the processing time. Efficient production line may reduce the defect and produce more unit of product in the manufacturing plant (Savsar, M., 2013).

By doing this research, somehow can figure out the most suitable model to enhance the machine utilization, eliminate the job queuing time and minimize the processing time. Find out the ineffective time of the machine in the production line and linked it to mathematical measurement and remodel the simulation system to make it more efficiency.

In conclusion, through this research, the processing line can become more speedy and the processing time can be minimized. Simulation is a good tool for the manufacturing company to make their production line more efficiency and productivity, so that the manufacturing company can remain competitive in the door frame industry.

1.9 OPERATIONAL DEFINITION

Key Terms	**Definition**
Simulation	The act of imitating the operation behaviour or process of the real world or propose system using the computer software (Robinson *et al*., 2010).
Modelling	Building the model in the computer software to test the behaviour without building in the real world. It can be used to model the process - the bank queuing, the weather sequence, logistic distribution and etc.

Production line	A line that is set together with the machine to let the raw materials that pass by to process from the first station to the last station until the final product comes out.
Discrete event simulation	Suitable to use in the production system that got variables change in separate time at different workstations.
Model	A model is the abstraction of the real world system.
Bottleneck	The neck of a bottle, the area where all the things clogged, a condition that causes a delay.
Efficiency	The ability to produce something using all the inputs (raw materials) and come out the outputs in a very short time.

1.10 EXPECTED RESULTS

Through this research, an abstraction model that mimics the real system that aims to give us the brief running of the whole process in graphical model. The production manager can have a clear understanding about how the production line runs, the processing time and the bottleneck, so that he can make effective decision by observing and make changes to the current system. This may minimize the process time and increases the company goals by maximize the profits.

Next, to find out the reasons that affects the efficiency of the door framing process. With the recognized bottleneck, a better model can be build to enhance the performance of the production system in the door framing. All these include reducing the processing time, increasing the machine and worker utilization and reorganize the task for the worker.

Moreover, the result expected to figure out the workstation that face bottleneck. So that, they can fulfills the customer requirement and deliver on time. Finally, the production manager can help the company to save the processing cost by eliminate the queuing and waiting time as well as the resource costs.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is the literature review from the previous study from other researcher. Reviewing the knowledge and ideas from the research journal, books may provide guidance to achieve the objectives of this research. The footsteps of the researchers on writing their literature review from the general to broader view on the research problems. Gain more understandings on the research with previous researchers work.

Today, the specifications of the product keep changing to fulfill the needs and wants of the customer. Therefore, there is a need for the manufacturing industries to make changes in the twinkling of an eye to remain competitive in the market. The layout of the production lines getting more complex. This may includes many parts, batch processing, machines and complex producing steps which needs high amount of preventive maintenance cost (Lin and Wang, 2012). The efficiency of the production line is difficult to evaluate as the systems is quite complex. So, the simulation software ARENA will be the pragmatic tool to model the complexity of the production and generate the results.

2.2 SIMULATION

Simulation is the most widely used in the industries to solute the inefficiency of the production line long time ago. According to Song and Lu (2015), simulation normally used to evaluate the existing system or a new built model, to decrease the chances of failure to meet specifications, to eliminate the unpredicted bottlenecks, to maximize the machine utilization and to push the system to the limits. The simulation is broadly use as it permits monitoring the behaviour of the model as time passing. So, it may give the answers to the question like why this is happening and how this is happening through the modelling, the analysis may give the value and details information.

The airplane flight simulator is quite popular amusement for the young generation. According to Simflightkl (n.d.), the flight simulator was fully model by the simulation software. The software was impressive because it give the exactly view outside of the window with the LED display screen that makes you feel like in the real plane, it will be a good choice to fulfill those people that had dream to become pilot but cannot make it in the real life. Moreover, it is very safe. This is how amazing simulation act as important role in our daily lives.

According to Yücesan and Fowler (2000), simulation modelling has few advantages as following:

Key Terms	Definition
Time compression	The potential to stimulate the data of many years from the existing systems in shorter time.
Component integration	Able to analyze the complexity of the production system components and their behaviours.
Risk avoidance	Risk can be avoid by stimulate the real world system into the simulation model.
Physical scaling	Able to analyze no matter how big or how small the simulation model.
Repeatability	Able to analyze the same system in different environment or different systems in similar environments.

Control	The simulation model can be well-managed and under control.

Simulation application has been grouped into twenty-four categories in manufacturing and business to do the analysis and comparisons (Jahangirian et *al.*, 2010). Each of the category lists out what is the simulation tool and technique being applied can look through all the researchers' paper to have more knowledge about simulation interrelation with many types of industries. One of the category is about manufacturing industry which need to use engineering process to change the layout design of the workstation, the delivery services that uses security rules, capacity, performance evaluation and bottleneck identification. Bottleneck will be identified and replace with the most suitable alternative. The simulation modelling will keep recycle till the most efficiency model being built.

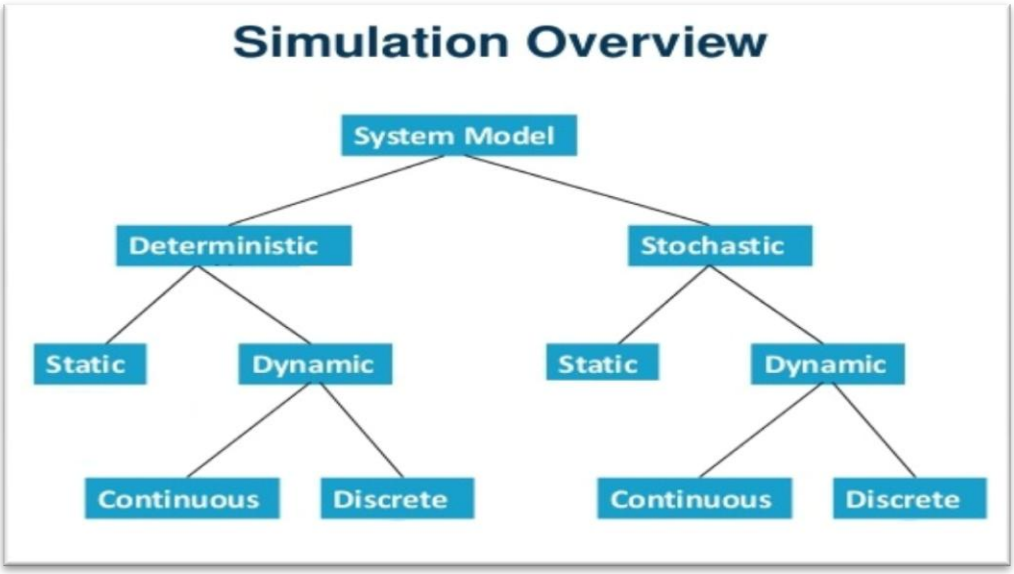

Figure 2.1: Different types of simulation model (Mochimaru et *al.*, 2014)

Simulation modelling using many approaches, the researcher will separate into different categories following the behaviour of the system and contrivance the problem. Figure 2.1 stated different types of simulation model. Simulation models consists of many types include: Deterministic vs. Stochastic, Static vs. Dynamic, Continuous vs. Discrete (Mochimaru et *al.*, 2014). A deterministic model does not includes any probabilistic component, so it is always the same results incurred with the same input key in, it is not affect by random and generate fixed outputs. A stochastic model includes probabilistic component, the same input may incurred different results. It is affected by random and generate different outputs. A static model about the systems changes in the specific time, the output is indifferent with the starting condition. A dynamic model about the system changes as the time passing. Discrete-event model is about the system changes in discrete point of time. Continuous model is about the changes continuing with time.

The ARENA simulation will be using in this research because ARENA already strong trust for the manufacturing industries. Many companies can reduce processing time and costs and also shorter lead time. Increase customer satisfaction by delivery on time and more productivity. ARENA is a discrete-event model that allows complex and large-size system. From the raw materials to the end product, the door frame needs to pass through many machines and process, although many process, but the ARENA can analysis well which process got high variability, constrained or limited resources or complex system interactions (Schriber et *al.,* 2013). Discrete event simulation allows " what if analysis" which can continue re-stimulate by changing the layout or process of the production line many times to enhance the productivity without any financial burdens. In addition, ARENA software consists of three modules which includes basic process, advance transfer and advance transfer. Many data key in the ARENA may generate the results in few hours, unlike the calculation that make manually will very time-consuming that need many days and the worst condition is cannot solute by manually counting especially for the complex system and long time processing in the heavy metal industry.

Nowadays, ARENA is the most usage software for the solution of manufacturing, medical systems, business process re-engineering, logistics, data communications in the world. Moreover, many universities start to put in ARENA simulation as one of the subject for the student to learn. So that, after graduation, the student can remain competitive in searching for job opportunities since many industries need expert to build the simulation model for their company. On the other hand, this advance technology may help the production manager to solute the critical problems in the factory. It will be more efficiency in managing the machine, worker, resource, time and business.

Simulation study is many applied in the manufacturing designs also. One of the best leading designers in the world, Jeremy Hall provides many training for the business company and stimulates the model for his clients company to enhance the efficiency of the company over the years. Since 1970, Jeremy already stimulate 68 business simulation models for his clients, it was no doubt that he makes many contributions for the simulation (Jeremy, 2013). After that, no only manufacturing industries, simulation also broadly applied in the hospital, bank, transportation, finance, manufacturing, military, telecommunications, universe and so on. The trend has change and simulation will not only be used by the production manager, but also engineers, researchers, engineering designers and also scientists.

2.3 PROCESS IMPROVEMENT

In order to have the production line with high efficiency, it is a need to eliminate all the unnecessary elements. Toyota is the good leader in monitoring process improvement. As the primary goal of Toyota is to reduce the time line from customers placed an order until the end of transactions, Toyota Production System (TPS) have been proposed and implemented by Taiichi Ohno with the main objective of eliminated non-value added wastes (MUDA). Seven types of wastes (MUDA) emphasized in TPS which included waste of over processing, waste of overproduction, waste of transportation, waste of rework, waste of inventory, waste of motion and waste of waiting.

The following shows the 7 types of wastes:

Types of waste	Definition
Over Processing	The process do not add value; customer unwilling to pay for extra value.
Over Production	Produce large quantities; production is excess than the needs of customer.

Inventory	Many inventories use the floor space of warehouse; need facilities to move them is a waste.
Motion	Unnecessary movement in the warehouse like walking, reaching and stretching; must reducing by having "good housekeeping".
Defects	Need to rework; add costs to the product.
Conveyance	Inefficiency of layout design which need operator to move in longer distance.

Moreover, TPS aims to determine and maximize company’s profit margins. Two pillars were needed to support TPS which were Just-In-Time (JIT) and autonomation (Jidoka) which can reduce idle time, produce quality products and improve customers’ satisfaction (Taiichi Ohno, 1988).

The starting concept of TPS was evolved by repeating asking “why” five times in order to figure out the root cause and simultaneously eliminate wastes. Next, Taiichi Ohno encourages workers to create standard work sheets for each procedure due to workers knew the procedures better and increase the probability on seeking for improvement. Teamwork is another issue concerned by TPS; therefore skills of passing baton have been applied and train whereby work cell will be set up nearby which easy for workers to backup for each other when needed. Besides, Taiichi Ohno also noticed on the supply issue by implementing JIT philosophy, the right parts will reach at right assembly line at the right time in the amount needed.

JIT have been managed by Kanban operating methods which basically provided workers the information on what, where and when of which part to pick up or assembly with quantity needed on a rectangular paper. Due to it starts from the final assembly and work backward to create a pull and systematic system, overproduction is prevented. Production leveling is the next methods after Kanban where it fine-tuned the number of production to make per day, ensure needed materials reach in final assembly line without delay in order to show no fluctuation in last process. On the other side, autonomation (JIDOKA) which means automation with human touch ensure defective parts will not be proceeding to the next process by involves of 100% inspection and apply “five why” to detect the root cause of defects.

In addition, TPS defines economy as manpower and cost reduction by looking for a simple change such as layout changing to reduce manpower and rethinking on replacing the old machine instead of buying new machines.

In a nutshell, TPS is a system that emphasized on continuous improvement by eliminating non-value added waste through encouraging workers to keep on thinking the root cause of defects, respect workers’ ideas, emphasized teamwork and focus on cost reduction. Application of TPS has improved productivity, better reliability, and product quality and provided greater return on investment in Toyota. Therefore, it is useful to implement in the production line.

2.4 PREVIOUS STUDY

Hassan et *al.* (2013) conducted a study using simulation known as NADS (National Advanced Driving Simulator) that gives the actual scene of the real world. Driver will be sitting into the car which equip with the scene in the highway road in the front visual and start driving. Driver will be given the opportunities to experience to driving in the bad weather like rainy day and night road which got very bad visual, driver may face accident if driving recklessly. The simulation model is perfectly matched with the movement of the car, you will feel the tremor when bump your car or face accident in the road which make you feel scary. Results indicated that simulation environment really give the new driver how to handle emergency situation in the highway hazards, experienced the traffic conflict situation and it also gives the awareness to the driver to drive safety and following the rules.

Next, Günal and Pidd (2010) study using the discrete-event model the hospital. The simulation model aims to test the patient flow and the daily bed usage variability. The simulation system can abstract the real world system. Results indicated that the simulation analyze the existing hospital resource's usage condition. The ARENA able to forecast the capacity needed for the beds, so that it enables the hospital to make changes like separate the patients into different types of patient's room according to types of illness they suffer may smoothing out the bed usage, re-arrange the staff working schedule, hiring more number of staffs to increase the satisfaction of the patients and decrease the less capacity of beds to fulfill patients' need.

Jithavech and Krishnan (2010) study the layout design of facility is important to fulfill the inconstancy of product demand. The stochastic demand will be risky and may cause lost. Results indicated that simulation help to decrease the risk due to changing of layout design, Acording to Vasudevan et al. (2010) study the simulation implementation in facility layout design to increase the performance in the steel-mill manufacturing factory. By changing the layout design, figure out the bottleneck in the heat mill insufficient temperature and saw do not cut the steel precisely caused many defects using simulation. Results indicated that simulation able to increase the productivity of the steel-mill and generate more profits. The most effective step is change the value-stream mapping and put all the machines in the more saving the floor space condition. It is shows that the facility design will be the main factors in affecting the productivity of the production line. Moreover, the more efficiency of the design facility, the more units of product will be produced; the production costs will be lower. The product also will be cheaper and more competitive in the market.

Sancak and Salmon (2011) study the shipment scheduling that have close relationship with the transportation and holding costs. The supplier will use the role of packaging like stowability to maximize the loading of the all types of stock in the container in the truck. Then, only delivery date will be scheduling. So, using the simulation to generate the demand uncertainty with the costs, results indicated that the most accurate the delivery date, the most higher the transportation costs incurred. Therefore, upon analyzing the data from bus manufacturer, transportation cost ineffective only can solute by delaying the shipment to the next period and use stowability to fill the container and reduce the transportation and holding costs incurred. In addition, it also reduces the stock out risk.

Razavi et *al.* (2015) study the maintenance aircraft engines time data to figure out the inefficiency time on the checking and maintenance that cause the flight delay. Discrete-event simulation will be using to stimulate the total time aircraft flying Time-On-Wing (TOW) and Remaining-Time-To-Fly (RTTF) to calculate the next maintenance date for the air flight. The queuing time for maintenance model being built using simulation. The time taken for maintenance is inconstantly for each aircraft. Results indicated that simulation analysis that the period of the maintenance cannot reduce. The aircraft delay can be solute by employing more technicians or adding more maintenance machines to reduce time of maintenance.

Amiri and Mohtashami (2012) study the buffer allocation in the factory aims to production rate is accurate at all time. The buffer will be allocate near the machine to make the speed of the machine more stable and reduces defects. But, if too much buffer places in the production lines, it will be costly as the machine over processing, waste the floor space. Moreover, the allocate size of the buffer also the main reasons of extra costs incurred. Therefore, the simulation being apply to build the model running time and the number of buffer is from little to many. Hybrid genetic algorithm and meta-model being built using simulation. The process time, failures time and repairs time being stimulate to make comparison. Results indicated that the suitable numbers of buffer allocation in the production line can solute the limitation of this research.

The disturbances in the production lines may cause unproductive. According to Padhi et al., (2013) the disturbances not only close relationship with efficiency but also worker utilization. The behaviour of the study will be evaluate using simulation to build DOE (Design of Experiment) to figure out the processing time by modelling all the process departments in process flow map and add in the cycle time data. The automotive factory normally uses semi-automated method to produce the products. The combination of fully-automated machine with semi-automated machine needs operator. Simulation is pretty accurate when applying to automation of the machine but high variability to semi-automated machine which needs operator. Results indicated that the efficiency of the machine depends on the automation of the machine and also the performance of the operator. If the operator lazy to perform, therefore the production rates will be dropped.

Ding et *al.*, (2015) study about types of evacuation strategies. A 28 floor of building being stimulate in this study. The simulation results show that the people live in lowest floor escape using elevator will be the fastest time, the people escape using the stairs will be the lowest time. Preventive measures can be carried out by maximizing the speed of the elevators and add more elevators can solute this problems. The results indicated by add more elevators are the fastest time to evacuation. This simulation study is very useful for the public to evacuation whenever fire and earthquakes that attacked suddenly.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, the research methodology is the methods and tools that will be use to conduct an investigation based on the study of simulation modelling. By choosing the most suitable methods to be applied in this research is very paramount, it will leads to a success in this research or study. The components of research methodology include process description, system observation, data collection and historical data. ARENA software will be used to assess the performance of the door framing process in the manufacturing plant.

3.2 SYSTEM DESCRIPTION

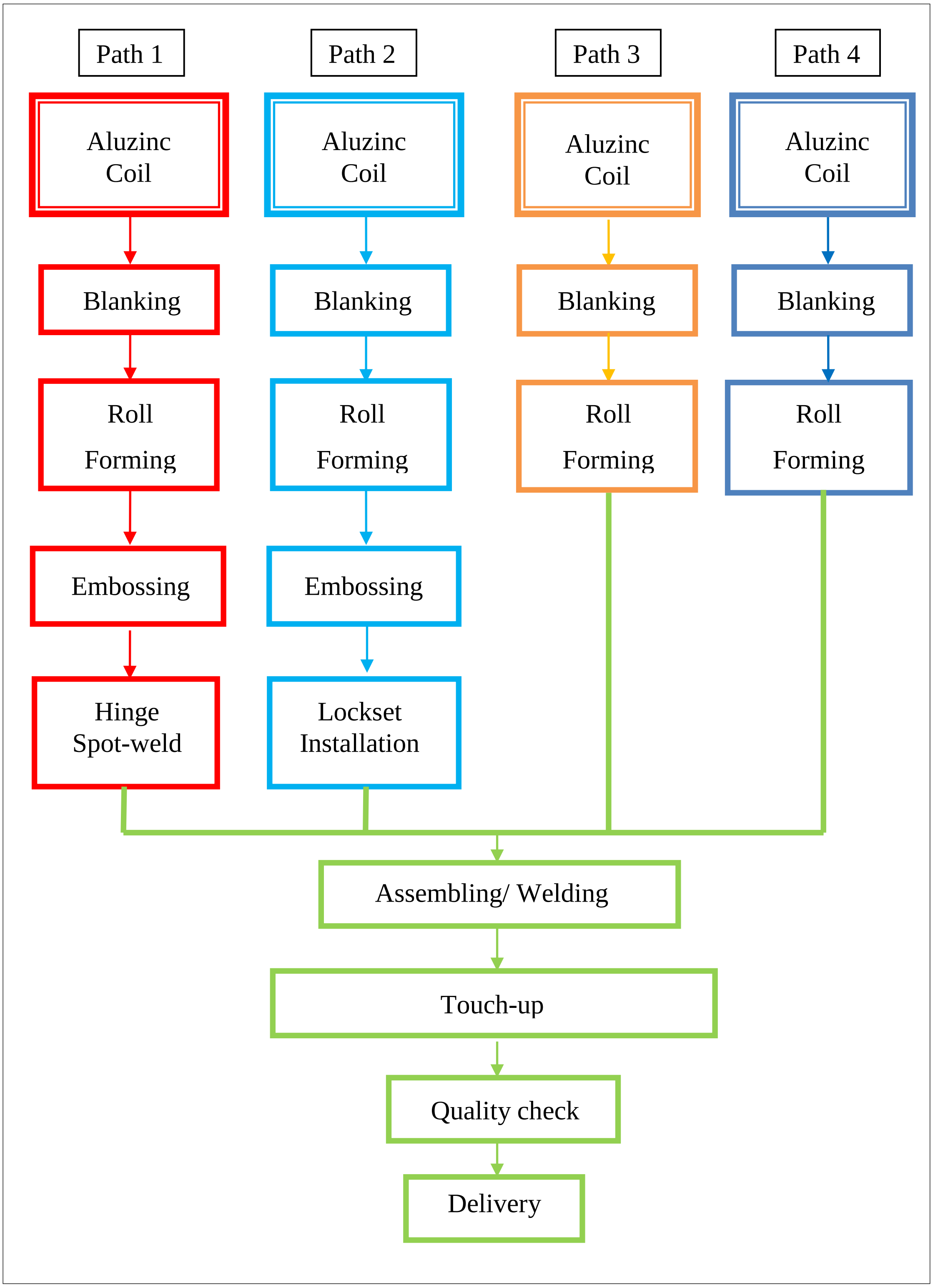

Figure 3.1: Process flow of the door framing in production system

Figure 3.1 shows the process flow of the door framing. A door framing consists of four vary separate operation routes which equip with the same raw material, aluzinc coil.

Path 1: The Aluzinc Coin weighted 1 metric ton is put into the uncoiler machine, then go through the blanking process to harden the metal sheets become roll forming, then pass through the embosser machine to embossing and spot weld machine to weld the hinges. The metal frame for part A finished (Figure 3.2).

Path 2: The Aluzinc Coin weighted 1 metric ton is put into the uncoiler machine, then go through the blanking process to harden the metal sheets become roll forming, then pass through the embosser machine to embossing and lockset installation. The metal frame for part B finished (Figure 3.2).

Path 3: The Aluzinc Coin weighted 1 metric ton is put into the uncoiler machine, then go through the blanking process to harden the metal sheets become roll forming, the metal frame for part C finished (Figure 3.2).

Path 4: The Aluzinc Coin weighted 1 metric ton is put into the uncoiler machine, then go through the blanking process to harden the metal sheets become roll forming, the spreader bar for part D finished (Figure 3.2).

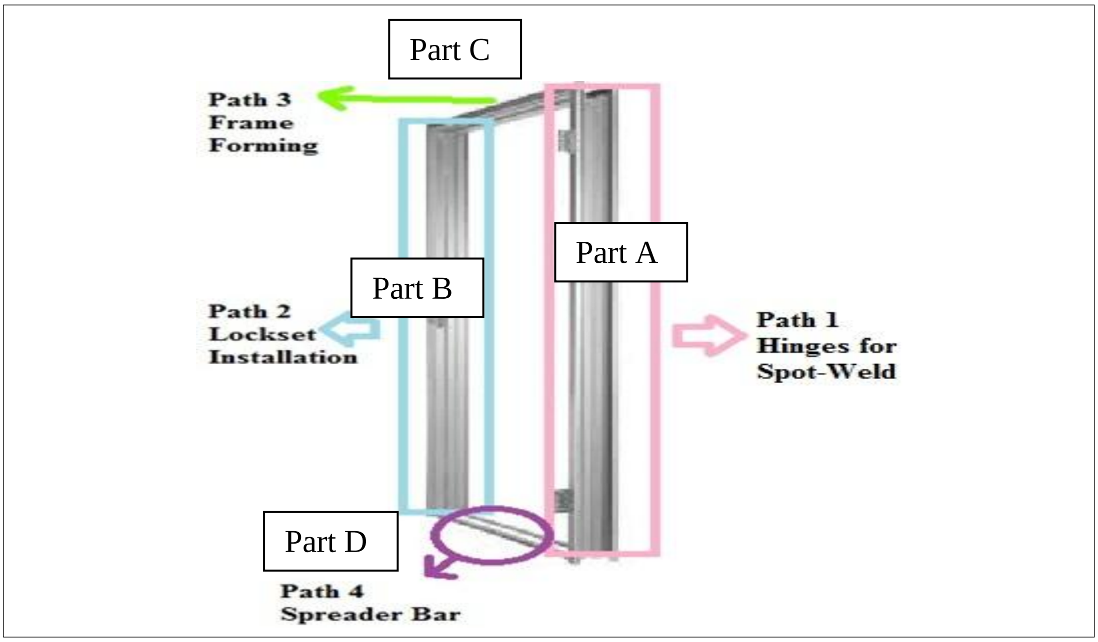

Figure 3.2: A complete assembly of door frame

After Path 1, Path 2, Path 3 and Path 4 finished, all the parts from each path will bring to assembling using welding. Then, do some touch-up to the area that friction occurs when assembling. Quality Check will be done and finally, the complete frames are really for delivery.

3.3 METHOD OF DATA COLLECTION

Data is the information that in the forms of statistical analysis, support the facts, no matter the data collected date, it still act as the basic to help the researchers to analyze and solute some problems (Akash, 2011). In this research, there are two types of data collected in this research, the primary data are the method of data collection that using are observation, collect historical data and interviewing the Production Executive. The secondary data are collection of data from the internet like E-book, articles, journals, books and studies.

The primary data is gained through observation. Through observation, the criterions are accuracy of the time processing, number of machines and number of workers for each workstation. Each of the workstation will be passed through observation; the function, the movement and the whole process work flow will be record down, types of machines, number of workstations and number of operators allocated in each workstation, the layout of the production system also will be observe to improve the understandings of the whole production line movement follow the sequences. Only the welding department is manually operated, so stop watch will be using to record down the time processing.

Through interview, the criterions are knowledge and technical skills. Knowledge will refer to the production executive. The production executive being choose to interview because they have the knowledge of the whole production systems operating, from the raw materials to the end products. They can more specify the type of raw material using is aluzinc. The engineering problem like defects in the production, the way they solute the defect problems, rework or throw away. For technical skills, the factory operator will be interview. It is because the technical problem like the setup time for each machine, number of machine that need to setup for producing different profiles of door frame, the speed of the conveyer. The operator knows well than production executive.

The historical data that gained from the company help to stimulate the model of the production system. The historical data includes the working time schedule for each operator daily, machine setup time, some workstations waiting time and work-in-process (WIP) times and customers order records. Data collection from the company is in the forms of documents, records and files. All the data collected is very helpful to generate and develop new model.

Furthermore, the secondary data are the extra information online like the E-books, journals and articles which leads me to have more understandings regarding simulation modelling. The online research guide book give me the references to do my report and analysis. In addition, the mathematical calculation model and analysis that get from internet can give me more understandings and hence can solve my research problems.

3.3.1 ELEMENTS OF THE OBSERVATION AND HISTORICAL DATA

i. The observation

The elements include direct observation of the process behavior. Observing the behavior of the process, write the description about types of the machines that are using includes embossing machine, uncoiler machine and so on. Then, records down the process activities like blanking, embossing, welding and others. Next, need to record down the process activities running time. Then, observe the moving of the machine whether affected by other factors like the speed, evaluate the situation like the quantity targeted achieved daily and unpredicted condition which got defects. Observing the conversation between the operator and the production executive, the so the basic operating of door frame production can be observe successfully. We can have more understandings about how the real worker working routine, so that we can verify whether the data collected by observation same with historical data given by thw production manager, if same; we know the correct data being used.

ii. Historical Data

The elements include the historical data collected will be the latest data from production executive. For instance, the time needed to finish one ton of door frame. The welding department spends the longest time to assembling the parts. The data collected from the historical data tally with the amount of factory produced daily. These may include annual report, daily production quantity, speed of conveyer belt and the time needed to from one machine to another machine.

3.4 MODELING WITH ARENA

Upon the data being collected, the process of door framing workflow will be transferred into the simulation software called ARENA to create a model. A model is represents the building and running of some system interest. It is an abstraction representation of the reality. Modelling increases the degree of abstraction and its core essential. People may find easier to understand the reality that existing and creation of new reality are more significant. Effective modelling should meditate the paths which modelling going to pass by. A model is much simpler than the system it represents. A model build must not too complex and should be roughly similar to the real system. Modelling allows the analyst to predict the problems when different types of data generate into the system.

ARENA is the software that was developed by Systems Modelling and acquired by Rockwell Automation in year 2000. ARENA simulation is a pragmatic tool that used for discrete-event system in this research (Automation, R., 2013). It is normally used in resource modelling, process design in visual and statistical analysis to replays an imploded simulation with graphical. Arena performs using the SIMAN processor and simulation language. Arena Smarts Template includes many simulation model samples which work as guideline to build the complex model in any field in the industry. The numbers of Arena users are increasing radically because users can have clear view on the behaviour of the process by running all the data on the modelling. It will generate out many types of results and summary. A good model is a judicious tradeoff between realism and simplicity with the Arena software.

3.5 SIMULATION MODELLING

Simulation study is a reliable tool to analyze the performance of the company. The simulation modelling starts with the modules (components that available in different shape) to display different processes in a simulation model. Simulation models comprise of the components like system entities, input variables, performance measures, and functional relationships. Connector lines will be connecting one module with another module in parallel or serial depends on the entities design layout of the reality. The system entities and module will represent the abstraction of the real world objects which modules have interrelation with the entities, process flow and timing. Computer simulation is a significant approaches to construct and analysis the composite production systems in manufacturing. Within this research, the ARENA simulation system will generate out the usage of time in the work in-process (WIP), waiting time, value-added time and all the results will be presented in the statistical analysis.

The steps to construct a simulation model and run the simulation with ARENA are shown as below (Figure 3.3):

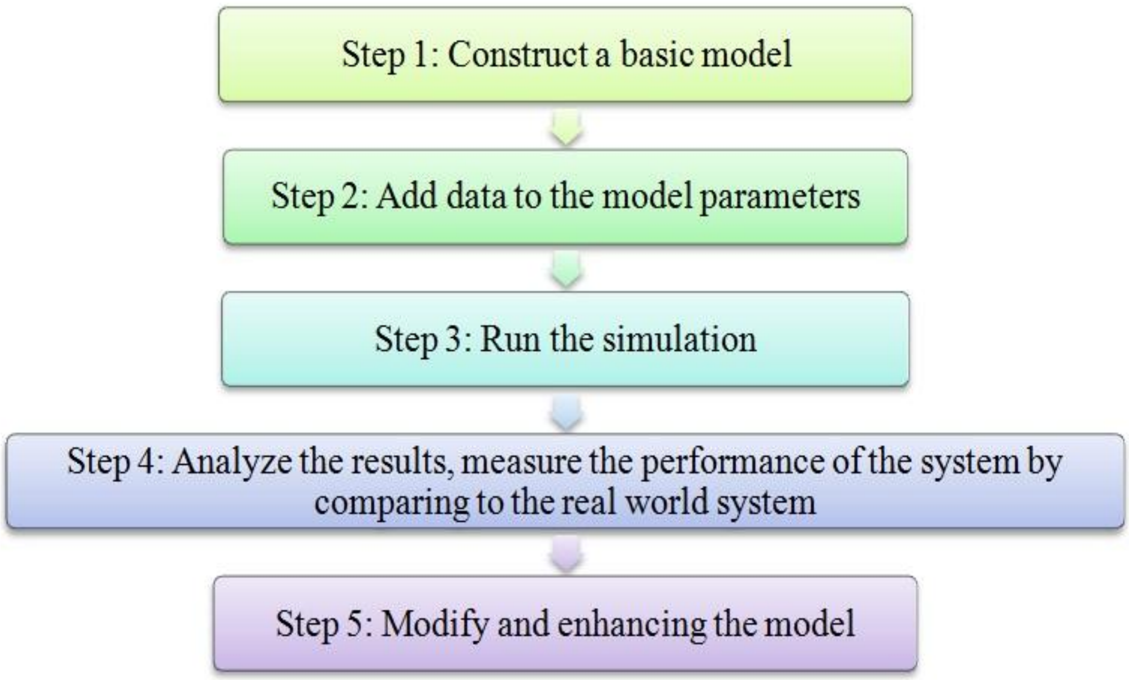

Figure 3.3: Steps in constructing simulation model (Law, A. M., 2009)

Step 1: Construct a basic model

ARENA provides three basic important modules which are basic process, advanced process and advanced transfer. ARENA furnishes a model window flowchart view in aims to construct a basic model. Draw out each workstation with the modules of different shapes, connects all modules together with connector lines to abstract the real manufacturing plant.

Step 2: Add data to the model parameters

The historical data collected from the company like the order records, each workstation processing time, quantities production daily. The data collected from observation like allocation of machine for each station, number of operators in each station and types of door framing. The data collect by interview are machine setup time, operators working time schedule.

Step 3: Run the Simulation

After model being built and key in all the necessary data, click on simulation runs.

Step 4: Analyze the results, measure the performance of the system by comparing to the real system

Through simulation runs, the performance of company can be assessed. Identification of the problems faced in which workstation can be verify. Mathematical calculation is indispensible in analyzing the results.

Step 5: Modify and enhancing the model

The model can be improved by model redesign. It can be done according to the user preference. Problem identification in step 4 can be removed by redesign and simulation runs again to get the most efficiency model.

In the Arena Process Template, the flowchart modules comprises of many basic process which includes Create, Process, Batch, Assign, Dispose, Design, Separate and Record. Figure 3.4 will display a basic model in the Arena which comprises of three modules, Create, Process and Dispose.

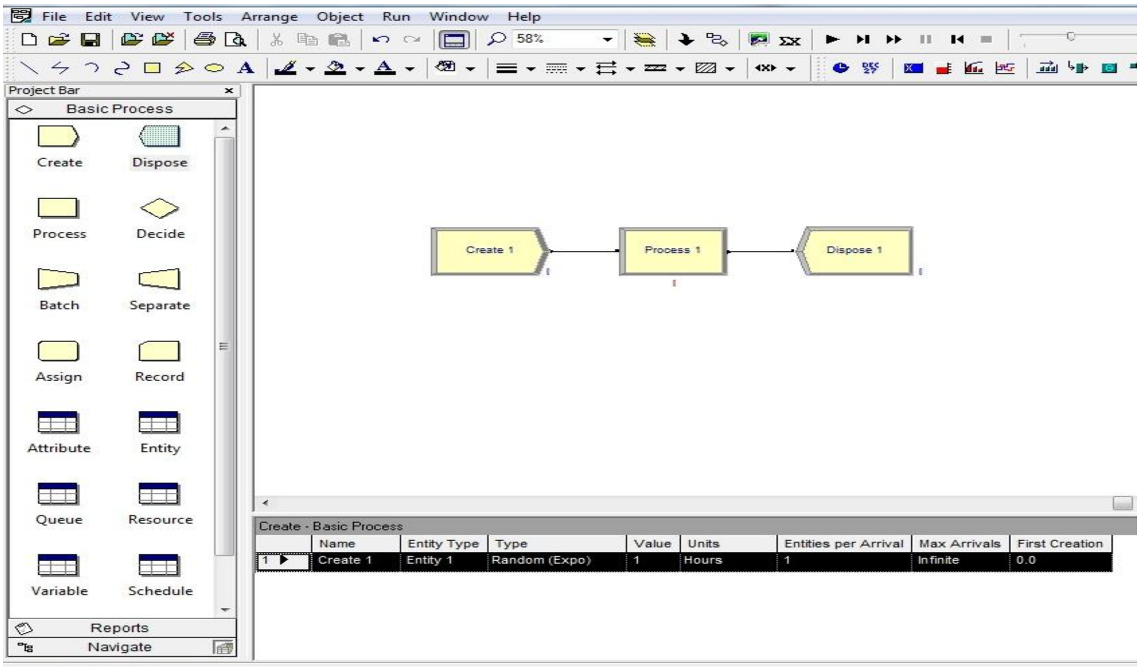

Figure 3.4: A basic model develop by Arena

- **Create module**: create the module by key in the name of job entities. The entities per arrival may be constant or random variables. Double-click on the entity, the create table will be pop out, can key in the time between arrivals, entities types, entities per arrival, maximum arrival,

- **Process module**: Key in the name of the process, the process entities will pass through range of process following the sequences, the processing time will be key in. The type of delay and allocation problem such as waiting also can generate by using process.

- **Dispose module:** Entities will quit the Arena system when all the process is finished. The entities will be disposed and end product already produced.

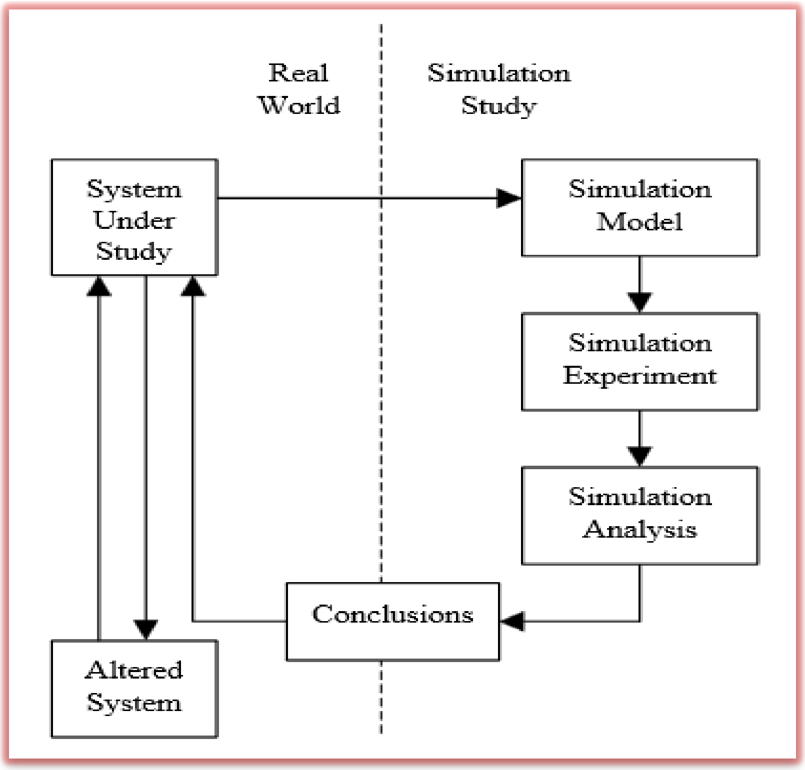

Figure 3.5: Simulation study schematic (Maria, 1997)

Figure 3.5 shows the interrelationship between simulation study with the real world. Simulation modelling can mimic the real production systems. The results that collected can use to make comparison with the real systems.

3.6 WHAT-IF ANALYSIS

What-if analysis is a pragmatic tool use to analyze the changes of the results in the spreadsheet calculation and statistical model that got consistent changing in the input. What-if analysis also recognized as sensitivity analysis. It can be used to figure out and make comparison within different scenario according to changing terms. In this research, there will have question bringing out like " What-if the productivity if speed up the embossing machines to 10%, 20%, 30% and more". In short, what-if analysis can analyze the thorough and in-depth data which aims to figure out the complex system's behaviour without any conjectures. What-if analysis is applicable to simulation modelling which can generate one or more substitute ways to accomplish goals (Golfarelli Proli, 2006).

What if analysis is positive relationship with the simulation modelling. Simulation mimics the real system. It applied to analyze the system behaviour by asking "What-if" question in the real system and help in redesign the system.

Workflow to implement What-if analysis in the manufacturing systems as below:

First and foremost, the achievement of the goal at the manufacturing line aims to figure out the defect during the manufacturing stage, each of the changing scenarios will be observe. Defect is the root cause that affects the quantity door frame available for packing. All the relevant data will be collected and analyzed using simulation and construct the model. After this, can predict the result based on every changing scenario. What-if analysis aims to generate the most high dependability simulation model, therefore, by changing the data and keep the simulation run and finally observe the result. If the process invalid, the system will have to redesign and retest. The simulation system will stop unless the result satisfied the user.

CHAPTER 4

DATA ANALYSIS

4.1 INTRODUCTION

In this chapter, the performance of the door frame production will be evaluated. The replication of the process flow in door frame production using simulation software called Arena. Arena is indispensable simulation software by Rockwell Automation. The data collected from the door frame manufacturing plant will implement into the Arena. Then, the Arena software will run and generate a comprehensive report which comprises of data analysis with entities time, the intervals time between the aluzinc coil arrivals till the end process, processing time, queuing time, worker schedules and resources. Data analysis is a body of methods that used to narrate the real situation, discover modes, establish clarifications and examine hypotheses. It is used in business, management and scheme (Shana. J et *al.,* 2013). Data analysis also can provide a more significant view on the model running and the workstations that run discordantly can figure out and troubleshooting must take over. The data collected from the door frame factory located in Segamat, Johor.

After the data analysis, measurements will be taken out. The processes that are less efficiently or got defects will be figure out. Model development will be the next step to develop the current model. Redesign the current model by increasing the number of machine, more workstations to decrease the defect, adjusting the worker schedules, redesign the machine layout to alter the production line becomes more efficiency and ensure all the resources were fully utilized. Data analysis allows the reasons that affect the efficiency and productivity process being modified. Therefore, Arena acts as a pragmatic tool to model all discrete, continuous and mixed models. Arena software modeling with ease without difficulty by high-level simulators with the flexibility of simulation language.

4.2 MODEL DEVELOPMENT

In this study, the Arena simulation software is using to replicate the real world door frame manufacturing line. It aims to test the efficiently of machine, queue of the process, worker utilization and machining utilization. All the processes involved are discrete event simulation. The historical data is collected from the factory will be apply into the Arena menus. The process flow of door frame producing is installation of four rolls of aluzinc coils to uncoiler machines using forklift. Each roll of Aluzinc coil weighted 1 ton. Figure 4.1 shows the production line for door frame starting from allocation of raw materials aluzinc coil till the end point and ready for shipment.

This research thesis is to exemplify the door frame production processes. The process involves in door frame production is discrete event process. The core processes in the manufacturing plant are blanking, roll forming, embossing, hinge spot weld, lockset installation, welding, touch-up, and quality checking. The door frame factory produces eight types of different profile which includes 105WA, 120STD, 130WA, 140WA, 150WA, E150A, 160STD and 166WA. For this thesis, the profile type 166WA was chosen to be the research types, which is more big size door frames, the width is 1800mm and the height is 2130mm.

Simulation result will display using Arena software. The result will be analyzed and summarized. The simulation system aims to transfer the complex production process into a graphical and easier to understand form (Taillandier *et al.*, 2012). Every discrete event process will be occurs at the specific instant at time and records a difference of state in the system.

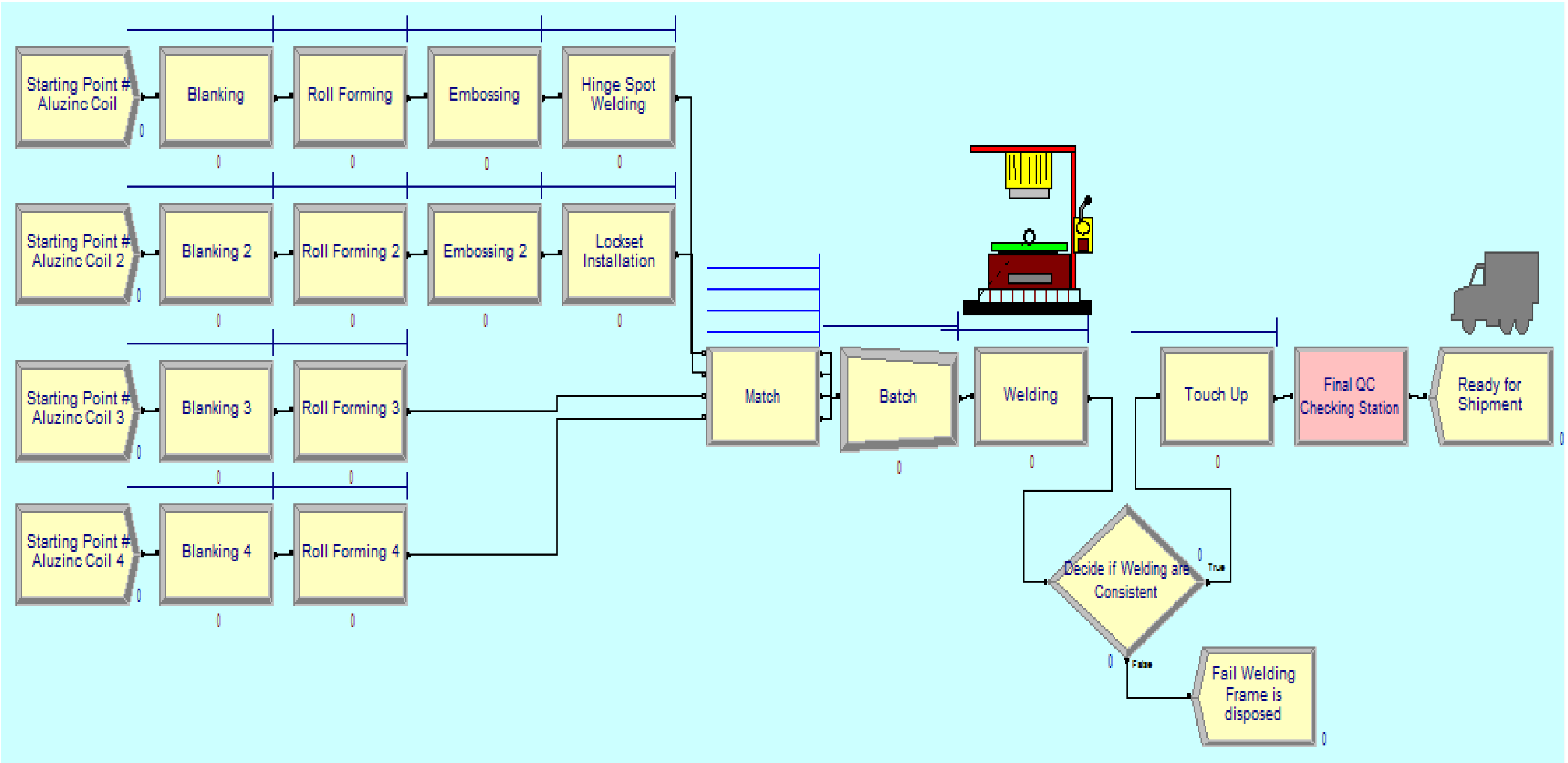

Figure 4.1: Model of door frame production

4.3 INPUT ANALYZER

Arena used for data analysis by applying through input analyzer tool, it main aim is to fit distributions with data collected. Input analyzer used to supply numerical approximates of the suitable parameters and a ready-made expression that can just copy and paste into the model (Rossetti, M. D., 2015). There are two types of distributions in the input analyzer, discrete and continuous. The continuous hypothetical distributions comprises of Triangular, Normal, Exponential, Gamma, Weibull, Erlang, Lognormal, Beta and Uniform distributions (Qin.F. et *al.,* 2012) Hence, the discrete distribution is Poisson distribution.

Input Analyzer usually use to resolve the processing stage of the door frame manufacturing plant by counting variety of practical statistics from the data collection. This may include statistics associated to moments (represent by mean, standard deviation, coefficient of variation) and statistics associated to distributions (represent by histograms) (Narahari and Subramanya, 2015). Parameters fill in the model will affect the model output. Therefore, in order to acquire an accurate result, the least square error expression from the input analyzer will be chosen to fill in the module.

Discrete events approaching when the aluzinc coil was send out from the warehouse using the forklift to the entry point. The interval time occurs when the operator start operating their machine to blanking, roll forming, embossing and welding. Normally, the operators will observe the machine running progress from time-to-time, whenever the aluzinc coil going to finish processing, they will discharge a new aluzinc coil that weighted 1 ton will carry from warehouse to the entry point. Nevertheless idle time happens when no operator mention the aluzinc coil going to finish, this happen very frequently especially during the peak season that all operators have hectic schedules and need overtime.

The company chosen for this thesis is Door Frame Company that based in Johor; it is a multinational company. The operating hours for door frame processing plant begin from 8:00 a.m. to 5:00 p.m. with one hour rest time on 12:00 noon. The data collected for aluzinc coil are five days. Below are the tables of analysis using input analyzer.

Table 4.1: Aluzinc Coil Arrival Time at entry point

DAY 1

Batch Number	Time In	Interval Time
011A	8:00 a.m.	23
012A	8:23 a.m.	23
013A	8:46 a.m.	24
014A	9:10 a.m.	24
015A	9:34 a.m.	24
016A	10:00 a.m.	26
017A	10:26 a.m.	26
018A	10:52 a.m.	24
019A	11:16 a.m.	24
020A	11:40 a.m.	25
021A	12:05 p.m.	24
Rest Hour		
022A	1:24 p.m.	23
023A	1:47 p.m.	24
024A	2:11 p.m.	24
025A	2:35 p.m.	24
026A	2:59 p.m.	24
027A	3:23 p.m.	24
028A	3:47 p.m.	24
029A	4:11 p.m.	24
030A	4:35 p.m.	25
031A	5:00 p.m.	
Total		483

DAY 2

Batch Number	Time In	Interval Time
032A	8:00 a.m.	28
033A	8:28 a.m.	26
034A	8:54 a.m.	23
035A	9:17 a.m.	26
036A	9:43 a.m.	26
037A	10:19 a.m.	28
038A	10:47 a.m.	23
039A	11:10 a.m.	24
040A	11:34 a.m.	27
041A	12:01 p.m.	22
Rest Hour		
042A	1:22 p.m.	21
043A	1:43 p.m.	23
044A	2:06 p.m.	22
045A	2:28 p.m.	24
046A	2:52 p.m.	22
047A	3:14 p.m.	22
048A	3:36 p.m.	22
049A	3:58 p.m.	24
050A	4:22 p.m.	26
051A	4:48 p.m.	21
052A	5:09 p.m.	
Total		480

DAY 3

Batch Number	Time In	Interval Time
053A	8:00 a.m.	24
054A	8:24 a.m.	25
055A	8:49 a.m.	25
056A	9:24 a.m.	22
057A	9:46 a.m.	25
058A	10:11 a.m.	21
059A	10:32 a.m.	25
060A	10:57 a.m.	23
061A	11:20 a.m.	23
062A	11:43 a.m.	23
063A	12:06 p.m.	23
Rest Hour		
064A	1:23 p.m.	24
065A	1:47 p.m.	26
066A	2:13 p.m.	26
067A	2:39 p.m.	26
068A	3:05 p.m.	26
069A	3:31 p.m.	23
070A	3:54 p.m.	23
071A	4:17 p.m.	23
072A	4:40 p.m.	24
073A	5:04 p.m.	
Total		480

DAY 4

Batch Number	Time In	Interval Time
074A	8:00 a.m.	26
075A	8:26 a.m.	25
076A	8:51 a.m.	26
077A	9:17 a.m.	26
078A	9:43 a.m.	26
079A	10:09 a.m.	26
080A	10:35 a.m.	23
081A	10:58 a.m.	24
082A	11:22 a.m.	21
083A	11: 43p.m.	18
084A	12.01 p.m.	22
Rest Hour		
085A	1:22 p.m.	27
086A	1:49 p.m.	25
087A	2:14 p.m.	24
088A	2:38 p.m.	24
089A	3:02 p.m.	23
090A	3:25 p.m.	24
091A	3:49 p.m.	25
092A	4:14 p.m.	22
093A	4:36 p.m.	23
094A	5:00 p.m.	
Total		480

DAY 5

Batch Number	Time In	Interval Time
095A	8:00 a.m.	24
096A	8:24 a.m.	26
097A	8:50 a.m.	22
098A	9:12 a.m.	22
099A	9:34 a.m.	24
100A	9:58 a.m.	24
101A	10:22 a.m.	25
102A	10:47 a.m.	24
103A	11:11 a.m.	26
104A	11:37 a.m.	24
105A	12:01 p.m.	25
Rest Hour		
106A	1:25 p.m.	25
107A	1:50 p.m.	24
108A	2:14 p.m.	23
109A	2:37 p.m.	23
110A	3:00 p.m.	23
111A	3:23 p.m.	22
112A	3:45 p.m.	28
113A	4:13 p.m.	23
114A	4:36 p.m.	24
115A	5:00 p.m.	
Total		481

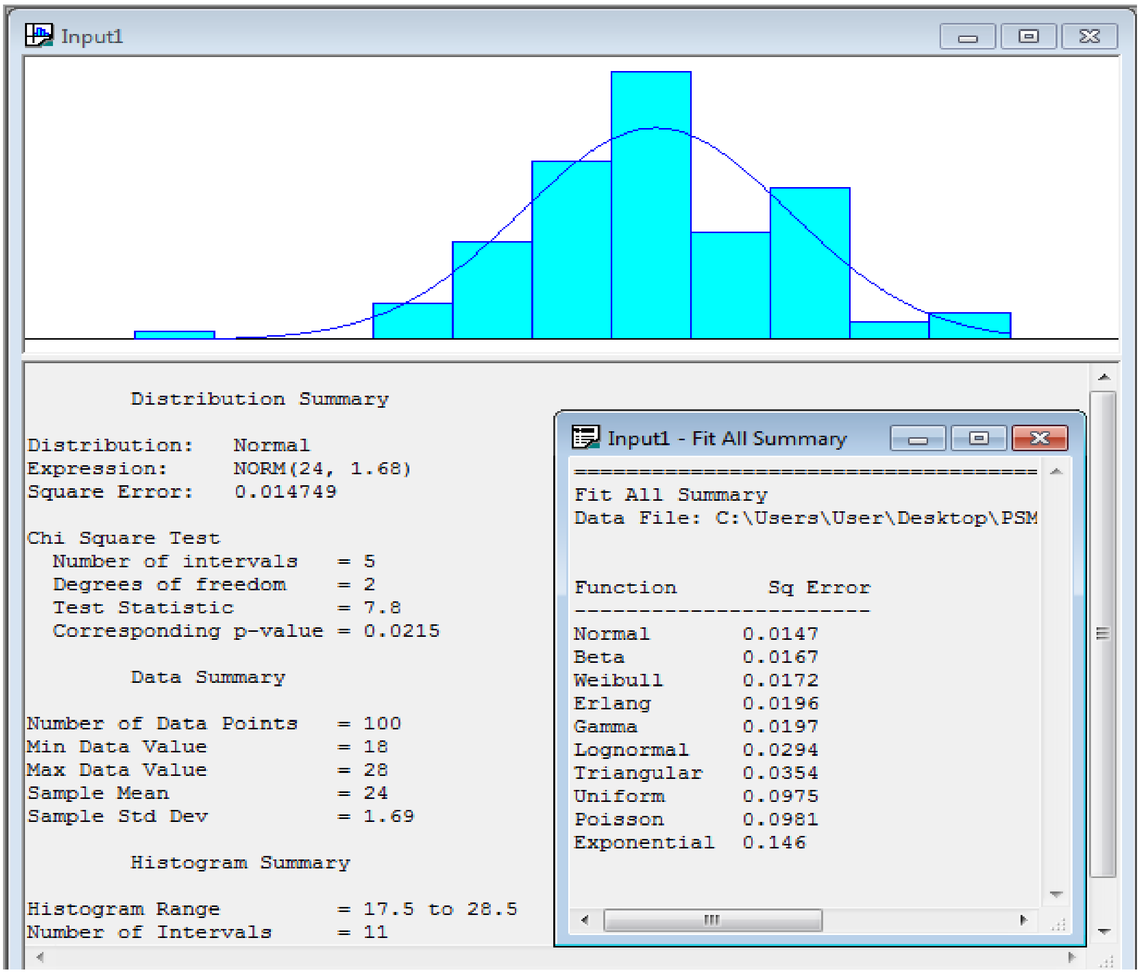

Figure 4.2: Distribution of Aluzinc Coil Arrival Time at entry point

Calculation:

$$\text{Average of Inter-arrival Time} = \frac{\text{Sum of the Inter-arrival Time}}{\text{Number of frames}} \quad \textbf{(Eq. 4.1)}$$

$$= \frac{(483+480+480+480+481)}{(20+20+20+20+20)}$$

$$= 24.04 \text{ minutes}$$

According to the calculation, the average time for each frame came to the entry point is 24.04 minutes.

From the input analyzer, the interval time for door frame is 24.04 minutes. It is same as the calculation above. Figure 4.2 shows the distribution of data using Input analyzer. NORM distribution shows the least square error value which is 0.014749.

Normal Expression with NORM (24, 1.68) will be pick as process type for the CREATE module of simulation model. The least square error has the least error, very precise and suitable to the distribution.

In the model building, the modules from basic process, advanced transfer and advanced process was used to build the virtual model of the door frame manufacturing process. The basic entity in ARENA model is CREATE module. Create module is act as beginning point entity in simulation modeling. The entity is aluzinc coil. The arrivals of time are the resource to create entity. The entities per arrival are one piece of door frame. Each replication of aluzinc coil flowing through the process is infinite. The interval time of door frame is analysis using NORM distribution with mean value of 24 minutes and standard deviation of 1.68. CREATE module is filled in as following table.

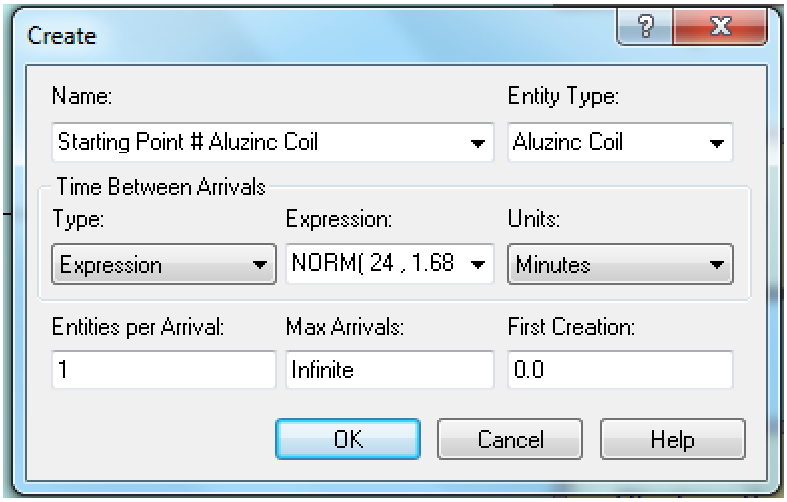

Figure 4.3: CREATE module with Input Analyzer Result

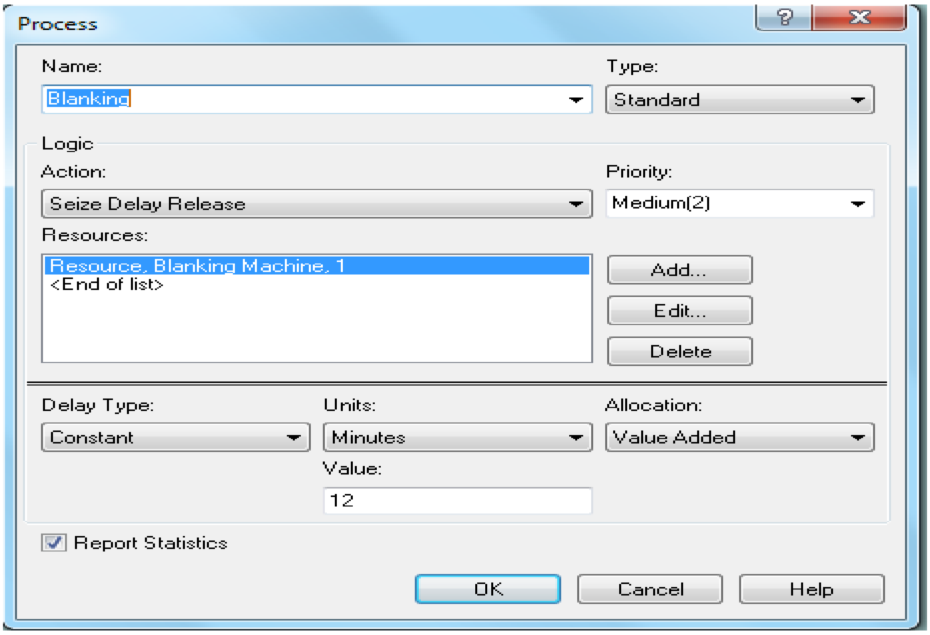

Figure 4.4: Module of blanking process

Blanking process is the first process of door frame. Figure 4.4 shows the module blanking process. Constant is using because this process only involved machine and aluzinc coil. Aluzinc coil will pass through the machine using the constant time, 12 minutes in this process. The Seize Delay Release is selected for logic action in Figure 4.4. The resources will be processed and release. In short, when the aluzinc coil being seized by resource, it will wait for the service interval, after completed its process, it will be release.

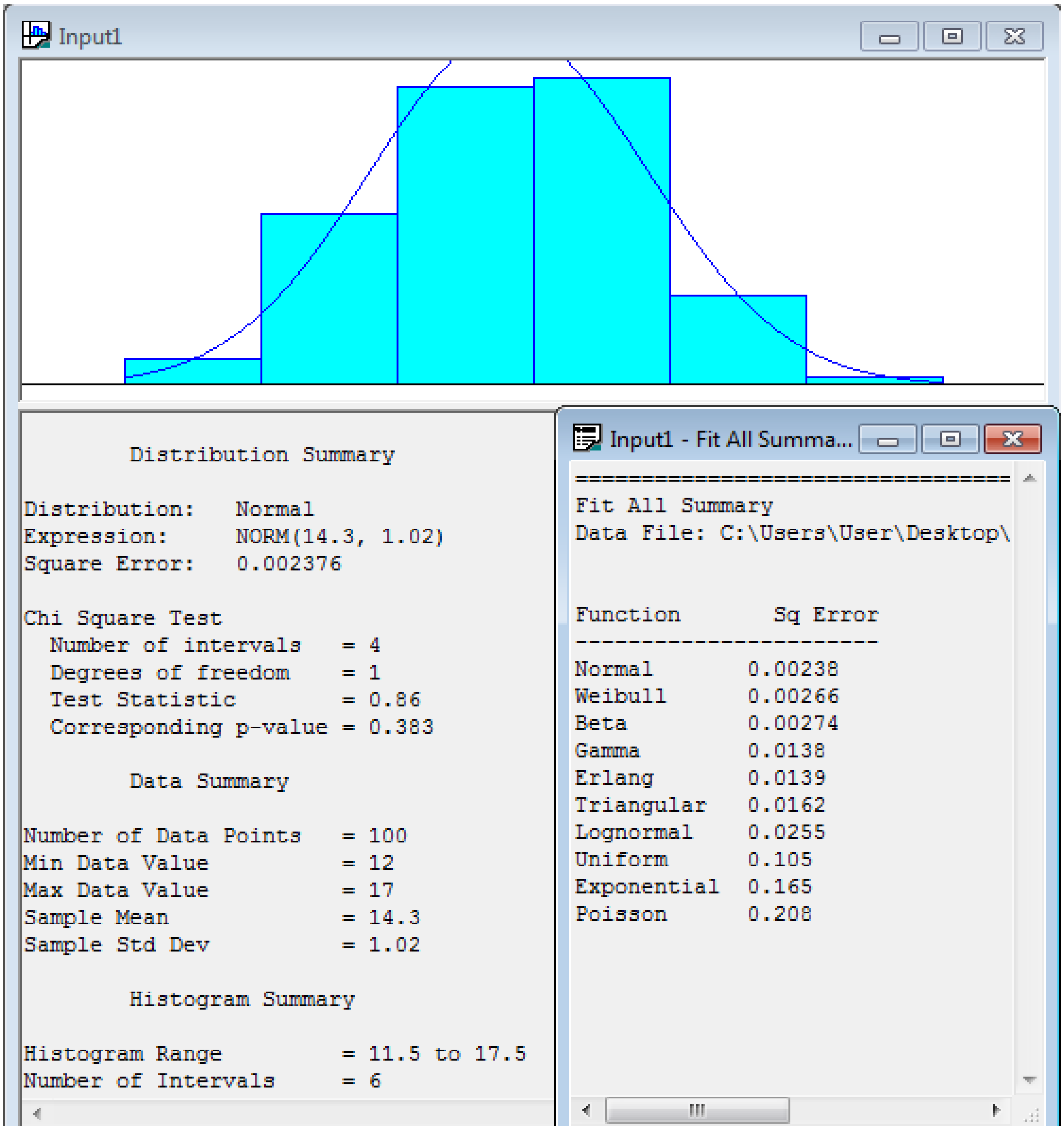

Figure 4.5: Distribution of roll forming process time

For Figure 4.5, the distribution of roll forming process time, the data analysis using input analyzer, the least square error which is Normal distribution was chosen. It has only 0.00238 square error and the least error if compare to Weibull, Beta, Gamma and others. The seize delay release for this process is NORM (14.3, 1.02). The Seize Delay Release is selected for logic action in Figure 4.6. Seize Delay Release explains the resources placed follow by a process delay and then the resources placed back and release. In short, when the aluzinc coil being size by resource, it will wait for the service interval, after completed its process, it will be release. The delay is means the inter-arrival time and manufacturing time.

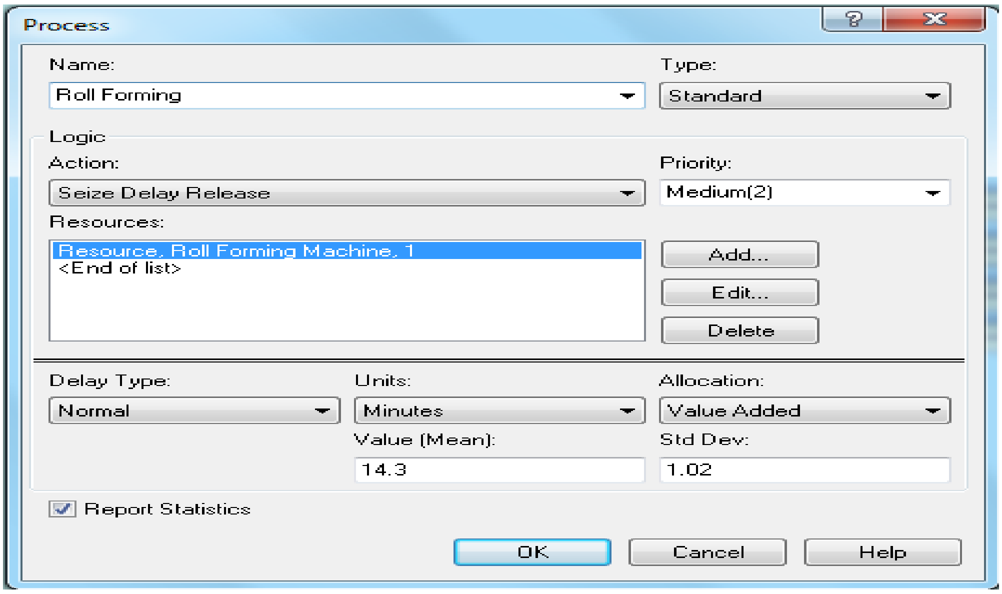

Figure 4.6: Module of roll forming process

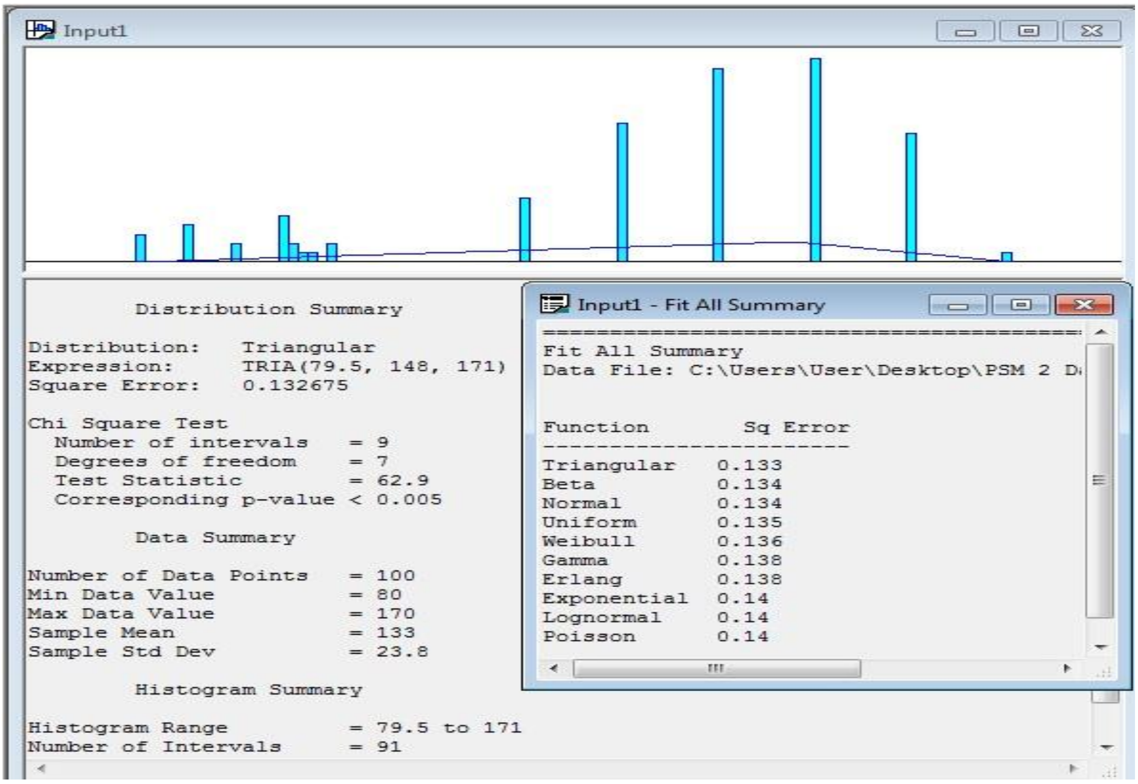

Figure 4.7: Distribution of hinge spot welding process time

From Figure 4.7, the distribution of hinge spot welding process time, the least square error distribution is Triangular distribution with 0.133. The seize delay release for this process is TRIA (79.5, 148, 171) will be apply. Triangular Distribution is suitable used for machine that are operated manually and the data collected is not uniformly distributed because operator may feels tired after long hours working, so the process time will be slower than before. In Figure 4.8, the Seize Delay Release is selected for logic action. Seize Delay Release using in this station with Operator 1 and hinge welding machine. When the operator receives one part of frame, operator will spot welding using machine, then will put back to the processing line. Delay may happen if operator cannot focus after long hours of working, so delay may happen at this stage due to the tired of repetitive works.

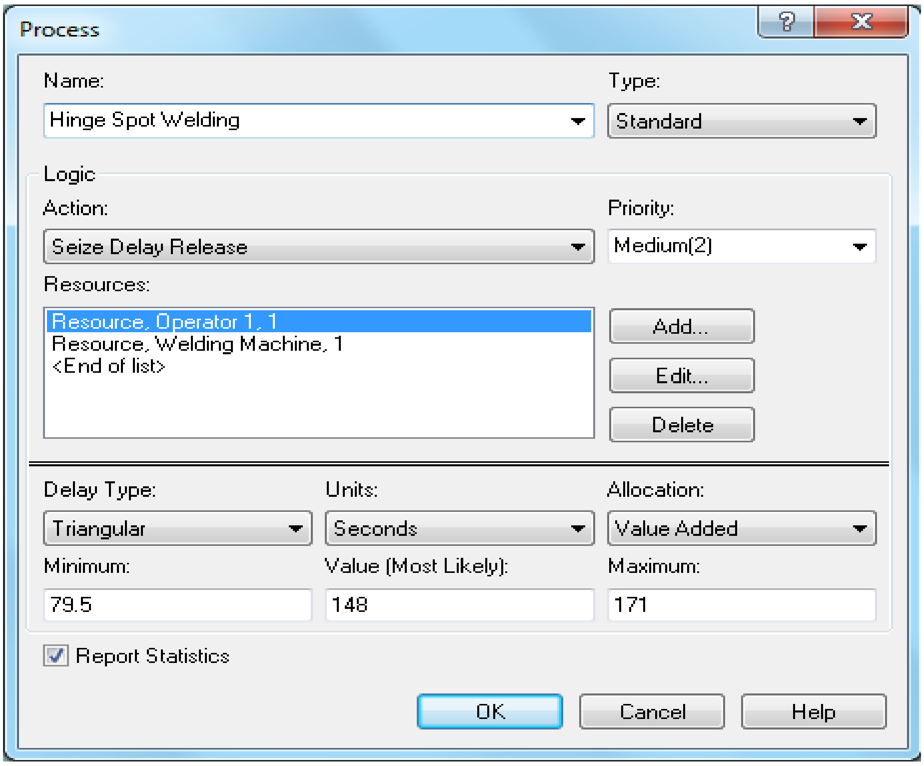

Figure 4.8: Module of hinge spot welding process

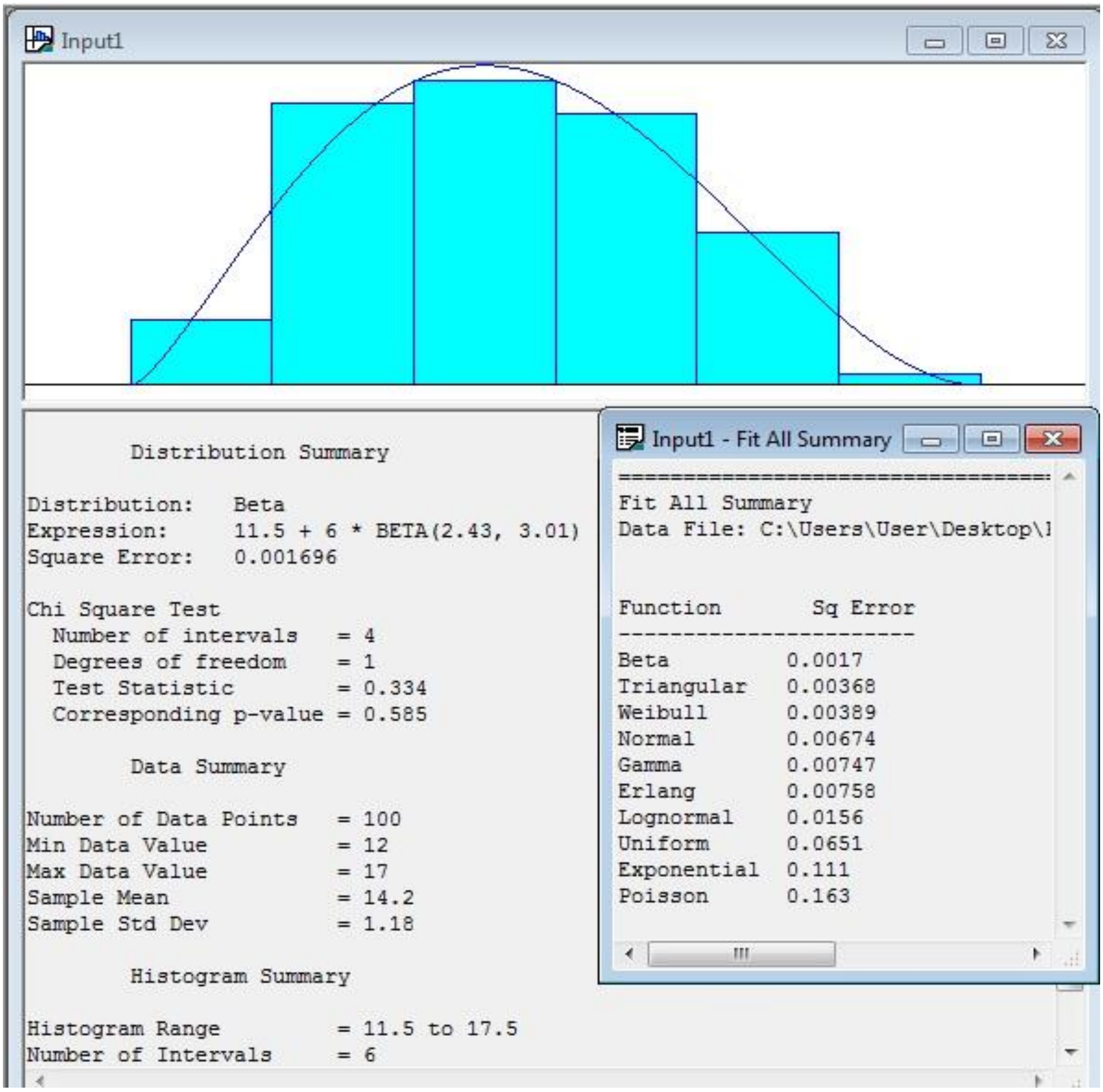

Figure 4.9: Distribution of embossing process time

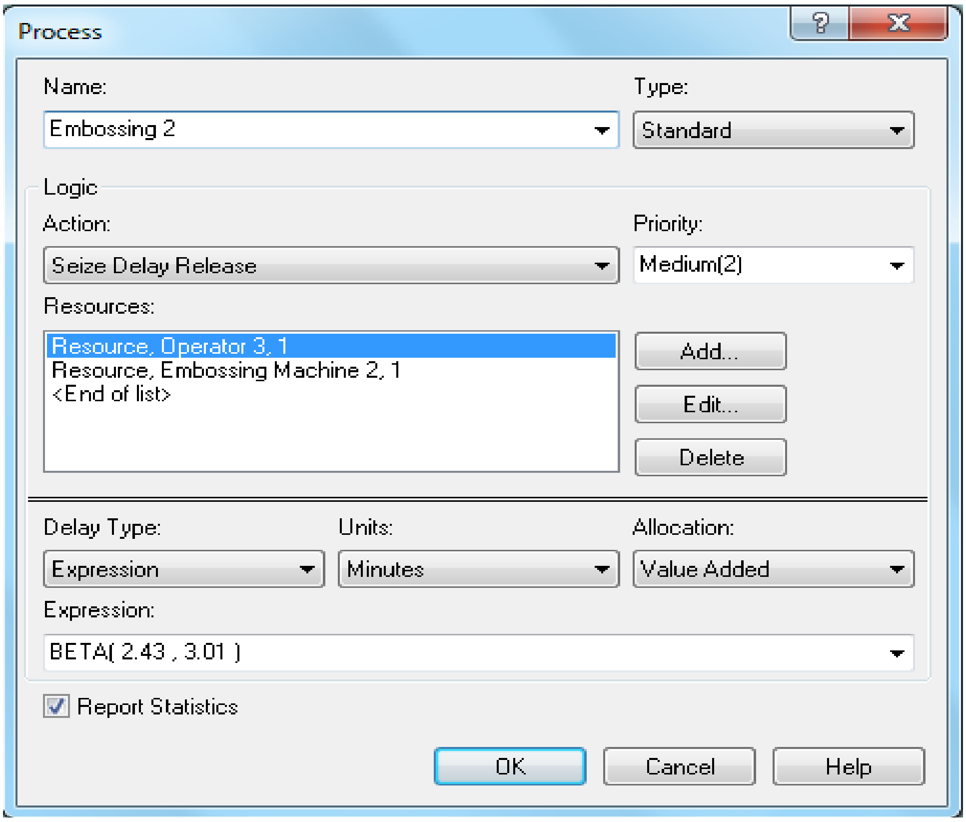

Figure 4.10: Module of embossing process

For embossing process operation, the operator will use the embossing machine to embossing the aluzinc sheet, so there is a mark for welding department to fix the hinge at correct allocated space. In Figure 4.9 shows the distribution of embossing process time. The summary results show that BETA (2.43, 301) distribution with expression 115 + 6 * has the least square error with the value of 0.0017.. The Seize Delay Release is selected for logic action in Figure 4.10. Seize Delay Release happen in this station when the operator receive one part of frame, operator will emboss using manual embosser machine, process time may cause delay as the operator need to move the frame to the machine to emboss, after emboss need to move out from the machine.

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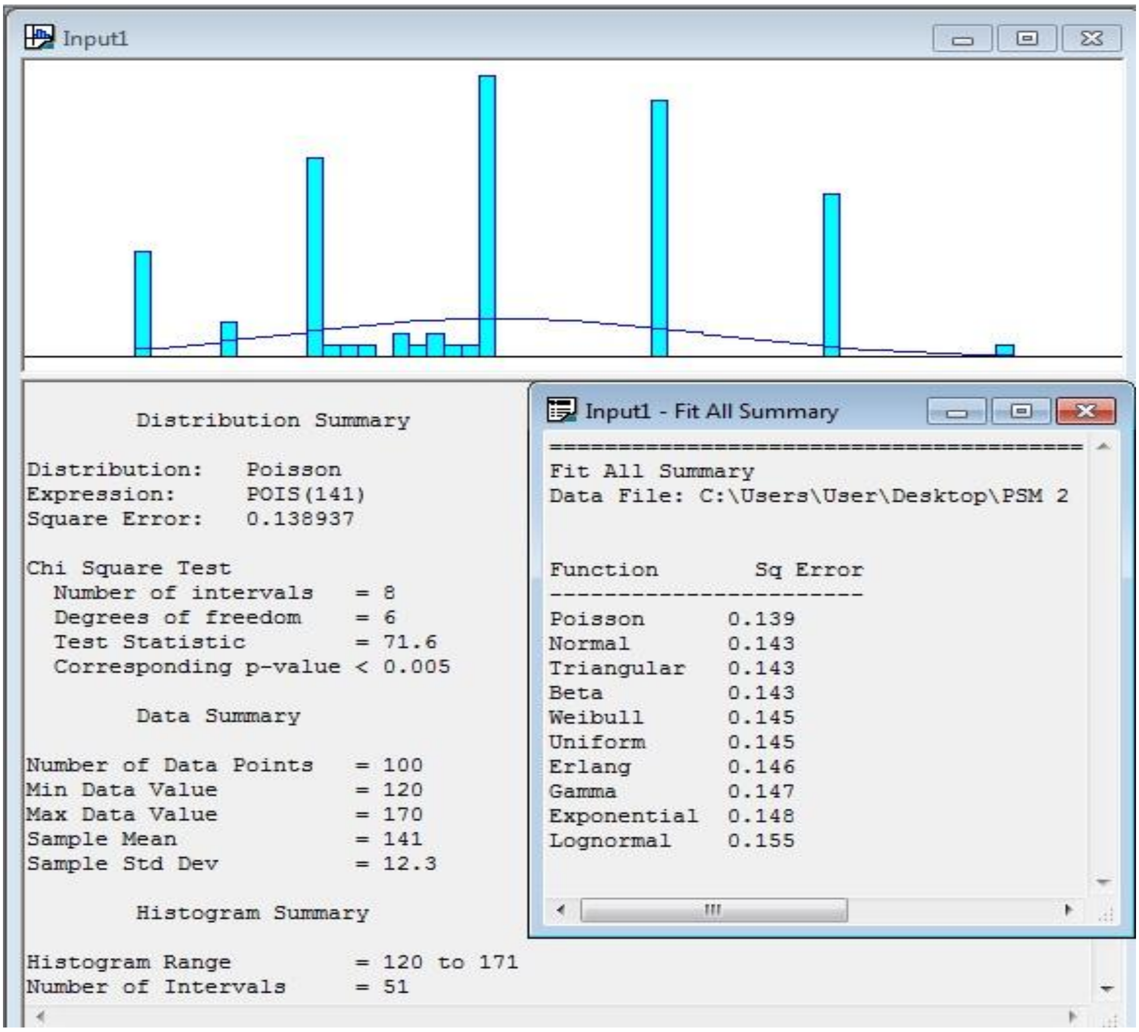


Figure 4.11: Distribution of lockset installation process time

For lockset installation process operation, the operator will use the magnetic nut driver to install the lockset. In Figure 4.11 shows the distribution of lockset installation time. The summary results show that Poisson distribution has the least square error with the value of 0.139. Poisson distribution (141) is filled in as the delay type for embossing process. The Seize Delay Release is selected for logic action in Figure 4.12. Seize Delay Release happen in this station when the operator receive one part of frame, operator 1 will install the lockset, process time may cause delay as the operator need to move the frame to the magnetic nut driver to screw the lockset and release. Repetitive work may slow down the time of completion in the lockset station as human energy is using.

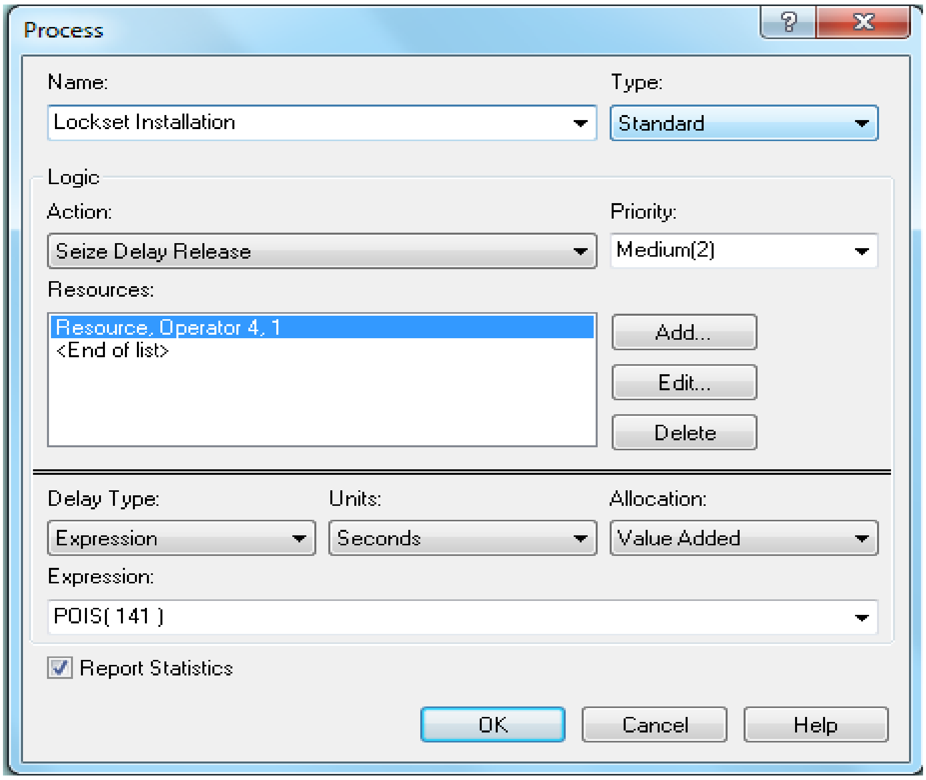


Figure 4.12: Module of lockset installation process

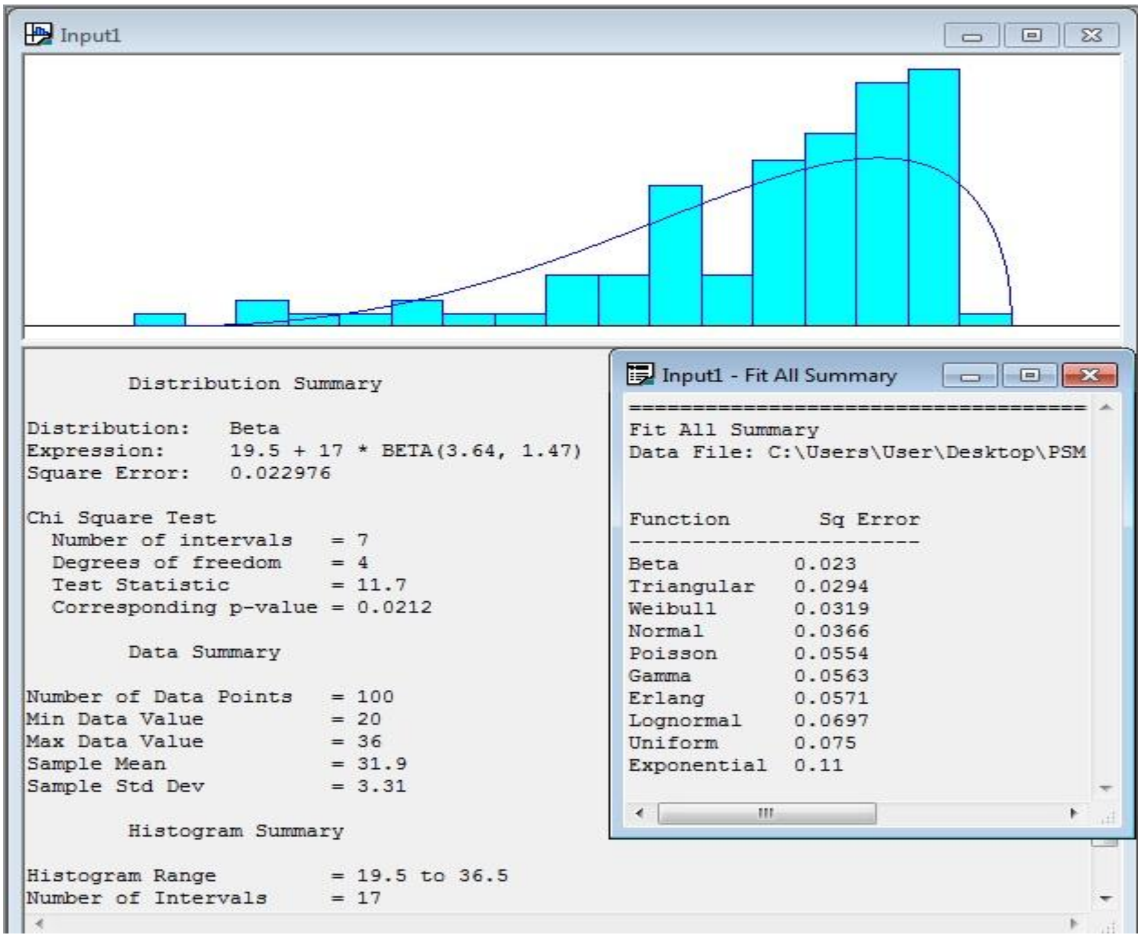


Figure 4.13: Distribution of welding process time

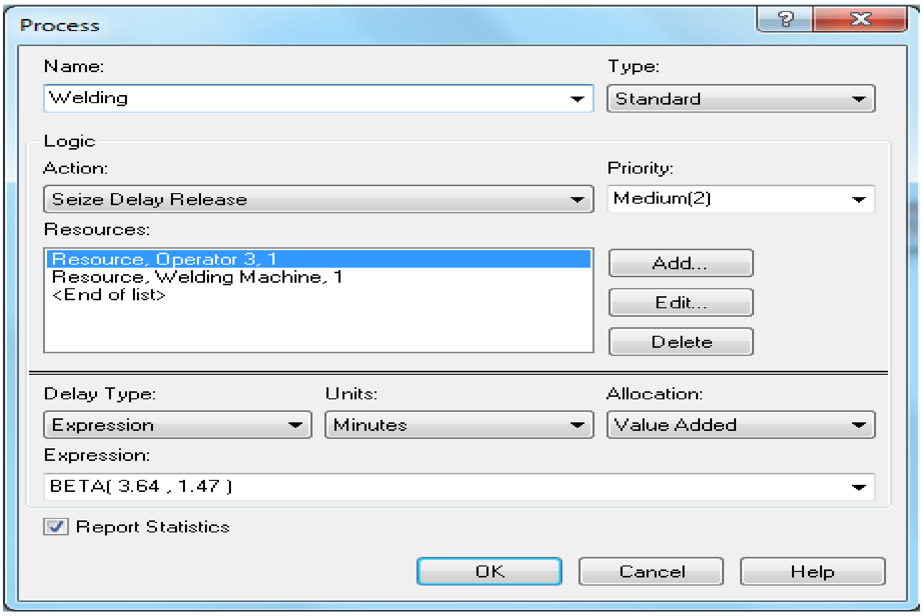


Figure 4.14: Module of welding process

For welding manufacturing process, the operator will use the welding manual machine to weld all the four parts together to become a complete door frame. In Figure 4.13 shows the distribution of welding process time. The summary results show that Beta distribution has the least square error with the value of 0.023. Beta distribution is filled in as the delay type for welding process. The Seize Delay Release is selected for logic action in Figure 4.14. The seize delay release for this process is BETA (3.64, 1.47) with expression 19.5 + 17 *. Seize Delay Release happen in this station, Operator 3 and welding machine being assigned as resources for this process. The operator receives four parts of frame; operator will weld all four parts together to become a complete door frame. The machine already set, operator need to use the machine to weld and release.

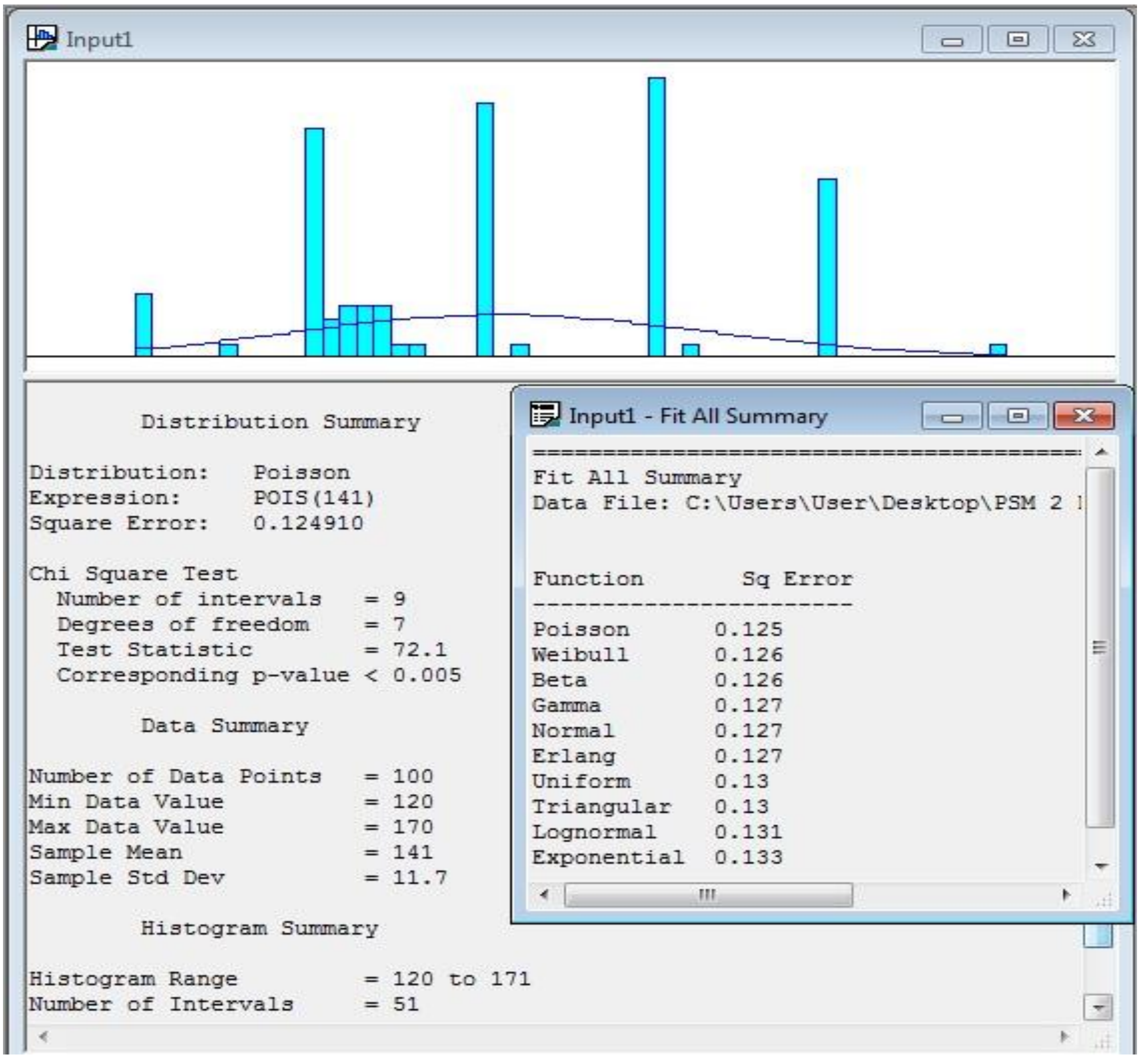


Figure 4.15: Distribution of touch up process time

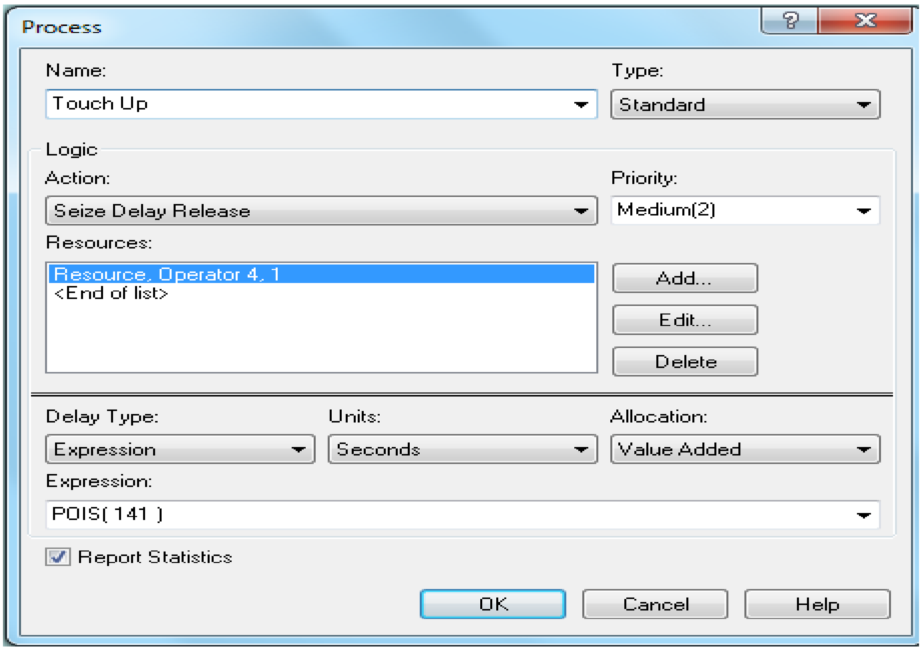


Figure 4.16: Module of touch up process

For touch up processing time, the operator will manually touch up the dark edge of frame after welding with paint. In Figure 4.15 shows the distribution of touch up process time. The summary results show that Poisson distribution has the least square error with the value of 0.124910. Poisson distribution (141) is filled in as the delay type for touch up process. The Seize Delay Release is selected for logic action in Figure 4.16. Seize Delay Release happen in this station, Operator 4 and painting tools are being assigned as resources for this process. The operator receives the door frame, do touch up and release.

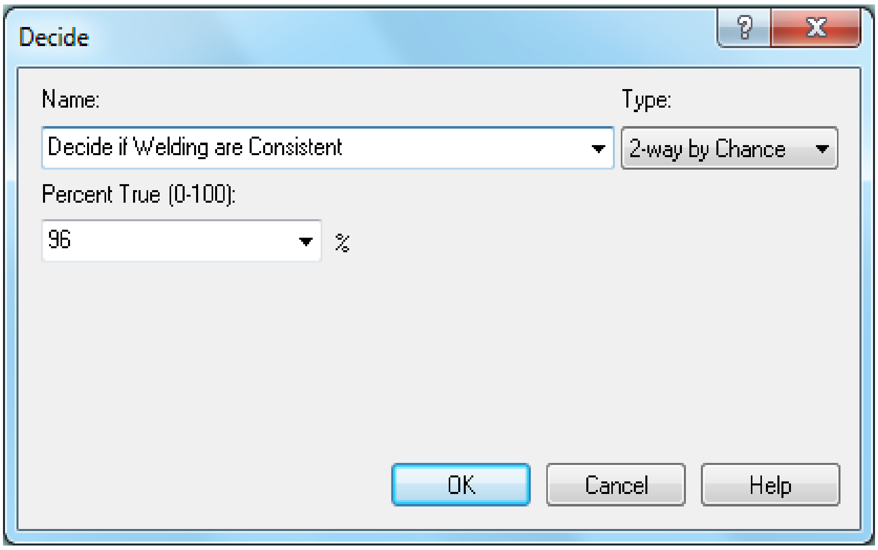


Figure 4.17: DECIDE module of welding process

The DECIDE module used in the welding process is showed in Figure 4.17. Decide module act as transfer station for an entity to pass through. It can be probabilistic or depends on the truth or falsity of some logical condition. Once the welding process finish, the operator will do the inspection to see whether the door frame produce is fulfill the requirement of the customer of good quality welding. The percent true is set on 96% as the probability to get a scrap from welding machine is estimated to be 0.04. Scrap will go to dispose and it cannot rework as aluzinc coil is a hard metal sheet. The door frame that passed through quality check will be really for shipping to customer.

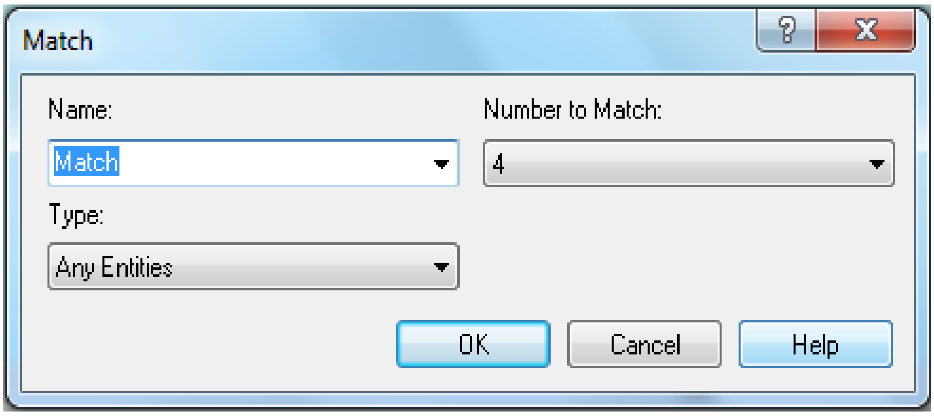


Figure 4.18: MATCH module

The MATCH module aims to connect a specified number of entities that waiting in different queues. When an entity arrives at the match module, it can be match up to five processes at the same time. Entities will stay in their own queue until match module exists. The matched entities will coincident to away from the module. In this thesis, four entities are waiting to be match together using match module. After matching, all the entities will quit the module and go for the next process.

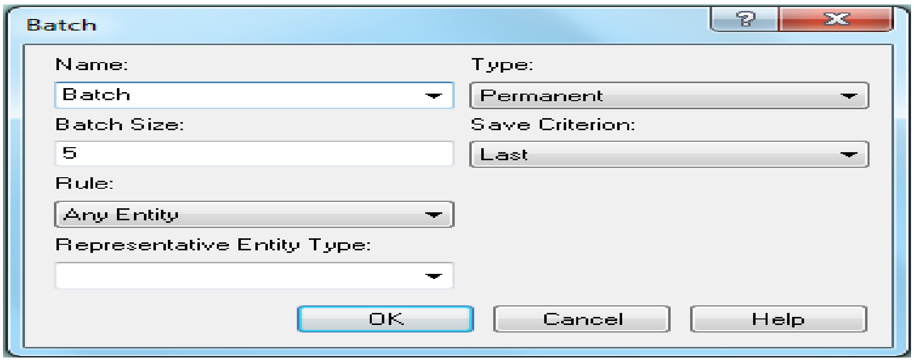


Figure 4.19: BATCH Module

The BATCH module in this study aims to combine all the parts from 4 production lines. The entities reaching at the batch module are waiting in a queue until the accrue number of entities are arrived. The door frame batch size is set to 5 as the starting point got four production lines. The type of the batching is permanent as all the entities will combine into a singular entity. This entity maintain the properties of the last entity to be added to the batch and will not separate to its original members.

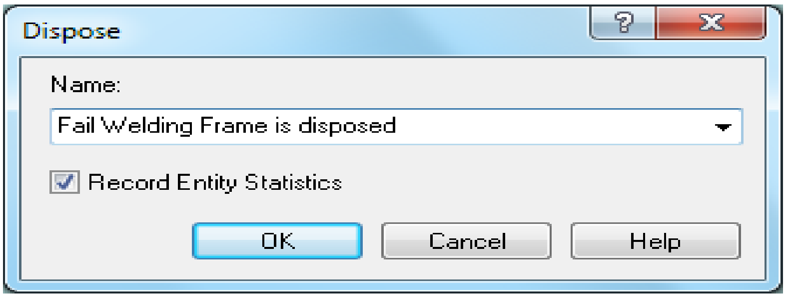


Figure 4.20: DISPOSE module

The DISPOSE module is the end point for entities in Arena model. It also shows that the process finished and going to terminate. The module is for the scrap in the welding process. The record statistics for entity will be joint down before the entity is disposed. In this final step before the welding process, the failing welding door frame like the edges not good welding and got holes will be throw away as aluzinc coil is a hard metal sheet after processing, cannot melted and rework.

Process - Basic Process

	Name	Type	Action	Priority	Resources	Delay Ty...	Units	Allocation	Minimum	Value	Maximum	Std Dev	Expression
1	Blanking	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Value Added	11.5	10	17.5	.2	1
2	Roll Forming	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	11.5	14.3	16.5	1.02	BETA(1.8 , 2.35)
3	Embossing	Standard	Seize Delay Release	Medium(2)	2 rows	Normal	Minutes	Value Added	11.5	14.3	17.5	1.02	BETA(2.92 , 2.55)
4	Hinge Spot Welding	Standard	Seize Delay Release	Medium(2)	2 rows	Triangular	Seconds	Value Added	79.5	148	171	.2	1
5	Blanking 2	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Value Added	10.5	10	16.5	.2	1
6	Roll Forming 2	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	10.5	14.3	16.5	1.02	BETA(3.77 , 3.14)
7	Embossing 2	Standard	Seize Delay Release	Medium(2)	2 rows	Expression	Minutes	Value Added	11.5	13.5	17.5	.2	BETA(2.43 , 3.01)
8	Lockset Installation	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Seconds	Value Added	120	140	171	.2	POIS(141)
9	Blanking 3	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Value Added	10.5	10	16.5	.2	1
10	Roll Forming 3	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	140	14.3	170	1.02	BETA(2.03 , 1.62)
11	Blanking 4	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Value Added	11.5	10	16.5	.2	1
12	Roll Forming 4	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	140	14.3	160	1.02	BETA(2.19 , 2.11)
13	Welding	Standard	Seize Delay Release	Medium(2)	2 rows	Expression	Minutes	Value Added	20	25	30	.2	BETA(3.64 , 1.47)
14	Touch Up	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Seconds	Value Added	120	150	171	.2	POIS(141)

Figure 4.21: Basic processes of door frame production

Figure 4.21 shows the vital processes in the door frame production. A piece of completed frame need to pass through blanking, roll forming, embossing, hinge spot welding, lockset installation, welding edges and touch up.

Basically, all the process is using Seize Delay Release as the production line, it is either using the machine or the operator or the combination of machine and operator. When the piece of aluzinc coil arrive, operator need to process using the machine and after this will release the product by put back the piece onto the machine to go to next stations. There have four rows of aluzinc coils processing with the machines and operators simultaneously. The expression parameters are base on the data collection and implement it input analyzer. The expression with the least square error will be chosen to fill in. Therefore, there are four types of expression using in my thesis which are Normal, Triangular, Beta and Poisson distributions.

	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6
Embossing	X					
Embossing 2		X				
Hinge Spot Welding			X			
Lockset Installation				X		
Welding					X	
Touch Up						X

Table 4.2: Operator Work Schedule

In the production line, there are six operators working in 6 workstations. For the starting point, the aluzinc coil enters the blanking process and then proceed to roll forming process, there is not listed in Table 4.2 because the process only use machine and no human energy to operate. Operator 1 needs to emboss a mark on the frame part to be easier for Operator 3 to do hinge spot welding on the correct path. Operator 2 receive the frame parts arrive, emboss a hole to be use to fix the lockset on that empty hole. Operator 3 will do hinge spot welding. Operator 4 will fit the lockset using magnetic nut driver. Operator 5 will assembly all the four parts together to become an individual door frame using welding and lastly Operator 6 makes the touch up on the welded edge frame.

Resource - Basic Process

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	Failures	R...
1	Blanking Machine	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
2	Operator 1	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
3	Blanking Machine 2	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
4	Blanking Machine 3	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
5	Blanking Machine 4	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
6	Welding Machine	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
7	Embossing Machine	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
8	Roll Forming Machine	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
9	Embossing Machine 2	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
10	Roll Forming Machine 3	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
11	Roll Forming Machine 2	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
12	Roll Forming Machine 4	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
13	Welding Machine 2	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
14	Operator 4	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
15	Operator 6	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
16	Operator 2	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
17	Operator 3	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓
18	Operator 5	Fixed Capacity	1	0.0	0.0	0.0	0 rows	✓

Figure 4.22: Resource Schedule

Resource is the usage of operator and machine. There are 18 resources appear in the door frame model as shown in Figure 4.22. Six operators are using for this thesis. Four blanking machines, four roll forming machines, two embossing machines and two welding machines.

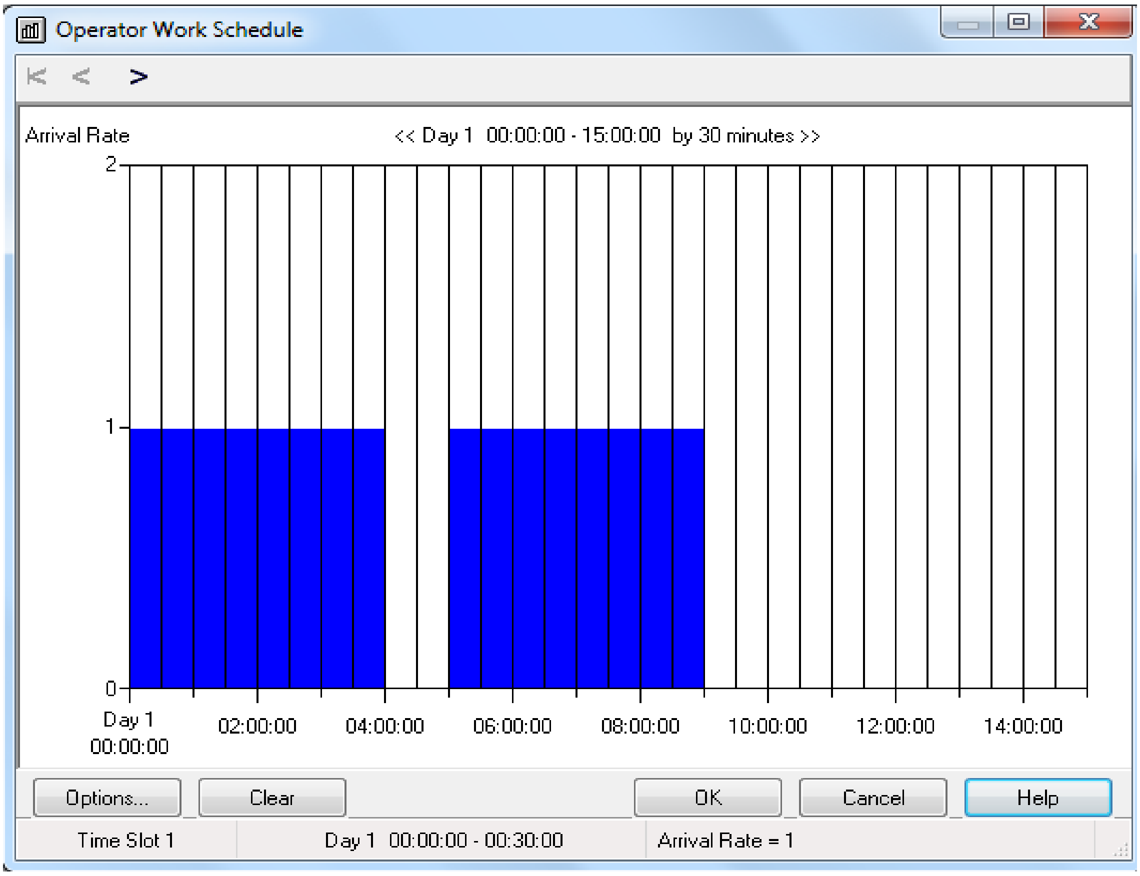


Figure 4.23: Operator Work Schedule Module for door frame process

In the production line, there are four operators working in 10 workstations. Referring to the work schedule given by production manager, four operators will be working for morning and afternoon shift. The operating schedule is 8:00 am to 5:00 pm. Daily working hours are 8 hours and 1 hour rest time. Figure 4.23 above shows a schedule module for door frame process.

Run Setup Menu is used to control and inspect the running conditions of Arena model. The model is runs 10 times of replication with the base times units, minutes. Every replication starts with warm-up period 0 and the running process finished in 480 minutes. Operation hour per day is 540 minutes. Upon the simulation finish running, 10 statistical reports are generated. Figure 4.24 below shows the run setup menu with parameters filled in.

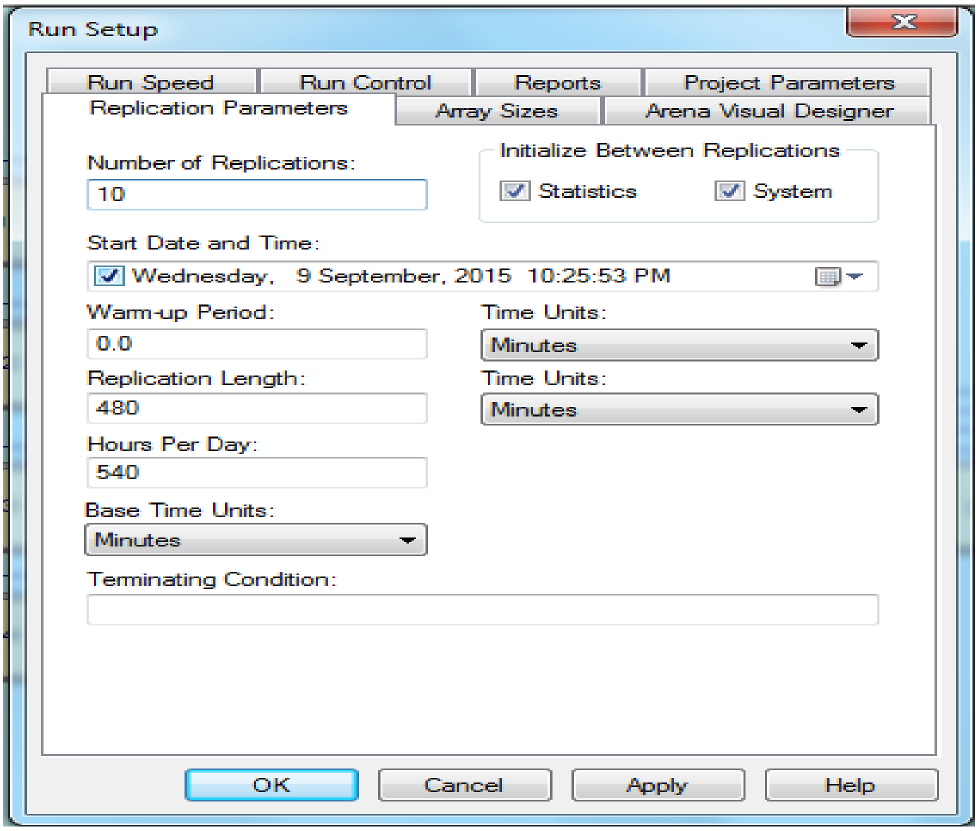


Figure 4.24: Run Setup Module for door frame process

4.4 DATA VERIFICATION AND VALIDATION

Regarding to the step in constructing the simulation model in Chapter 3, after the data collection, a conceptual model will be build based on the actual real world manufacturing line in door frame production. Therefore, it is needy to verify that the model development already passed the verification and validation process. With this, then the model only can implement in the real world system. The simulation model is the "software or system" that need to verified and the model must be validated (Sargent R.G., 2013). From here, it is known that both verification and validation are vital in model development.

Verification is aware of constructing the *model right*. It is useful to implement the real situation using the Arena software to build conceptual model and make comparisons, the most productivity model will be selected. Verification to ensure the model behaved as intended (Netland *et al.*, 2013). The primary goal of verification is to testing the performance of each module is precise in the Arena model. The whole door frame production line will be predict using the verification, running of Arena with animation aims to show the workstations process in the Arena whether similar to the current process in real situation. Door frame model is verified to confirm that the picked model is accurate, precise, logic and applied correctly.

On the other hand, validation model is aware of building *right model*. It examined the model performance metric, and similar compared to the real world. Validation aims to confirm that the simulation model built is similar to the real world model and no obvious difference. From testing on the model, it might be no doubt that the model is unrealistic and illogic although the simulation model able to performs satisfactory excellent underlying assumption. Many industries also implement simulation to remain competitive in the market. Mismatches should be taken necessary action to adapt the model, if not a serious damage may be incurred (Tosti *et al.*, 2013). Hence, if mismatches solute, match will be set up, the model can be adapt and continue to validate.

The simulation model will key in different parameters data, therefore the model run setup menu to continue running for the model. Repetition is the crucial criteria to ensure the performance of model similar to the actual world system. Upon the model run to 10 repetitions, it will stop and the data analysis report will pop up. The output report may make the comparison with the data collected from the factory. Regarding to the statistical report, Arena will show us the average of every replication result. The output report comes out in the form of statistic.

In order to prove the validation of the door frame model, the differences between the actual production line outputs with the simulation output must be in the range of ± 10% of the actual output. From the ARENA simulation statistical report, the output number of the system is able to run to maximum of 14 units, however in the real world the actual output is on 13 units according to the production supervisor, Mr. Alex She, The differences percentages between two systems are about 7.69%. Therefore, the door frame model can considered validate.

Calculation:

The differences percentages of output between actual output and simulation output

$$Differences\ (\%) = \frac{Simulation\ Output - Actual\ Output}{Actual\ Output}\ x\ 100\% \quad \textbf{(Eq. 4.2)}$$

$$= \frac{14\text{-}13}{13}\ \text{x}100\%$$

$$= 7.69\%$$

The simulation model will key in different parameters data, therefore the model can be verify and validate through the computer codes contains of any programming error ('bugs').

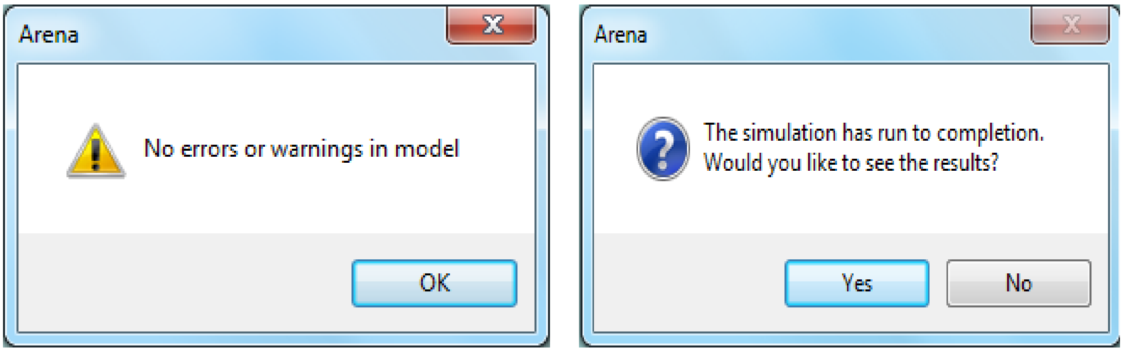


Figure 4.25: Verification and Validation in Arena model

4.5 ANALYSIS OF SIMULATION RESULT

The analysis of simulation result carried out after the running the door frame simulation model. The Arena software will generate out the appropriate results and data from the model. Upon the finish running of the model, the menu Category Overview will be pop out. If choosing for the SIMAN Summary Report (.Out file) from the run setup menu, more details of data like worker utilization, work-in-process time, the total number of input and output, waiting time, queue time, value-added time and so on. The inefficiently of the model can be predict and figure out. Therefore, model improvement can be done to improve the efficiently.

Discrete event is happened when all the operators working on the processing at the workstations. Operator need to use time in operating and controlling the machine. The main objective of the thesis is to assess the performance of the worker and machine, the utilization level for both worker and machine; it is either busy or idle, finally to enhance the performance of the process.

4.5.1 EFFICIENCY AND PRODUCTIVITY

The production line can create efficiency and productivity is the most important part in the manufacturing industries. In this thesis, the productivity of each workstation will be generated using the unit of entities that enter and out from the process. The process time is 480 minutes which is the daily working hours. In order to get a mode precise and accurate result, 10 replications will be carried out. Normally, the input and output will be the same. Nevertheless, the door frame model may have dispose output due to output is a defect or idle. In addition, daily output may be reduce due to some of entities are still waiting in queues.

Calculation:

$$\text{Productivity } (\%) = \frac{\text{Output}}{\text{Input}} \times 100\% \qquad \textbf{(Eq 4.3)}$$

Process	Number In (Input)	Number Out (Output)	Productivity (%) = $\frac{Output}{Input}$ x 100%
Blanking	20.600	19.900	96.60%
Blanking 2	20.500	20.300	99.02%
Blanking 3	20.400	20.000	98.04%
Blanking 4	20.400	20.000	98.04%
Roll Forming	19.900	19.500	97.99%
Roll Forming 2	20.300	19.500	96.06%
Roll Forming 3	20.200	19.300	95.54%
Roll Forming 4	20.000	19.400	97.00%
Embossing	19.500	18.800	96.44%
Embossing 2	19.500	19.500	100%
Hinge Spot Welding	18.800	18.700	99.47%
Lockset Installation	19.500	19.500	100%
Welding	14.700	14.700	100%
Touch Up	14.100	14.000	99.29%

Table 4.3: Productivity of operation

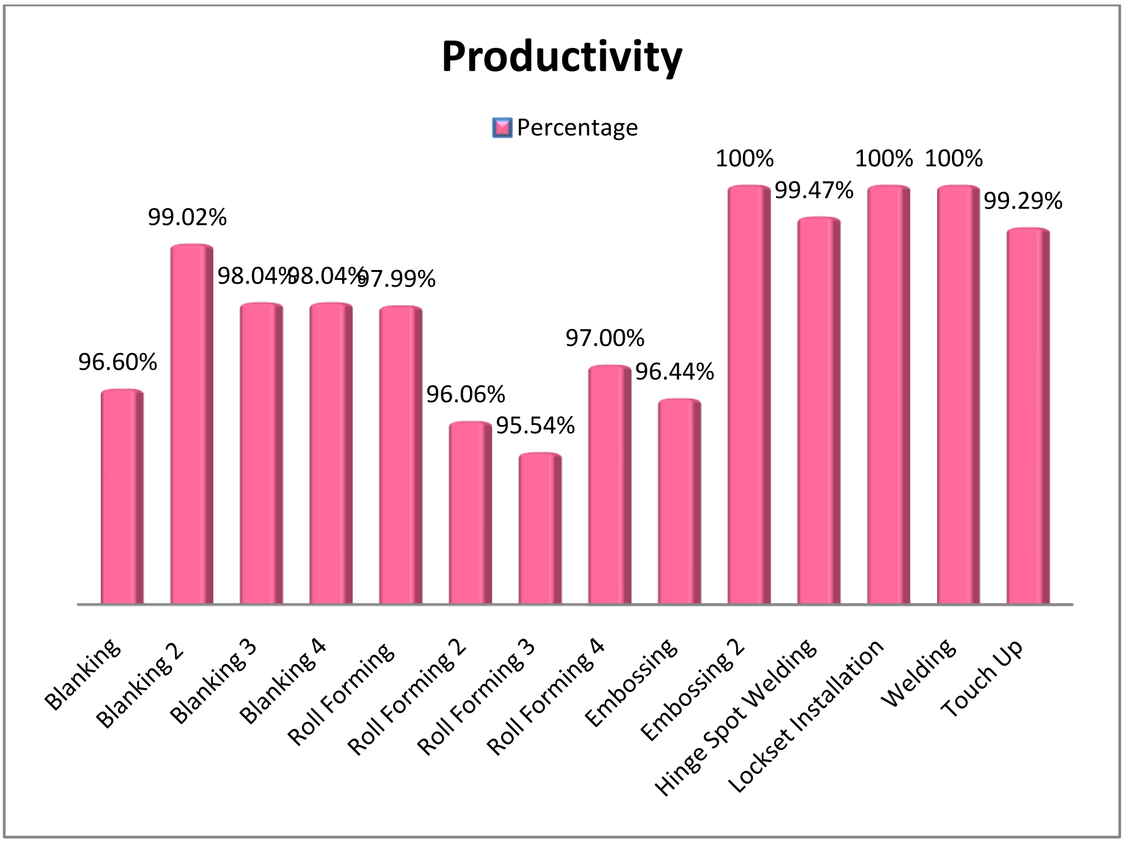


Figure 4.26: Productivity of production operation

According to Figure 4.26 above, embossing 2, lockset installation and welding have high productivity of 100%. This is a good phenomenon as company always strives to sustain competitive by improving the efficiency and increasing the percentages of productivity. There is close correlation between efficiency and productivity. The more efficiency of the process, the more jobs can be finished on time and resulting in higher productivity. The other workstations like blanking, roll forming, hinge spot welding and touch up also creates a high productivity which are 95% and above, therefore the queue is smoothly in each station due to the processing time of each station is constant and the machine speed also average. The entity do not need to waste time to enter each process. Although the production system can consider high efficiency and productivity, but measures still can be taken to enhance the system.

4.5.2 VALUE ADDED TIME

Process	Average	Minimum Average	Maximum Average
Blanking	12.000	12.000	12.000
Blanking 2	10.000	10.000	10.000
Blanking 3	10.000	10.000	10.000
Blanking 4	10.000	10.000	10.000
Roll Forming	14.330	11.934	16.490
Roll Forming 2	14.589	12.059	16.853
Roll Forming 3	14.2123	13.080	16.438
Roll Forming 4	14.984	11.736	16.544
Embossing	14.088	11.913	15.946
Embossing 2	0.47721	0.8026	0.877793
Hinge Spot Welding	2.1169	1.5106	2.6082
Lockset Installation	2.4116	2.0333	2.8666
Welding	0.64741	0.34209	0.96326
Touch Up	2.3035	1.8166	2.650

Table 4.4: Average of Value Added Time per entity

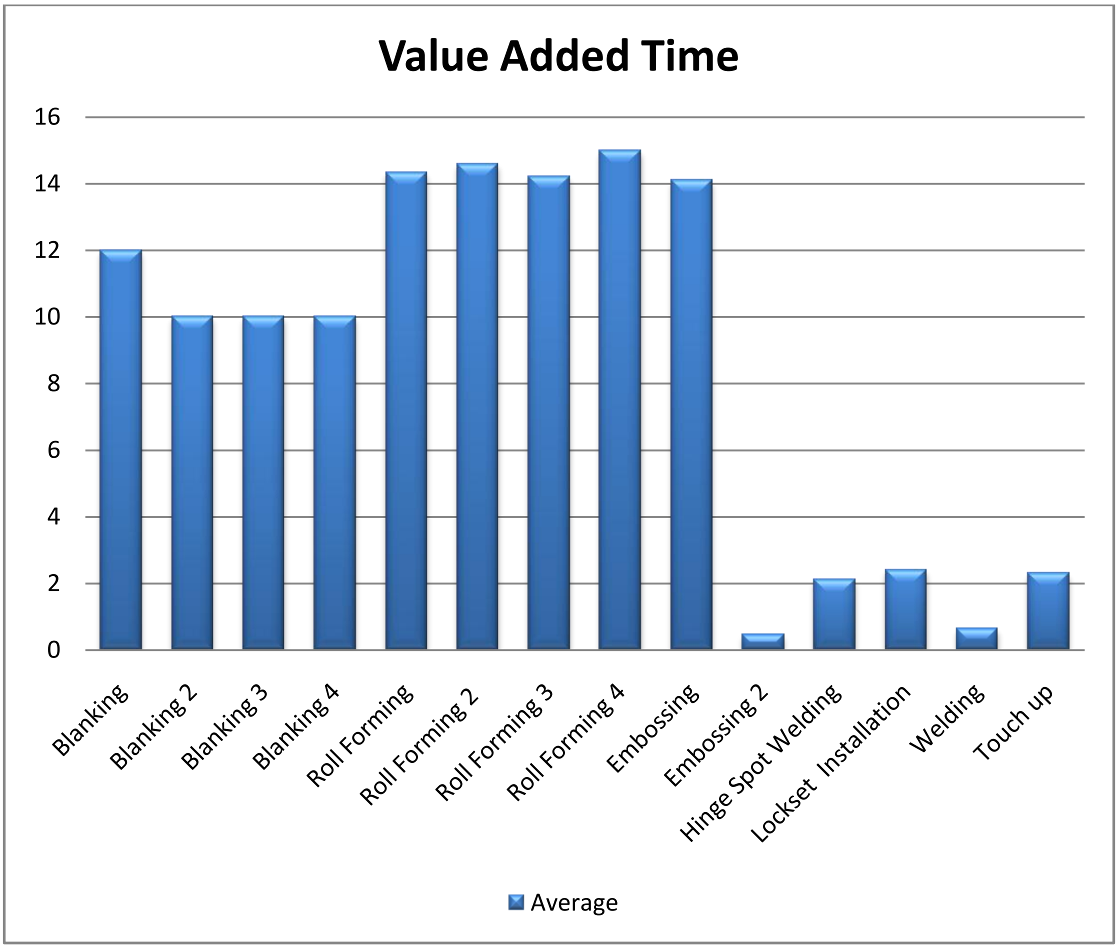


Figure 4.27: Average of Value Added Time per entity

From the graph shown in Figure 4.27, the average of value added time per entity after analyst simulation results from Arena. The parameters are type in for each entity. Roll Forming 4 is the station that spends the longest time in processing, which is 14.984 minutes. The next will be roll forming 2, which is 14.589 minutes.

4.5.3 ACCUMULATED VALUE ADDED TIME

Process	Average	Half-Width	Minimum Average	Maximum Average
Blanking	238.80	2.7144	228.00	240.00
Blanking 2	203.00	4.8279	190.00	210.00
Blanking 3	202.00	3.0160	200.00	210.00
Blanking 4	200.00	0.0000	200.00	200.00
Roll Forming	280.16	5.6597	264.21	289.86
Roll Forming 2	277.81	6.9603	264.96	291.79
Roll Forming 3	277.40	5.6597	264.21	289.86
Roll Forming 4	290.97	5.2351	279.52	300.73
Embossing	271.25	6.2062	253.88	281.16
Embossing 2	8.8778	0.60910	7.4690	10.318
Hinge Spot Welding	40.793	1.9382	37.149	46.021
Lockset Installation	46.525	0.93319	44.616	48.233
Welding	10.412	0.53957	9.5290	11.928
Touch up	32.641	1.8478	27.016	35.416

Table 4.5: Average of Accumulated Value Added Time per entity

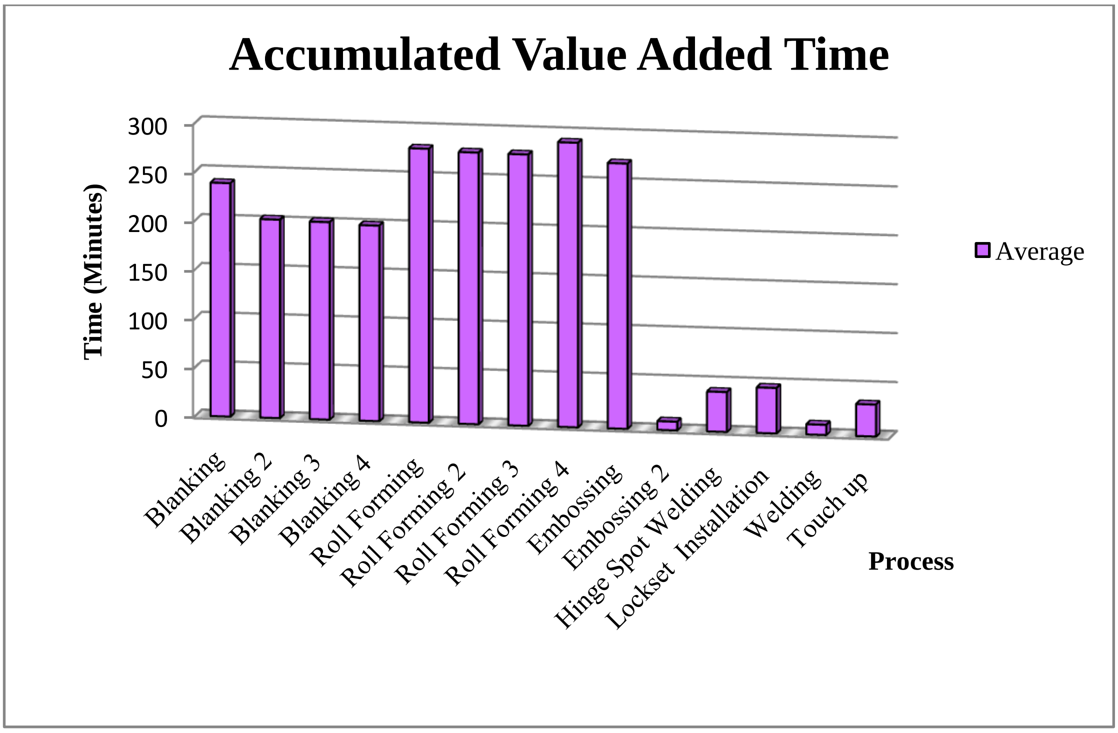


Figure 4.28: Accumulated Value Added Time per entity

From the graph shown in Figure 4.28, the average of accumulated value added time per entity after analyst simulation results from Arena. The parameters are type in for each entity. Roll Forming 4 is the station that spends the longest time in processing, which is 290.97 minutes. The next will be roll forming which is 280.16 minutes.

4.5.4 TOTAL TIME PER ENTITY

Process	Average	Minimum Average	Maximum Average
Blanking	12.000	12.000	12.000
Blanking 2	10.000	10.000	10.000
Blanking 3	10.000	10.000	10.000
Blanking 4	10.000	10.000	10.000
Roll Forming	14.330	11.934	16.490
Roll Forming 2	14.589	12.059	16.853
Roll Forming 3	14.423	11.736	16.544
Roll Forming 4	14.984	13.080	16.438
Embossing	14.088	11.913	15.946
Embossing 2	0.47721	0.08026	0.87793
Hinge Spot Welding	2.1169	1.5106	2.6082
Lockset Installation	2.4116	2.0333	2.8666
Welding	0.64741	0.34209	0.96326
Touch Up	2.3035	1.8166	2.6500

Table 4.6: Average of Total Time per entity

Total time per entity in every producing operation plays a vital role in the manufacturing plant for producing a product. According to Hecker (2010), a precise assumption shows that the shortest the manufacturing time, the more units of products can product and gains more profits and client portfolio.

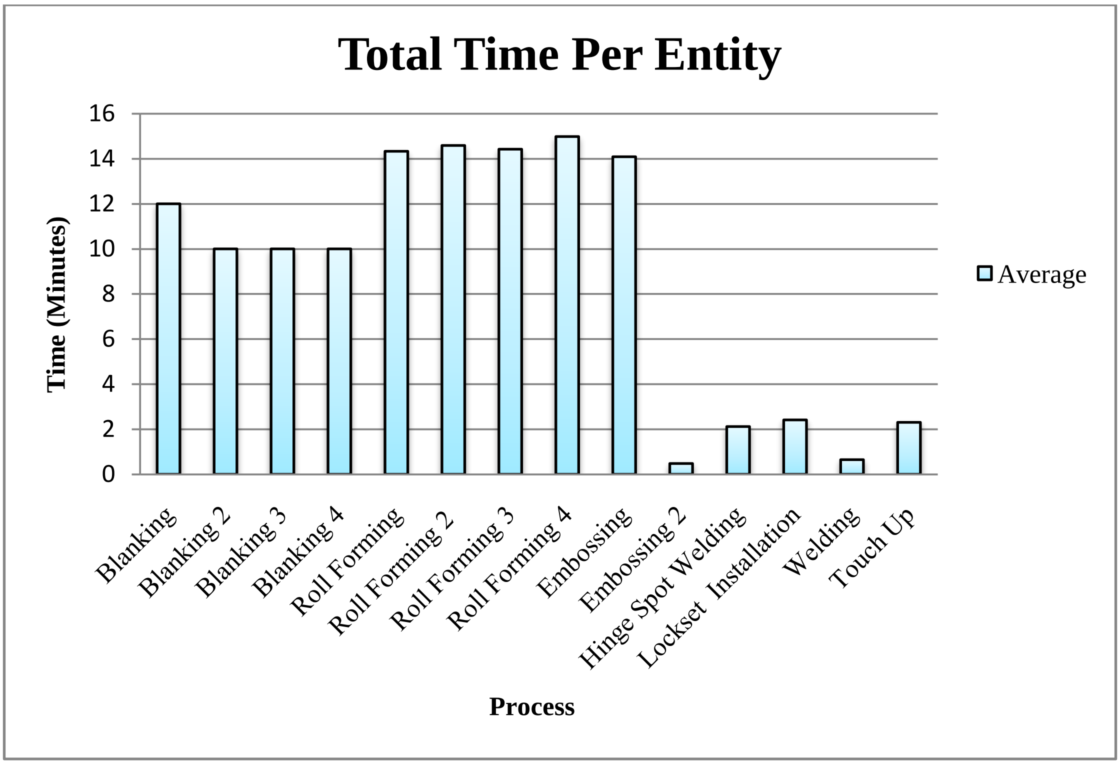


Figure 4.29: Average of Total Time per entity

Calculation:

Total time per entity = Value Added Time Per entity + Wait Time Per entity

(Eq. 4.4)

Total time per entity is the time usage for production. Roll forming 4 has the highest total time per entity which is 14.984. The longer the total time; the longest the processing time it will be. This may coincident the production system becomes slow and influences the efficiency of the system. Therefore, it is a must to reduce total time of process to stay competitive and sustain the market.

4.5.5 WAIT TIME PER ENTITY

Process	Average	Minimum Average	Maximum Average
Aluzinc Coil	139.82	130.06	146.83
Aluzinc Coil 2	137.41	126.06	151.59
Aluzinc Coil 3	105.76	85.614	124.67
Aluzinc Coil 4	91.257	66.012	105.83

Table 4.7: Average of Wait Time per entity

Waiting time or queuing is amount of time it incurs when submitted an order till first response is made and not output. In the process module where an entity have a wait time before enter the process station. The long wait time may affect the efficiency and productivity of the company as it may slow down the processing speed. In addition, long queuing also may cause bottlenecks in the production system. Therefore, necessary measures may be taken to eliminate the long queue and increases the productivity. The wait time for aluzinc coil using the most time which is 139.82 minutes. It is followed by the aluzinc coil 2 which is 137.41 minutes, aluzinc coil 3, 105.76 minutes and aluzinc coil 4 is 91.257 minutes.

4.5.6 RESOURCE UTILIZATION

In the Arena simulation, the resource using in the production line are machine and worker. The analysis of arena output summary allows the analyst to know about the efficiency level of the factory. The company also set the high utilization in machine and worker as blueprint of their company. According to Altuntas *et al*.(2012), machine utilization is the main reasons that always being assessed by the management level which may causes the failure and decrease the productivity yield. The percentages of machine utilization analyzes the usage rate, productive time of machine tools with the working load for overall process workstations. A utilization of machine rate in 75% and above will considered as high utilization and efficiently. Hence, it is difficult to implement on fully utilize the resources.

In this study, assess and make improvements to the resource utilization is the main aims to achieve. Operator utilization is to reflect on the production operation using its operator. It will look clearly the time usage for each operator use for every workload and assignments as a percentage of them having time on the job. Nevertheless, if compare machine utilization, operator utilization is totally difference. If operator utilization is above 60%, it will consider high. This is because human factor is the main influence of the performance of the production line; humans have limited physical capability, they may feel fatigue and boredom after long hours of working. They are not robot and cannot work like machine, more consistently.

Operator	Average	Percentage	Minimum Average	Half-Width	Maximum Average
Operator 1	0.57158	57.16%	0.55466	0.00808	0.5875
Operator 2	0.08509	8.51%	0.07841	0.00393	0.09588
Operator 3	0.01850	1.85%	0.01556	0.00127	0.2150
Operator 4	0.09693	9.69%	0.09295	0.00194	0.10049
Operator 5	0.02169	2.17%	0.01985	0.00112	0.02485
Operator 6	0.06836	6.84%	0.05985	0.00327	0.07378

Table 4.8: Resources utilization - Operator Utilization

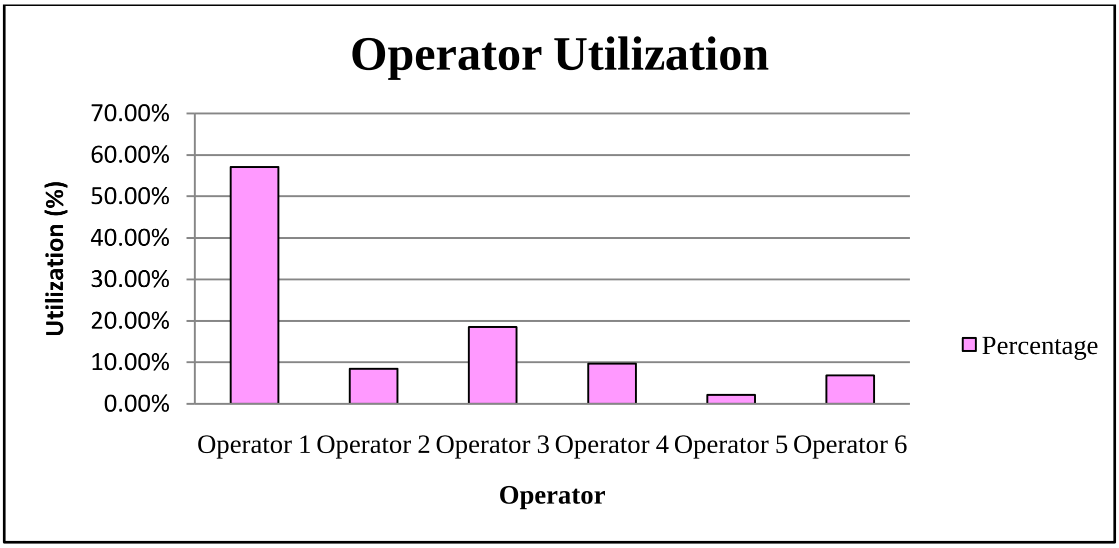


Figure 4.30: Percentage of Operator Utilzation

From Table 4.8 and Figure 4.29, the operator utilization rate with the highest percentage is Operator 1 which is only 57.16%. All 6 operators can consider low utilization as below 60%.So, the improvements must be made to balance the workload for each station and worker schedule must be amend to maximize the operator utilization and eliminate operator idle time.

Machine	Average	Percentage	Minimum Average	Half-Width	Maximum Average
Blanking Machine	0.50567	50.57%	0.49047	0.00339	0.42944
Blanking Machine 2	0.42606	42.61%	0.40812	0.00858	0.43750
Blanking Machine 3	0.42126	42.13%	0.41667	0.00618	0.43750
Blanking Machine 4	0.41956	41.96%	0.41667	0.00339	0.42944
Roll Forming Machine	0.59128	59.13%	0.57549	0.00862	0.61182
Roll Forming Machine 2	0.59142	59.14%	0.56559	0.1243	0.62947
Roll Forming Machine 3	0.59282	59.28%	0.56019	0.1282	0.62411
Roll Forming Machine 4	0.61643	61.64%	0.59682	0.00644	0.62653
Embossing Machine	0.57158	57.16%	0.55466	0.00808	0.58575
Embossing Machine 2	0.01850	1.85%	0.01556	0.00127	0.02150
Welding Machine	0.08509	8.51%	0.07841	0.0393	0.09588
Welding Machine 2	0.02169	2.17%	0.1985	0.00112	0.02485

Table 4.9: Resources utilization - Machine Utilization

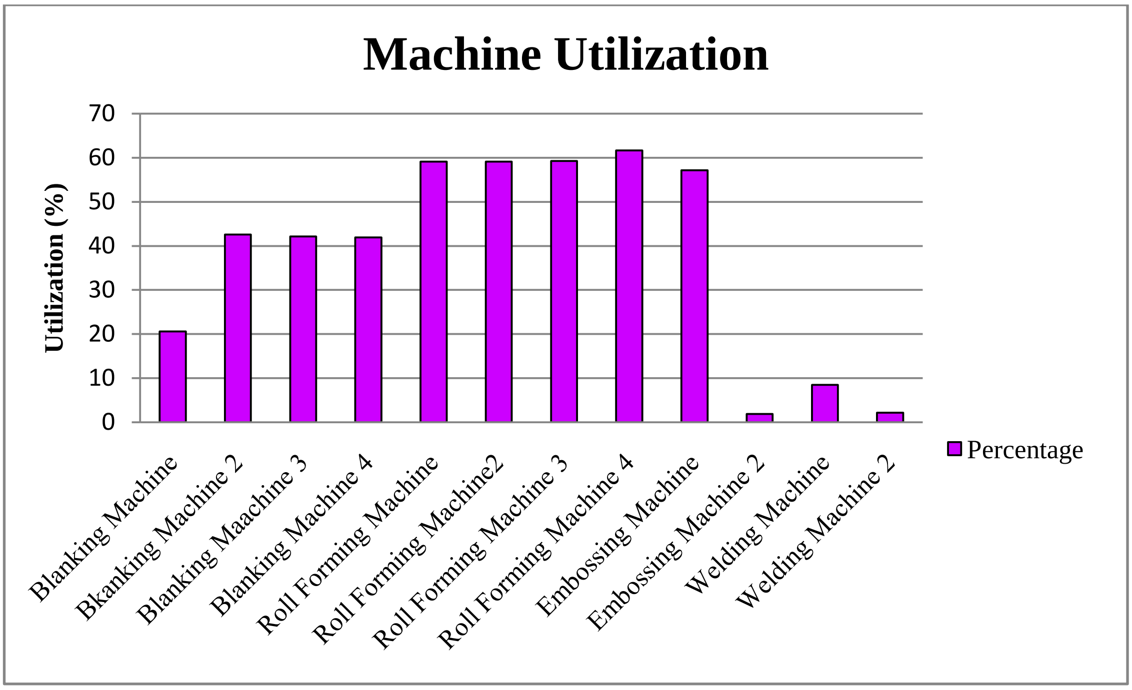


Figure 4.31: Percentage of Machine Utilization

Machine utilization is another resource for entity. Table 4.9 and Figure 4.30 above indicate that all the machine utilization still in low level, below 75%. There are 12 machines are using in the production line. Roll Forming Machine 4 is the highest percentage of utilization which is 61.64%. Meanwhile, the embossing machine 2, welding machine and welding machine2 create the lowest percentage of utilization, which are 1.85%, 8.51% and 2.17%. Lower percentage of usage must be take steps to increase as under utilization may cause a negative impact to the company throughput. Moreover, if the machine is not fully utilize, it may incur a loss to the company as the unit of output cannot achieve and efficiency and productivity target cannot reach.

4.6 WHAT-IF ANALYSIS

What- if analysis is also known as sensitivity analysis to generate the outcome of the statistical model by applying logical changes to the input. The output report shows a series of output results which includes the value added time, total processing time, resource utilization, work in progress, queuing time, input and output for each process. Machine utilization is the vital concern in this thesis. The research has been carried out by replication of the model in the Arena software. The machine and worker utilization is very low, so improvement has to do to propose a more efficiency and productivity model. Many industries also applied what-if analysis in the factory nowadays.

From the data collected from the factory is only five days. The constraints that facing is the company do not permit any extension or give extra days for visitation. These are the entire situation that observes from the factory, they have faced the problems which the quantity of process cannot fulfill the customer quantity demanded. The ordering is big and producing time is very limited. Moreover, many defect and reject by the customers. Company faces loses as aluzinc coil cannot rework. In addition, company does not apply too much on Lean or Kaizen Management. So, the working time for Operator 1 is more than Operator 2, 3, 4, 5 and 6. A new work schedule has to separate and balance the workload for each operator and enhance the utilization of machine.

What-if analysis can conduct by offering a variety of scenarios depend on the desire of the analyst. It is very crucial as the management level can save cost to enhance the performance of the production system. On the other hand, what-if analyses can help to get know the output of real world situation and time-saving. If without what-if analysis and just testing in the machine and running, most probably no changes to the machine or machine spoilt, it is just wasting time and cause loses. Three scenarios will be created to analyze the changes that affect the production output.

4.6.1 Scenario 1: *What-If* Removing Operator 2, Operator 3 and Operator 5 to Replace with Operator 1, Operator 4 and Operator 6 in the Hinge Spot Welding, Embossing 2 and Welding Process Respectively

From Table 4.8, Operator 2, Operator 3 and Operator 5 have operator utilization which are 8.51%, 1.85% and 2.17% respectively. The percentages of utilization are below 60%, therefore can consider low productivity. The low utilization of operator is a waste and causes the production line inefficiency. In order to increases the utilization of the worker, rescheduling must be carried out to allocate balance workload for operator and also give guidance to the operator to respond quickly to any changes in fulfilling the customer demand. It is also to achieve the production goals by increasing the efficiency. The run time is 480 minutes and 10 replications. Running more replications aims to get more accurate results. Lower operator utilization may cause operator become boredom and demoralized if no workload. The result of the simulation is showing the percentage of operator utilization has been increased. The new model development is runs and the new results will be displays in below and comparison has been used to compare with current model.

	Operator 1	Operator 4	Operator 6
Embossing			
Embossing 2			
Hinge Spot Welding			
Lockset Installation			
Welding			
Touch Up			

Table 4.10: Operator utilization for scenario 1

	Current Model	New Model
Operator 1	57.16%	65.67%
Operator 2	8.51%	Removed
Operator 3	1.85%	Removed
Operator 4	9.69%	11.54%
Operator 5	2.17%	9.01%
Operator 6	6.84%	Removed

Table 4.11: Results comparison of operator utilization between current and new model

Referring to the Table 4.11, the percentage of operator utilization got obvious increasing after removing operator 2, operator 3 and operator 6. The workload becomes more balanced and operator 1 can considered achieve productivity with 62.67% of utilization rate. Removing of low utilization operator can reduce waste and idle in the production and increase the productivity of production line.

4.6.2 Scenario 2: *What-If* Changing the parameter of aluzinc coil arrival time to constant, 15 minutes.

Scenario 2 is changing aluzinc coil inter arrival time to constant, 15 minutes because change the engineer in charge to set up the machine and the arrival time of aluzinc coil is reducing from 24 minutes to 15 minutes. Normally, the operator 1 in charge to set up the machine, but the unskillful skills of operator 1 always cause delay and inter arrival time increases. The delay in arrival may increases the cost burden to the factory as the use of machine need a huge amount of electricity, cause the machine need to run overtime to get the desired amount of output which is a waste. The machine utilization percentages will increase for each production processes. Therefore, by changing the arrival time, it may increase the machine utilization for each process entity and create more high efficiency. The run time is 480 minutes and 10 replications. Running more replications aims to get more accurate results.

	Machine Utilization	
Process	Current Model	New Model
Blanking Machine	50.57%	80.00%
Blanking Machine 2	42.61%	66.67%
Blanking Machine 3	42.13%	66.67%
Blanking Machine 4	41.96%	66.67%
Roll Forming Machine	59.13%	93.00%
Roll Forming Machine 2	59.14%	93.53%
Roll Forming Machine 3	59.28%	92.98%
Roll Forming Machine 4	61.64%	96.60%
Embossing Machine	57.16%	90.20%
Embossing Machine 2	1.85%	2.91%
Welding Machine	8.51%	13.70%
Welding Machine 2	2.17%	3.47%

Table 4.12: Results comparison of machine utilization between current and new model

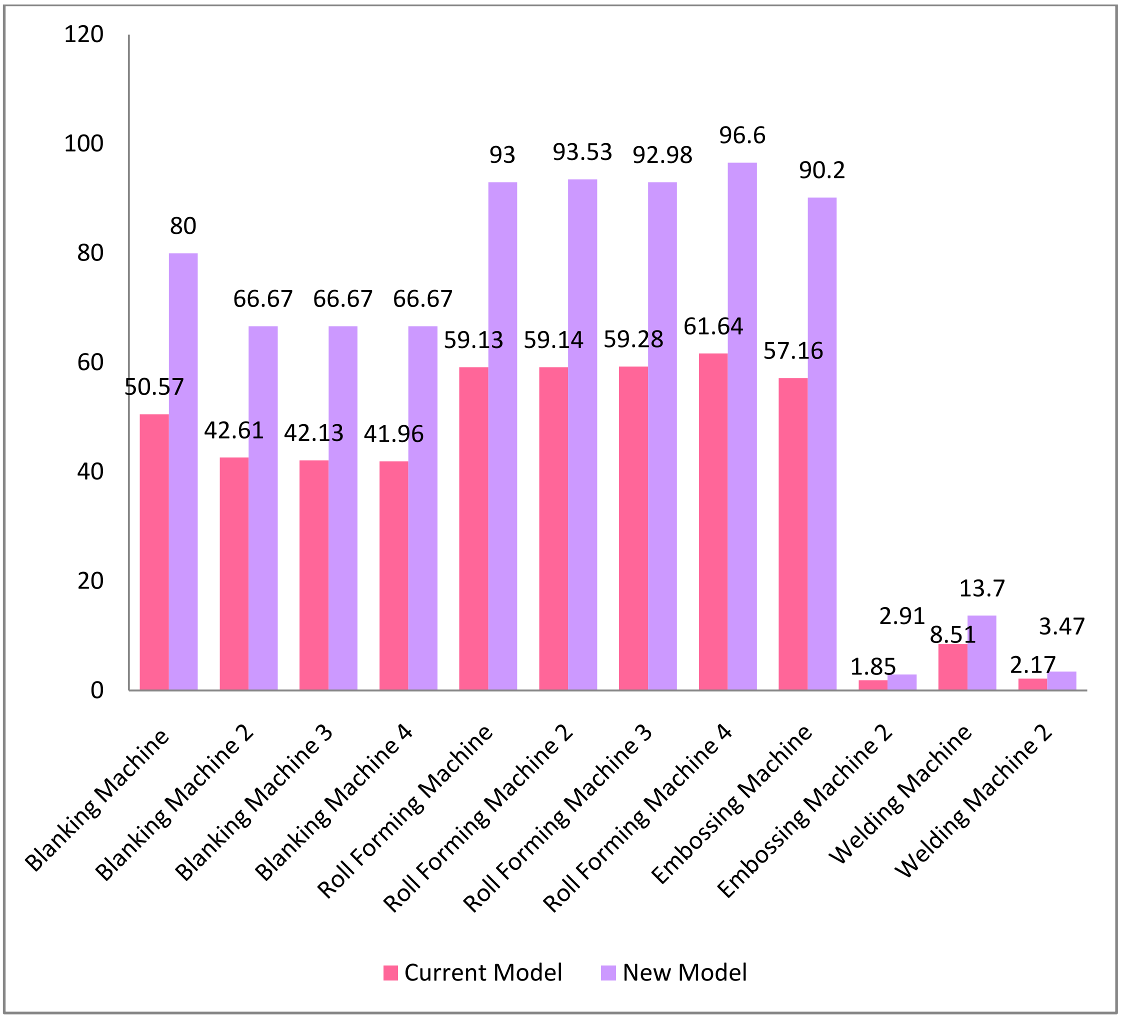


Figure 4.32: Machine Utilization between current model and new model

	Operator Utilization	
Operator	Current Model	New Model
Operator 1	57.16%	90.20%
Operator 2	8.51%	13.70%
Operator 3	1.85%	2.91%
Operator 4	9.69%	15.16%
Operator 5	2.17%	3.47%
Operator 6	6.84%	11.06%

Table 4.13: Results comparison of operator utilization between current and new model

4.6.3 Scenario 3: What-If Combination of Scenario 1 and 2

Scenario 3 is removing 3 operators with low utilization rate and shortening the arrival time for the entry point to 15 minutes. The test run will go through the same process as the current model. The run time is 480 minutes and 10 replications. Running more replications aims to get more accurate results.

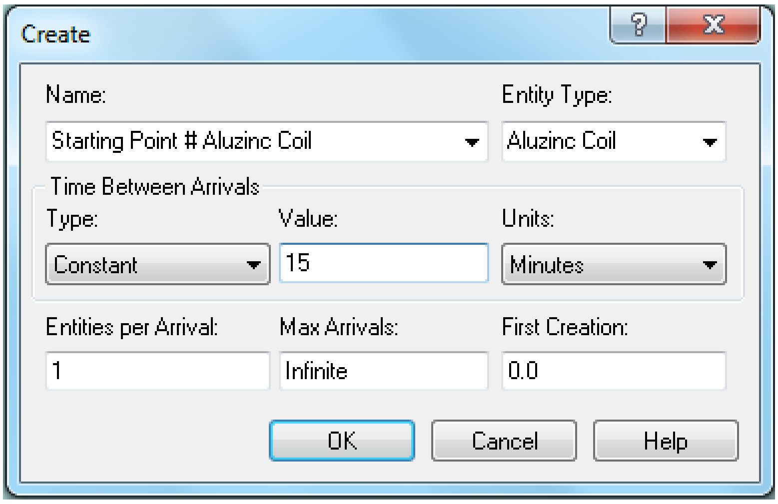


Figure 4.33: Change the parameter (Change value to constant, 15 minutes)

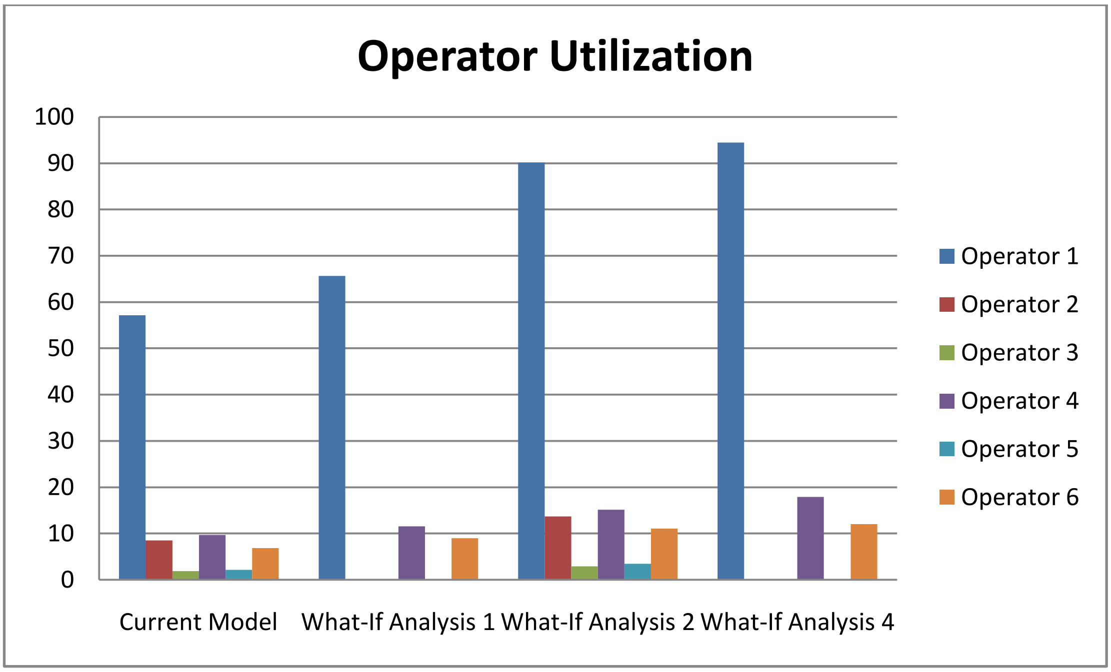
Combination of scenario 1 and scenario 2 will generate what kind of result, the performance of the production line will be improve or decline. The new results will shows after running of the new model. A new feature of the model is shown as below.

In the beginning, a conclusion can be made according to the newly construct model. The output of the production line is increase three units of door frame if compare with old model.

Table 4.14: Comparison between operator utilization between current model and What-If analysis scenarios.

Operator Utilization	Current Model	What-If Analysis 1	What-If Analysis 2	What-If Analysis 3
Operator 1	57.16%	65.67%	90.20%	94.48%
Operator 2	8.51%	Removed	13.70%	Removed
Operator 3	1.85%	Removed	2.91%	Removed
Operator 4	9.69%	11.51%	15.16%	17.90%
Operator 5	2.17%	Removed	3.47%	Removed
Operator 6	6.84%	9.01%	11.06%	12.01%

Figure 4.34: Comparison of operator utilization between current model and what-if analysis scenarios.



From Table 4.14, it is shown that the percentage of operator utilization got obvious increase in utilization for What-If analysis 1, after removing the Operator 2 and replaced with Operator 1, the operator utilization have obvious increasing of 8.51%, from 57.16% to 65.67%. This same goes to Operator 4, after take over Operator 3 job, the utilization rate increases from 9.69% to 11.51%, which is increasing 1.82%. Lastly

Operator 6 took over Operator 5 job and utilization rises 2.17%. Higher operator utilization is vital as it can avoid operator feel boredom and demoralized if no workload. For What-If Analysis 2, by setting the inter-arrival time to constant, 15 minutes, all 6 operators also got obvious increases of percentage utilization. For what-if analysis 3, the workload of 94.48% is too tired for Operator 1. What-If Analysis 2 is the most suitable scenario.

Table 4.15: Comparison between machine utilization between current model and what-if analysis scenarios.

Machine Utilization				
Machine	Current Model	What-If Analysis 1	What-If Analysis 2	What-If Analysis 3
Blanking Machine	50.57%	50.57%	80.00%	80.00%
Blanking Machine 2	42.61%	42.61%	66.67%	66.67%
Blanking Machine 3	42.13%	42.13%	66.67%	66.67%
Blanking Machine 4	41.96%	41.96%	66.67%	66.67%
Roll Forming Machine	59.13%	59.13%	93.00%	92.57%
Roll Forming Machine 2	59.14%	59.14%	93.53%	93.54%
Roll Forming Machine 3	59.28%	59.28%	92.98%	93.15%
Roll Forming Machine 4	61.64%	61.64%	96.60%	97.05%
Embossing Machine	57.16%	57.16%	90.20%	83.19%
Embossing Machine 2	1.85%	1.85%	2.91%	2.81%
Welding Machine	8.51%	8.51%	13.70%	11.30%
Welding Machine 2	2.17%	2.17%	3.47%	2.95%
Average Machine Utilization	40.51%	40.51%	63.87%	63.05%

Figure 4.35: Comparison of machine utilization between current model and what-if analysis scenarios.

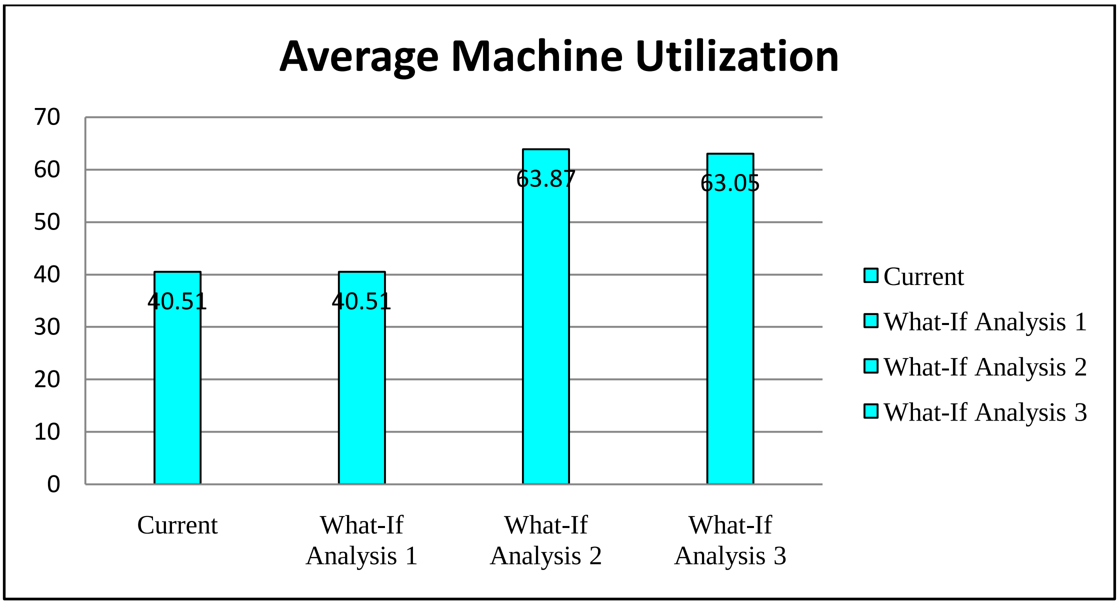


Table 4.16: Comparison of outputs between current model and what- if analysis scenarios.

	Current Model	What-If Analysis 1	What-If Analysis 2	What-If Analysis 3
Total output	14	14	23	19
Percentage (%)	25	-	41.07	33.93

Figure 4.36: Comparison of output between current model and what- if analysis scenarios.

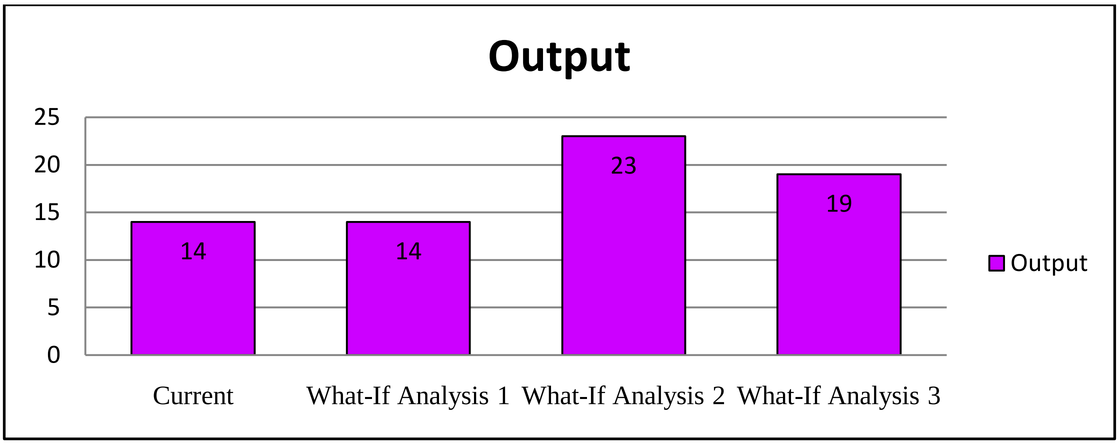
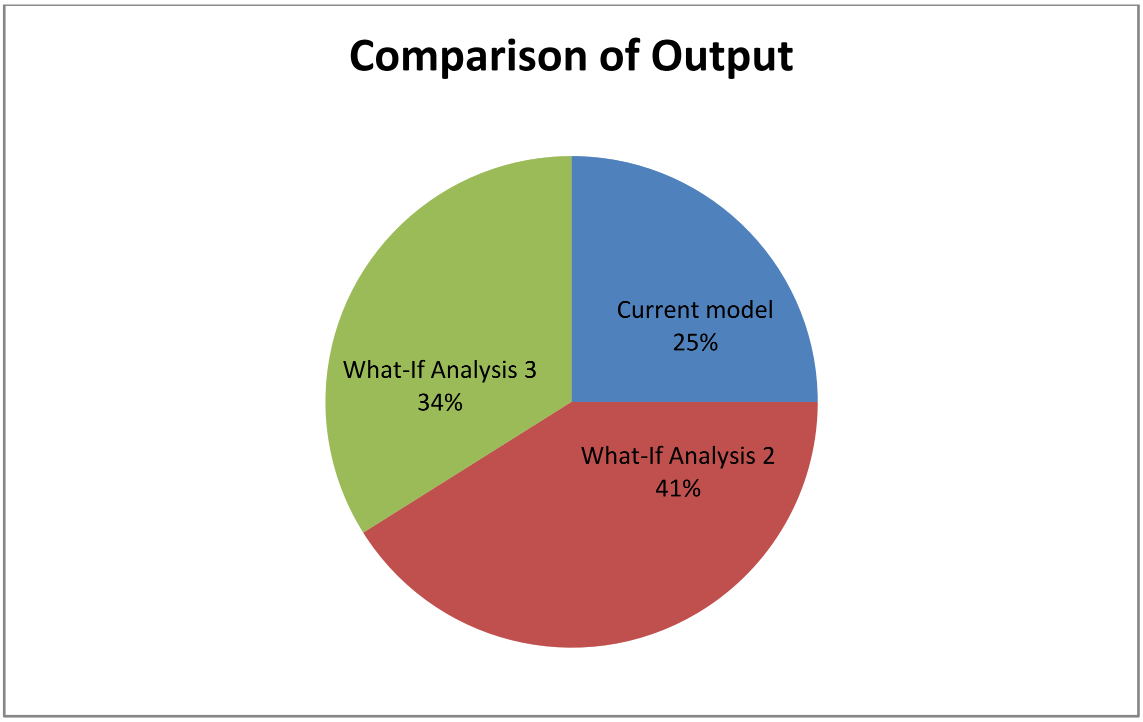


Figure 4.37: Pie chart of output comparison between current model and what- if analysis scenarios

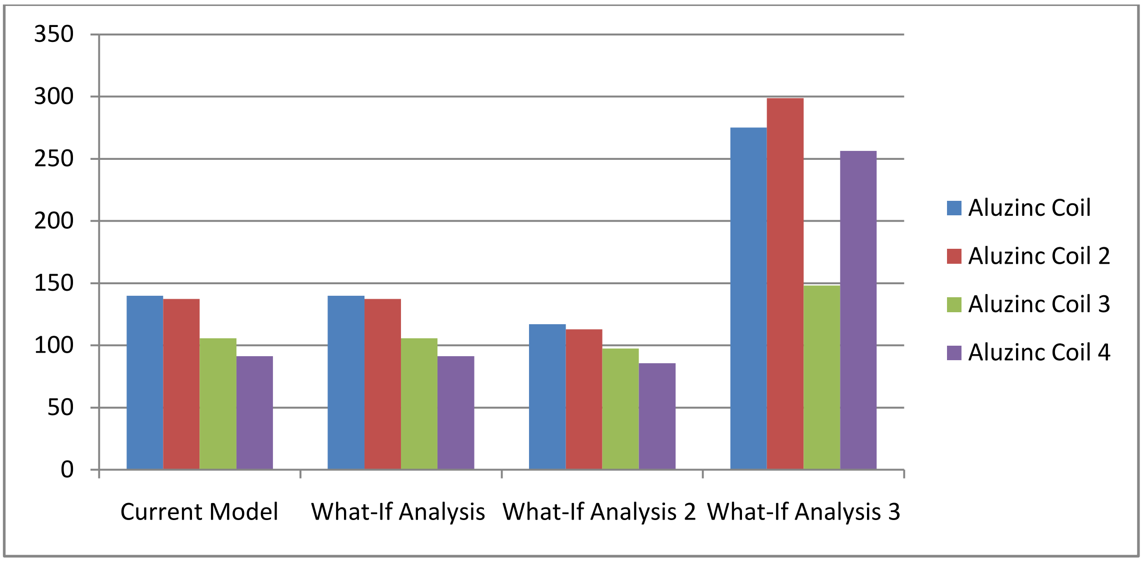


According to Figure 4.37, the output of What-If Analysis 2 has significant increasing of 9 units, which is 16.07% percentage of increasing if compared with the current model.

Table 4.17: Comparison of wait time between current model and what- if analysis scenarios.

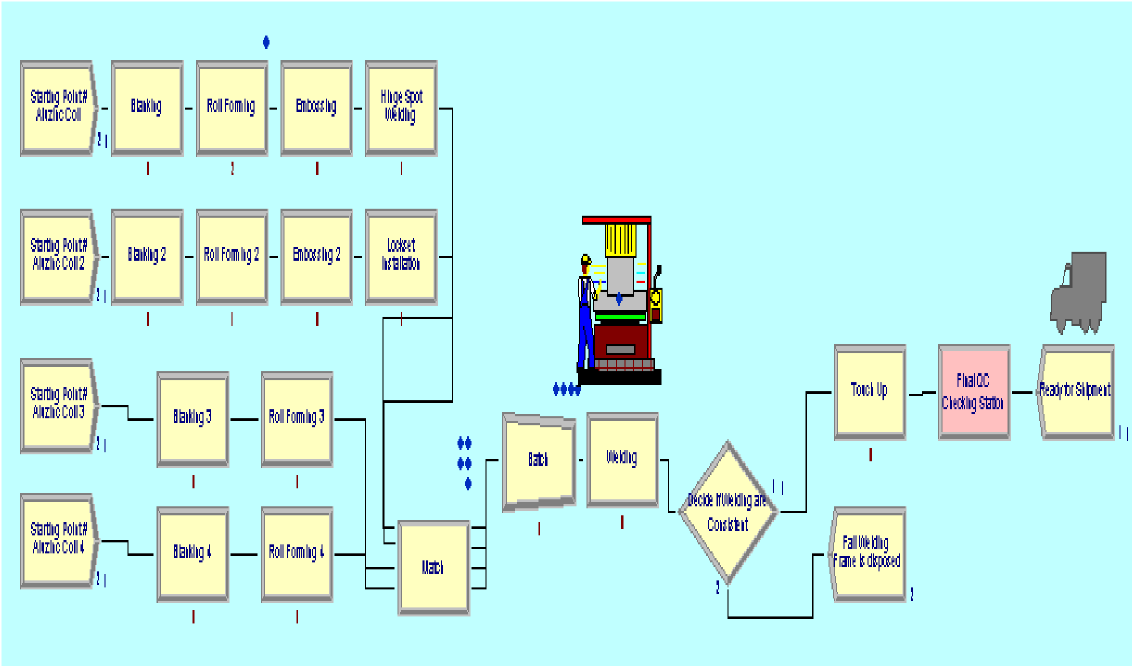
Process	Current	What-If Analysis 1	What-If Analysis 2	What-If Analysis 3
Aluzinc Coil	139.82	139.82	117.12	275.07
Aluzinc Coil 2	137.41	137.41	112.83	298.72
Aluzinc Coil 3	105.76	105.76	97.514	148.19
Aluzinc Coil 4	91.257	91.257	85.758	256.37
Total of wait time	474.247	474.247	413.222	978.35

Figure 4.38: Comparison of average wait time between current model and what- if analysis scenario.



From Figure 4.38 above show the wait time between the current and what-if-analysis. What-If analysis 2 got obvious reducing of wait time 61.03 minutes. What-If Analysis 1 got no changes of wait time and What-If Analysis 3 wait time increasing 504.103 minutes which is not an ideal in production due to long wait time and will increase total production time.

Figure 4.39: Final Model (What-If Analysis 2)



4.7 CONCLUSION

By referring to the data analysis discuss in the above, it is able to predict and specifying the suspected data by test run for 10 replications was able to get more accurate and precise result. The output report shows a series of output results which includes the wait time, resource utilization, and operator utilization for each model. Although the company look efficiency and productivity, but the worker utilization is not very high. Therefore, the company maybe can do machine layout plan and put all the same line workstation in more near to reduce the wait time. Due to the delay in the inter-arrival time, it causes the whole production line become not efficient. What-if analysis scenario 2 is selected. By reducing the inter-arrival time of aluzinc coil to constant 15, the obvious reducing of wait time of 61.03 minutes and the total output increasing from 14 units to 23 units, which is 9 units extra.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

In this chapter, there will be a discussion on the suggestion and recommendation for the company to enhance the performance of the door frame production. The company face the problem cannot fulfill the customer order. The company hopes to produce more units of output at the daily production line.

Today, the production market is getting more competitive. Many companies strive to fulfill the customer needs. Therefore, there is a need for the manufacturing industries to make changes in the twinkling of an eye to remain competitive in the market. In order to predict the behaviour of the simulation model, what-if analysis being used to analyze the possible output and reduce the production time. The performance is being observed in different criteria. The Arena software is data-based generated, the parameters fill in may be varied, constraints may be loosen (Reichert, P., 2014). Other variables influence the assumptions can be known by seeing the effect on the model.

5.2 RESULT DISCUSSION

Simulation is the most widely used in the industries to solute the inefficiency of the production line. After the summary output is being generate from the simulation model, the bottlenecks that faced by the production line can be track. The solution is to reduce the wait time and increases the output of the production line. The most crucial step is to reduce the machine set up time to reduce the inter-arrival time per batch.

The wait time of aluzinc coil has been using the longest time of 139.82 minutes. It can be reduce to 22.7 minutes using What-If Analysis 2. The total output also increase from 14 units to 23 units.

For resource utilization for machine has a significant increase, average of 23.36% increase in the machine utilization.

For worker utilization, the What-If Analysis 3 reduce 3 operators in the production line and got high percentage utilization especially for operator 1 is 65.67% but the processing time no reduction, so it is better to reduce the arrival time to have significant changes. Smoothening the production line and producing more outputs, from 14 units to 23 units.

5.3 RESEARCH LIMITATION

Several limitations are found in this thesis as listed in the following:

The main limitation in this research will be lack of budget and time in conducting this project. The research is main focus on machine utilization, worker utilization and productivity and not focus on others like material handling. The research is conduct only in one of the door frame factory in Segamat. The scope of the research is small; the results cannot use to represent the condition of the whole door frame industries.

5.4 RECOMMENDATION

According to the simulation report by Arena, it is summarizing that the validated model to figure out the low utilization in process station. The company can stay competitive with high efficiency and productivity in the market. The door frame production company is produce based on the batch production because the customer is Make-To-Order method. The arrival time of the production is shorten to constant, 15 minutes has significant changes to the total outputs, from 14 units to 23 units. According to Tavakkoli *et al.*, (2012) maximize the machine utilization can reduce the processing time, the production line become more productivity.

Simulation aims to help the company by replication of the whole process workflow, so that solution can be taken based on the problem predict in the model, reduce the inadequacies and finally enhance the performance of production line. What-If Analysis is built to make 3 different experiments to try on and observe the changes. What-It Analysis 2 able to generate the best results, with the reduction on the wait time and arrival time, able to produce extra more 9 units.

Hence, many recommendations suggest by the researchers by stabilize the production line and increases the productivity are:

i) Use simulation modeling to detect the bottlenecks of the system.

Simulation model is build to detect the bottlenecks in the production system. The software can analyze complex system, saving time and significant impact to the efficiency and productivity of the system. Simulation allows the manipulation of resources like machine, station, conveyer, time and others. Entities for each process will be seize and control the capacity when they are process. The analyst can build the model carefully and implement the most suitable model in the real world.

ii) Maximize the resource utilization

The workers and machines are the main resources. The utilization must push to the optimal. Machine can be push to limit by speed up at the desired limit, the machine can product more quantities without creating scraps or affect quality. The worker can have more workload and utilization can be increase to 60%, which is the situation, fulfills the company needs for utilization and the worker do not feel boredom or demoralized by waiting.

iii) Use Manufacturing Execution System (MES)

According to Zhong et *al*., (2013), Manufacturing Execution System (MES) is a useful tool to track the processing time. It aims to improve productivity by reducing the total time, work-in-process time and cycle time to generate more units of outputs by interface with the enterprise resource planning (ERP) software. This system is very popular and applied by big company like Robert Bosch and Tata Motors to do their production schedules to control the production process. The system provides a module to calculate the critical path, provide data to eliminate the process downtime, predict the bottlenecks, so that you can tweak and adjust the processing time to maximize the utilization and finally increasing the productivity by produce more outputs.

iv) Installing sensor at the starting point

The worker can save the time of waiting, It is because the worker need to drive the forklift to go to the warehouse to collect and put onto the uncoiler machine. If got sensor, when the raw materials is going to finish, the sensor will beeping, the worker can go to collect from machines, it may save many times as there are 4 starting points.

v) Machine layout plan

The machine distances within one production line can be put more close to save the excessive moving of the worker which is an idle and waste (Jain et *al*., 2014). Moreover the distance between the machine and worker can put on oval shape to make the job station more close and reduce the waste time.

vi) Backup machine

Backup machine need to prepare especially for the station that only have one machine like lockset installation machine, it is act as prevention step to avoid the manufacturing line has to stop when the whole production system break down which is a waste and idle.

vii) Lean Manufacturing

Lean is a system that emphasized on continuous improvement by eliminating non-value added waste through encouraging workers to keep on thinking the root cause of defects, respect workers' ideas, emphasized teamwork and focus on cost reduction

(Fullerton *et al.*, 2013). Application of lean has improved productivity, better reliability, and product quality and provided greater return on investment. Therefore, it is useful to implement in the production line.

This thesis is recommended for future study. Nowadays, many organizations also strive to become competitive in the market. Therefore, this thesis can help the industries to solve the processing bottlenecks. Simulation is a useful pragmatic tool that uses to replicate the real world system into the computer software. It can save the maintenance fees because without this software, we may need to straight forward trying to make the changes on the machine by put in many raw materials or fasten the speed of the machine which may cause the machine breaks down suddenly. Moreover, with the what-if analysis, many scenarios can be tried on the simulation software. The best model will implement in the real world machine. In addition, it can solve many complex modelling system problems and act as the planner to finish the work on time. Therefore, it is really deserve to have further study.

5.5 CONCLUSION

Simulation is getting more used in the manufacturing industries nowadays. The simulation software simplifies the complex production system. It is saving the time and provides more alternatives and testing on the outcome before implement in the real world situation. It can reduce the cost of causing the machine spoilt or inefficiency after buying a new machine to put on the workstation without testing on simulation runs. The forecasting result is a preview for the production manager to enhance the performance of the production line.

In this thesis, the most obvious bottlenecks is the performance of the production line is the inter-arrival time too long already. After reducing the time from 24 minutes to constant 15 minutes, the production line becomes smoother. It increases the machine utilization from 40.51% becomes 63.87%. It is increasing of 23.36%. The total outputs also increasing 9 units, from 14 units to 23 units. The wait time for aluzinc coil also reducing from 474.247 minutes to 413.222 minutes, which is reducing 61.03 minutes.

In conclusion, it is hope that this thesis can act as reference for other analyst doing simulation on door frame production. It is also act as the most suitable software tools to solve most of the activities and processes that involved the assembly and production line and more persuasive in decision making. Manufacturing factories are highly recommended to implement simulation software to remain competitive in the industries.

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APPENDIX A

Images of Finished Door Frames, Uncoiler Machine and Blanking Machine

Finished Door Frames

Uncoiler Machine

Blanking Machine

APPENDIX A (CONTINUED)

Images of Roll Forming Machine, Embossing Machine and Hinge Spot Welding Machine

Roll Forming Machine

Embossing Machine

Hinge Spot Welding Machine

APPENDIX B

Gantt Charts of FYP 1 and FYP 2