IMPROVING OF MANUFACTURING PRODUCTIVITY THROUGH SIMULATION

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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Approved by,

____

(Dr Masdi bin Muhammad)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own as specified in the references and acknowledgements, and that the original work contained herein not been undertaken or done by unspecified sources or persons.

(MUHAMMAD AFIF BIN ZAINUDIN)

ABSTRACT

Improvement of manufacturing system is must do process due to development of manufacturing technology and increase in customer needs. Due to development of technology, companies need to do improvement of their current system in order to survive in competition. This study will analyse overall productivity and identified critical process that consider bottleneck. This study also will quantify impact of batch capacity in manufacturing productivity. Computer aided simulation software will be used as main method. Data of manufacturing system will be collected and will be used as input in simulation software.. Altering several parameters such as machines quantity and batch size helps author to studied final output. It helps author reduce time to do trial for new design as simulation software will done based on real time and system performance will be address to help improvise new design. Simulation also can be applied at both the justification phase and design phase. By using this method, critical area can be identified in manufacturing system and explore several solution based on different scenario.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

As market demand keep increasing and development of manufacturing technology, competition in manufacturing industries is tougher. Many companies had invested in productivity improving efforts in order to meet their customer demand. The performance of production measures production's ability to generate income. In modern business, capital and labour are both become main constraint. Hence, by maximising both resources allow industry to achieve higher productivity. Productivity enhancements come from technology advances, such as computers and the internet, supply chain and logistics improvements, and increased skill levels within the workforce.

In order to improve quality and productivity, continuous improvement had to be made to current process or service. Companies that have ability to effectively implement on-going product, service, and process improvisation has an advantage to stay competitive. Before any improvement to manufacturing system can be done, it is important to study the current situation of current process and determine problems occur in the system.

In this advancing world, manufacturing technology keep improving by time , manufacturing systems and processes are becoming complex and are increasingly characterized by high levels of automation and integration, greater demands on performance, and various forms of human supervisory control [1] and consists of many discrete operations that occur randomly [2]. Simulation modelling will be used as primary method to analyse current system and highlight critical area that need improvisation therefore helps in increasing overall productivity.

In this study, data is gathered from HICOM-Yamaha Manufacturing (M) Sdn Bhd. HICOM-Yamaha production output is motorcycle engine. The areas investigated were machining process, paint shop processes, and assembly line. Parts that come from warehouse first will move to machining line for machining process. After machining process, parts will move to paint shop. At paint shop, parts will undergo treatment process before going into dry oven. After that, parts will be paint using spray in spray booth then undergo baking process using baking oven. After finishing painting process, parts will transport to assembly line and will be assemble to produce motorcycle engine.

1.2 PROBLEM STATEMENT

In manufacturing industries, competition had become much tougher as technology used keep developing. In order to survive in competition, improving of manufacturing productivity of current system had to be done. This study will analyse overall productivity and identified critical process that holding back manufacturing output. Improvisation will be done to the system in order to increase production output as it will help to remain competitive.

1.3 OBJECTIVE OF STUDY

In order to address the problems, a number of objectives were settled upon.

i. To develop simulation model of current manufacturing system using WITNESS simulation software
ii. To identify and fix bottleneck stations in manufacturing system
iii. To quantify impact of batch capacity increment in manufacturing productivity.

1.4 RELEVANCY OF STUDY

The project will weight more on research project which will lead to improvement of manufacturing productivity. With help of simulation software, this project will develop simulation model that mimic of real manufacturing system. Overall manufacturing system will be analysed and critical area in the system can be identified. This project also will study affect of increasing in batch capacity towards production output. This project also will give a new approach when designing new manufacturing system. Proper analysis of this study will help the author to put theoretical knowledge learned throughout the course of Mechanical Engineering into practical use.

1.5 FEASIBILITY OF STUDY

The overall timelines of this project covers the duration of two semesters (8 months) and is broken down into two subjects namely Final Year Project I and Final Year Project II. Referring to the Gantt chart constructed in chapter 3, this project is expected to be completed over the course of 8 months

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

Today's market competitions are getting tougher and company requires a production system quickly respond to continuously changing demands and customer needs. A large number of industrial organizations already use simulation for their manufacturing system to solve practical production problems relating to their daily operations. Computer simulation has been identifiable as modern and advanced numerical problem solving technique that allows to mimic the behaviour of real life system. Simulation help to study and experiment on the model on a computer to obtain detail information about internal interactions and interactive effects of individual variables and components in order to determine the key and important elements and to get a measure of its performance[3]. Computer simulation model also can help in development of new design of manufacturing system [4].

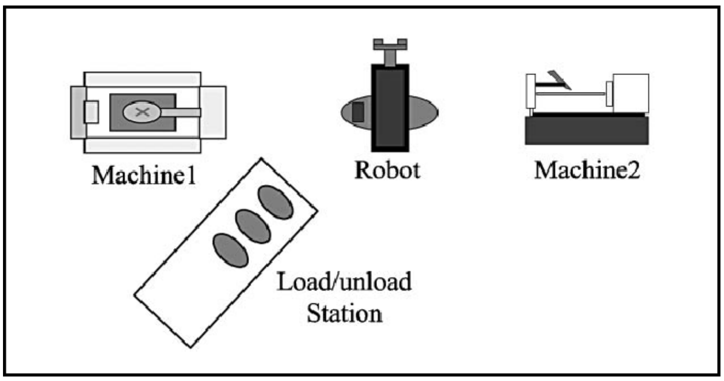


Figure 1 A system with two machines, a load/unload station and a robot

Data driven modelling and simulation is usually defined as a method that allows a user to create and run simulation model without the need to do any programming[5]. By building a model like a system in Fig 1, computer simulation can analyse performance of the system, like machine utilisation, production disturbance and production output. Simulation also can simulate the outcome of manufacturing system if any engineering changes done to system, such as increasing in buffer, addition of machine and changes in processing procedure [6]. It will greatly reduce the risk involved when planning new manufacturing system. Simulation can be classified between steady-state simulation, where the process is indefinite, such as a continuously-operating production plant, and terminating simulation, such as where a specific number of items are to be processed. Within such steady-state, non-terminating simulation there are four key components of an "experiment", namely *run selection, run-in (or warm-up), run-length,* and *sensitivity analysis*. [7]

2.2 METHOD FOR SIMULATION MODELLING

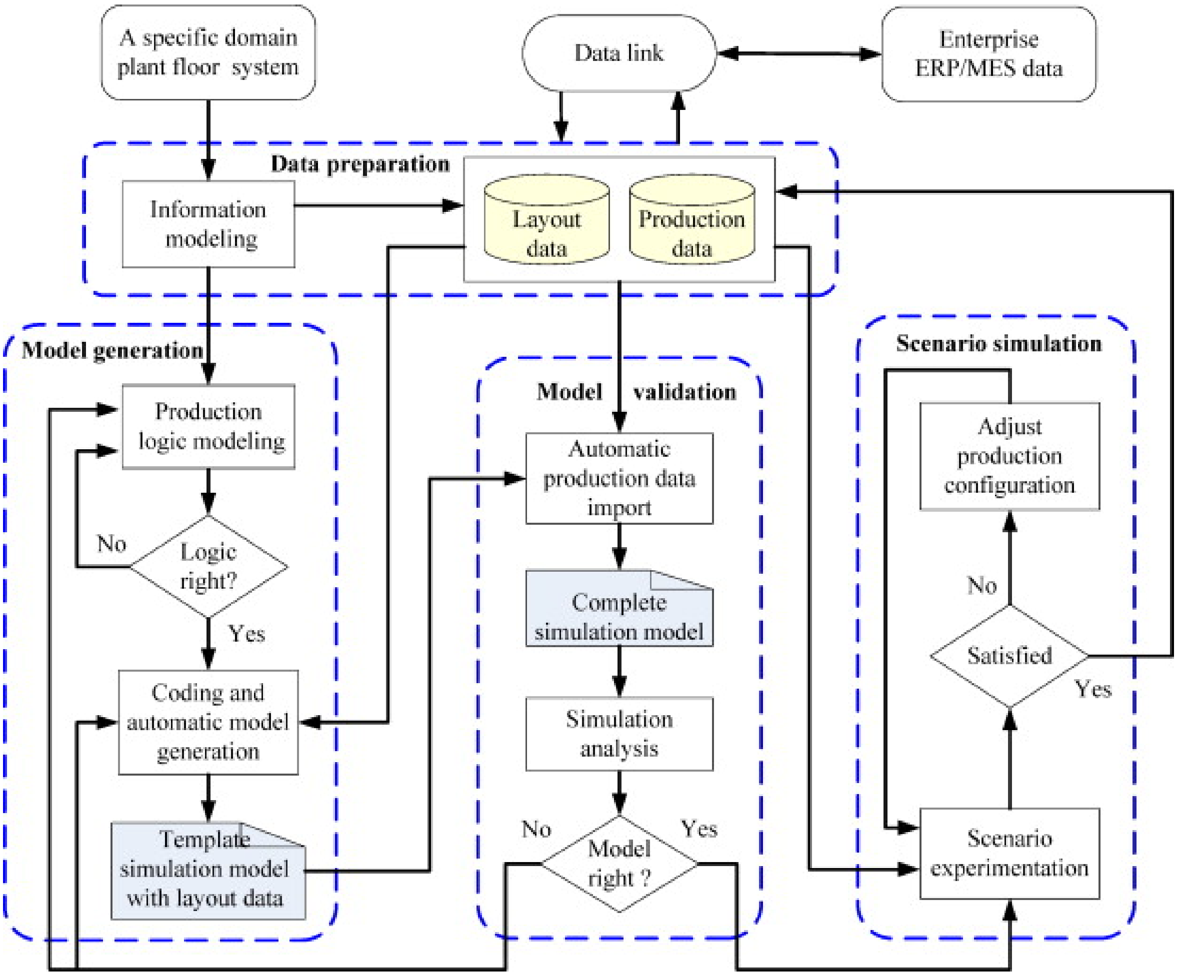


Figure 2 The framework of data driven production modelling and simulation.[6]

The overall framework of the proposed data driven modelling and simulation methodology for the production systems is demonstrated in Fig 2 [6]. Before using simulation technique to manufacturing system, it is important to understand physical layout, processes involved and workflow in manufacturing system. Simulation projects initiated with poor understanding have a higher risk of failure due to excessive time being invested in collecting inappropriate data. Deep understandings about the system make us aware of problems that occur inside manufacturing system. Simulation objectives must be cleared first so that related data needed to run a simulation can be identified. Typically, more than one third of project time is spent on identification, collection, validation, and analysis of input data. Several studies were done to find systematic approaches for rapid data collection [8].

Model built for simulation studies must be accurate. A simulations result is as good as model built. Models are created from a mass of data, equations and computations that mimic the actions of things represented. Model is build by developing schematics and network diagram of part flows. After model built, verification of model required. Verification is done by varying input parameters and observes the printed result. If model are not verified, it need rebuilding by checking the input data and process flow.

Accepted simulation model must be validating with the real system before it can proceed to next phase. Models performance is compared to real system under known conditions. Validation process discusses 1) obtaining real-world data, 2) comparing simulated and real data through simple tests such as graphical, Schruben-Turing, and *t* tests, 3) testing whether simulated and real responses are positively correlated.[9] To obtain a valid model, the analysts should try to measure the inputs and outputs of the real system, and the attributes of intermediate variables. Model validation affirms that the simulation model is an accurate representation of the system with the modelling objectives.

Next phase in simulation modelling is scenario simulation. At this phase, various input data are varied and report are generated and analysed. Positive increment of output data based on varied input data can be considered as improvement to manufacturing system. As best scenarios are decided, company may consider the implementation as it helps in improving of company productivity in future.

2.3 BOTTLENECK ANALYSIS

Simulation modelling will give result of current manufacturing system performance. Analysing simulation result will exposed stations that are holding up production productivity. These stations are called bottlenecks. The bottleneck analysis carried out with DES utilizes either the *average waiting time* detection method or the *utilization* detection method. [10]

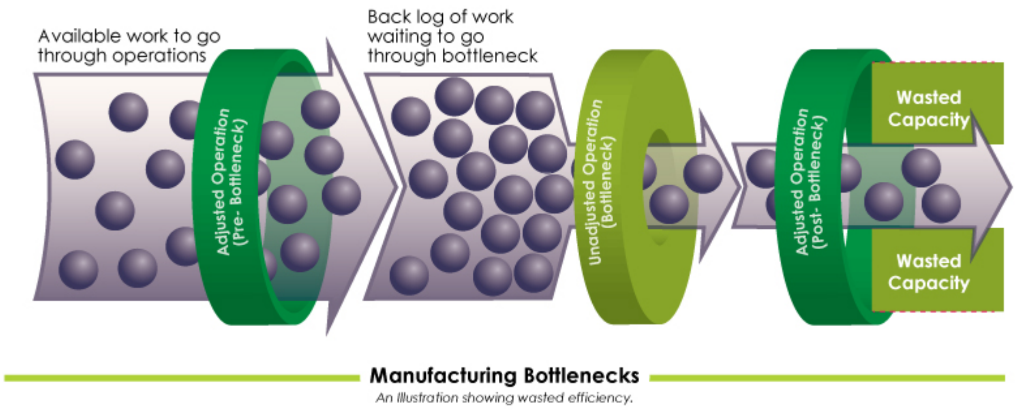


Figure 3 Illustration showing wasted efficiency

Bottleneck detection can be divided into two groups, analytical and simulation based. Analytical methods are suitable for long-term prediction and not for short-term bottleneck detection [11]. Shifting Bottleneck Procedure had been suggested by decomposes the job shop problem into a number single machine sub problems. At each iteration a critical or bottleneck machine is identified and scheduled with scheduling decisions at subsequent iterations being subordinated to those scheduled earlier [12]. A method for predicting the throughput bottlenecks of a production line using autoregressive moving average (ARMA) model also had been used before. This method has used time series analysis It consider the production blockage and starvation times of each station to be a time series used to predict throughput bottlenecks [13]. A study about bottleneck analysis also was done using material flow analysis by means of discrete event simulation. . Different scenario representing varying production program and warehouse allocation principles were simulated [14].

2.4 WITNESS SIMULATION SOFTWARE

Next phase is model building and validation. In this paper, simulation tool that used is WITNESS simulation software. Schematic layout of manufacturing system created from data obtains as above. Elements in WITNESS are placed in drag-and-drop fashion. Data gathered earlier act as input variable to build simulation model. Machines and buffer are placed accordingly as real system at fixed position. The WITNESS simulation package is capable of modelling a variety of discrete and continuous.

Modelling element in WITNESS software can be defined as Parts, Buffers, Machines, and Conveyors. Parts are objects that travel from one location to another. They may be pulled passively into the model by the simulation, pushed into the system by an active part arrival schedule. Buffers are simply passive storage areas of finite capacity. Buffers can be configured as “delay” buffers, where parts must stay in for a minimum amount of time. They can be configured as “dwell” buffers, where they cannot stay in the buffer any longer than a specified time.

Machines are main elements in WITNESS simulation model. In WITNESS, machines can be distinguished in several types like:

- single
- batch
- assembly
- production
- multiple station

Conveyors are defined by a length in parts and an index time which represents the time it takes a part to move from one position on the conveyor to the next. Conveyors may be fixed or queued. A fixed conveyor maintains the space between parts if the part on the front of the conveyor is blocked. A queuing conveyor allows parts to compact together even though the conveyor may be stopped. The only time a queuing conveyor stops is when there are no gaps left, it’s completely full, and no parts are being removed from it.

CHAPTER 3

METHODOLOGY

3.1 PROJECT FLOW CHART

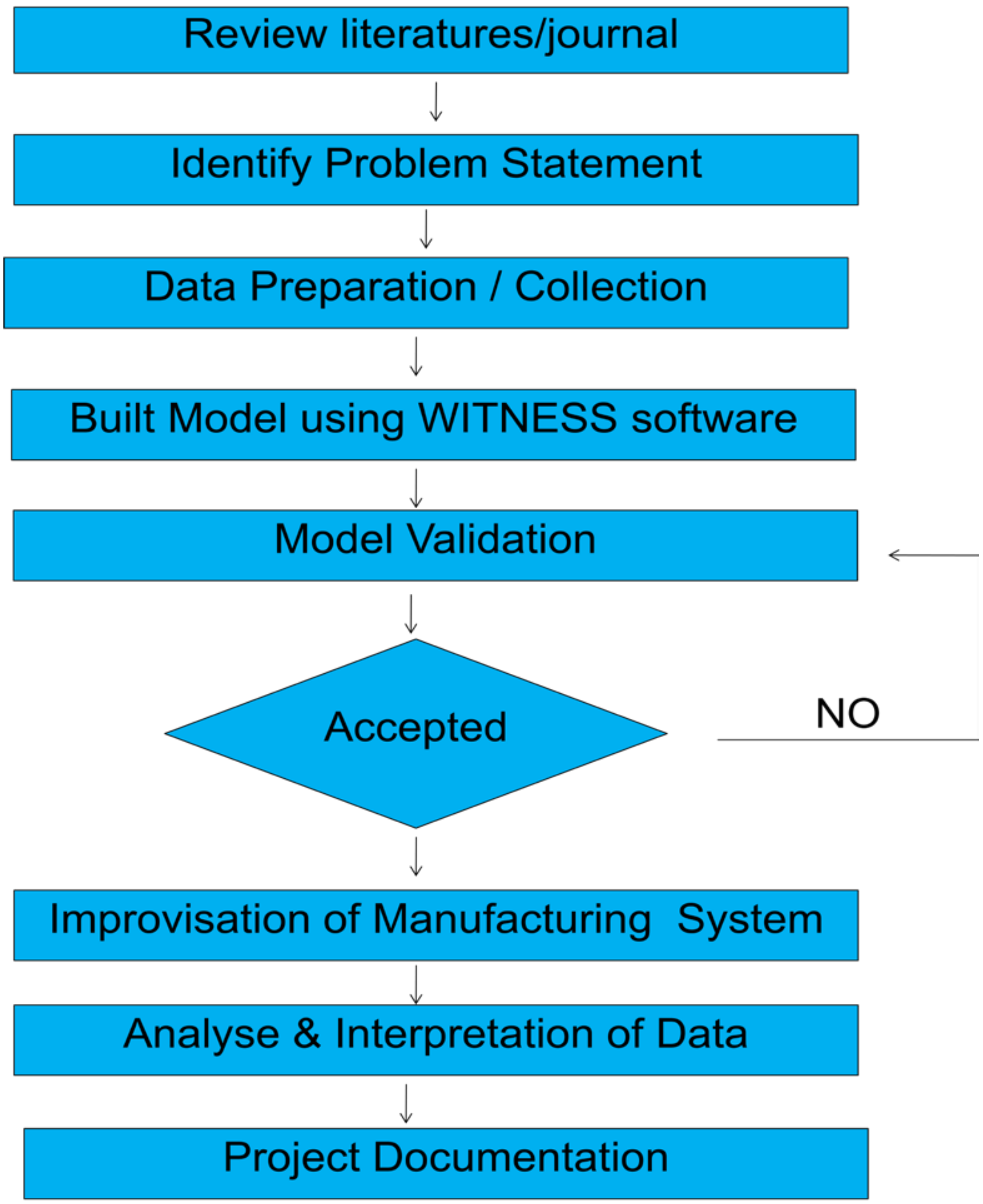


Figure 4 Methodology for modelling development and improvisation of manufacturing system

3.2 PROJECT ACTIVITIES

3.2.1 DATA PREPARATION

Data Preparation involves checking or logging the data in; checking the data for accuracy; entering the data into the computer; transforming the data; and developing and documenting a database structure that integrates the various measures. Data gathering may come from different source like pre-test or post-test data or observational data.

In this study, data is gather from observation and recorded data that had been done earlier. Observation data is done by visiting manufacturing plant at HICOM Yamaha Manufacturing (M) Sdn Bhd. During plant visit, author observed real time process and recorded several data like average processing time. To do time studies of real time process, a stopwatch will be used. Several numbers of trials were done to find average of processing time for each station involve. This to make sure data gathered were accurate and to avoid discrepancy when building simulation model. Data gathered consist of:

- a description of parts and their routings through the factory
- production times, setup times and batch sizes for each machine in the operation
- product data, including number of units to be produced per day and any other attributes to be considered
- machine buffer size

3.2.2 WITNESS SIMULATION

Once basic model had been developed in WITNESS, simulation model can be run. For simulation run, author can indicates warm-up period and simulation run time. Simulation will be run for total 14400 minutes, which is for 10 working days. At the end of simulation run, author can view system report in tabular or graphic format. Author also can viewed statistic summary of each elements in the system. Pie charts, time series and histograms provide a meaningful, easily-read format for data from a simulation model run. In addition, data can be read from and written to external files.

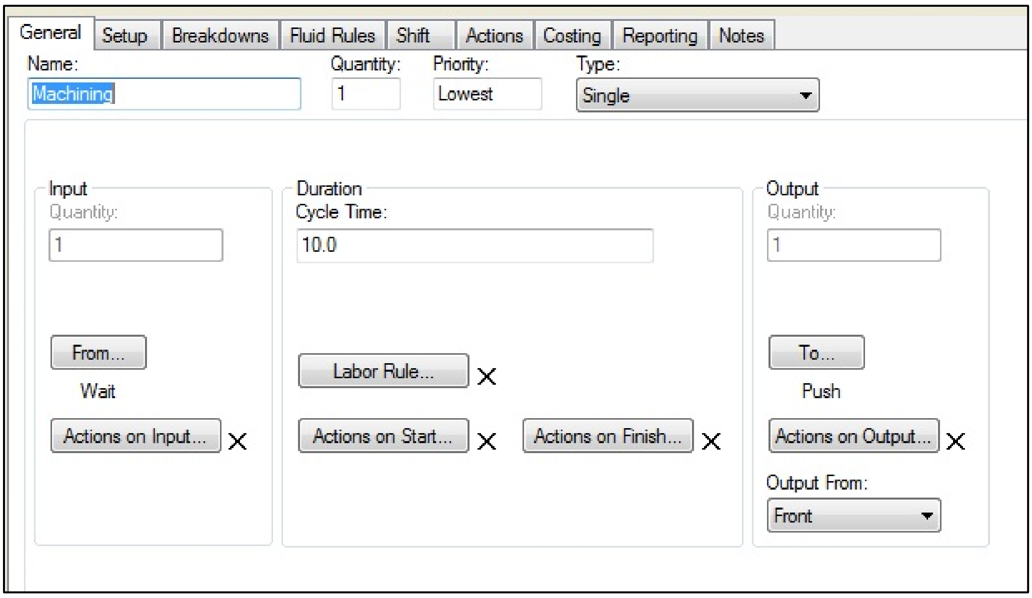


Figure 5 Sample interface of machine general setup in WITNESS

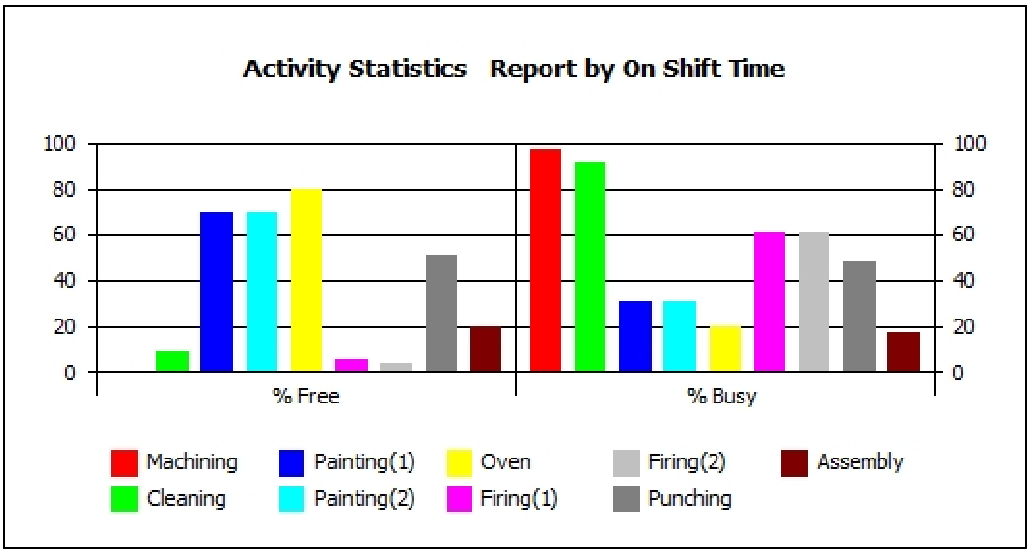


Figure 6 Sample interface of statistic report of simulation model

3.3 MODEL VERIFICATION AND VALIDATION

Model developed then need verification and validation before further studies are done on simulation model. Model validation can be done in several ways. First option is by having two models with different inputs and outputs. Relationships between both models are compared for expected system behaviour. Second option is to compare simulation models to the real system using results obtain from simulation run. This is important to make sure simulation model in an accurate representation of system under study.

Once the system validate and verified, further analysis of manufacturing system can be done. In this study, author will analyse station that have bottlenecks issues and resolve the issue that arises. A bottleneck is a phenomenon where the performance or capacity of an entire system is limited by a single or limited number of components or resources. Bottlenecks occur when one production station produces more than a subsequent station can keep up with, causing a slowdown in the production line. System production is based on bottleneck production.

3.4 GANTT CHART

No	Task / Activities	Weeks														
		1	2	3	4	5	6	7	MID SEMESTER BREAK	8	9	10	11	12	13	14
1	**Consolidation of FYP Topics**															
2	**Topic assignments to students**															
3	**Research for the topic assigned**															
	- Journals review															
4	**Preparation for Extended Proposal**															
5	**Submission of Extended Proposal**						●									
6	**Research for the experimental procedure and work**															
7	**Preparation for Proposal Defence**															
8	**Proposal Defence**															
9	**Preparation for Interim Report**															
10	**Submission of Interim Draft Report**														●	
11	**Submission of Interim Report**															●

Figure 7 Gantt chart for FYP I

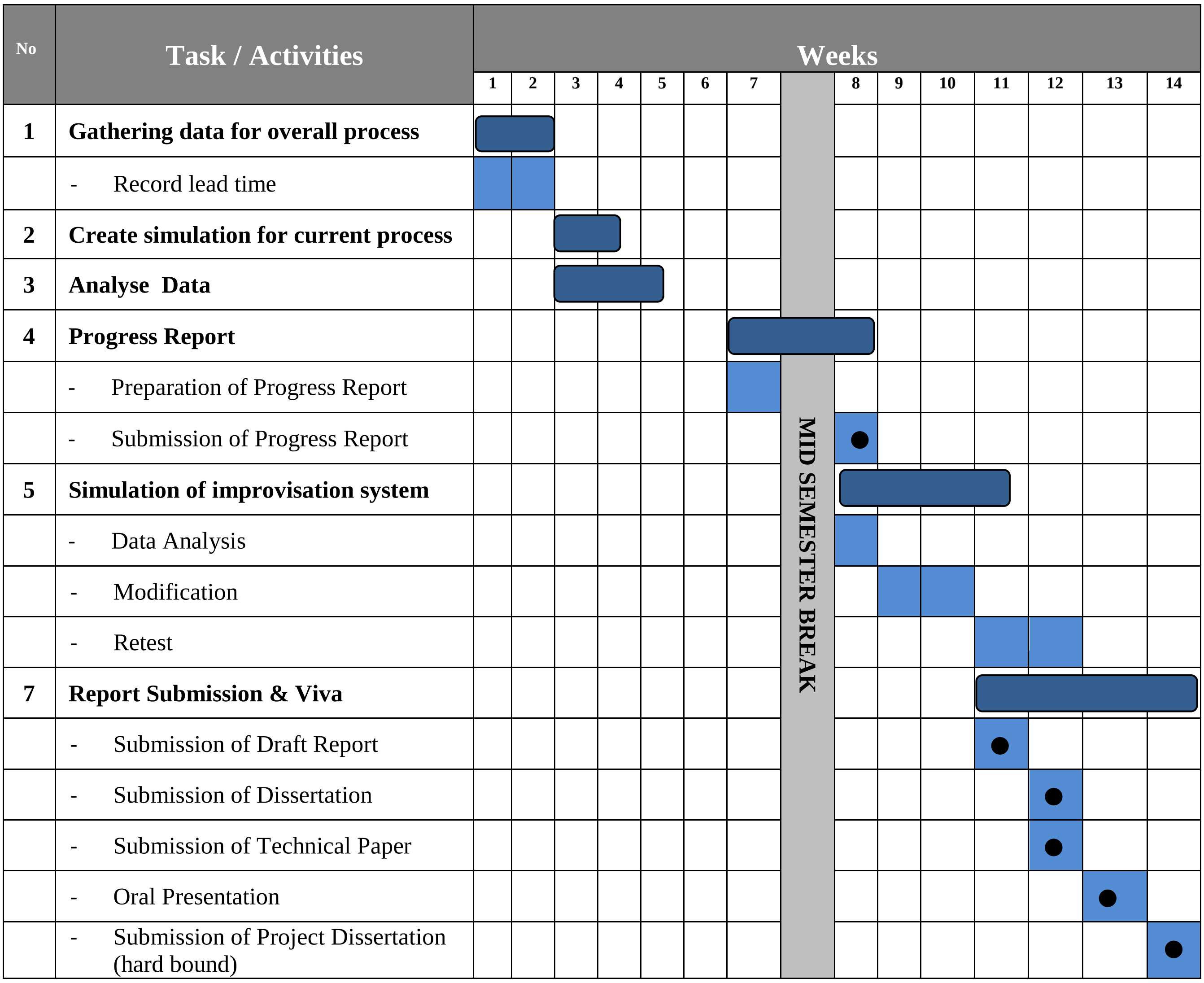


Figure 8 Gantt chart for FYP II

CHAPTER 4

RESULT AND DISCUSSION

4.1 PROCESS LAYOUT

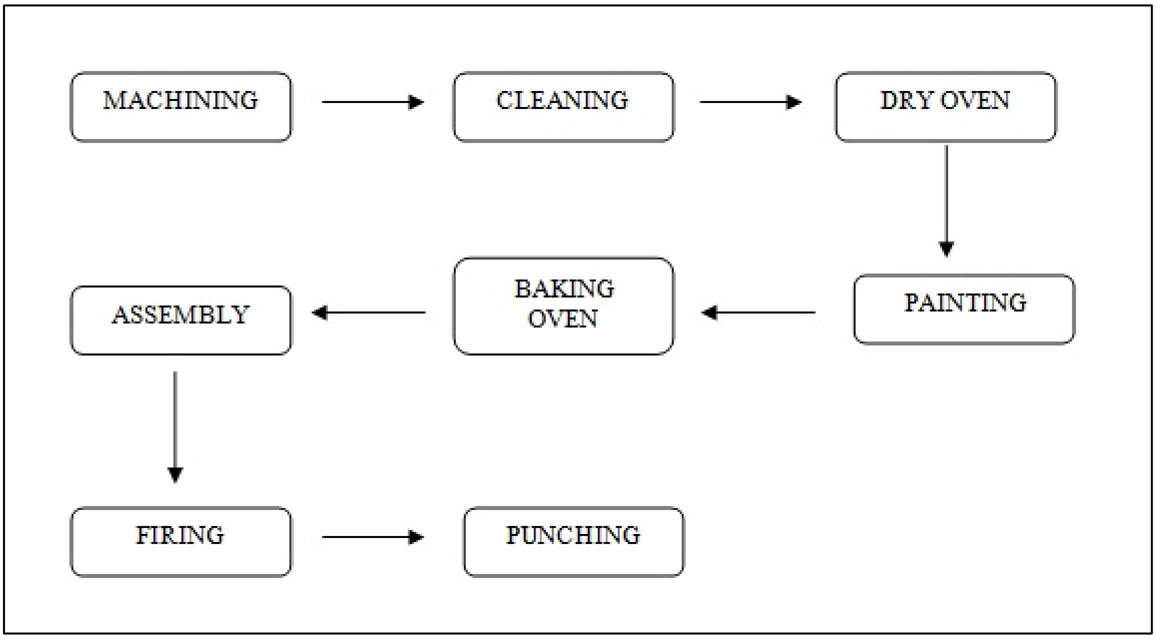


Figure 9 Overview of part flow

4.1.1 MACHINING OPERATIONS

The first step in process is part undergo machining process. Machining sections will do operations like drilling, milling and lathe according to drawing for each part. CNC machine are used for machining in order to get high quality end product. After machining, parts will be supplied to paint shop and assembly sections.

I. Data for incoming material

Arrive as continuous part (first arrival at time 0.0 min).

II. Data for machining

Cycle Time : 20 mins

Batch Capacity : 1 part per operation

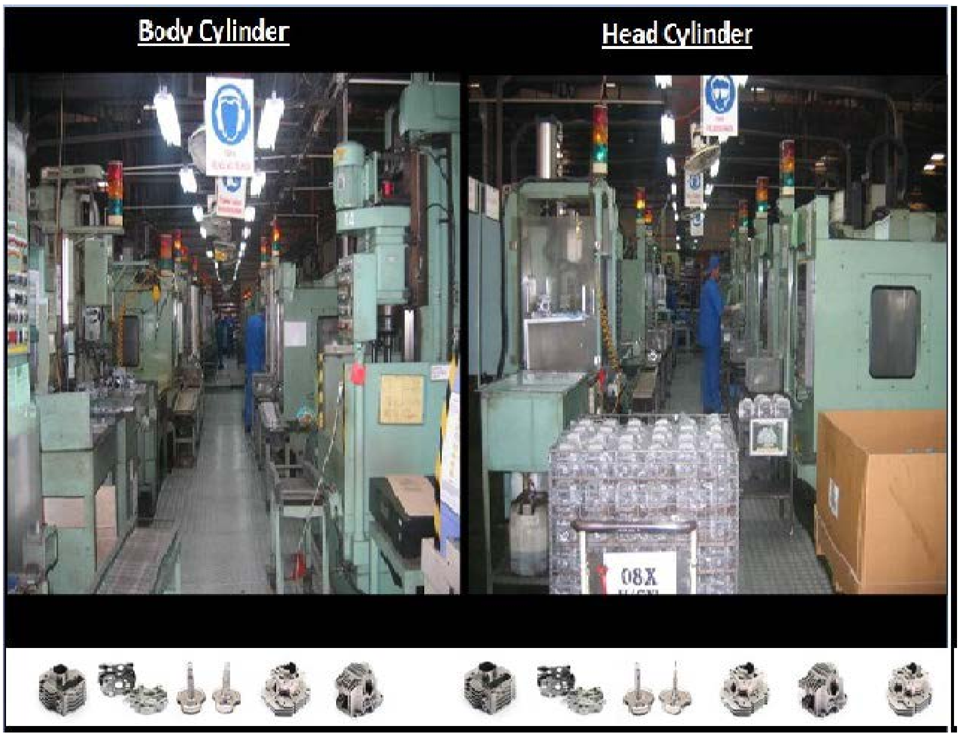
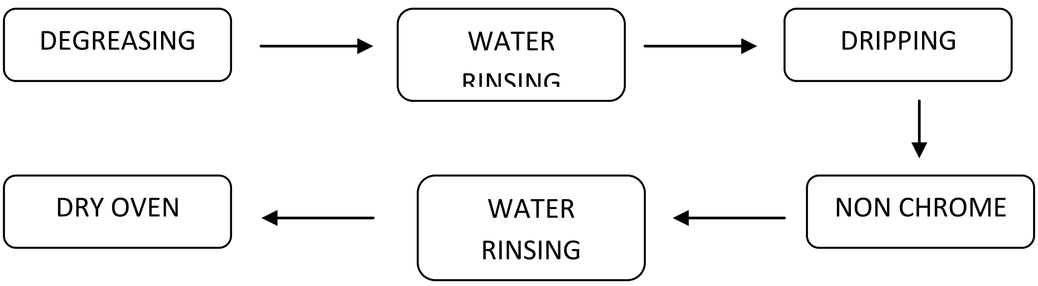


Figure 10 Machining Operation

4.1.2 PAINT SHOP OPERATIONS

After being machined, parts will supply to paint shop for painting. Not all part will go through this process. Only cover crank case and cover element are involved. Before painting, parts will undergo treatment/cleaning process first.



After treatment, parts will be paint in spray booth and then will undergo baking process.

Figure 11 Spray booth and baking oven

I. Data for Cleaning Process

Cycle Time : 15 mins

Batch Capacity : 4 parts per operation

II. Data for Painting Process

Cycle Time : 10 mins

Batch Capacity : 4 parts per operation

III. Data for Dry Oven

Cycle Time : 60 mins

Batch Capacity : 50 parts per operation

IV. Data for Baking Oven

Cycle Time : 40 mins

Cycle Time : 50 parts

4.1.3 ENGINE ASSEMBLY OPERATIONS

Production line is divided into two sections; main line and sub assy. Main line consist of two conveyor lines with total of 45 stations. Every station will have 1 operator with different jobs. To make sure high quality product, jigs are used during assembly process. Jigs function as aiding tool during assembly process. Air tool are used for tightening process and QL for torque check. In this project, an assembly operation is considered as 1 machine with 45 stations. Output of this station is 1 complete assembled motorcycle engine. Complete assembled engine will be moved to firing station for next process. Engine is transport using conveyor.

I. Data for Assembly Operations

Cycle Time : 31.5mins

II. Data for conveyor

Length in parts : 10

Max capacity : 10 parts

Figure 12 Assembly Station

4.1.4 FIRING OPERATIONS

Complete assembled engine will undergo firing operations. Firing operation is important to maintain quality of motorcycle engine. Engine will be test either it fully function or not. Firing is single station that handles 1 engine at a time. Engine will transport to punching station using conveyor

I. Data for firing
   Cycle time : 15 minutes
   Batch Capacity : 1 parts per operation

II. Data for conveyor
   Length in part : 10
   Maximum Capacity : 10 parts

4.1.5 PUNCHING OPERATION

After under firing operation, engine will go to punching. At this station, serial number will be punch to each engine. This station will punch 1 engine at a time.

I. Data for punching
   Cycle Time : 1 mins

4.2 SIMULATION RESULT

From Figure 13, it shows simulation model of current manufacturing system. Parts will undergo 8 processes before shipped to customer. This model was chosen to base layout for further analysis of the system. Base layout is produced after several models had been built. This occurs because earlier model does not mimic current system. Result obtain from layout were compared with real system to get base model that validate with real system.

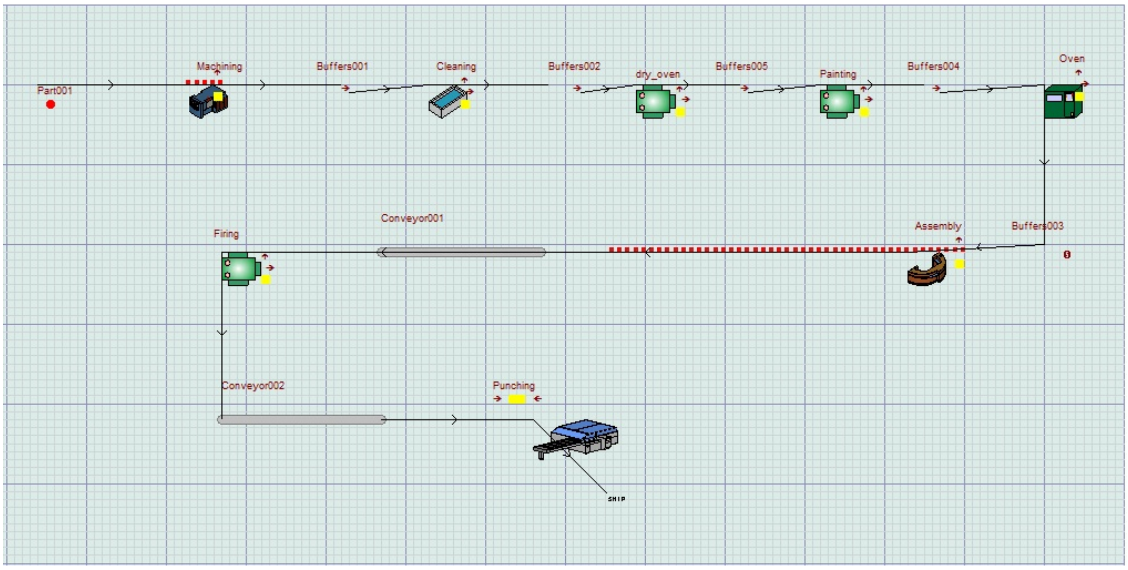


Figure 13 Base layout of manufacturing system

Figure 14 shows current statistics of the system base on part statistics. Parts enter for the whole simulation run time were 2672 parts and produced 1880 parts. Average processing times for each part were 2062.15 minutes.

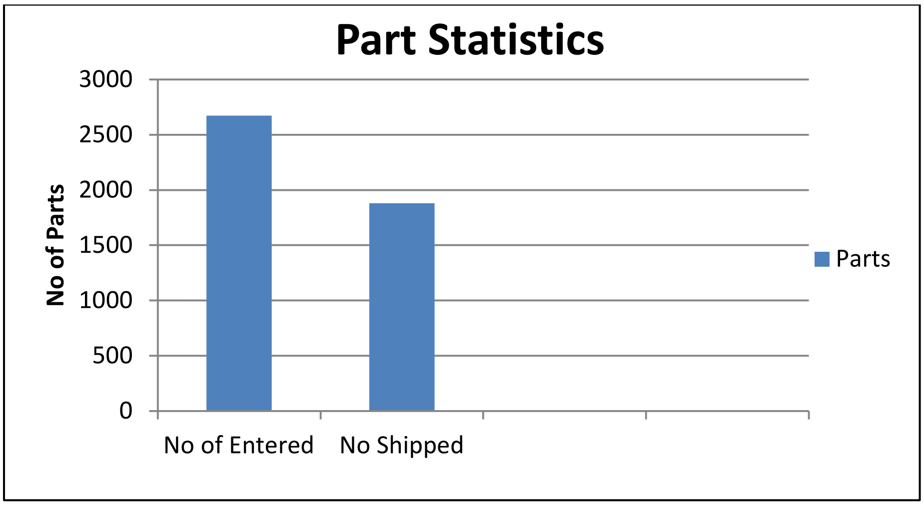


Figure 14 Part Statistics of current system

Machine statistics for current system is illustrated in Figure 15. Firing shown highest percent busy that is 100% and assembly process has the least percent busy with 14%. Highest percentage busy means that machine is working full hours in the system. High percentages also cause increasing in work-in-process (WIP). As assembly show low percentage busy, it means that parts are piling in buffer and waiting to be process. Manufacturing costs are accumulated in the raw materials account, the work in process account, also known as work in progress account, and the finished products account. Increasing WIP in system will cause in increasing of manufacturing cost until the finished product is sold.

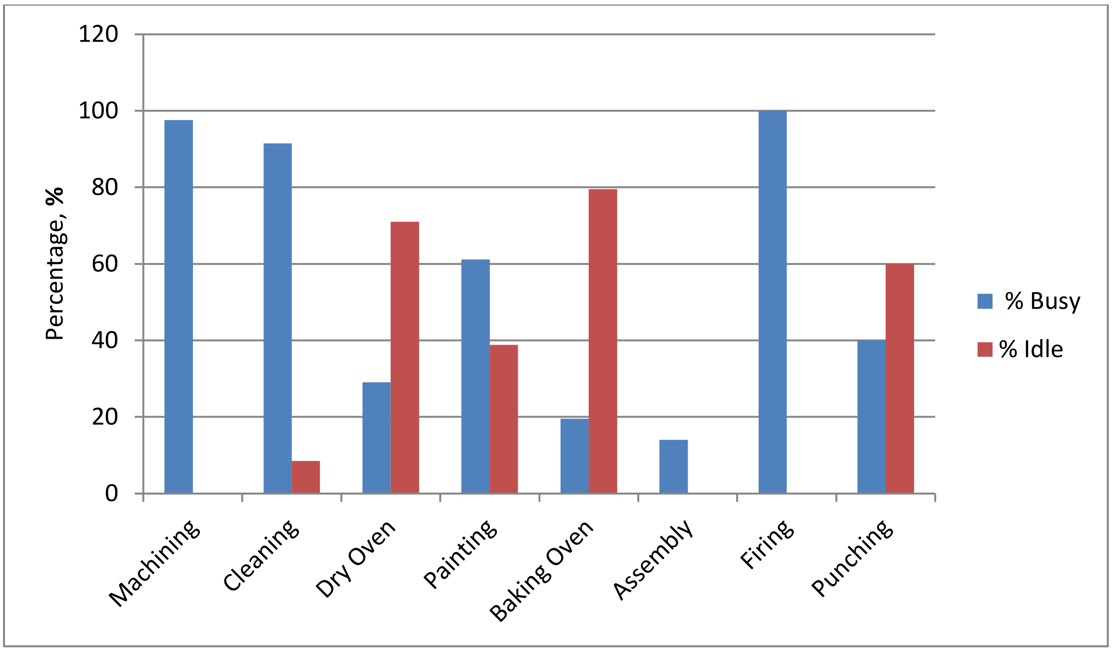


Figure 15 Machine statistics of current system

Table 1 Statistics for each process

Process	% Busy	No of Operation	Batch Capacity	Production/hour
Machining	100	2292	1	10
Cleaning	91.46	573	4	10
Dry Oven	29.04	46	50	10
Painting	61.17	575	4	10
Baking Oven	19.51	45	50	9
Assembly	14	1880	1	8
Firing	100	1880	1	8
Punching	40	1880	1	8

Bottleneck station is station that limits production output. In this system, firing station is considered as bottleneck station because of highest percentage busy and least number of product output per hour. Bottleneck station need to fix as it will cause a lot of problem in term of revenue and plant productivity. Bottleneck can be resolved by increasing number of operation to firing station by adding new machine.

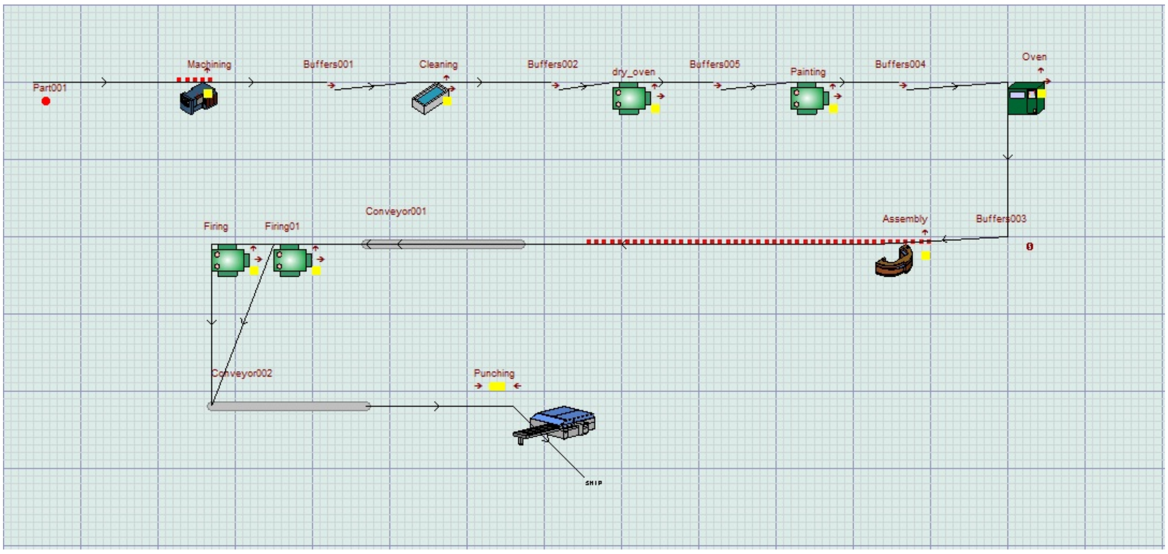


Figure 16 New system layouts in addition of firing machine

Figure 16 shows new layouts by adding a new firing machine. New machine is assumed to have same input variable, like cycle time and machine capacity. Both firing machines were set as single type that process one part at a time.

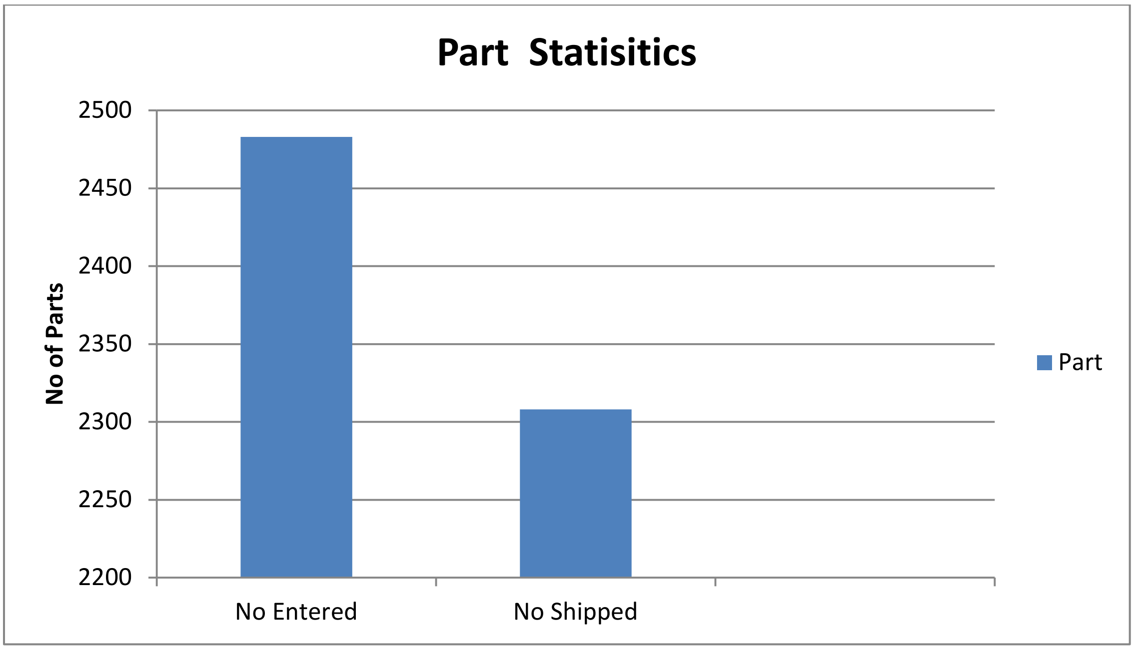


Figure 17 Part statistics of system with addition of firing machine

Figure 17 illustrated part statistics of new system after addition of new firing machine. From the graph, it shows that part entered were 2483 parts and produced 2308 parts. Average times for each part were 692.69 minutes.

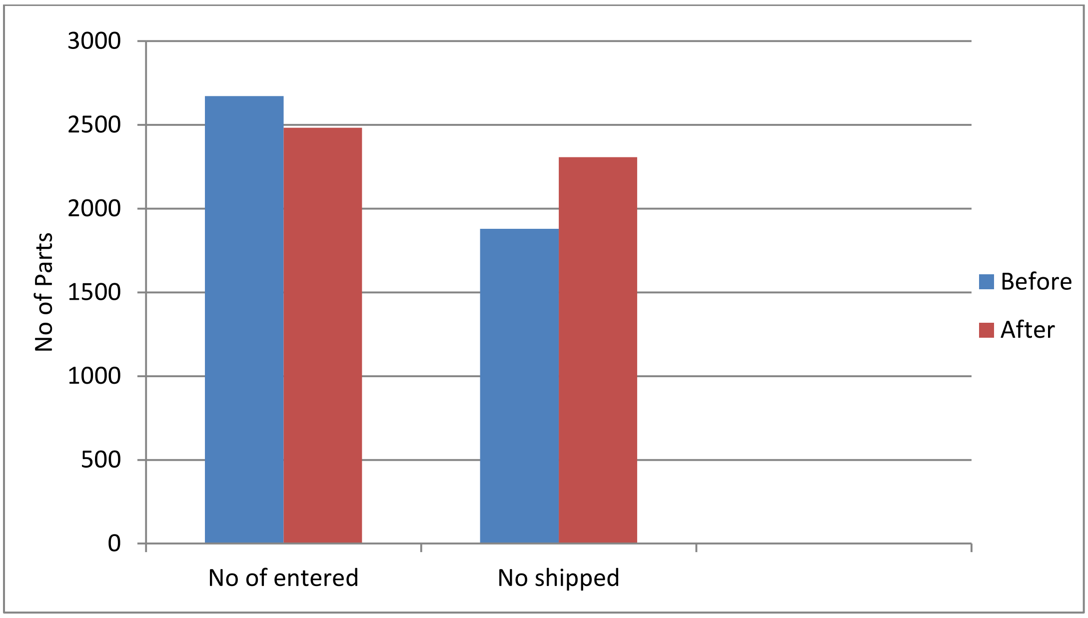


Figure 18 Part statistics before and after adding new firing machine

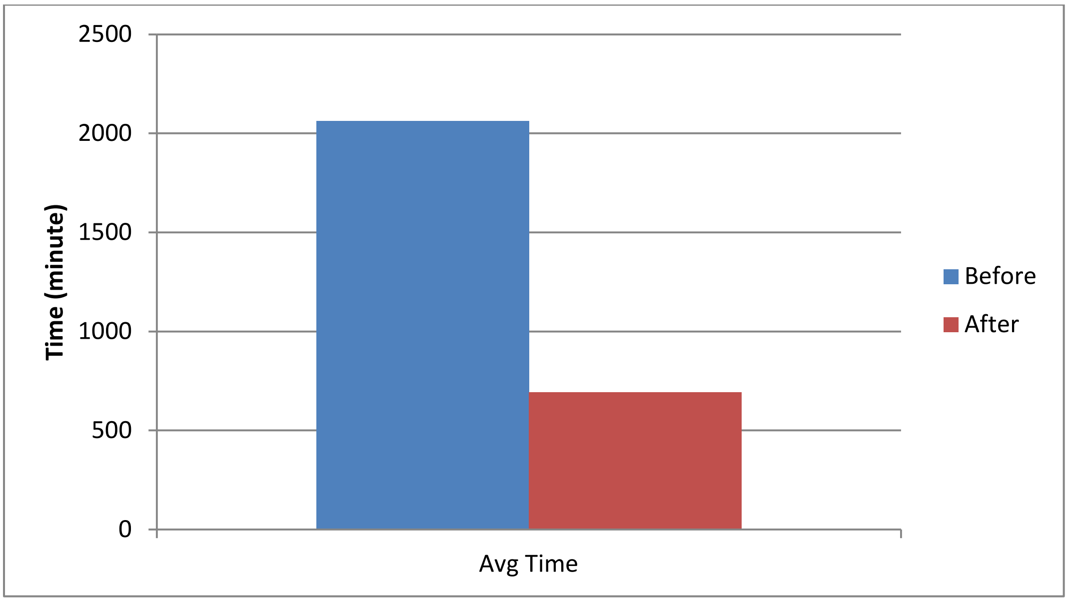


Figure 19 Average processing time for part before and after adding firing machine

Based on Figure 18, it shows different of part statistics before and after addition of new firing machine. Part entered into system has reduced 189 parts but it shows increment in production output for total 428 parts. Figure 19 shows average processing time has reduced by 1369.46 minutes.

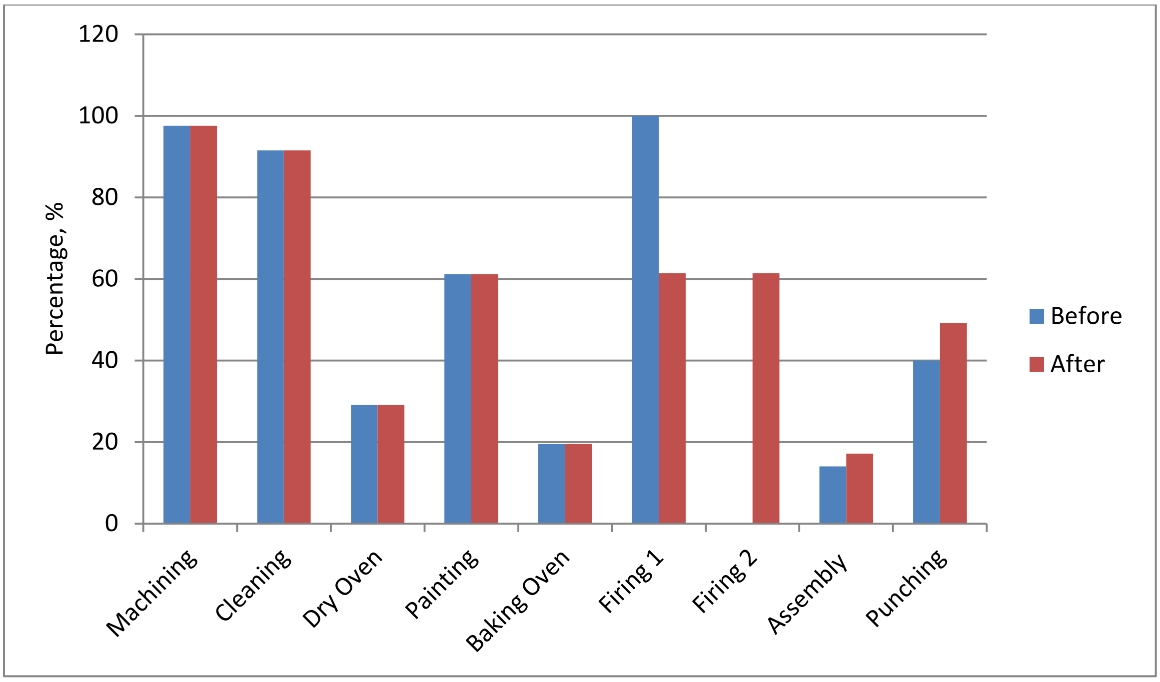


Figure 20 Machine statistics before and after addition of new firing machine

Figure 20 shows that after adding new firing machine, percentage busy of firing machine has reduced by 38.63 %. Both firing machine have equal percentage busy that is 61.37%. By analysing Figure 18 & 19, the bottleneck station had been fixed. In the current layout, output of system was being controlled by the amount of work that could be processed by firing station. Addition of new firing machine results in increase in output, and reduces part lead time and machine utilisation. Addition of worker also required to operate this machine. Calculation of total cost need to be done if this improvisation will be implement to real system.

When visiting manufacturing plant, author had done some discussion with the company. They revealed new improvisation of system that still under study. Company wants to increase number of batch capacity for dry oven and baking oven in paint shop. By simulating these new batch capacity along with adding of new firing machine, production output can be predict and help in decision making of implementation. As the new layout shows positive result, it is now considered as base model for further improvisation.

Several number of batch capacity will be used in this new simulation. Simulation of this capacity was done in three different scenarios; 1) adding batch capacity for dry oven only 2) adding batch capacity for baking oven only 3) adding batch capacity for both oven. Production output and average process time will be observed as well as machine utilisation.

Table 2 and Figure 21 illustrate part statistics after increasing of batch capacity for dry oven while other machines setting still remain same. Increasing of batch capacity affect number of part entered and average processing time for each part by increasing them. It differs for product output. Product output keeps increasing as batch capacity increase but it decrease when batch capacity exceed 20% of increment from original capacity. If this scenario going to be used, author would choose batch capacity increment of 20% because it produce highest number of product output and least number of increasing average time.

Table 2 Part statistics in addition of batch capacity of dry oven

Batch Capacity Increment	No entered	No shipped	Average time(min)
0%	2483	2308	692.69
10%	2484	2289	737.24
20%	2491	2294	743.13
30%	2495	2292	771.8
40%	2498	2287	784.55
50%	2505	2292	802.14

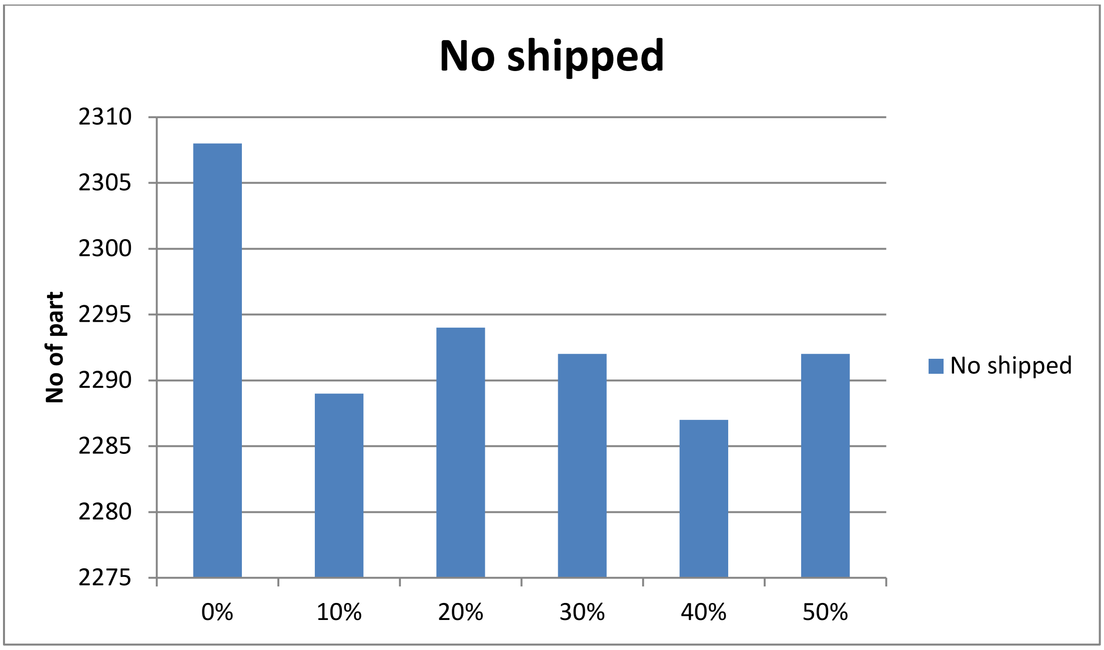


Figure 21 Part statistics of increasing batch capacity for dry oven

Table 3 and Figure 22 shows part statistics after increasing of batch capacity for baking oven while maintaining other machines setting. Increasing of batch capacity affect number of part entered product output and average processing time for each part by increasing them. Product output keeps increasing as batch capacity increase and stay remain as batch capacity exceed 40%.

Table 3 Part statistics in addition of batch capacity of baking oven

Batch Capacity Increment	No entered	No shipped	Average time(min)
0%	2483	2308	692.69
10%	2478	2281	730.41
20%	2487	2290	738.82
30%	2499	2295	767.56
40%	2507	2300	781.74
50%	2512	2300	806.75

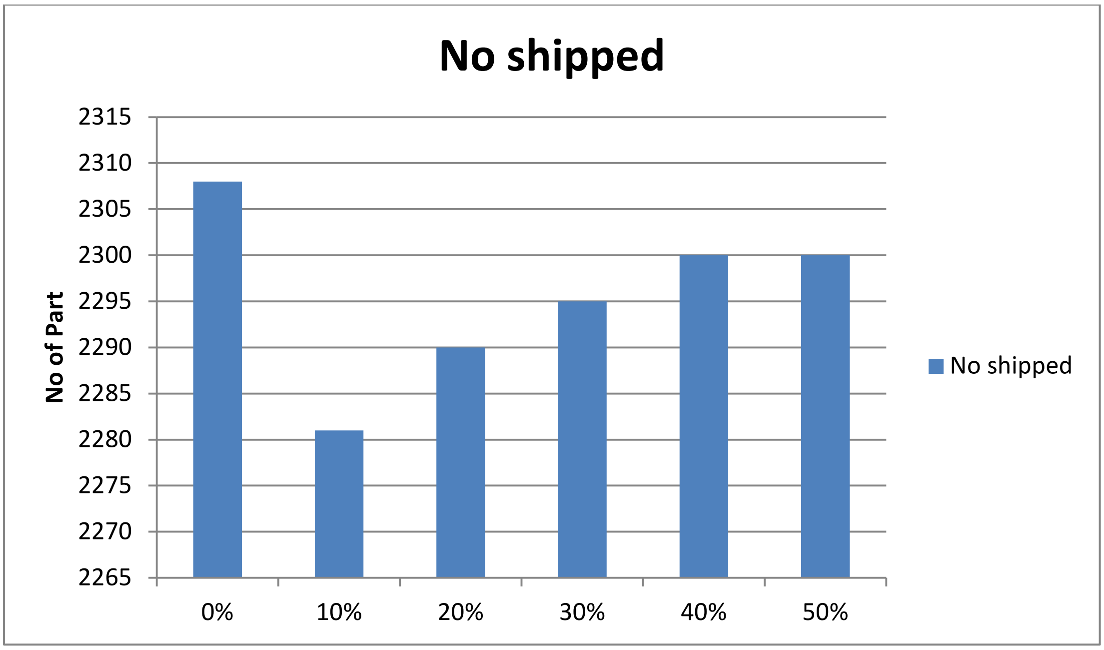


Figure 22 Part statistics in addition of batch capacity of baking oven

Part statistics after increasing batch capacity for both dry and baking oven are shown in Table 4 and Figure 22. From the table, production output shows highest value when batch capacity increase to 40%. Average processing time also increase as batch capacity increase.

Table 4 Part statistics with addition of batch capacity of dry oven and baking oven

Batch Capacity Increment	No entered	No shipped	Average time(min)
0%	2483	2308	692.69
10%	2478	2281	730.41
20%	2487	2290	738.82
30%	2499	2295	767.56
40%	2507	2300	781.74
50%	2512	2300	806.75

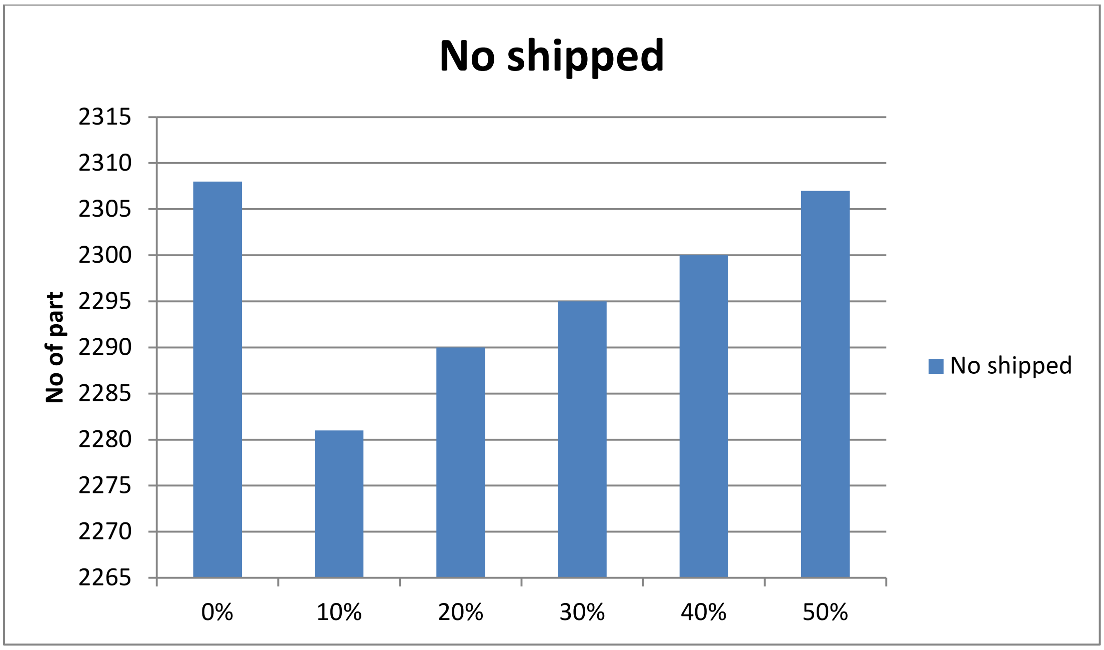


Figure 23 Part Statistics with addition of batch capacity of dry oven and baking oven

Average processing times keep increasing for all scenarios because part still stuck at buffer before assembly process. By increasing batch capacity, set up time for machine will reduced but machine cycle time will be maximised. Generally, even when the queue time has been reduced, the wait time for each piece will be large. The first piece spends most of the run time waiting after being processed while all the other pieces are being processed. The last piece spends most of the run time waiting before being processed while all the other pieces are being processed. Pieces in the middle of the batch wait equal amounts of time before and after being processed.

CHAPTER 5

CONCLUSIONS

Simulation modelling in this study was a progressive activity. 17 models were built to complete this study. First model was built to produce accurate emulation of the existing system. First model was used to analyse bottleneck station in system. Second model was built to do fixed bottleneck station by adding new machine at firing station. Others 15 model uses to simulate different scenario regarding addition of batch capacity for dry and baking oven.

Main aim of this study was to build simulation model of current manufacturing system and identified bottleneck station. This study also aims to do improvement of current system in order to increase manufacturing productivity. Over all this study fulfilled its objective. Fixing bottleneck station shows positive increment in production output and reduces the average processing time. This study also found that manufacturing productivity also can be improved by increasing batch capacity of machine. This has to be done with careful analysis so that when implement to real system, it will not give any risk.

The use of simulation in this study has proven that whenever a strategic decision is to be made, it can be taken with confidence in the outcome and implemented with minimal down-time.

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