A SIMULATION STUDY TO IMPROVE LINE BALANCING IN MANUFACTURING PRODUCTION LINE

AHMAD AIMAN HAZIQ BIN AHMAD SYAMSUL
B092010129

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A Simulation Study To Improve Line Balancing In Manufacturing Production Line

Ahmad Aiman Haziq Bin Ahmad Syamsul

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AHMAD AIMAN HAZIQ BIN AHMAD SYAMSUL

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DECLARATION

I declare that this Choose an item. entitled " A Simulation Study To Improve Line Balancing In Manufacturing Production Line " is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	AHMAD AIMAN HAZIQ BIN AHMAD SYAMSUL
Date	:	9 JANUARY 2024

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (BMMW) with Honours.

TS. DR. MOHD SOUFHWEE BIN ABD RAHMAN
Ketua Jabatan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
Universiti Teknikal Malaysia Melaka

Signature	:	
Supervisor Name	:	TS. DR. MOHD SOUFHWEE BIN ABDUL RAHMAN
Date	:	24 JANUARI 2024

DEDICATION

The greatest thanks and praise go to Allah (SWT) for His benevolence and love. My parents, Ahmad Syamsul and Noor'Azah Binti Harun, who have always been encouraging, supportive, and wise, are honoured in my thesis.

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ABSTRACT

Lean manufacturing, the waiting time is the type of waste in Lean and it create a bottleneck in line productioin. Line balancing is a method used in the sector to get rid of unnecessary waiting. Productivity can be greatly increased after system bottlenecks are located and fixed since production downtime will be reduced. The challenge facing manufacturing organisations today is finding solutions that would enable them to increase output and performance. For this reason, companies are seeking for fresh approaches to raise production line productivity. Lean manufacturing concepts are now being implemented into the organisations of expanding manufacturing enterprises. Solving production line productivity issues is crucial in the industrial sector. This study was carried out at PEPS-JV Sdn. Bhd.The case company has found that they are not paying enough attention to cycle time precision and that the operator workloads are uneven. Lean manufacturing methods will be used to make decisions in order to resolve this issue. Another tool to help researchers find solutions to production line bottlenecks is the lean tool line balancing. The purpose of this study is to carry out a line balancing analysis using WITNESS simulation software in order to enhance the productivity of the production line. The productivity of the new workstation design is examined using the WITNESS simulation software. Bottlenecks will be employed as the first step in the construction of a WITNESS simulation model that can be used to make strategic decisions about process optimisation. This model can benefit from the information required to make such a decision. Simulation can be used to analyse the impact of utilising the right lean tools on a manufacturing line. A manufacturing company's production line's overall productivity aims to capture the ideal future state for the manufacturing company. As a result, the production line was examined using the time study approach in this study, which also gave the production line a more useful selection tool. Overall, this study provides PEPS-JV Sdn. Bhd. and other manufacturing companies interested in maximising line balancing utilising cutting-edge simulation tools and Lean Manufacturing concepts with useful and actionable advice. Companies can successfully improve the efficiency of their manufacturing lines, achieve long-term competitive advantage, and streamline operations by utilising the study's findings.

ABSTRAK

Pembuatan Lean, masa tunggu adalah jenis limbah dalam Lean dan ia mewujudkan kesesakan dalam produksi baris. Keseimbangan garis adalah kaedah yang digunakan dalam sektor untuk menyingkirkan menunggu yang tidak perlu. Produktiviti boleh meningkat secara besar-besaran selepas sistem kesesakan ditempatkan dan diselesaikan kerana masa tamat pengeluaran akan dikurangkan. Cabaran yang dihadapi organisasi pengeluaran hari ini ialah mencari penyelesaian yang akan membolehkan mereka meningkatkan pengeluaran dan prestasi. Oleh itu, syarikat-syarikat sedang mencari pendekatan baru untuk meningkatkan produktiviti barisan pengeluaran. Konsep pembuatan Lean kini sedang diimplementasikan ke dalam organisasi-organisasi syarikat-syarikat pengeluaran yang berkembang. Penyelesaian masalah produktiviti barisan pengeluaran adalah penting dalam sektor industri. Kajian ini telah dijalankan di PEPS-JV Sdn. Syarikat kes telah mendapati bahawa mereka tidak memberi perhatian yang mencukupi kepada ketepatan masa kitaran dan bahawa beban kerja pengendali tidak seimbang. Kaedah pengeluaran lean akan digunakan untuk membuat keputusan untuk menyelesaikan masalah ini. Alat lain untuk membantu penyelidik mencari penyelesaian kepada hambatan dalam barisan pengeluaran adalah keseimbangan barisan alat lean. Tujuan kajian ini ialah untuk menjalankan analisis keseimbangan garis menggunakan perisian simulasi WITNESS untuk meningkatkan produktiviti barisan pengeluaran. Produktiviti reka bentuk stesen kerja baru diuji menggunakan perisian simulasi WITNESS. Bottlenecks akan digunakan sebagai langkah pertama dalam pembinaan model simulasi WITNESS yang boleh digunakan untuk membuat keputusan strategik mengenai pengoptimuman proses. Model ini boleh mendapat manfaat daripada maklumat yang diperlukan untuk membuat keputusan sedemikian. Simulasi boleh digunakan untuk menganalisis kesan menggunakan alat lean yang betul pada barisan pengeluaran. Produktiviti keseluruhan barisan pengeluaran sebuah syarikat pembuatan bertujuan untuk menangkap keadaan masa depan yang ideal untuk syarikat pembinaan. Akibatnya, barisan pengeluaran telah diperiksa menggunakan pendekatan kajian masa dalam kajian ini, yang juga memberikan barisan produksi alat pemilihan yang lebih berguna. Secara keseluruhan, kajian ini menyediakan PEPS-JV Sdn. Bhd. dan syarikat-syarikat pengeluaran lain yang berminat untuk memaksimumkan keseimbangan garis menggunakan alat simulasi canggih dan konsep Pembuatan Lean dengan nasihat yang berguna dan boleh dilakukan. Syarikat-syarikat boleh berjaya meningkatkan kecekapan garis pengeluaran mereka, mencapai kelebihan persaingan jangka panjang, dan menyederhanakan operasi dengan menggunakan temuan kajian.

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LIST OF SYMBOLS AND ABBREVIATIONS

LM	-	Lean manufacturing
LB	-	Line balancing
TPS	-	Toyota Production System
JIT	-	Just-in-Time
CI	-	Continuous Improvement
WIP	-	Work-in-Process
SMED	-	Single-Minute Exchange of Die
KPIs	-	Key Performance Indicator
OEE	-	Overall Equipment Effectiveness
CT	-	Cycle Time
ALB	-	Assembly line balancing
ALBPs	-	Assembly line balancing problems
SALBPs	-	Simple Assembly Line Balancing Problem
GALBPs	-	Generalized Assembly Line Balancing Problem
DES	-	Discrete-event simulation

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CHAPTER 1

INTRODUCTION

1.1 Background

Lean manufacturing (LM) is an efficient production method that focuses on minimizing waste in manufacturing operations to increase overall efficiency. In line with the principles of lean, waste is defined as any activity that does not provide value to the customer and is not considered something they are willing to pay for. LM was first developed in 1950s as the solution to improve manufacturing process and reduce the waste by Toyota. It was the idea of improvement for resolving the issues. To increase quality, cut costs, and increase customer satisfaction, lean manufacturing has now been widely embraced across a variety of industries, including manufacturing, healthcare, and service sectors.

Line balancing (LB) is to maximise the effectiveness of an assembly line or production line, LB is a technique used in production planning and scheduling. In order to ensure that each workstation has an equal amount of work to accomplish and that the overall production cycle time is kept to a minimum, it entails balancing the workload and the flow of materials and parts between the various workstations or processes in the line. LB aims to optimize resource utilization in the production process by eliminating bottlenecks and reducing downtime. Its goal is to ensure that all resources are used effectively, resulting in a smoother and more efficient workflow. This can be done by analysing the manufacturing process to determine which operations or procedures take up the most time, then redesigning the workstations or reorganising the line to cut down on the time needed for those operations.

In addition, line balancing supports the design of the plant, which lowers production costs by reducing the number of workers and idle time. A manually drawn precedence diagram is used to show an assembly line with workers arranged in their appropriate workstations.

Simulation technology is a crucial tool for complicated technological system planning, implementation, and management. Many simulation programmes, such the ARENA and WITNESS software, were developed specifically to construct the virtual layout of the assembly area. Simulating actual behaviour using proper computer software is a type of analysis technique that uses systems, models, and applications. Without interrupting the actual manufacturing processes, simulation models can be used to examine and quantify the consequences of changes on the industrial production line. Because the model is simulated on a computer, there are additional benefits of simulation, including reduced analytical needs, ease of demonstration, and quicker experimental simulation runs.

1.2 Problem Statement

Manufacturing is one of the big reason for a country to improve the innovation of technology but there still have problem to produce product efficiently with an optimization input and output. Firstly, the lack of organized workstation. The workstation layout is to complicate and more to scattered layout. The bad structure layout of workstation will affect to the cycle time of the process for production. Furthermore, in certain assembly-line processes, the cycle times may exceed the Takt times assigned by marketing. When this situation arises, it can pose challenges for the line to meet its daily production targets. Additionally, there is too much of bottleneck in one time production for one product. This effect will causing a delays and inefficiencies to be achieving the production target.

1.3 Research Objective

a) To suggest an improvement by eliminate bottleneck from the actual layout of the company.

b) To simulate the actual company layout by using WITNESS software for gather data comparison actual and simulation.

c) To develop simulation model for improvise LB for in assembly line in Manufacturing production line.

1.4 Scope of Research

The goal of the study is to comprehend production line balancing improvements in manufacturing production line. A smooth flow of production and the biggest possible productivity increase. This study will conduct by using the line balancing method in PEPS-JV(M) Sdn Bhd. Furthermore, a validated simulation model will be utilized to analyze important factors such as throughput, bottleneck processes, and equipment utilization within the assembly area. Each process in the assembly area will be modeled with relevant data, including cycle time, setup time, overall equipment efficiency, lot sizes, number of workers per machine, idle time, available working hours, and labor activities.. WITNESS software will mimic the findings and analysis using the information gathered from the company. Lack of attendance and operator skills are not modelled. Additionally, warm-up conditions must be taken into account when running the simulation model to guarantee that it accurately represents the environment of a manufacturing line.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review provides an in-depth analysis of the existing body of work on a particular subject by esteemed scholars and researchers. The primary aim of this section is to expound upon the information and concepts that have been developed on the topic, while also scrutinizing their strengths and limitations. Additionally, the literature review identifies gaps in previous research and suggests areas that require further exploration. Moreover, this chapter elucidates all relevant terminology, definitions, concepts, and equations associated with line balancing. Finally, the literature review also introduces the simulation topic and its related sub-topics.

2.2 LM Concept

The only focus of the Lean is productivity improvement initiative is waste reduction. The idea is to assist businesses in boosting output, increasing efficiency, and making the most of their available resources. It was created with the goal of maximising value through ongoing improvement and waste reduction. Any expenditure incurred that does not raise the value of the final product is waste, including inventory, setup fees, scrap, and rework. According to users' perceptions, waste is the consumption of internal and external resources without a corresponding increase in customer value. Nallusamy S, (2016)

2.2.1 History of LM

The history of LM may be traced back to the early 20th century, when the foundations of this ideology were first out by various significant personalities, according to M. Del Rocio (2019). The roots of lean manufacturing can be traced back to Japan, specifically with the development of the Toyota Production System (TPS). Over time, lean ideas and principles originating from TPS have spread and gained popularity in the Western world.. Lean has its origins from Japan, specifically the founding of TPS in the 1930s. At that time, Toyota had to contend with a number of difficulties, including little resources and fierce competition. Toyota's manufacturing engineers, under the direction of Taiichi Ohno and Shigeo Shingo, were looking for ways to increase efficiency and get around these challenges for the TPS was created. The Just-in-Time (JIT) production method, often known as the TPS, sought to increase quality while reducing waste.

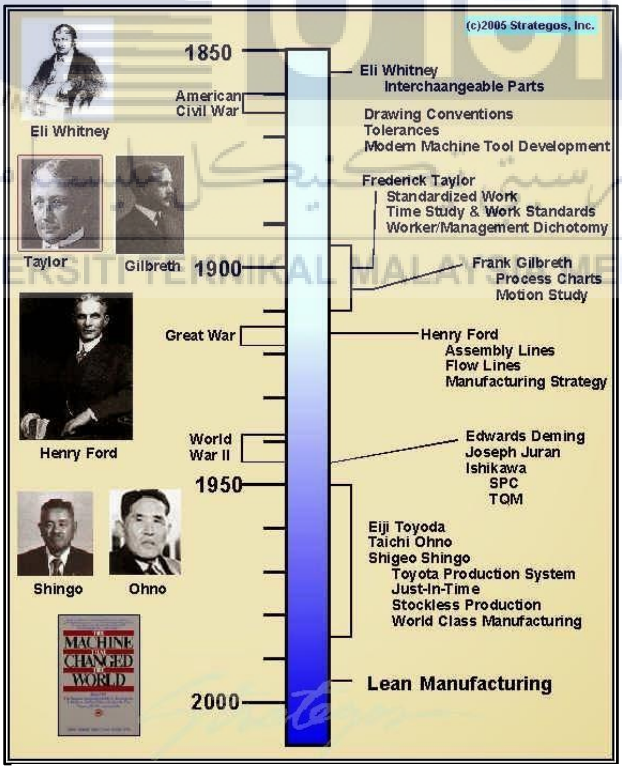


Figure 2.1 History of LM

In the 1980s and 1990s, as various scholars and practitioners examined the TPS and realised its potential advantages, the idea of LM began to gain popularity in the West. The concept of lean production was first introduced by James P. Womack in influential book "The Machine That Changed the World" (1990). In this book, they not only coined the term "lean production" but also emphasized the numerous benefits associated with the implementation of lean manufacturing methods.. As the concept of LM gained traction, it expanded beyond the automotive industry and became embraced by businesses in various sectors worldwide. Companies adopted lean principles to enhance product quality, optimize processes, reduce waste, and enhance customer value. Value stream mapping, Kanban systems, the 5S approach, and Kaizen events are a specific tool and practice associated with lean methodologies that have been developed and implemented to achieve lean objectives. Dave P (2020)

2.2.2 Principle of LM

Research by Womack J and Jones D (1996) , LM, commonly referred to as lean production is a set of fundamental ideas that aims to minimise waste and maximise value generation. Five fundamental Lean principles have been outlined.

Table 2.1 Principle of LM

Lean Principle	**Definition**
Value	Value is what the requirment of need for the product
Value stream mapping	Connecting multiple relationships to create a suitable working environment is how mapping is best understood.
Flow	Flow makes ensuring that the product's route from planning to production to client is uninterrupted.
Pull	Pull systems claim that customers can pull products with quicker manufacturing cycles, frequently reducing what might have taken months to a few weeks.
Finding Perfection	There is no end to the process of reducing time, space, cost and mistakes.

2.2.3 Philosophy of LM

According to Gupta S. and Jain S. (2013), The lean philosophy encompasses not only the definition of lean itself but also its guiding principles and key concepts. The Lean process consists of a step which is defining customer value, defining the value stream, ensuring smooth flow, establishing pull, and striving for excellence. LM is a combination of various essential elements or key areas, crucial for successful application. During the 1980s, the transition from mass manufacturing to lean production was considered highly challenging.

The workforce did not initially perceive themselves as responsible for the product's quality. Their response was triggered only when they felt genuine respect for their abilities from the management. The maxim of doing it right the first time serves as a motivational factor for employees to take ownership of their work. From craft manufacture to mass production, and finally to lean production, the auto industry witnessed a transition. Henry Ford played a significant role in standardizing vehicle parts and assembly procedures. This revolution enabled the affordability of vehicles through the utilization of low-skilled labor and specialized machinery. Womack et al. in (1990)

Research of Lean by Bhasin and Burcher (2006) is more than specific approach. To really benefit from lean practises, an organisation must involve its suppliers. LM should also be viewed as a method of continual improvement for improved outcomes. Different approaches are used in Continuous Improvement (CI) to improve outcomes in an organisation. Among these approaches are LM, six-sigma, lean six-sigma, and the balance score card. With the help of continuous improvement initiatives, high levels of pull production can be attained. By eliminating system variability, the overall number of organizational defects is reduced.

2.2.4 Waste of LM

Waste in LM is waste from the process of production which doesn't have a value to the product after process. The waste does not affect to the customer, but it effect the company because the waste that come for the raw material is cost. There is different type of waste the come from the process in manufacturing. Categorises various types wastes in a process into the following categories. It's noteworthy notice that the wastes that environmental management organisations normally target, including among the manufacturing wastes that lean practitioners frequently target, non-product output and waste from raw materials aren't specifically specified. (Shabeena et al,2013)

According to Hines P, and D. Taylor. (2000), waste that can be identified at the manufacturing is seven type of waste. It involves excessive manufacturing, waiting, transportation, improper or excessive processing, a surplus of inventory, waste, flaws, and superfluous motion. After a few year there is new waste that have been found according to Thakur (2016) it is unused employee creativity.

Figure 2.2 Waste of Lean

Table 2.2 Waste in Lean

Defects	Production of Products not as per Specification, Components or Services which Consequence in scrap, Rework, Replacement Production, going over, and/or Defective Materials
Waiting	Delays associated out of stock, delay in processing, equipment downtime, competence bottlenecks
Unnecessary Processing	Process steps that are not required to produce the product
Overproduction	Manufacturing of extra items for which no orders are there.
Movement	Human motions that are unnecessary or straining, and work-in-process (WIP) transporting long distances
Inventory	raw material in excess, or finished goods
Unused Employee Creativity	Failure to tap employees for process improvement suggestions
Complexity	More parts, complicated process steps, or requirement of time more than necessary to meet customer needs

2.2.5 Tools of LM

LM is production management to maximize the efficiency to improve the quality of the product. To improving it, there is a tool that useful to the LM.

Table 2.3 Tools in LM

Type	Definition
Line Balancing Mondenet al,(1983)	The manufacturing strategy aims to optimize the efficiency and productivity of a production line by balancing operator and machine time to align with the production rate known as takt time.
Cellular Manufacturing Rother, M et al(1999)	The idea of cellular manufacturing broadens the variety of products while minimising waste. To keep everything moving through the process smoothly in terms of resources and parts, a cell is made up of tools and workstations and is organised in an orderly fashion.
5S Tasdemir et al.(2020)	5S is generally applied to medium to large scale industries
JIT Dieste et al., (2019)	The latest advancements in the Japanese car sector and looks at how Process management affects securing productivity Gains.
Jidoka Güttler, F(2011)	It is an autonomation which the automation that has a human intelligence. This term as a quality control that prevent from defect production process that can immediately fix and investigate the root of the cause to terminate the problem from reoccurring.
Kaizen Thakur A,(2016)	The Japanese developed this management concept to foster continuous small improvements for the betterment of the organization, involving all levels from managers to workers. The term continuous improvement originates from a Japanese expression that conveys the idea of change leading to growth and excellence.

Kanban Thakur A,(2016)	Created to manage inventory levels, production, and component supply, Kanban is a component of the broader LM system.
Poka-yoke Iranmanesh et al. (2019)	a phrase with the meaning "mistake-proofing" or "inadvertent error prevention" in Japanese. It is to eliminate the defect in a product by preventing or correction mistake as early as possible.
Heijunka Naeemah and Wong (2022)	A process of dampening variation and levelling production schedule.
Hoshin Kanri Rother, M et al(1999)	Hoshin Kanri synchronises the company's objectives (Strategy), middle management's plans (Tactics), and factory floor labour (Action).
Value stream mapping Cherrafi et al. (2016)	It can be helpful to implement a strategy to identify value-added and non-value-added activities within the value chain in order to reduce pointless processes and focus attention on those that bring value. By eliminating or optimising non-value-added operations, this method helps streamline processes and improve overall efficiency.
Gemba Naeemah and Wong (2022)	Tool that encourages a thorough grasp of actual production difficulties through direct observation and conversation with workers on the shop floor.
Six Sigma Thakur A,(2016)	A systematically organized method for achieving quality control and reducing variations in manufacturing operations.
Total Productive Maintenance (TPM)	A device designed to maximise machine efficiency and reduce downtime throughout the manufacturing process

Cherrafi et al. (2016)	
Root Cause Analysis Thakur A,(2016)	Methodology for solving problems that emphasises on finding long-term solutions rather than using band-aid solutions to address merely the current symptoms.
Single-Minute Exchange of Die (SMED) Iranmanesh et al. (2019)	A method aimed at minimizing equipment replacement time.
Standardized Work Janie W. et al,(1998)	Standardized performance plays a crucial role in establishing the most effective methods and sequence data for procedures, as well as for each operator, with the goal of minimizing waste.
SMART criteria Busse, R(2011)	SMART is an acronym that can be used to guide goal setting. It stands for Specific, Measurable, Attainable, Relevant, and Time-Specific.
Andon Iranmanesh et al. (2019)	Andon is a visual feedback system implemented on factory floors that enables operators to stop production, indicates when assistance is required, and displays the output level. It serves as a real-time communication tool to enhance operational visibility and facilitate timely responses to issues or challenges in the production process.
Visual control Cherrafi et al. (2016)	A company can create a system with straightforward indicators that are easy to see and understand, giving managers a clear understanding of the state of the production line and the activities taking place on the shop floor.

Key Performance Indicator(KPIs) Rother, M et al(1999)	KPIs are measurement instruments that are used to examine the development of production efficiency in the sector.
Overall Equipment Effectiveness (OEE) Thakur A,(2016)	A productivity measurement tool commonly utilized in the manufacturing sector.
Total Quality Management (TQM) **C**herrafi et al. (2016)	A tools that increase the system's operational efficiency
Bottleneck Analysis Yusup et al. (2015)	Identifying the bottleneck in the manufacturing process enhances the performance of bottlenecked analysis, as it helps pinpoint the specific area that is restricting overall throughput.
Takt time Thakur A,(2016)	A time of production to complete the process that meet the customer demand.
Continuous flow Thakur A,(2016)	To facilitate the smooth flow of work-in-process between various steps of the manufacturing process, it is essential to minimize buffers. This enables seamless progression and prevents unnecessary delays or disruptions.

2.3 The Concept of Assembly Line Balancing(ALB)

LB aims to establish a manufacturing line for ensures fair production movement from one station to another. This involves balancing the task time at each workstation, which also serves as an effective technique for minimizing bottlenecks, preventing delays, and ensuring that no worker is overburdened.

Falkenauer (2000) ALB or LB, is defined as the process of optimally assigning operations to workstations on an assembly line. In an assembly line, most of the workstations are arranged in a linear fashion, and tasks are organized based on precedence constraints and cycle time, making use of both labor force and equipment. The ALB problem, as referred to by M. Baskak (2008), is The decision problem of optimally distributing assembly work among workstations is crucial in achieving an efficient manufacturing process.

According to Saptari, Lai, & Salleh, (2011), the main obejective LB is the workstation and distributing tasks in a balanced manner can help minimize idle time. By ensuring that work is evenly distributed among team members or workstations, idle time can be reduced, leading to increased productivity and efficiency without reach the limit because the limitation is to optimize the production process and decrease the cost of total equipment.

2.4 Terminology of ALB

According by Pekin (2006), produce a product on an assembly line, the task must be broken down into a series of basic activities. The smallest, indivisible component of the overall work content is a task. The task time required for a task to be completed by a piece of equipment is referred to as the processing time. To do the duties, the same or different equipment may be needed.

- **Cycle Time** (CT)

  CT is one of the crucial pieces of information for balancing line in Manufacturing. CT is the overall the duration or amount of time required to complete a task or process one product or for a product to travel from one workstation to the next. CT and throughput are inversely connected; a reduction in cycle time results in an increase in throughput, as shown in the following equation:

$$Cycle\ time = \frac{Production\ time\ avaiable\ per\ day}{Units\ required\ per\ day}$$

Formula of Cycle Time

Due to technology constraints known as precedence relations or precedence constraints, the tasks are produced in a specific order. A task cannot be processed until some other tasks have been produced. These duties are referred to as the ones that came before that one. The tasks that cannot be completed prior to the completion of a task are its successors. The precedence relations can be graphically depicted, as seen in Figure 2.

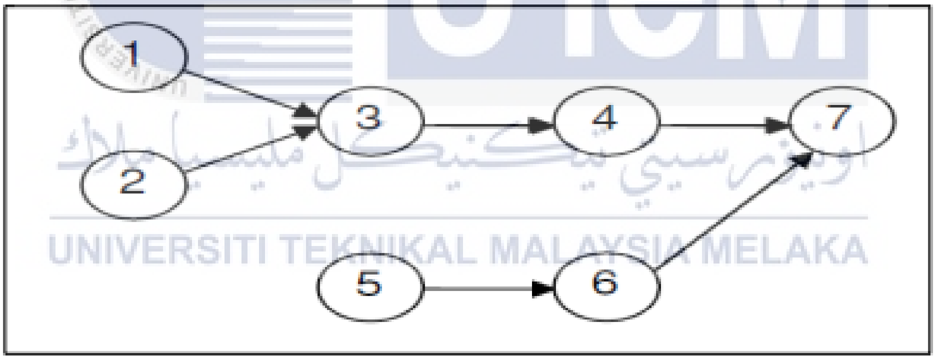


Figure 2.3 Precedence diagram

In the given figure, workstations are represented as nodes in the diagram, and the arrows symbolize the paths or flow of tasks between the workstations. From the diagram to complete the task 3, task 1 and 2 become an immediate predecessors of task 3 and for task 4 the immediate predecessors will be task 3. Task 7 will be the last task to complete the production and become the successor to all task.

2.5 Assembly Lines Balancing Problem (ALBP)

Assembly line balancing problems (ALBPs) can be divided into two main categories: the Simple Assembly Line Balancing Problem (SALBP) and the Generalized Assembly Line Balancing Problem (GALBP). SALBP is suitable for scenarios with mass production of a single homogeneous product, fixed cycle times, deterministic operation times, no assignment restrictions beyond precedence constraints, a serial layout, and equally equipped workstations for workers and machines. However, GALBP addresses the complexities of real-world ALBPs, including mixed model production, stochastic operation times, workstation paralleling, assignment restrictions beyond precedence constraints, and other factors. Extensive research has been conducted to develop line balancing strategies, particularly in GALBL. SALBP is considered overly restrictive and may not be applicable to most real-world ALBPs. **(Becker and Schools, 2003)**

Through the advent of several mathematical modelling methodologies, precise algorithms, and heuristic approaches, the ALBPs and their variations have been researched. Binary integer programming and goal programming are examples of mathematical modelling techniques, whereas dynamic programming and branch-and-bound algorithms are examples of precise algorithms. The generic algorithms used in tabu search, and an optimization strategy are examples of heuristic approaches.

Heuristic approaches are most frequently used in ALPB. Heuristic approaches, or intuitive problem-solving methods, are typically experienced-based techniques or known as the most basic form of heuristic trial and error. The line balancing problem may be solved with good, and occasionally ideal, sets of assignments using heuristic methods.

2.6 Classification of LB Model

Essentially, assembly lines are utilized by certain businesses as a means to achieve cost-effective mass production of identical products. Assembly lines have become more sophisticated as a result of organisational and technological advancements and single product lines have been replaced with assembly lines that can handle multiple product variations. Three major categories can be used to group product and assembly line setups. There are three types of ALB which is single-model assembly line, mixed-model assembly line, and multi-model assembly line. Fortuny-Santos, Jordi(2020)

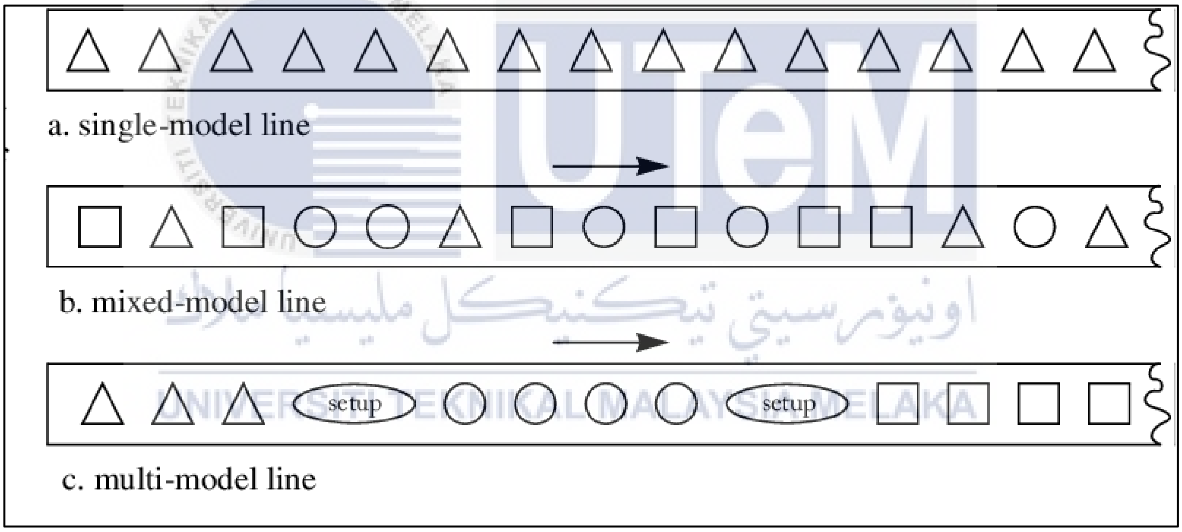


Figure 2.4 Line Balancing model in Assembly line

2.6.1 Single-Model Assembly line

Single-model is the simple model. This method is most typically applied in mass manufacturing facilities. There are a great deal of the exact same physical things on the line. The success of a line depends heavily on this model's sequence because task times for various products can differ considerably between the product. (Sivasankaran and Shahabudeen, 2013)

2.6.2 Mixed-Model Assembly lines

A mixed-model assembly line is characterized by its ability to produce units from different models in an arbitrary order. In this paradigm, the task precedence rules for each product are unique and are merged to create a precedence diagram for the entire product family. This strategy is mostly used in automobile manufacturing facilities because these businesses typically only manufacture a limited fixed number of product families. The goal of this model is to increase overall balancing effectiveness. (Sivasankaran and Shahabudeen, 2013)

2.6.3 Multi-Model Assembly lines

Mutli-model assembly line is produce a sequence batch which the batch contain of unit of one model or a group of similar model. Rearranging the line's equipment is necessary when products change since the production processes differ significantly. So as to reduce setup inefficiencies, the items are put together in different batches. Although increasing batch sizes lowers setup costs, stocking expenses go up. (Sivasankaran and Shahabudeen, 2013)

2.7 Problem in LB

Tanbin Haque (2018) proved the problem that will occur in LB is bottleneck at the workstation. Bottleneck is the operation that have the longest CT where the process will slow the time production in the assembly line. To identify the bottleneck in a production line, one can observe the CT data for each workstation. If the cycle time exceeds the takt time, it suggests that the production line should be reconsidered as a potential bottleneck. It will reduce the efficiency of the production line and become the main reason for problem.

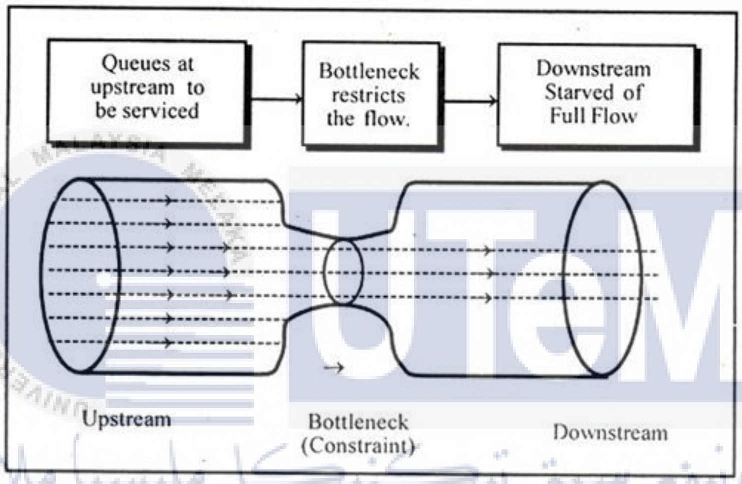


Figure 2.5 Occurrence of Bottleneck

Syahputri K. (2018) stated from her study that the overload workstation in production is also a problem in LB. When the overload workstation will give an imbalance workload due to the different variant of task in production line, and it can lead to the delay the production flow . Each workstation has its own limited capacity because of the restricted amount of work. The impact to this limitation is affect to the LB.

2.8 LB Analysis

A manufacturing line's workload distribution and efficiency are both systematically assessed through line balancing analysis. To find areas for improvement and create a more balanced and effective workflow, it entails analyzing the activities, workstations, and resources used in the production process. This is the procedure of solving the line balancing from G.Andrew (2006).

I. Draw a precedence diagram

To demonstrate the link between two workstations, a precedence diagram must be constructed. Prior to specific tasks being generated, processing of a task cannot begin.

II. Determine the CT

CT is the total time that allowed for production line at each time. The formula of cycle time:

$$Cycle\ time = \frac{Production\ time\ avaiable\ per\ day}{Units\ required\ per\ day}$$

III. Calculate Takt time

Takt time is rate time of production to complete that meet the customer demand. Formula of Takt time:

$$Takt\ time = \frac{Total\ time\ available}{Total\ customer\ demand}$$

IV. Calculate the number of workstation

$$Number\ of\ Workstation = \frac{Total\ time\ for\ all\ task}{cycle\ time}$$

V. Calculate number of worker

To find the number of worker that are available for this production line. The formula:

$$Number\ of\ workers = \frac{Total\ work\ content}{Takt\ time}$$

VI. Calculate the efficiency

This is to find out the efficiency of production. Efficiency formula:

$$Efficiency = \frac{Total\ Task\ time}{No.of\ workstatuion\ x\ \text{Takt time}}\ \text{x}\ 100\%$$

VII. Calculate productivity

$$Productivity = \frac{Output}{Labor\ x\ prodcution\ time\ per\ day\ (hour)}$$

Simulation analysis can be employed to identify the optimal layout in a production line, especially considering that different manufacturing layouts often utilize conveyors to transport products. By determining the best layout, transportation time between workstations can be reduced, leading to improved efficiency in the production process.

2.9 Simulation

A technology in the modern world continues to advance, the production system is becoming more complicated. Due to the complexity of the contemporary manufacturing system, it typically takes a long time to ramp up output to the predetermined objectives for assessing performance or making important decisions. The management of these production systems makes use of simulation modeling, which is crucial. Simulation is a method that is used practically to comprehend the high-level dynamics of a complex industrial system. The advantages of simulation include time compression, component integration, risk mitigation, physical scaling, repeatability, and exact system monitoring.

Simulation is a process or system in the actual world over time is referred to as simulation. According to Banks et al. (2010), Simulation involves the imitation of a dynamic process using a model, with the aim of obtaining results that can be applied to a real system. It allows for the replication and analysis of various scenarios to gain insights into the behavior and performance of the system under different conditions. Due of complexity and the necessity to adapt, simulation is mostly used in the industrial system. It has been demonstrated that simulation can handle tasks involving productivity and efficiency increases where various complexity overlap and interact.

2.9.1 WITNESS Simulation

The Lanner Group Ltd has created a software called WITNESS Simulation. This software offers a user-friendly and interactive interface, making it easy for users to navigate through simulations. WITNESS Simulation is software that enables discrete, systemic occurrence, and continuous simulations of processes. Its purpose is to facilitate rapid, incremental, and precise debugging for individuals familiar with the studied process. It allows the inclusion and verification of complex models. The software includes a grid interface that presents different features, including the toolbar, window modeling, and window structure support. Users have the ability to construct models by utilizing elements available in the tabs of the model element window. (Yusoof M, 2021)

2.9.2 Simulation modeling

Simulation modelling is frequently used to evaluate the functionality and behavior of production systems. The manufacturing process simulation model, sometimes referred to as the virtual factory, replicates all the steps that are present in the actual production line into a computer model (Kelton, D., 2006). The use of simulation has numerous benefits, including the ability to analyze resource utilization for both fixed and variable resources, the ability to test a model without affecting or changing the original model, and the ability to calculate operational characteristic or objective function values and analyze issues.

2.9.3 Discrete and continuous simulation models

Continuous-event simulation is used a model manufacturing processes such as in petrochemical like shell refinery, Petronas gas and palm oil processing, Textile manufacturing and beverage such as coke, Pepsi, Revive and etc. Discrete-event simulation (DES) is used to model finite customer products such as shirts, Shoes, electrical device goods, automotive, etc. (Banks et al., 2010)

2.9.4 Discrete-event simulation

Modelling a system using DES involves just changing the state variables at discrete times in time. DES is a crucial tool for simulating the movement of things inside a system with finite resources. The DES algorithm is also simply able to integrate unpredictability in the pace at which users enter the system or uncertainty in the amount of time they will use a certain resource. Instead of using analytical approaches, numerical analysis is used to examine the simulation models. In order to solve the model, analytical approaches use deductive reasoning from mathematics. Numerical techniques utilize the minimal cost policy for various inventory models.

2.9.5 Continuous-event simulation

Continuous-event simulation models deal with variables that are continuous and often differentiable in nature. In these models, the primary focus lies in studying continuous variables such as temperature, flow of thermal energy, pressure, stress, or the quantity of a desired chemical produced through a reaction.

2.9.6 Summary

In this research. The most suitable simulation model is using DES. Based on the journal, most of it, the best choice for solving problem in line balancing.

2.10 Previous study of method Simulation for improve LB

Table 2.4 Previous study of method Simulation for improve LB

No.	Author & Year	Title	Software	Finding
1	Supsomboon S (2019)	Simulation for jewelry production process improvement using line balancing: A case study	Technomatix Plant Simulation	It is demonstrated that simulation results not only predict the average throughput of the changed process but also reveal how the system would use the workers.
2	Kitaw D, Matebu A, Tadesse S (2010)	Assembly Line Balancing using Simulation Technique in a Garment Manufacturing Firm	Simul-8	The simulation reduced the bottleneck of process modeling from 762 pieces to 160 pieces and its productivity was increased to 389 pieces, allowing the production to produce 692 polo shirts every shift.
3	Hossain A (2022)	Assembly line balancing and sensitivity analysis of a single-model stochastic sewing line using arena simulation modelling	Arena professional (Version 14)	The initial model's throughput was 741 pieces per day, and its line efficiency was 75.76 %. However, the throughput climbed to 904 pieces per day when the model was optimized using OptQuest, and line efficiency significantly increased to 92.43%.
4	Yasir A, Mohamed N (2018)	Assembly Line Efficiency Improvement by Using WITNESS Simulation Software	WITNESS software	The more effective Layout 2 shows efficiency of 3.93%, while the less effective New Layout 1 only shows efficiency of 1.97%. Furthermore, compared to the present layout, New Layout 2 shows a higher production rate of 0.0006692 units per labour hour, which is greater than 0.0006439 units per labour hour.

5	Syahputri K, Leviza J, Sari S, Indah R, Napitupulu H, Anizar A (2018)	Assembly line balancing in an electronics company using simulation approach	ProModel 7.5 Student Version	The improvement of the alternative model give a big impact to the output 34% improvement with the highest capacity 9.24 units per hour.
6	Abdullah R, Rahman M, Rasib A, Abdullah M, Mansoor H (2022)	Simulation-based Assembly Line Balancing and Manpower Allocation in a Cellular Manufacturing System	WITNESS software	According to the simulation's findings, the operators were utilized between 60% (1 man to 2 machines) and 80% (1 man to 3 machines). The utilization of this specific operator attained a high level of 98% during stagger breaks when there was only one operator available at the test cell.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will be explained more for this research methodologies. It is the approach and technique for this research to develop a solution and problem. In this study to improve LB in manufacturing production line by using simulation, it include planning of this study, the process flow, data collection and analysis.

3.2 Gantt Chart of the Study

The Gantt Chart for this research will be presented at table 3.1 and table 3.2. There is two phase which is phase one, Final Year Project I and phase two is Final Year Project II. This topic covered the process flow of the research from Final Year Project I that contained an Introduction, Literature Review and Methodology. For Final Year Project II will contained Result, Discussion and Conclusion.

Table 3.1 Gantt Chart for PSM 1

No	Project Activities	Plan vs Actual	March		April				May					June				July
		Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	PSM briefing	Plan						MID SEM BREAK										
		Actual																
2	Chapter 1: Introduction	Plan																
		Actual																
3	PSM: WORKSHOP	Plan																
		Actual																
4	Chapter 2: Literature Review	Plan																
		Actual																
5	Chapter 3: Methodology	Plan																
		Actual																
6	Chapter 4: Result	Plan																
		Actual																
7	Formatting and Grammer improvement	Plan																
		Actual																
8	Final Improvement	Plan																
		Actual																
9	Slide Presentation	Plan																
		Actual																
10	Final Presentation	Plan																
		Actual																
11	Report Submission	Plan																
		Actual																

Table 3.2 Gantt Chart for PSM 2

No	Project Activities	Plan vs Actual	October		November					December				January		
		Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Company Visit	Plan														
		Actual														
2	Data Collection	Plan														
		Actual														
3	Compilatin Data	Plan														
		Actual														
4	WITNESS simulation model	Plan														
		Actual														
5	Outcome of result	Plan														
		Actual														
6	Improvement of Simulation model	Plan														
		Actual														
7	Discussion, conclusion and recommendation	Plan														
		Actual														
8	Do correction of Chapter 4 and chapter 5	Plan														
		Actual														
9	Submit Full report of FYP 2	Plan														
		Actual														
10	Prepare for presentation of FYP 2	Plan														
		Actual														
11	Presentation for FYP 2	Plan														
		Actual														

Proposed Methodology

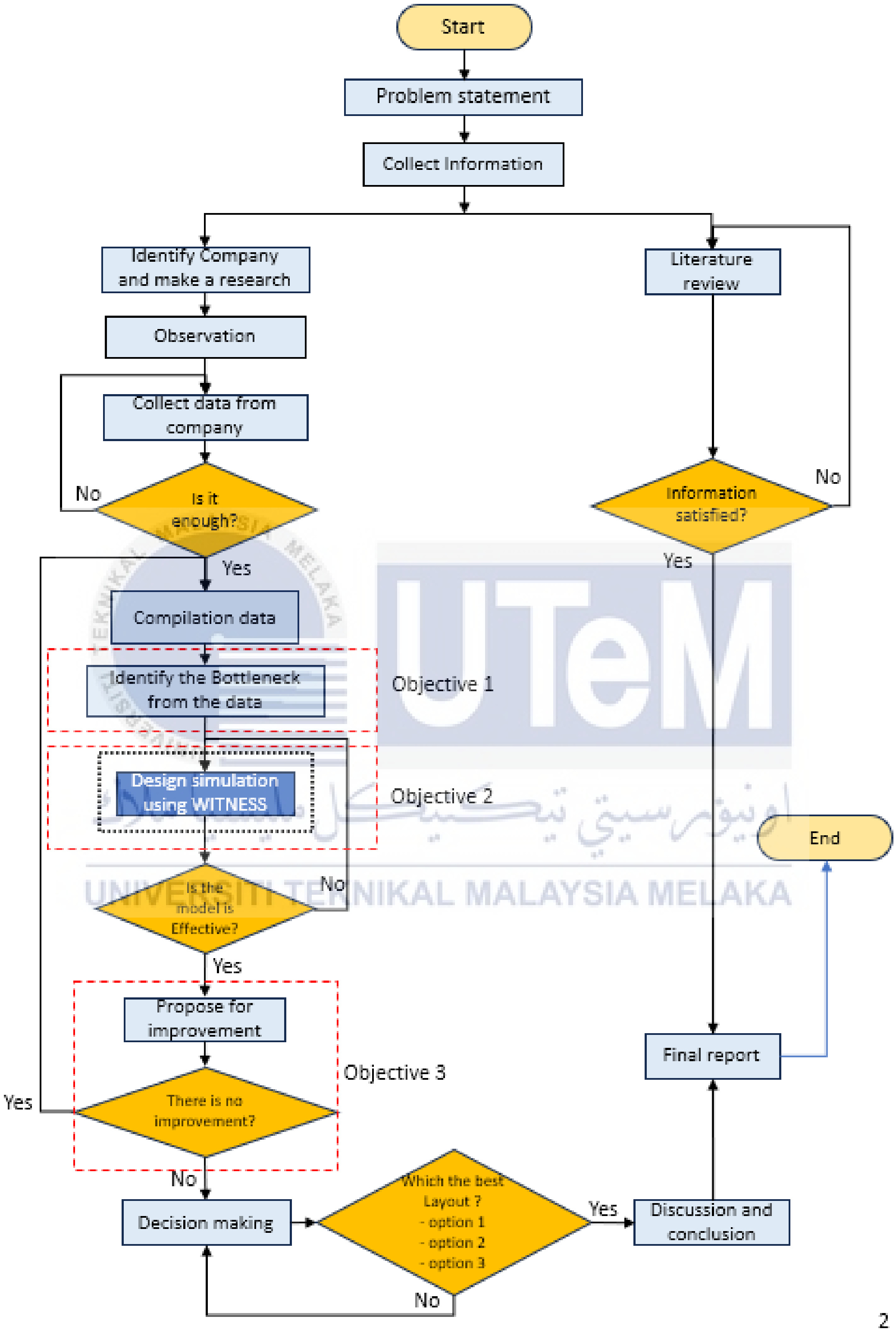


Figure 3.1 Methodology of Research

3.2.1 Collect Information

Data collection for this research is divided into two type information from company and informatioin from journal. The data from company is based on observation, result, recording and experiment. Futhermore, data from journal is gathered infromation in many journal to find the information that need for understanding of the topic and to implement the information at the report.

3.2.2 Identify Company

For this section, The choosen of company need to releatable with the topic research. For this company is based on the Manufacturing company that has a production line. Make a research a company to idetify company that suitable for doing the research so that can be apply the LB tecnique to improve the assembly line.

3.2.3 Observation

Observation of the selected company to see the layout of the company to get an overview before getting data so that the process of getting data is easier.

3.2.4 Collect Data

Data collection for this topis is a main data of this research. Data will be collected from the actual layout company for examinate the data to convert to the simulation model and to calculate data with a construct a precedence diagram for a better visualize before design a simulation model. There is a example table for collect data that will be used in result.

Table 3.3 Method to improve LB

No	Step	Formula
1	Cycle Time	$\frac{Production\ time\ avaiable\ per\ day}{Units\ required\ per\ day}$
2	Takt Time	$\frac{Total\ time\ available}{Total\ customer\ demand}$
3	Minimum Workstation	$\frac{Total\ time\ for\ all\ task}{cycle\ time}$
4	Line Balancing Efficiency	$\frac{Total\ Task\ time}{No.of\ workstatuion\ x\ \text{Takt time}}$ x 100%
5	Productivity	$\frac{Output}{Salary\ x\ hour\ x\ No\ Of\ Operator}$

Table 3.4 Data collection

Process:	**Product Model:** **Model:** **Varient:**							**Observer:**					**Date:**
Station	**Child Part**	**CT, (sec)**					**No. Of Operator**	**Setup Time, (sec)**					**Capacity**
1													
2													
3													
4													
Demand													
Capacity													

3.2.5 Compilation Data

Compile the gathering and organisation of the relevant firm data after it has been collected in order to be used in building the simulation model. For precise and successful simulation-based line balance improvement, data compilation is crucial.

3.2.6 Design Simulation

The steps in a simulation study can be used to construct the simulation model. Following model validation, analysis and performance measures including throughput, labour, and bottlenecks are examined. The simulation model has been updated, and work on line balancing-related possible improvements has begun. The simullation model need to redesign when the simualtion is not effective.

3.2.7 Propose for Improvement

Improvement of line balancing for the new layout by contruct through the WITNESS simulation to see there is better layout with a best ouput in term of increse of efficiency, eliminate of bottleneck, the balance of assembly line production. If there is more improvement can be done to perform a better result data need to be redo and check the data and create another simulation model.

3.2.8 Decision Making

The improvement need the be consider the value of similarity is above than 95% from the actual layout from the company and the simulation layout by using the WITNESS simulation. There will be three option for in the propose improvement. The best layout with a better output will be choose for the discusion for comparison result.

3.2.9 Discussion and conclusion

Discussion of the result to see whether the improvement is achieved and objective is solve the problem of line balancing in assembly line production. The study's summary includes all primary and secondary data that were gathered in order to achieve the intended outcome.

3.2.10 Literatur review

This serves as the study's secondary data. The information gathered will be retrieved and scanned, with a focus on the methodologies employed and related studies that can be associated with this study. To grasp the present state of knowledge and research gaps in the field, it entails looking through and analysing academic publications, reports, articles, and other sources.

3.2.11 Final report

Final report consists of all chapter of the research from chapter one until chapter five. It is comprehensive document that presents the findings, outcomes, and conclusions of a project or study. It is typically generated at the conclusion of research, investigation, or analysis and serves as a detailed record of the entire process. The final report offers a comprehensive overview of the project's goals, methodology, data collection, analysis, results, and the recommendations or conclusions derived from the findings.

3.3 Milestone of the research

Phase 1

a) Milestone : Analyzing the data from journal for literature review

b) Milestone : Observing the layout and collecting data

Phase 2

c) Milestone : Implementation of WITNESS software

d) Milestone : Design the actual layout through WITNESS software

e) Milestone : Analyze the ouput of production line

f) Milestone : Validation on Line balancing and WITNESS software

Phase 3

g) Milestone : Proposed improvement based on output

h) Milestone : Redesign the layout based on recommendation improvement

i) Milestone : Discussion and conclusion

j) Milestone : Final report

3.4 Step in Simulation Study

The flowchart below is the step for Simulation study that will be used in this research

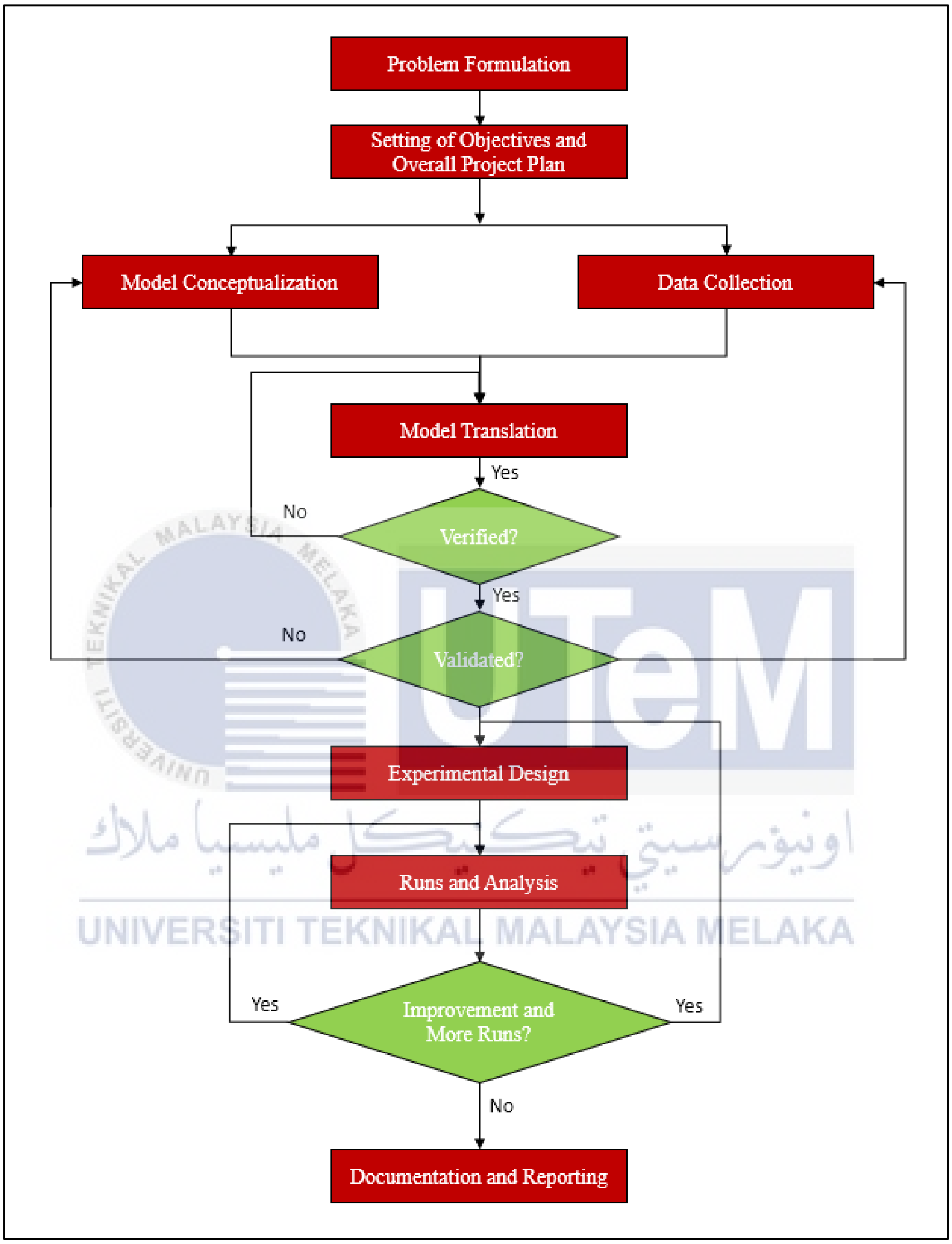


Figure 3.2 Step in Simulation study

3.4.1 Problem Formulation

In this study is about the problem statement for the research of A simulation study to improve LB in Manufacturing production line. This study is to identify problem by using simulation in the manufacutring system.

3.4.2 Setting of Objective and Overall Project Plan

Objective is the answer of solution to solve the problem. In this statement, simulation need to be concern whether this methodology is appropriate for solving the problem that meet the objective. The overall project plan need to include a description of the various systems that should be taken into consideration, along with a mechanism for determining how effective they are. It should also outline the study's plans in terms of the persons who will participate, the study's budget, the number of days needed to complete each step of the work, and the outcomes anticipated at the conclusion of each stage.

3.4.3 Model Conceptualization

The components of the investigation, particularly the data requirements, are impacted by model design. It is a description of the simulation model that will be created in the conceptual modelling process. The objectives, inputs, outputs, content assumptions, and model simplifications are necessary outlines of the essential components in this part in order to conceptualise the model. The goal of simulating the model is one of the aims. In the meanwhile, inputs defined the factors known as experimental factors that affected performance. The outcomes of the model's inputs are determined by the simulation model's simulation run. The model's interconnected components and their relationships make up the content. Additionally, in conceptual modelling, the uncertainties and components that are significant but weren't modelled are expressed in the model's assumptions. Last but not least, the model is simplified to make it less complex and allow for continual use and refinement

3.4.4 Data Collection

Data collectioin is the purpose for input data to insert in the model construction. It is important for the valuation of the result to find the accurate improvement. Data collection need to be precise to avoid any wrong data. The data collection already discuss at the section 3.3.4.

3.4.5 Model Translation

Since most real-world systems produce models that need a lot of information storage and calculation, the model must be entered into a format that is understandable by computers..The simulation programme utilised in this study's translation is called WITNESS. When using WITNESS, the user can simulate real-world processes in an animated, dynamic computer model and then test out several "what-if?" situations to determine the best course of action.

3.4.6 Model Verfication

The computer programme created for the simulation model is subject to Verification. Verification involves making sure the model was built properly. The conceptual model and the simulation model will be compared using computer representation in order to confirm. It must ensure that the model's input parameters and logical structure are accurately represented.

3.4.7 Model Validation

Validation is often accomplished through model calibration, an iterative process that compares the model's predictions with the actual system behaviour and uses the differences between the two and the knowledge obtained to enhance the model. Until the model's accuracy is deemed adequate, this process is repeated.

3.4.8 Experiment Design

Experiment design are simulating the model in many alternative or different model concept to gather the optimized output. Each of the system model need to concerning the length of the initialisation period, the length of simulation runs, and the replication to be made of each run.

3.4.9 Runs and Analysis

Measures of performance for the simulated system designs are estimated using production runs and their subsequent analysis.

3.4.10 Improvement and more runs

After make amany runs and analysis for the model need to make sure the simulation model is the best layout, otherwise need to make another improvement ot get the best optimized output for the simulation model .The analyst decides whether new runs are required and what design those additional trials should adhere to based on the analysis of the completed tests.

3.4.11 Documentation and Reporting

The report presents the analysis' findings succinctly and precisely. This is to make sure that the model user receives a clear review of the final formulation and any suggestions for changes.

3.5 Summary

This chapter provides a comprehensive explanation of the methodology and process employed in conducting the study. It includes a clear description of the project background and scope, which sets the stage for developing a viable solution to the stated problem. The focus is on achieving the objectives, gathering relevant data, and developing a systematic approach to address the workflow challenges. The final outcome of the study is the completion of a comprehensive project report. The purpose of the report is to communicate the study's results and progress to others and serve as evidence of the study's completion. A well-prepared report also facilitates tracking the progress of the study in a systematic manner. In the conclusion, the objectives are reviewed to assess the research's effectiveness and determine the percentage of achievement.

CHAPTER 4

RESULT

4.1 Introduction

This chapter's discussion centers on the use of simulation by WITNESS software for data gathering, processing, and assembly line production to enhance line balancing in industrial production lines. the information gathered from the business at the EPMB Peps-Jv Melaka Sdn. Bhd. (Pegoh Plant) manufacturing facility. Data collected on the product description, manufacturing process flow, downtime observation, total workload calculation and the optimal processing time for each workstation are all included. For the purpose of improvement, WITNESS simulation software will be used.

4.2 Company Background

This research was conducted at PEPS-JV (M) Sdn Bhd, a subsidiary of EP Manufacturing Bhd situated in Melaka (Pegoh Plant). The primary focus of this company is the automotive industry, specifically supplying body components for Honda, Perodua, Mazda, Proton, and Toyota in the Middle East at figure . The majority of the metal goods produced by EPMB are made in Batang Kali, while the majority of the composite and plastic goods are made in Shah Alam's Hicom-Glenmarie Industrial Park. Kedah and Melaka plants also produce metal components for Honda and Mazda. The assembly of the company's products was carried out using spot welding robots.

Figure 4.1 Product Automotive of EPMB

The EPMB Peps-Jv Melaka Sdn. Bhd. (Pegoh Plant), which manufactures automobile parts with a sole concentration on Honda children's parts, is where this study is being carried out. The business offers side and underbody parts.

4.3 Product Flow of Company

There are five production lines at EPMB Peps-Jv Melaka Sdn Bhd, with Lines 4 and 5 not in use on Thursdays and Fridays. Line 1 was chosen for our study since it doesn't fulfil the company's output goals. For the Honda City Variant Petrol model T00A-4DR in particular, our study intends to improve line balancing in Production Line 1. An automatic spot welding robot is used on the manufacturing line, and we will conduct a thorough examination using the simulation software WITNESS. Our objectives are to increase performance overall, decrease bottlenecks, and increase efficiency. We want to enhance productivity and maximize resource usage in Production Line 1 by optimizing line balancing. EPMB's Melaka Plant (Pegoh Plant) is depicted in Figure 4.2

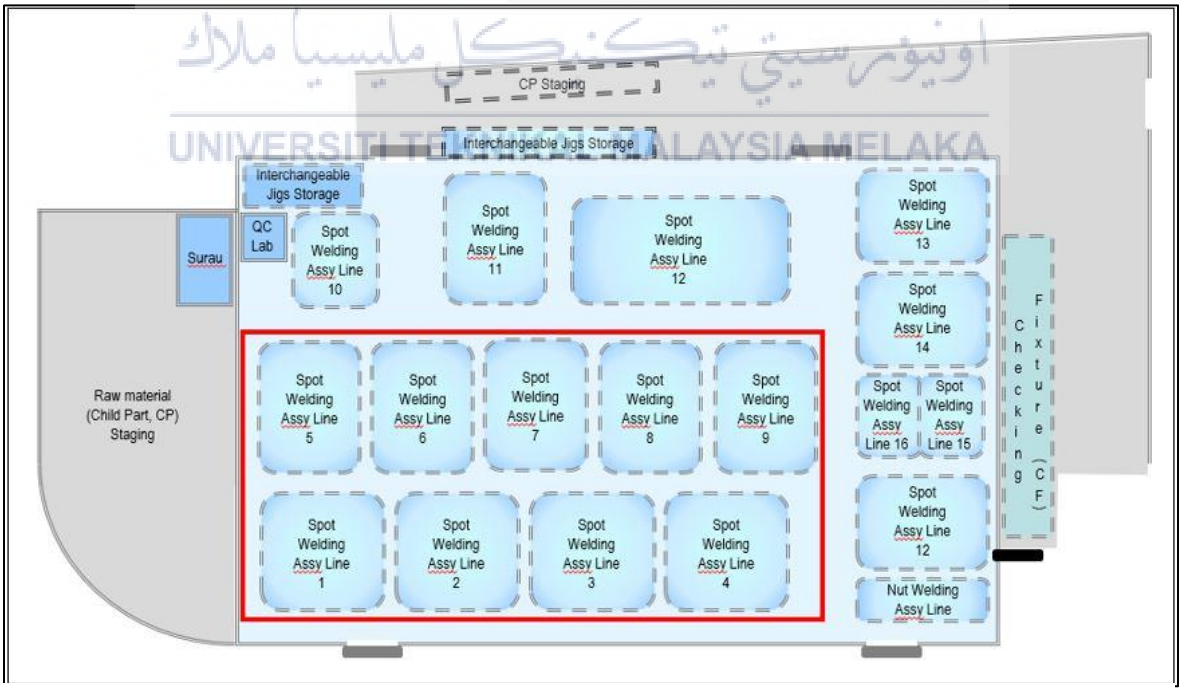


Figure 4.2 EPMB's Melaka Plant (Pegoh Plant)

The investigation will concentrate on production Line 1, which creates the child specific Honda City component known as the model T00A-4DR on the assembly line. This production line uses an autonomous spot welding robot to assemble the components. Figure 4.3 depicts the spot welding robot used by EPMB Peps-Jv Melaka Sdn. Bhd. on the manufacturing line.

Figure 4.3 Spot Welding Robot

4.3.1 Product Description

In the production Line 1, the manufacture product is Frame Comp Rear RH and Frame Comp Rear LH it is the model of Honda City with varient Petrol model T00A-4DR. The child part of Frame Comp Rear RH and Frame Comp Rear LH will be assembled at the station W1 and continous until W8 station for inspection quality. Figure

Figure 4.4 Final assembly of Frame Comp Rear RH

Figure 4.5 Final assembly of Frame Comp Rear LH

4.3.2 Overall process description

Table 4.1 Detail of Production Line 1

			Production Line 1: Line RH and Line LH
Workstation	**Child Parts**	**Operator**	**Robot**
W1	S01, S02 RH	OP1RH	R1
	S01, S02 LH	OP1LH	
W2	S03 RH	OP1RH	
	S03 LH	OP1LH	
W3	S04 RH	OP2RH	R2
	S04 LH	OP2LH	
W4	A10 RH	OP2RH	
	A10 LH	OP2LH	
W5	A20 RH	OP3RH	R3
	A20 LH	OP3LH	
W6	A30 RH	OP3RH	
	A30 LH	OP3LH	
W7	A50 RH	OP3RH	R4
	A50 LH	OP3LH	

Production line 1 has two operation that operate simultaneously time for assembly Frame Comp Rear RH and Frame Comp Rear LH. There is three operator (OP1, OP2 and OP3) for handling the spot welding robot in eight workstation

Operator (OP1) is the person in charge for a workstation W1 and W2. Operator (OP2) in charge for workstation W3, W5 and operator (OP3) in workstation W5 and W6. Final Assembly will be in W7 by operator (OP4).

Spot welding robot is programming with a first-come, first-served system. At the station where the child parts have been loaded into the jigs station is where the welding procedure starts. The two sides of the production lines each have access to five robots. By clicking the green button, the operator gives the robot the following job.

4.3.3 Target and Working Hour

The target of the company for production line 1 T00A-4DR in 10 hours is 180 units of product. Production line 4 only has a single shift every day. The shift will be from 8:00 a.m. until 5:30 p.m. All operators will have two fifteen-minute breaks during the twelve-hour shift and one forty-five-minute lunch break. Thus, the working hours are between ten hours and forty-five minutes every shift. Table 4.1 is shown the working hour for production line 4 T00A-4DR.

Table 4.2 Working Hour Production Line 1

Product Demand	180 unit per shift
Production Time	1 shift x 10 hours per day
Lunch Break	45 minute
Short Break per day	2 x 15 minutes

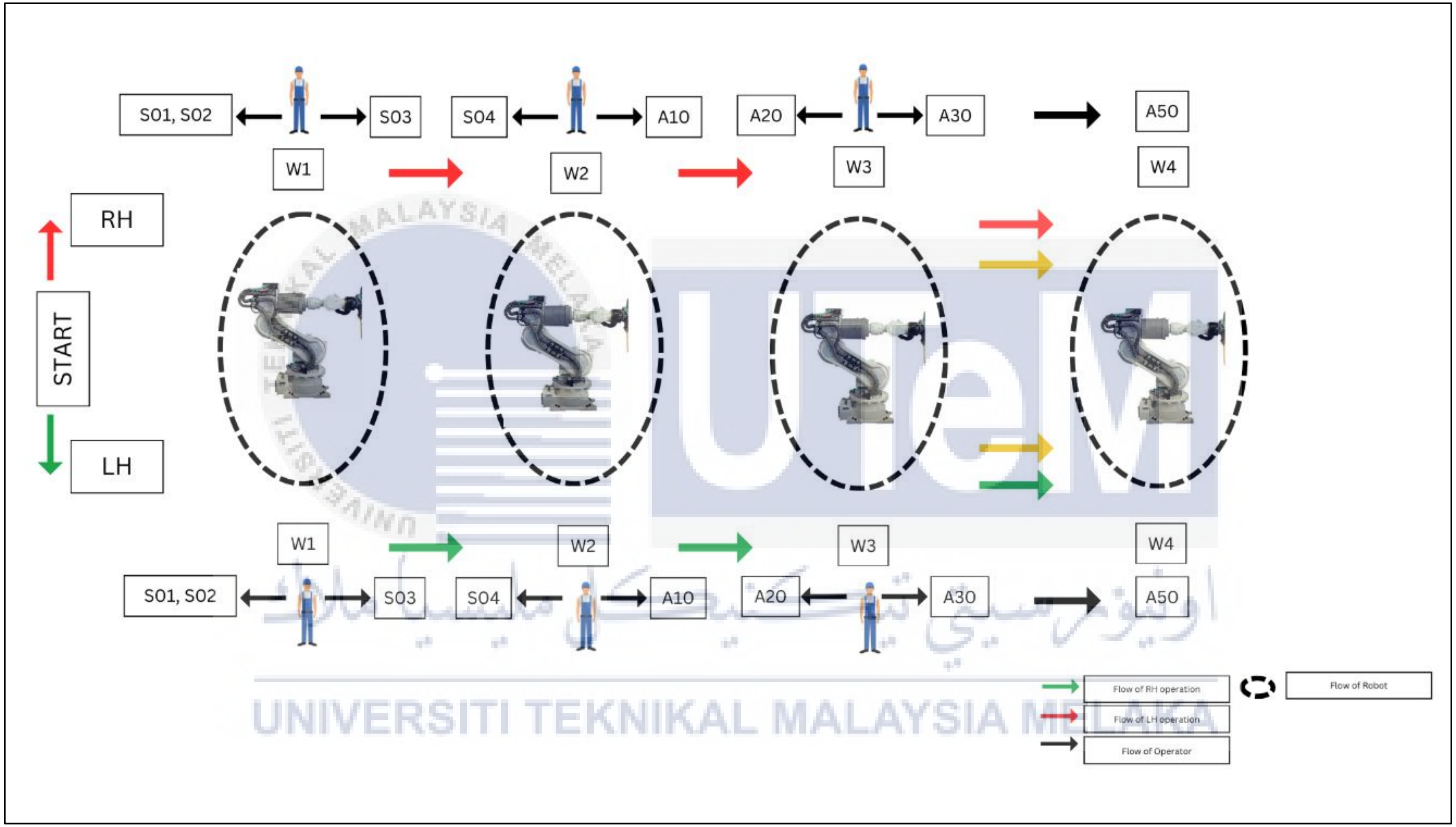


Figure 4.6 Layout of production line 1

Table 4.3 Data for Frame Comp RH

<table>
<tr><td colspan="2">Process: Spot Weilding</td><td colspan="6">Product Model: Frame Comp RH, T00A-4DR
Model: Honda City
Varient: Petrol</td><td colspan="5">Observer: Ahmad Aiman Haziq Bin Ahmad Syamsul</td><td>Date:
15/11/23</td></tr>
<tr><th>Station</th><th>Child Part</th><th colspan="5">CT, (sec)</th><th>No. Of Operator</th><th colspan="5">Setup Time, (sec)</th><th>Capacity</th></tr>
<tr><td rowspan="2">1</td><td>S01 RH
S02 RH</td><td>33.10</td><td>32.43</td><td>33.02</td><td>33.12</td><td>35.00</td><td rowspan="2">OP1</td><td>23.73</td><td>24.58</td><td>23.52</td><td>24.55</td><td>23.14</td><td rowspan="2">90</td></tr>
<tr><td>S03 RH</td><td>50.89</td><td>52.88</td><td>59.32</td><td>69.57</td><td>69.83</td><td>15.49</td><td>17.14</td><td>16.25</td><td>15.68</td><td>15.76</td></tr>
<tr><td rowspan="2">2</td><td>S04 RH</td><td>22.11</td><td>20.98</td><td>23.11</td><td>23.32</td><td>23.19</td><td rowspan="2">OP2</td><td>12.38</td><td>11.85</td><td>12.72</td><td>12.30</td><td>12.60</td><td rowspan="2">90</td></tr>
<tr><td>A10 RH</td><td>71.72</td><td>71.92</td><td>71.61</td><td>63.89</td><td>63.57</td><td>15.89</td><td>16.39</td><td>15.20</td><td>15.55</td><td>15.85</td></tr>
<tr><td rowspan="2">3</td><td>A20 RH</td><td>55.47</td><td>53.43</td><td>54.66</td><td>54.58</td><td>54.73</td><td rowspan="3">OP3</td><td>21.10</td><td>22.01</td><td>21.62</td><td>21.19</td><td>20.87</td><td rowspan="2">90</td></tr>
<tr><td>A30 RH</td><td>30.75</td><td>31.42</td><td>30.58</td><td>32.31</td><td>30.69</td><td>18.76</td><td>18.20</td><td>18.50</td><td>18.74</td><td>18.44</td></tr>
<tr><td>4</td><td>A50 RH</td><td>73.61</td><td>80.24</td><td>81.55</td><td>81.33</td><td>81.35</td><td colspan="5">-</td><td>90</td></tr>
<tr><td>Demand</td><td colspan="6">180</td></tr>
<tr><td>Capacity</td><td colspan="6">344</td></tr>
</table>

Table 4.4 Data for Frame Comp LH

Process: Spot Weilding	**Product Model:** Frame Comp LH, T00A-4DR **Model:** Honda City **Varient:** Petrol	**Observer:** Ahmad Aiman Haziq Bin Ahmad Syamsul	**Date:** 15/11/23

Station	**Child Part**	**CT, (sec)**					**No. Of Operator**	**Setup Time, (sec)**					**Capacity**
1	S01 LH S02 LH	32.40	32.56	33.42	33.24	35.33	OP1	22.73	23.58	23.02	23.55	23.04	90
	S03 LH	51.89	52.82	58.32	69.22	69.43		16.49	16.14	16.22	16.10	15.93	
2	S04 LH	21.10	21.80	22.21	23.12	23.02	OP2	12.28	12.85	12.11	12.21	12.20	90
	A10 LH	72.71	71.23	71.50	63.19	62.22		15.56	15.34	15.22	15.51	15.35	
3	A20 LH	54.47	53.33	53.76	54.18	54.23	OP3	21.09	22.10	21.34	21.22	20.18	90
	A30 LH	30.15	30.22	30.11	32.30	31.33		18.22	18.56	18.39	18.79	18.42	
4	A50 LH	72.61	79.24	80.55	80.33	80.55		-					90

Demand	180
Capacity	325

Table 4.5 Data Average for Frame Comp RH & LH

Process: Spot Weilding		**Product Model:** Frame Comp RH, T00A-4DR **Model:** Honda City **Varient:** Petrol					
Robot	**Child Part**	**Average time (sec)**					
		CT			**Setup Time**		
		RH	**LH**	**Total**	**RH**	**LH**	**Total**
1	S01 RH/LH S02 RH/LH	33.39	33.39	66.78	23.90	23.18	47.08
	S03 RH/LH	60.50	60.34	120.84	16.06	16.18	32.24
2	S04 RH/LH	22.54	22.25	44.79	12.37	12.33	24.70
	A10 RH/LH	68.54	68.17	136.71	15.78	15.40	31.18
3	A20 RH/LH	54.57	53.99	108.56	21.36	21.19	42.55
	A30 RH/LH	31.15	30.82	61.97	18.53	18.48	37.01
4	A50 RH/LH	79.62	78.66	158.28	-		
TOTAL		350.31	347.62	697.93	108	106.76	214.76

4.4 Available time

Table 4.6 Available Time

Information	Calculation
Product demand = 180 unit per day	Available Time = 10 hours x 60 minute = 600 minute x 60 seconds = 36000 seconds
Production Time = 12 hour per shift	
Lunch Break = 45 minute x 60 seconds = 2700 seconds	Total available Time = 36000 seconds – 2700 seconds – 1800 seconds = 31500 seconds
Short Break per day = 2 x 15 minute = 30 minute x 60second = 1800 seconds	

4.4.1 Process cycle time

Takt time is the rate at which the production process must be completed in order to meet the goal. Cycle time must be calculated using the total time available and the level of consumer demand.

Table 4.7 Calculation for Cycle Time

Formula	Calculation
Cycle Time, CT = $\frac{\text{Production Time per day}}{\text{Required unit of production}}$	Cycle Time, CT = $= \frac{31500}{180\ unit\ per\ day}$ = 175 sec per unit

4.4.2 Minimum Workstation

Mininum worstations that is the actual number of workstations required for this operation. The cycle time and takt time is required to calculate the minimum number of workstations.

Table 4.8 Calculation for Minimum Workstation

Formula	Calculation
Takt time = seconds $\frac{\text{Takt time}}{\text{Cycle Time, CT}}$	Ni $= \frac{697.93}{175\ sec}$ = 3.98 ≈ 4 workstation

4.5 Existing production line Based on standard time and task time

The computed standard time and takt time are used to create a graph that depicts the current manufacturing line. The graph indicates that every workstation is below the takt time. This demonstrates that all workstations met the target by finishing the task within the allocated time.

Figure 4.7 Histogram Data Existing Production Line 1

4.6 Model Simulation For Existing Production Line

Model translation must be used in order to depict the production system. Cycle time estimates for each product must be provided as input data in order to support the simulation model. One can estimate how long it should take for a batch of components to arrive at the inspection station by measuring the amount of time needed to make one unit of the finished product.

Model simulation is used to illustrate the simulation model's notion. The intricacy of the system and the availability of data are essential for developing a simulation model. Two simulation models one for the current inspection station and the other for the suggested configuration will be used in this investigation. These models will be built using the manufacturing line's present layout, specifically manufacturing Line 1.

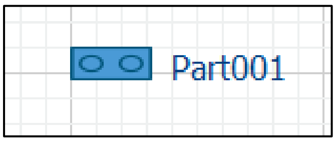
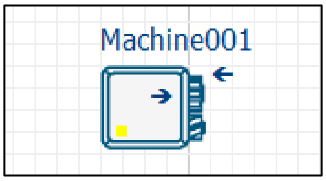
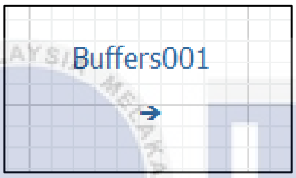
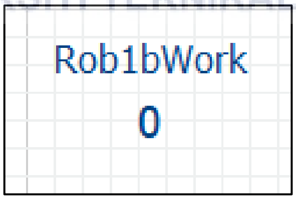
4.6.1 Model logic

These models are designed to be easily modified and to make it easier to observe the corresponding outputs and manipulate the input parameters. The cornerstone for accomplishing the model objectives is the development of the simulation model that mimic with the actual layout, which direct the information and data collection process during the study. Throughout the investigation, the model incorporated and consistently used the following points.

4.6.2 Element of the Models

A good simulation model should have an extensive set of components, features, logic, and attributes. The WITNESS software accomplishes this by simulating real-life operations using a variety of components, which are referred to as elements. These components are adaptable enough to depict both concrete things like labour and machinery as well as abstract ideas like variables and attributes.

Table 4.9 Element in The Witness

Elements	Elements Display in Witness	Description
Parts (Entities)		Discrete objects that move within the model are represented by parts. It moves through the model and could be a representation of tangible elements.
Machines (Activities)		Strong components that can be used to symbolise anything that receives parts (entities) from one place, processes them, and then sends them on to another.
Buffers (Queues)		Places where Parts (Entities) can be held.
Labor (Resources)		One resource that can be required for a task or process to be completed is labour. For example, loading, unloading, setting up, and recording model tasks.
Variable		Variables are frequently used to store data that could change while the model runs, such as text, integers, and element names. Variables' values can be evaluated from any point in the model.
Conveyor		Conveyors are used in facilities to convey Parts (Entities), usually from one fixed place to another. Parts (Entities) travel forward on a conveyor after entering it from the back.

4.6.3 Create Simulation Model

Create a new model in the Witness Horizon Software to allow enter the layout windows. There is designer element for the purpose to put each element to create a model. In this simulation, each element has their own role to create a production line that mimic with the actual production line in factory of Peps-JV. Put all the elements that needed to create the model. Figure 4.8 show the Designer Element and Figure 4.9 show the details of elements in the layout windows.

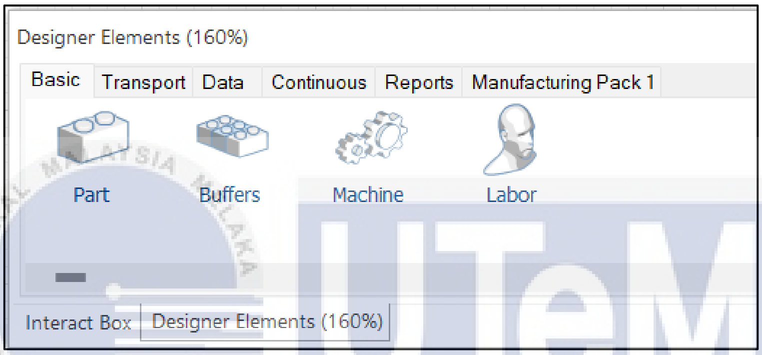


Figure 4.8 Designer Element of Simulation

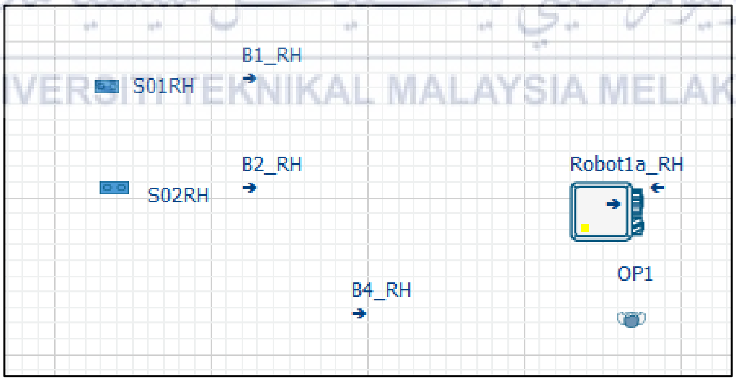


Figure 4.9 Element in the Simulation

4.6.4 Line up the production line 1

Drag all the element to the layout windows that mimic with the actual produciton line. Name all the element with the suitable name that can used it for clarify in the setting for each element.

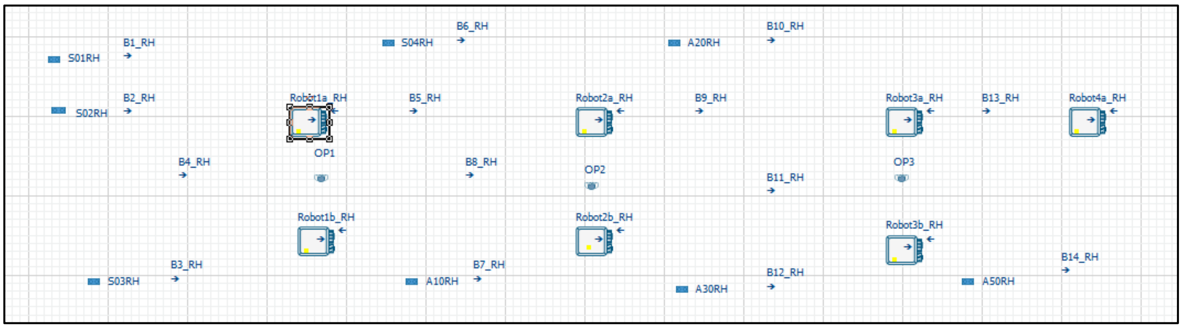


Figure 4.10 Actual Production Line 1 setup

4.6.5 Set Input and Output Rule

Each the element needed to assign the input and output rule to clarify the element flow in the model. Connect the output rule of part to push the part to the buffer for hold the part before enter the machine for process. Connect the Machine Input rule to the buffer as the machine is to accept part pull from buffer. Assign the operator based on actual production line 1. Figure 4.10 show the element flow of model

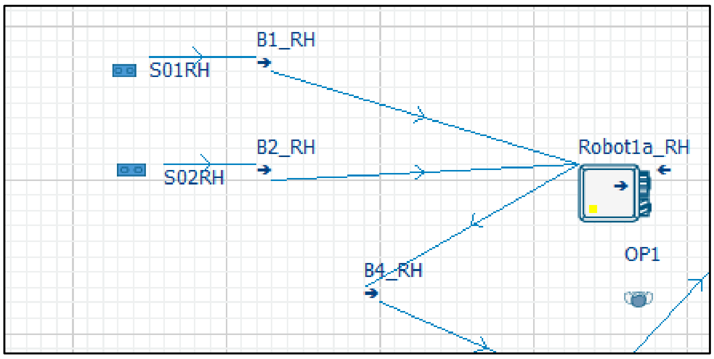


Figure 4.11 Connect Flow of Element

4.6.6 Setting for each Element in simulation model

Set the Part as a Active type and for all inter Arrival time set to one with lot size one because for each part assembly in the machine is one part of each child part. There is a part that not attach with any buffer and machine for a simulation to read as a variable for declare at as a Sub Combination for each part assemble.

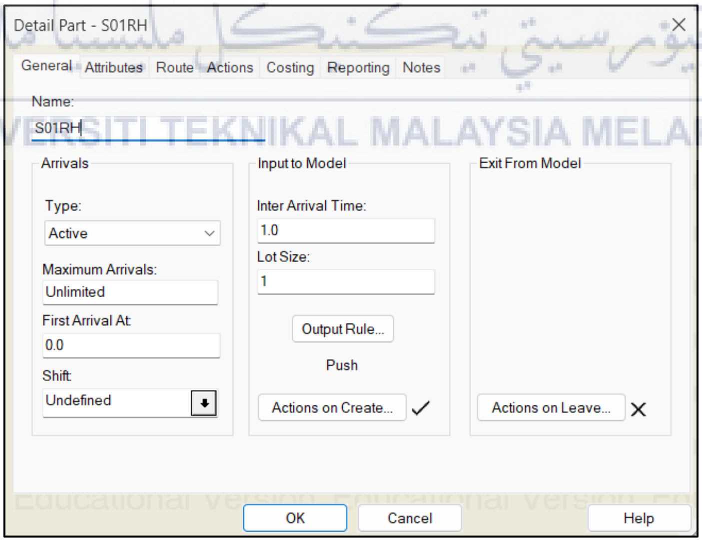


Figure 4.12 Setting of Parts

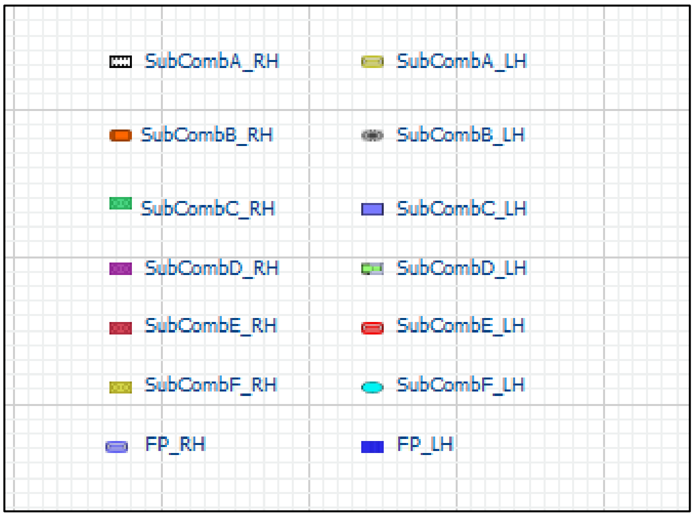


Figure 4.13 Sub Combination of each part assemble

The setting for buffer set with the 30 capacity and the output is set to conditional for the purpose of coding at the machine to declare the output rule will push when the Rob1bWork = 0. This declaration of conditional is set only in B1_RH, B2_RH, B5_RH, B6_RH, B9_RH, B10_RH, B1_LH, B2_LH, B5_LH, B6_LH, B9_LH, B10_LH and the rest of the buffer set to output option to the first.

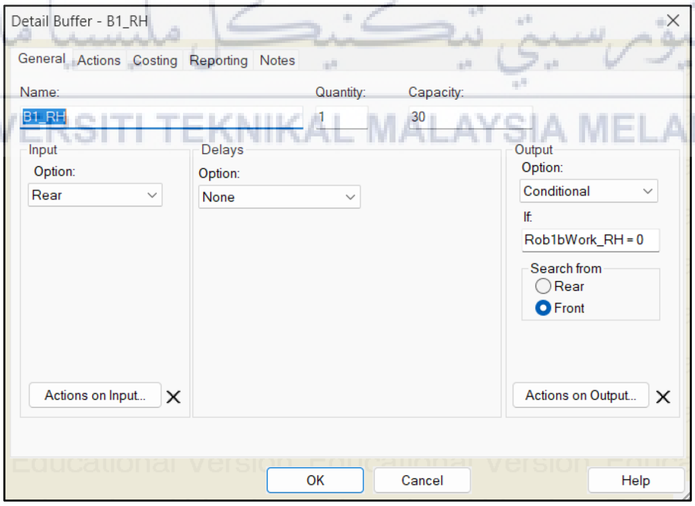


Figure 4.14 Setting of Buffer

The setting for each machine is set to the type of assembly machine with quantity is two because each machine only accepted two part only for assembly and the input rule set for a sequence /wait that allow machine assembly when the part form buffer push to the machine until all part that connect to the machine is arrived or machine will wait.

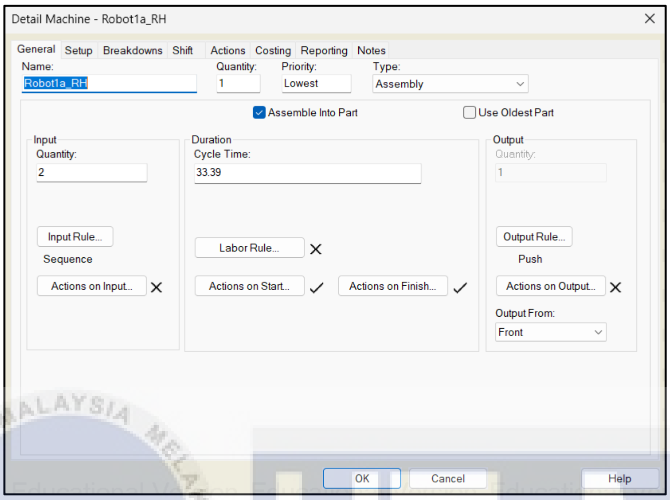


Figure 4.15 Setting of Machine

There is three operator that handle for four spot welding robot. Each of operators have 1.5 allowance. The operator only set at the machine as a setup for change part for each machine in the simulation.

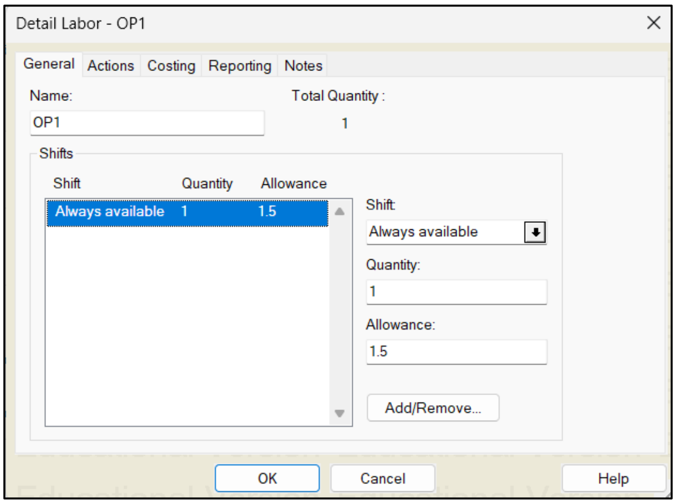


Figure 4.16 Setting for Operator

For this part the setup for integer is only applied in the machine and buffer to declare the variable in the machine action on start and action on finish and the conditional output for buffer.

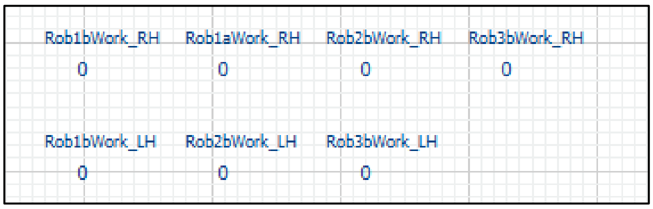


Figure 4.17 Data Integer

4.6.7 Running the Model

To run the model with better efficiently, the inputs that were considered:

(a)Part Inter-Arrival Time

Because the product is an integrated circuit chip that is only a tiny piece in size, the simulation study models the Inter-Arrival Time for the part launch as a very small and consistent arrival.

(b) Warm-up Period

In order to create a realistic setting and gather any statistical data, a warm-up time must be included. It is necessary to determine how long the warm-up time should last if the response is negative. At time zero, normal working conditions were accurately reflected in our models.

In order to guarantee that a steady level is reached prior to the start of data collection, a warm-up phase is still included.

(c) Runtime

After the warmed-up of the assembly production line 1, the simulatoin run based on the user decide how long the simulation run until finish the simulation by referering the parameter setting of time for this simulation.

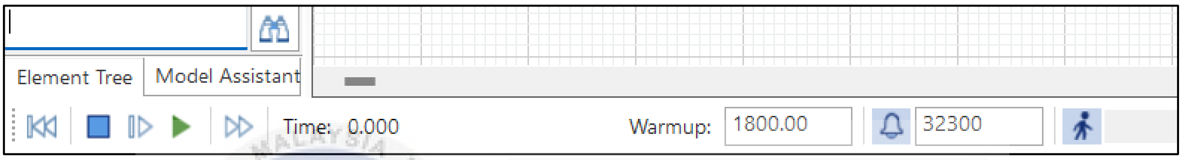


Figure 4.18 Parameter Setting for Time

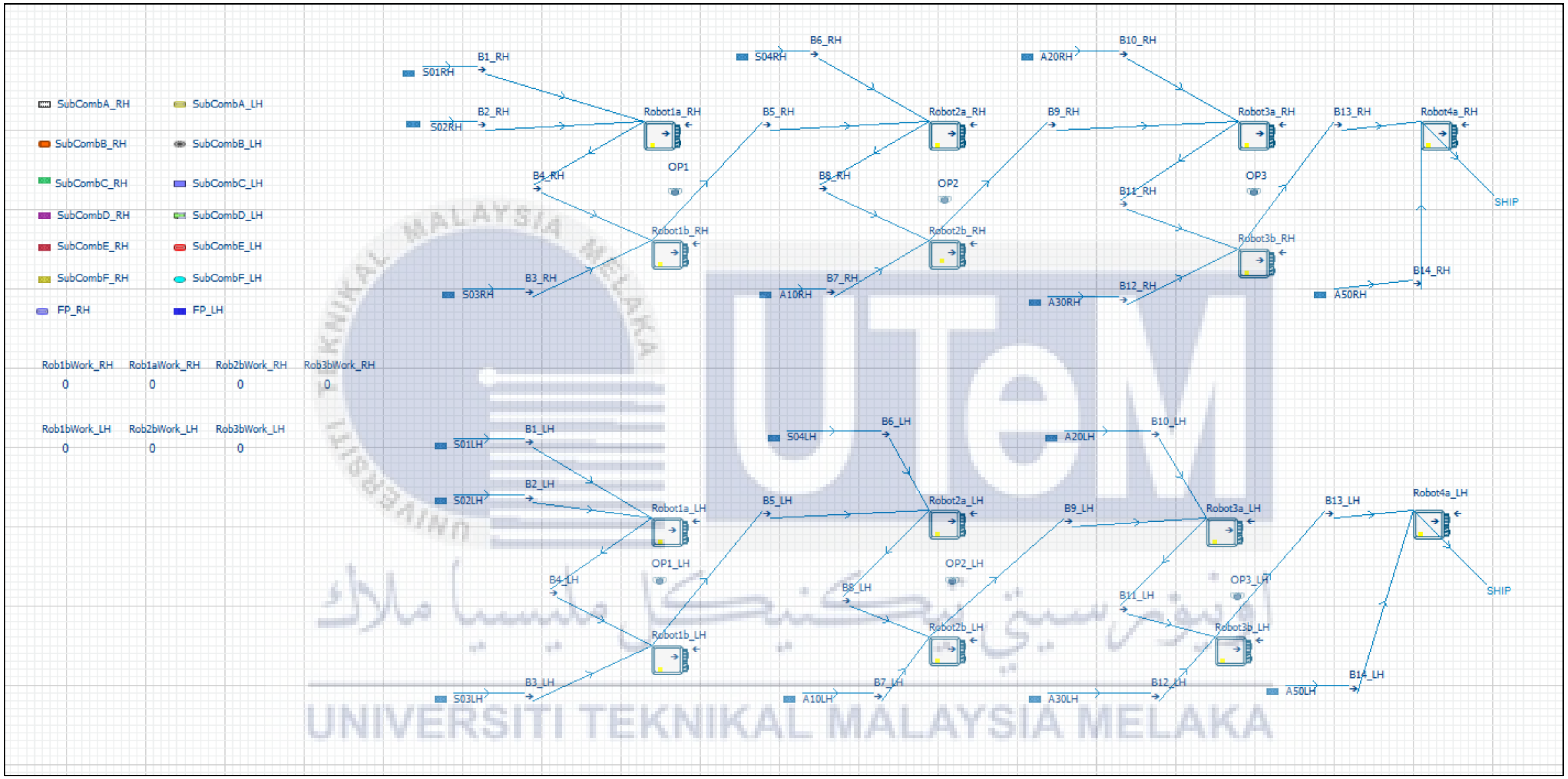


Figure 4.19 Existing Simulation Model of Production Line 1

4.6.8 Result of Simulation

After the simulation model has been run, the outcome is produced. As indicated in the simulation's results in Figure 4.20 Final Result of Assemble Product are 335 for Frame Comp RH and 338 for Frame Comp LH units per shift. It produces a product that is 99.40% identical to the actual output from the production line. Based on each side percentage b comparing with existing layout data is for Frame Comp RH is 97.38% and Frame Comp LH is 96.15%. Figure 4.21 show the Comparison Capacity of Existing and Simulation. Consequently, this simulation allows for the determination of the manufacturing line's current state and its current production capabilities.

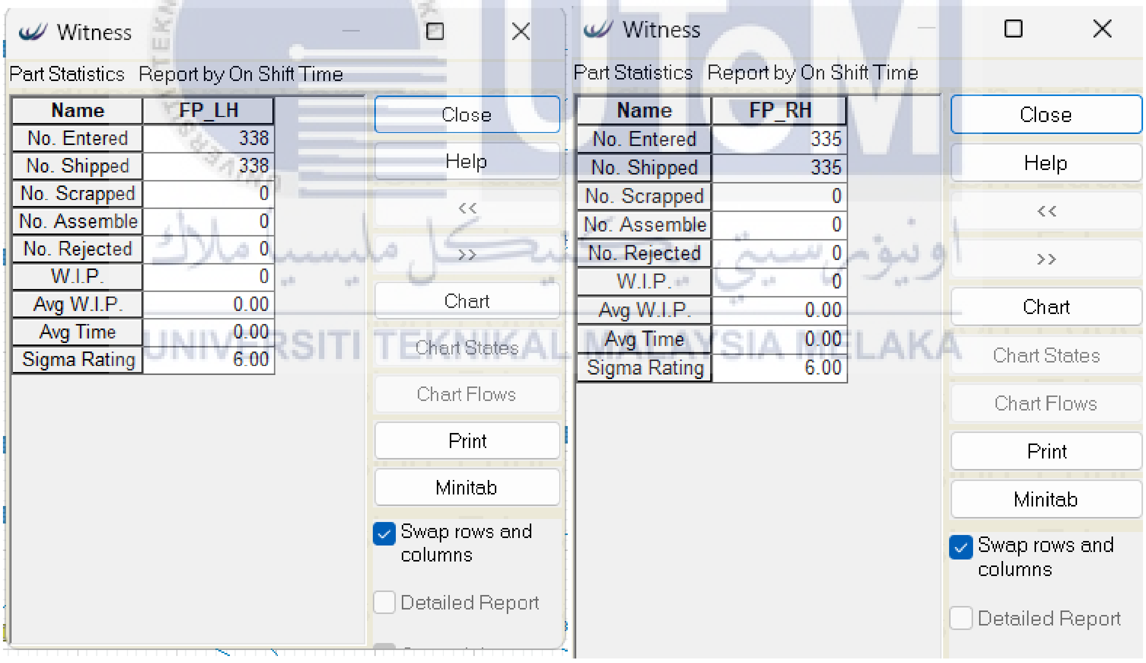


Figure 4.20 Final Result Of Assemble Product

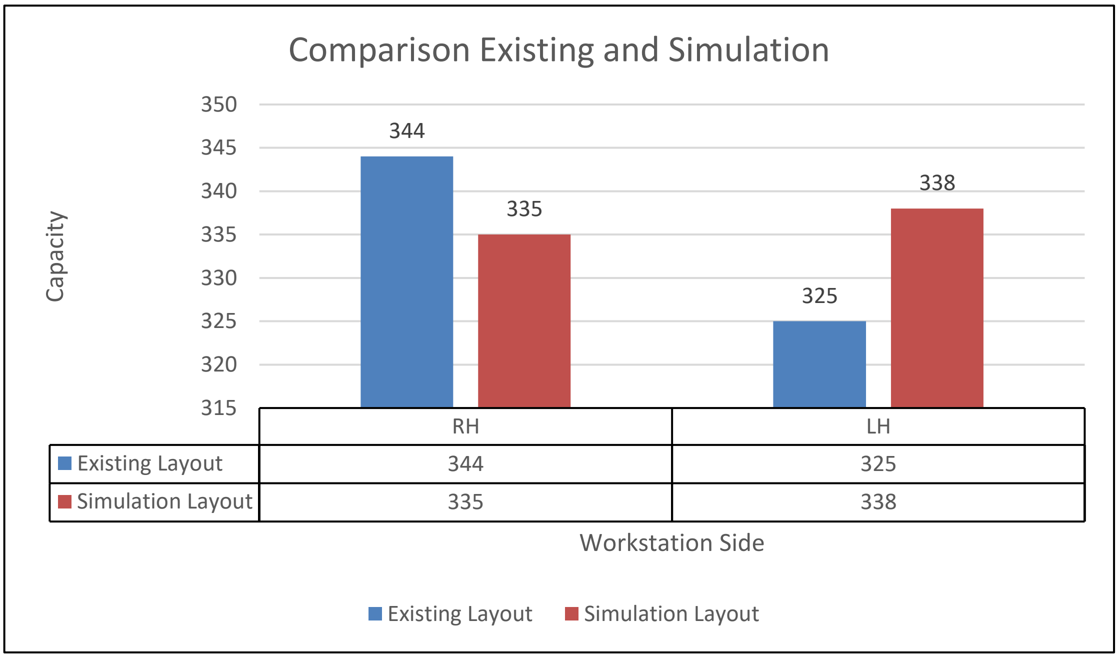


Figure 4.21 The Comparison Capacity of Existing and Simulation

4.6.9 Verified

By comparing the process flow of the simulation to an established conceptual model, the simulation is verified. In addition, data from the model conceptualization was supplied into the simulation model concerning process flow, cycle time, setup time, and other variables.

4.6.10 Validation

Determine whether or not a model faithfully represents the system in question by going through the procedure of validation. When compared to the output of the production model, which is 344 for Frame Comp RH and 325 for Frame Comp LH units per shift is 95% consistent. The 12-hour shift on the assembly line managed to turn out 335 for Frame Comp RH and 338 for Frame Comp LH units per shift.

4.7 Discussion of result Simulation

The data collecting and processing time needed for bottleneck process analysis and Witness Horizon simulation to increase production line productivity are covered in this chapter. Software for Witness Horizon simulation will be employed to undertake an improvement solution after the data has been analysed. The three primary topics that require discussion in this area are the use of Witness Horizon simulation software, line balancing improvement, and productivity enhancement.

4.7.1 Application of Line Balancing for Improvement

According to the result of the actual Production Line 1, The total of workstation is eight workstation from right side and eight workstation from left side. The histogram show the finding analyse the result of cycle time and setup time after the improvement in Figure 4.22 existing of the production line 1. From the Figure 4.7 histogram, the value of the cycle time for S04 RH/LH and A30 RH/LH is the lowest cycle time compared with other workstation. For this reason the workstation of S04 RH/LH and A30 RH/LH is combine with other workstation that suitable to reduce the workstation. For S04 RH/LH workstation combined with S03 RH/LH workstation and for A30 RH/LH workstation combined with A20 RH/LH workstation.

Based on the result after improvement, the value of the cycle time for all workstation still not exceed the takt time. The production still can meet the customer demand without any problem. The combination of workstation reduce the workstatioin and the time of transfering the part to other station.

Futhermore, The another suggestion for improving the line balancing by adding the conveyor to transfering the part from robot station 1 to next robot station. Figure 4.24 Production Line 1 After Improvement Add Conveyor show the improvement in the capacity machine. The buffer B5_RH, B9_RH and B13_RH, B5_LH, B9_LH and B13_LH is changed with the conveyor to show the movement the part from robot station 1 next robot station. From this suggestion the output for capacity is increased in 1.45%.

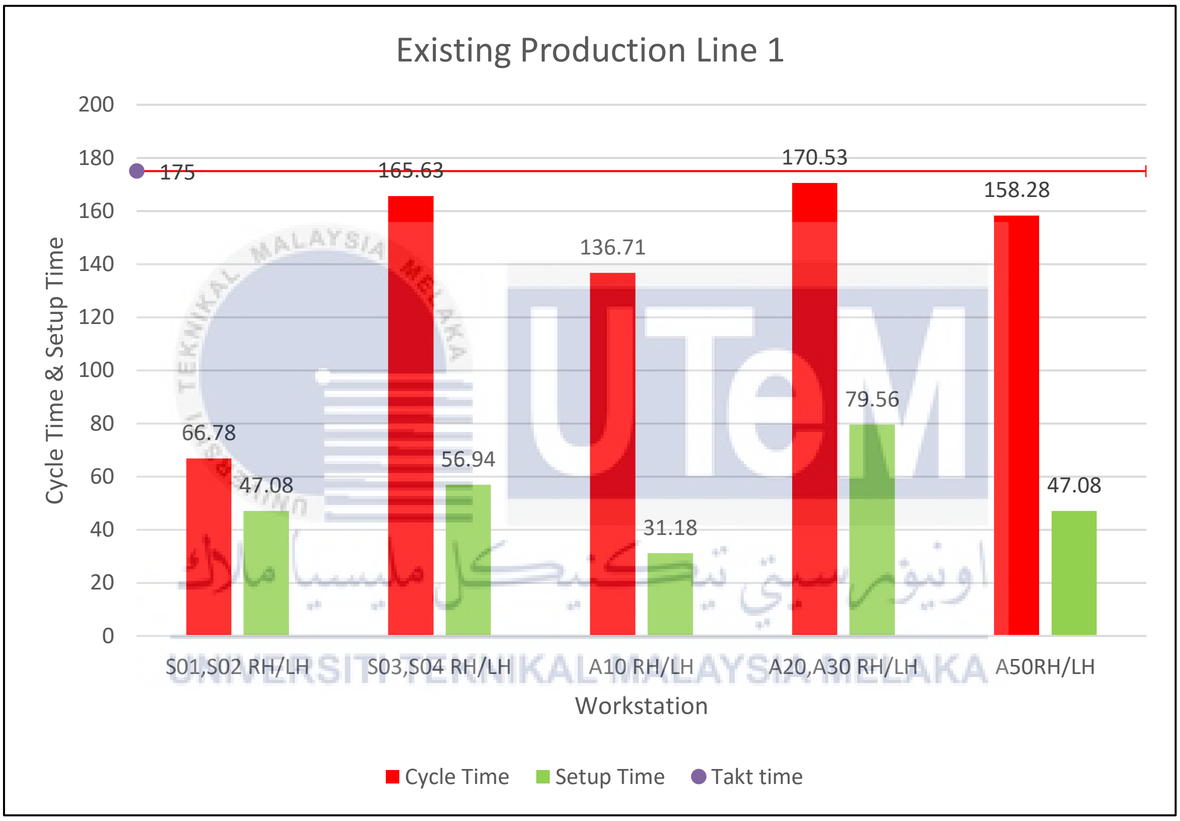


Figure 4.22 Production Line 1 After Improvement Reduce Workstation

The result of Figure 4.23 and Figure 4.24 show the comparison of final product assembly before and after improvement by using the suggestion of reduce the workstation and add conveyor as a replaced with the buffer to transfer part assemble. It give an impact of capacity for the production line 1 to complete the assemble the final product without go through the QC check.

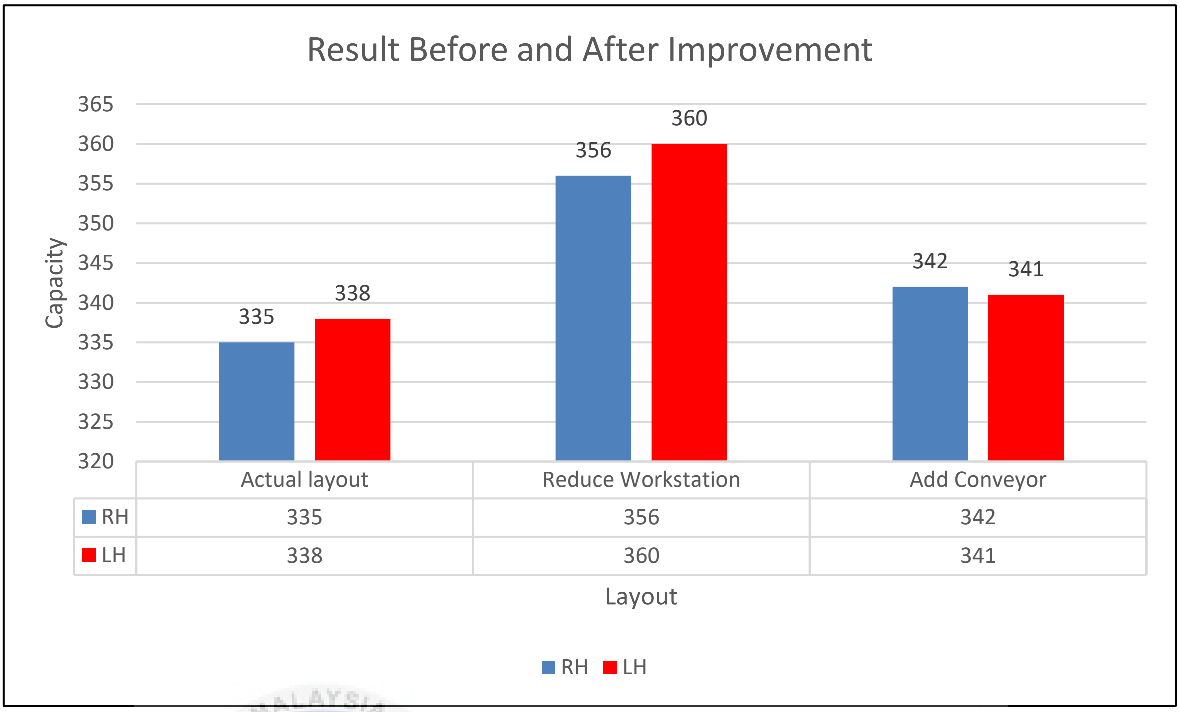


Figure 4.23 Result Capacity After Improvement

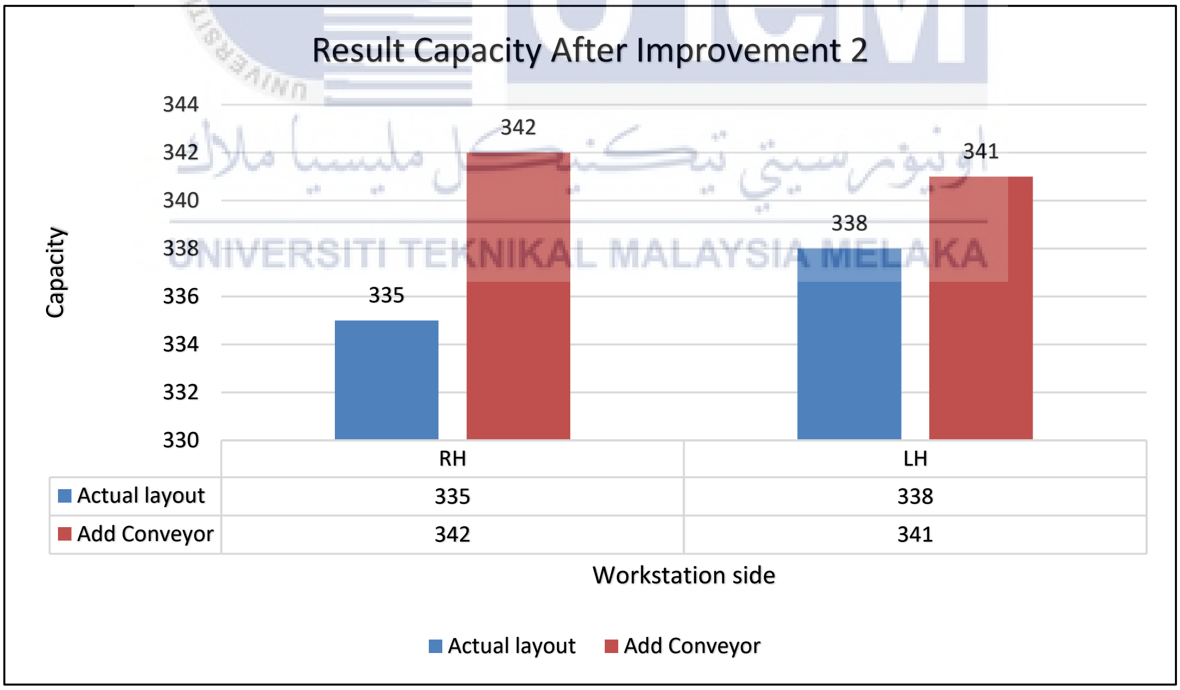


Figure 4.24 Production Line 1 After Improvement Add Conveyor

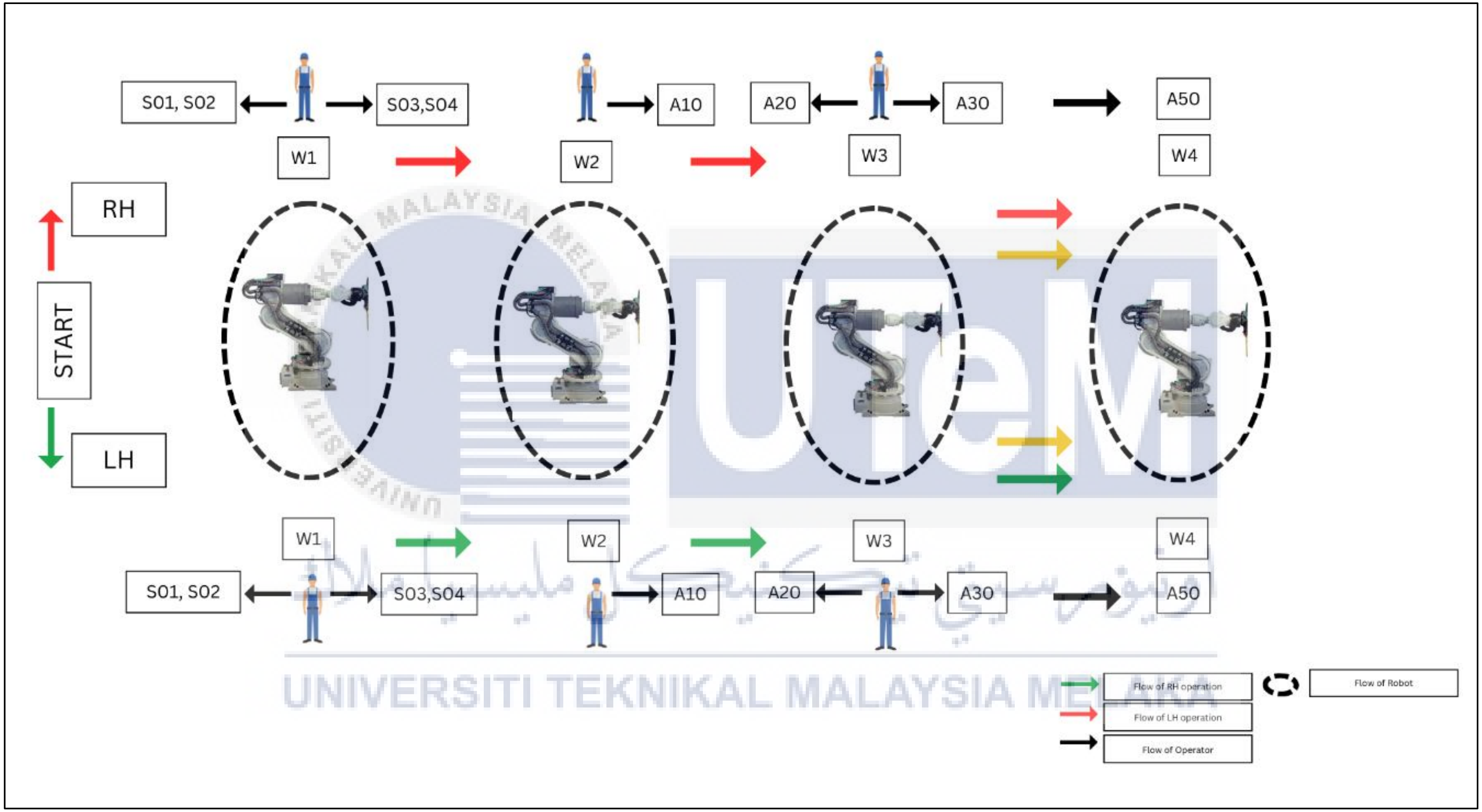


Figure 4.25 Layout Production Line After Reduce Workstation

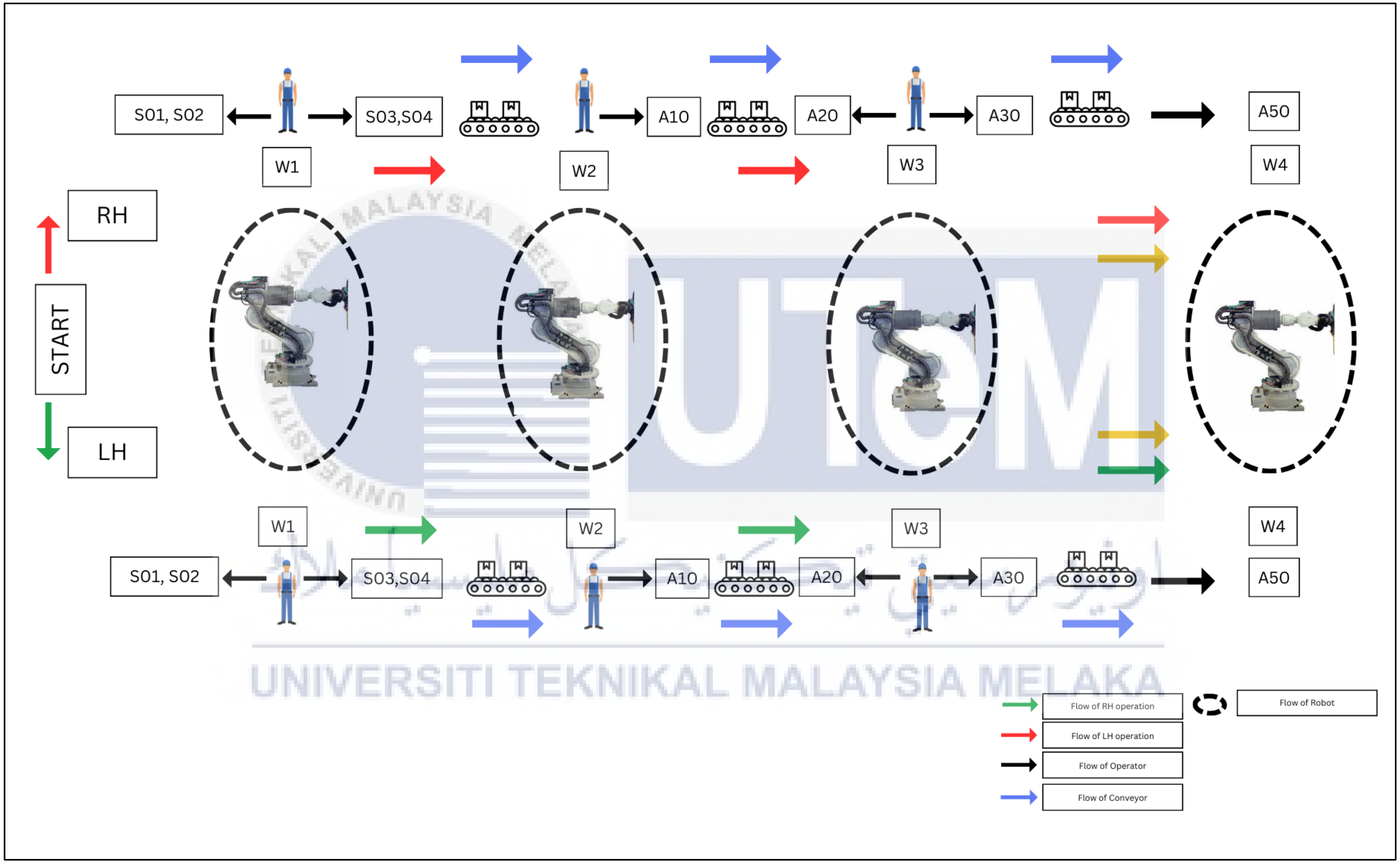


Figure 4.26 Layout Production Line After Add Conveyor

4.7.2 Productivity Improvement

The output of the existing production line, as determined by a simulation model, is 335 products for Frame Comp Rear RH and 338 goods for Frame Comp Rear LH each shift. Alternatively, a greater overall output of 356 products for Frame Comp Rear RH and 360 products for Frame Comp Rear LH per shift is predicted by the upgraded simulation model, which has a shorter cycle time and a changed layout. To better optimise manufacturing, it has been suggested that a conveyor be added to the simulation setup. As a result, the capacity for Frame Comp Rear RH and Frame Comp Rear LH would increase to 342 and 341 end products, respectively.

Enhancements to the workstations and shorter cycle times in the current manufacturing line replicate the beneficial adjustments suggested in the alternative option. The operator discloses an hourly pay of RM4. The number of output products has significantly risen as a result of the applied modifications, enhancing productivity. In particular, the productivity increases for Frame Comp Rear RH and LH after workstation reduction are 6.27% and 6.51%, respectively. Furthermore, productivity increases of 1.18% and 0.89%, respectively, for Frame Comp Rear RH and LH are brought about by the insertion of the conveyor.

$$\text{Formula piece per RM productivity} = \frac{Output}{Salary\ x\ hour\ x\ No\ Of\ Operator}$$

Formula for Calculation of Productivity

Table 4.10 Productivity For Frame Comp RH

Productivity		
Existing Production	After Reduce Workstation	After Add Conveyor
$=\frac{335}{RM4*10\ hours*6\ Operator}$ = 1.40 piece per RM	$=\frac{356}{RM4*10\ hours*6\ Operator}$ = 1.48 piece per RM	$=\frac{342}{RM4*10\ hours*\ 6\ Operator}$ = 143 piece per RM

Table 4.11 Productivity For Frame Comp LH

Productivity		
Existing Production	After Reduce Workstation	After Add Conveyor
$=\frac{338}{RM4*10\ hours*6\ Operator}$ = 1.41 piece per RM	$=\frac{360}{RM4*10\ hours*6\ Operator}$ = 1.5 piece per RM	$=\frac{341}{RM4*10\ hours*\ 6\ Operator}$ = 1.42 piece per RM

Side	Reduce Workstation	Add Conveyor
RH	Percentage Increased Productivity = $\frac{New\ Output-Old\ Output}{Old\ Output}$ x 100 $=\frac{356-335}{335}$ x 100 = 6.27%	Percentage Increased Productivity = $\frac{New\ Output-Old\ Output}{Old\ Output}$ x 100 $=\frac{342-335}{335}$ x 100 = 1.18%
LH	Percentage Increased Productivity = $\frac{New\ Output-Old\ Output}{Old\ Output}$ x 100 $=\frac{360-338}{338}$ x 100 = 6.51%	Percentage Increased Productivity = $\frac{New\ Output-Old\ Output}{Old\ Output}$ x 100 $=\frac{341-338}{338}$ x 100 = 0.89%

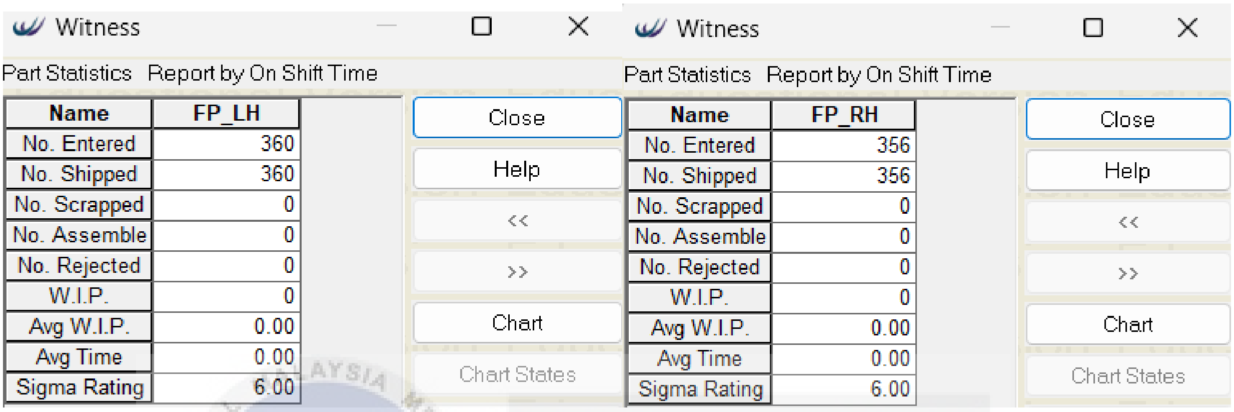
4.7.3 Witness Simulation Software Improvement

Witness Horizon Simulation is employed in this research project to analyse the status of the T00A-4DR production line and suggest a remedy. Simulation plays a critical role in the transition to Industry 4.0 and will continue to do so as industrial technology advances. There is no denying the strong relationship between financial success and simulation technology, which also greatly improves the performance and efficiency of the business. The incorporation of Witness Horizon simulation software streamlines data gathering and aids in production line scheduling.

When developing and testing prototypes of production line behaviours, Witness Horizon software comes in quite handy. Notable outcomes were obtained from the production line's reduction of workstations and cycle time. Engineers are better able to understand how variability functions in the manufacturing process thanks to the statistical analysis of Witness Horizon simulation data. To sum up, simulation tools are essential to the company's journey towards Industry 4.0 since they allow it to meet client needs as quickly and cheaply as possible, which boosts its competitiveness worldwide.

The model is run, and the simulation results are produced. Following the recommendation to decrease workstations on both sides, the output for Frame Comp Rear RH is 356 products after making changes, and for Frame Comp Rear LH, it is 360 items per shift. The second proposal increases the capacity from 335 final products for Frame Comp Rear RH and 338 final products for Frame Comp Rear LH to 342 final products and 341 final products per shift, respectively, by adding a conveyor to production line one. While certain buffers are removed and a conveyor is added, the Witness Horizon Simulation model

It is possible to ascertain the manufacturing line's present condition as well as its current production capability thanks to this simulation. The Witness Horizon Simulation design following line balancing improvement is shown in Figures 4.27 and 4.28.has the same layout as the original.



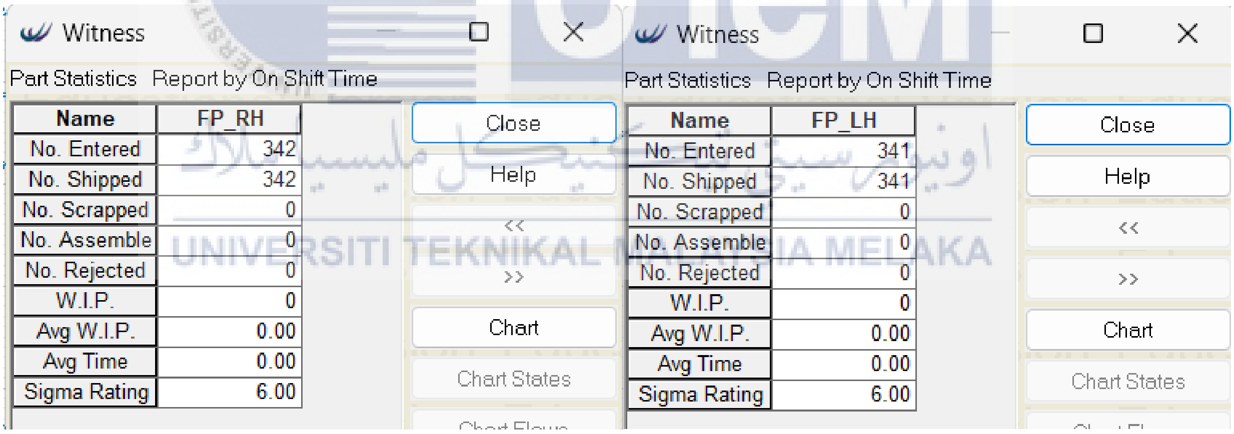
Witness — Part Statistics Report by On Shift Time

Name	FP_LH
No. Entered	360
No. Shipped	360
No. Scrapped	0
No. Assemble	0
No. Rejected	0
W.I.P.	0
Avg W.I.P.	0.00
Avg Time	0.00
Sigma Rating	6.00

Witness — Part Statistics Report by On Shift Time

Name	FP_RH
No. Entered	356
No. Shipped	356
No. Scrapped	0
No. Assemble	0
No. Rejected	0
W.I.P.	0
Avg W.I.P.	0.00
Avg Time	0.00
Sigma Rating	6.00

Figure 4.27 Product Output After Improvement 1



Witness — Part Statistics Report by On Shift Time

Name	FP_RH
No. Entered	342
No. Shipped	342
No. Scrapped	0
No. Assemble	0
No. Rejected	0
W.I.P.	0
Avg W.I.P.	0.00
Avg Time	0.00
Sigma Rating	6.00

Witness — Part Statistics Report by On Shift Time

Name	FP_LH
No. Entered	341
No. Shipped	341
No. Scrapped	0
No. Assemble	0
No. Rejected	0
W.I.P.	0
Avg W.I.P.	0.00
Avg Time	0.00
Sigma Rating	6.00

Figure 4.28 Product Output After Improvement 2

4.7.4 Selection for the best Layout

Table 4.12 Option of Layout Simulation

Option	Layout	Workstation Side	Capacity	Productivity	Operator	
1	Simulation	RH	335	1.40 piece per RM	6	
		LH	338	1.41 piece per RM		
2	Improvement 1: Reduce Workstation	RH	356	1.48 piece per RM	6	✓
		LH	360	1.5 piece per RM		
3	Improvement 2: Add Conveyor	RH	342	143 piece per RM	6	
		LH	341	1.42 piece per RM		

Based on the data for this research, the best layout of simulation that meet the actual layout with the best output and improvement is by the layout of simulation improvement one with reduce the workstation. By comparing the result of capacity, productivity and operator the option one is the best layout. Even all layout had the same amount of operator but still option one is the best layout.

4.7.5 Witness Module After Line Balancing Improvement

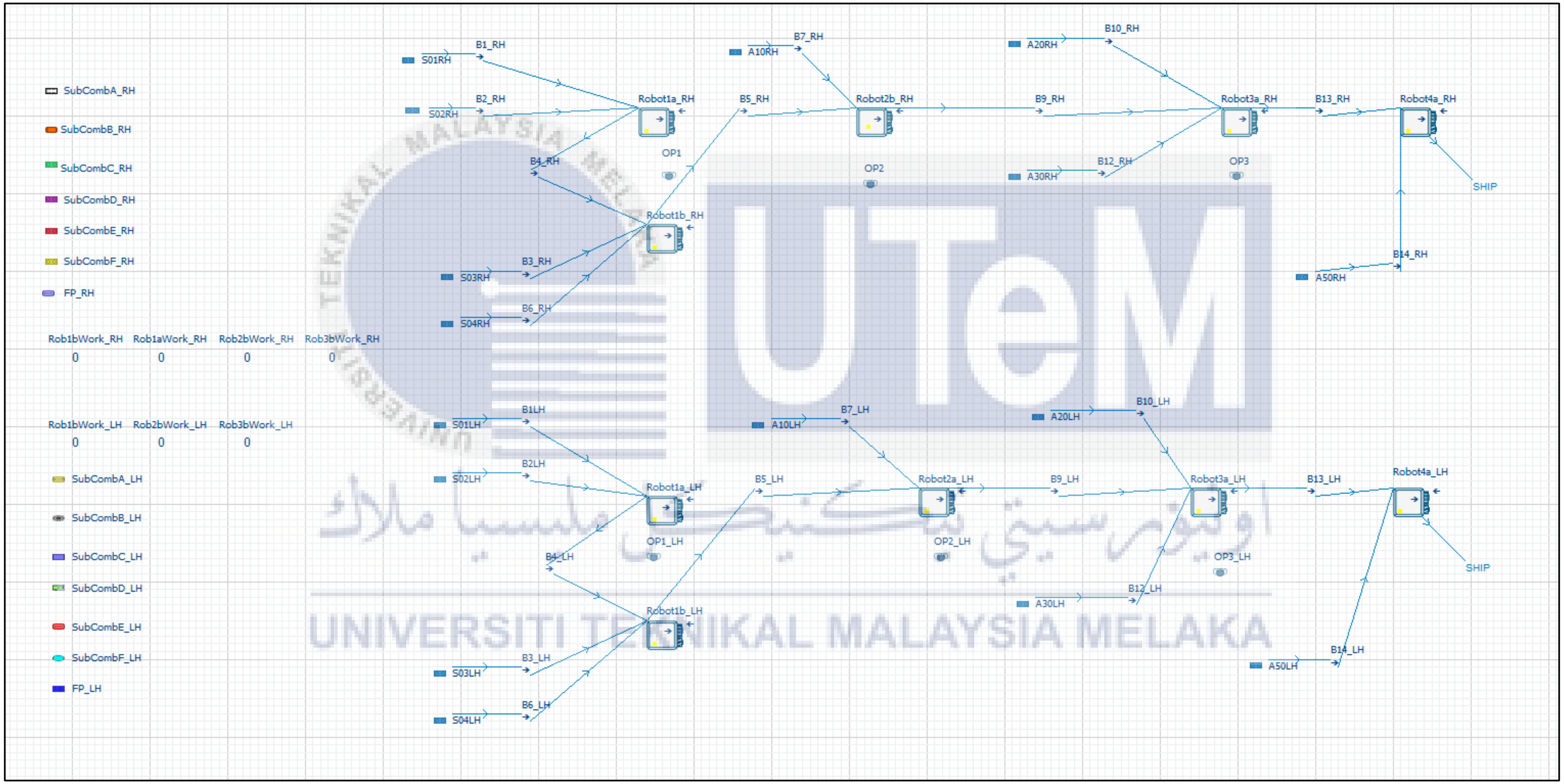


Figure 4.29 Layout After Improvement 1 for Production Line 1

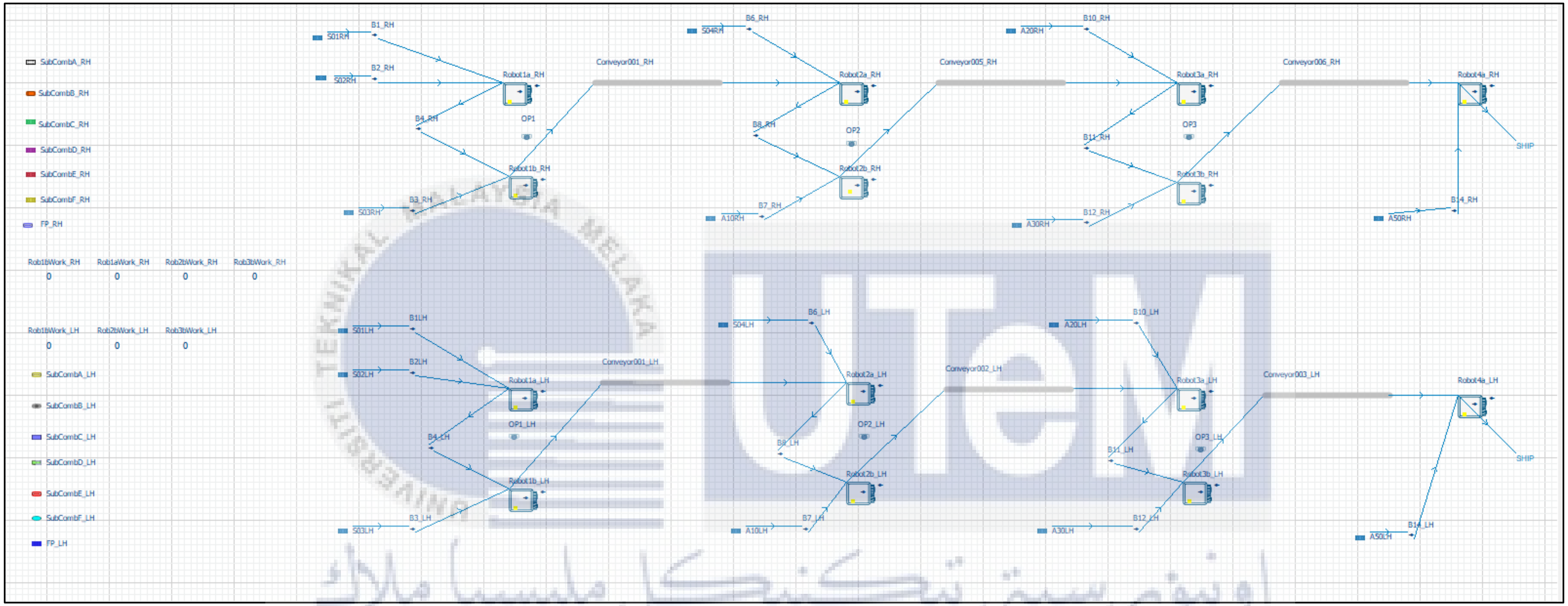


Figure 4.30 Layout After Improvement 2 for Production Line 1

4.8 Summary

This chapter looks at the information gathered and identifies the areas that are bottlenecks. Following that, a simulation model has been constructed and rigorously verified. Experiments have been conducted on this simulation model, allowing recommendations for improvement. These recommendations stem from a detailed analysis of the simulation model and the insights gleaned from line balancing. As a result, by creating an excellent written report, the project research will be improved and made easier to understand. 95% effectiveness in relation to research is the study's goal. The researcher will offer so me advice and ideas for how to make the study better in the future.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This final chapter of the study is the conclusion chapter which consists of the overall description mainly on the achievement of the objectives of study, the recommendation for future work and last but not least is the important lesson learnt from the simulation study.

5.1 Conclusion

An overview of the semiconductor assembly process flow is given before exploring simulation-based line balancing in the semiconductor sector. It is stressed in Chapter Four that building a simulation model that faithfully mimics real-world situations requires an understanding of the actual production line. The operations of the manufacturing line are determined, and conceptual modelling is started simultaneously with the gathering of pertinent data needed to feed the simulation model. This method of gathering data emphasises how important it is to shape the response of the simulation model, which is in line with the second objective of the simulation study. establishing the basic model and validating and testing it are among the steps in the critical stage that follow in establishing the simulation model. The simulation models are created using Witness Horizon software, and thorough testing and validation procedures guarantee accuracy and dependability for next experiment runs. The created models are then employed to carry out line balancing via meticulously planned trials, culminating in a thorough assessment of the simulation model's results. The verified model offers important information about how well line balancing methods work.

This study's main goal is to improve the smoothness of the production line by removing bottlenecks through the use of line balancing techniques and the creation of a simulation model with Witness Horizon simulation software. Starting with line balancing analysis of the production line bottleneck, as shown in Figure 4.19, which duplicates the current architecture, all goals are accomplished with success. In order to compare the simulated and real outputs, the second goal of Witness Horizon is to mimic the actual manufacturing line configuration. Creating a simulation model to enhance line balancing in the industrial production line is the third goal. Witness Horizon simulation software is used to produce models for the current production line as well as the suggested alternative. In improvement one, productivity grew by 6.27% for Frame Comp RH and 6.51% for Frame Comp LH after fewer workstations were used, while in improvement two, productivity increased by 1.18% for Frame Comp RH and 0.89% for Frame Comp LH. This study shows that line balancing and Witness Horizon simulation are very successful in addressing production line bottleneck problems. A smaller workstation is suggested as a more efficient alternative than the second choice.

5.2 Recommendations

A number of suggestions are made for the PEPS-JV Sdn.Bhd company's production line study. This study's main goal is to balance the production line and increase productivity by lowering the number of workstations. The study's conclusions show that production rose by an astounding 11.7% once fewer workstations were used. Further research may look into extending the simulation model's functionality to include a complete workday's worth of manufacturing processes. To tackle production line productivity issues, it is recommended that strategic decision-making in process improvement—specifically, in bottleneck management—be done through the use of Witness Horizon simulation models. Important information can be included in this model to help in decision-making.

In order to minimise operator idle time, it is also advised to optimise the spot welding process by speeding up the welding robot. PEPS-JV Sdn. Bhd. could see an increase in manufacturing productivity as a result of this modification. The company will decide whether to use the Witness Horizon simulation method in the production line; this study only makes recommendations to the management, not requiring them to increase production line productiv.

5.3 Lesson learn from the simulation study

Simulation's importance in the industrial area is a crucial lesson learned during the study. Not only can simulation accelerate the time to result, but it is also an effective tool for making important decisions without interfering with the real production line. The response (output) of the simulation model can be used to quickly acquire the best results while conducting experiments on various scenarios utilising simulation in this setting. In addition, the WITNESS simulation software, which has an appealing graphical user interface and is both flexible and user-friendly, has been used to gather knowledge throughout the study.

REFERENCES

Abdullah, R., Rahman, M. N. A., Rasib, A. H. A., Abdullah, M. I. H. C., & Mansoor, H. O. (2022). Simulation-based Assembly Line Balancing and Manpower Allocation in a Cellular Manufacturing System. In *International Journal of Nanoelectronics and Materials* (Vol. 15).

AICPA, "lean management techniques," j. Account., no. Abril, pp. 34–41, 2016. [2] M. Del Rocio Quesada Castro and J. G. A. Posada, "implementation of lean manufacturing techniques in the bakery industry in medellin," gest. E prod., vol. 26, 27 no. 2, pp. 1–9, 2019

Alghazi A, Kurz ME. Mixed model line balancing with parallel stations, zoning constraints, and ergonomics. Constraints. 2018;23(1):123–53.

Ağpak, K., & Gökçen, H. (2005). Assembly line balancing: Two resource constrained cases. *International Journal of Production Economics*, *96*(1), 129–140. https://doi.org/10.1016/j.ijpe.2004.03.008

Alexandra, S., & Gozali, L. (2020). Line balancing analysis on finishing line dabbing soap at PT. XYZ. *IOP Conference Series: Materials Science and Engineering*, *1007*(1). https://doi.org/10.1088/1757-899X/1007/1/012030

Banks, J., Carson II, J.S., Nelson, B.L. and Nicol, D.M. (2010). "Discrete-Event System Simulation 5th Ed." New Jersey: Pearson Education Inc.

Becker, C. and Scholl, A. (2003), "A survey on problems and methods in generalized assembly line balancing." *European Journal of Operational Research*, vol. 168, no. 3, pp. 694-715.

Bhasin, S., & Burcher, P. (2006). Lean viewed as a philosophy. Journal of Manufacturing Technology Management, 17, 56 – 72.

Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A., Benhida, K., 2016. The integration of lean manufacturing, six sigma and sustainability: A literature review and future research directions for developing a specific model. J. Clean. Prod. 139, 828–846.

Dave, P., & Dave, P. Y. (2020). *The History of Lean Manufacturing by the view of Toyota-Ford Synthesis and characterization of carbon dots based luminescent gel formulation for Anti-counterfeiting application View project The History of Lean Manufacturing by the view of Toyota-Ford*. http://www.ijser.org

De Bucourt, M., Busse, R., Güttler, F., Wintzer, C., Collettini, F., Kloeters, C., Hamm, B., & Teichgräber, U. K. (2011). Lean manufacturing and Toyota Production System terminology applied to the procurement of vascular stents in interventional radiology. *Insights into Imaging*, *2*(4), 415–423. https://doi.org/10.1007/s13244-011-0097-0

Eryuruk, S. H., Kalaoglu, F., & Baskak, M. (2018). *Assembly Line Balancing in a Clothing Company Welding of E-Textiles for Interactive Clothing View project T100001 View project*. https://www.researchgate.net/publication/242759892

Falkenauer, E. (2000). "Line Balancing in the Real World." *International Conference on Product Lifestyle Management.*

Fortuny-Santos J, Ruiz-de-Arbulo-López P, Cuatrecasas-Arbós L, Fortuny-Profitós J. Balancing workload and workforce capacity in lean management: application to multi-model assembly lines. Applied Sciences. 2020;10(24):1–21.

Gupta, S., & Jain, S. K. (2013). A literature review of lean manufacturing. *International Journal of Management Science and Engineering Management*, *8*(4), 241–249. https://doi.org/10.1080/17509653.2013.825074

Heizer, J. H. and Render, B. (2008). Operations management. Pearson Education India. 1: Imai, M. (2012). Gemba kaizen, A commonsense approach to a continuous improvement strategy. 2nd ednMcGraw Hill Professional.

Hines, Peter., & Taylor, David. (2000). *Going lean : a guide to implementation*. Lean Enterprise Research Centre.

Hossain, A. (2022). *Assembly line balancing and sensitivity analysis of a single-model stochastic sewing line using arena simulation modelling*. https://doi.org/10.21203/rs.3.rs-2228748/v1

Husien, W. A., Abduljabbar, W. K., & Attallh, S. N. (2018). Cycle time reduction in automotive manufacturing. *Journal of Social Sciences Research*, *2018*(Special Issue 6), 1086–1090. https://doi.org/10.32861/jssr.spi6.1086.1090

Iranmanesh, M., Zailani, S., Hyun, S.S., Ali, M.H., Kim, K., 2019. Impact of lean manufacturing practices on firms' sustainable performance: Lean culture as a moderator. Sustain 11, 1112–1132

Janie W. Flinchbaugh, Implementing Lean Manufacturing through Factory Design, Masschautes Institute of Technology, 1998

J. Banks, J.S. Carson II, B.L. Nelson, D.M. Nicol, "Discrete-Event System Simulation" 5th Ed. New Jersey: Pearson Education Inc. (2010).

Kelton, D. (2006). Simulation with arena. Boston: Mc Graw Hill.

Kitaw, D., Matebu, A., & Tadesse, S. (2010). ASSEMBLY LINE BALANCING USING SIMULATION TECHNIQUE IN A GARMENT MANUFACTURING FIRM. In *Journal of EEA* (Vol. 27).

Kriengkorakot, N., & Pianthong, N. (2007). *The Assembly Line Balancing Problem : Review articles * U-Shaped Assembly Line Balancing by using the Differential Evolution Algorithm View project The IDE Algorithm for Multi-Floor Facility Layout Problems View project*. https://www.researchgate.net/publication/283044233

Kumar, N., Shahzeb Hasan, S., Srivastava, K., Akhtar, R., Kumar Yadav, R., & Choubey, V. K. (2022). Lean manufacturing techniques and its implementation: A review. *Materials Today: Proceedings*, *64*, 1188–1192. https://doi.org/10.1016/j.matpr.2022.03.481

M. Del Rocio Quesada Castro and J. G. A. Posada, "implementation of lean manufacturing techniques in the bakery industry in medellin," gest. E prod., vol. 26, 27 no. 2, pp. 1–9, 2019

Monden Y, Toyota Production Systems, Industrial Engineering and Management Press, Norcross, GA, 1983

M ShabeenaBegam, R. Swamynathan, J. Shekkizhar, International Journal of lean thinking, Volume 4, Issue 2(December 2013)

Naeemah, A.J., Wong, K.Y., 2022. Positive impacts of lean manufacturing tools on sustainability aspects : a systematic review. J. Ind. Prod. Eng. 39, 1–20.

Naeemah, A. J., & Wong, K. Y. (2023). Sustainability metrics and a hybrid decision-making model for selecting lean manufacturing tools. *Resources, Environment and Sustainability*, *13*. https://doi.org/10.1016/j.resenv.2023.100120

Nallusamy, S. (2016). Enhancement of productivity and efficiency of CNC machines in a small scale industry using total productive maintenance. *International Journal of Engineering Research in Africa*, *25*, 119–126. https://doi.org/10.4028/www.scientific.net/JERA.25.119

Paramawardhani, H., & Amar, K. (2020). Waste Identification in Production Process Using Lean Manufacturing: A Case Study. *JIEHIS*, *1*(1).

Pekn, N. (2006). MULTI CRITERIA ASSEMBLY LINE BALANCING PROBLEM WITH EQUIPMENT DECISIONS A THESIS SUBMITTED TO GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES OF MIDDLE EAST TECHNICAL UNIVERSITY.

Rahman, A., Atikur, S. M., Md, R., Rahman, F., Kamal, T., Tseng, T.-L., Fitts, T. E. P., Rahman, S., Rahman, M., & Tseng, K. &. (n.d.). *A SIMULATION-BASED APPROACH FOR LINE BALANCING UNDER DEMAND UNCERTAINTY IN GARMENTS INDUSTRY*. https://www.researchgate.net/publication/370763160

Rother, M., Shook J; learning to see: value added stream mapping to eliminate muda, the lean enterprise institute, Brookline, MA, 1999

Sivasankaran, P., & Shahabudeen, P. (2017). Comparison of Single Model and Multi-Model Assembly Line Balancing Solutions. In *International Journal of Computational Intelligence Research* (Vol. 13, Issue 8). http://www.ripublication.com

Syahputri, K., Leviza, J., Sari, S., Indah, R. T., Napitupulu, H., & Anizar, A. (2018). Assembly line balancing in an electronics company using simulation approach. *MATEC Web of Conferences*, *197*. https://doi.org/10.1051/matecconf/201819714010

Tanbin Haque, M., Rahat Hossain, M., & Shamim Hasan, M. (2018). Bottleneck problem reduction of a garment manufacturing industry in Bangladesh by using line balancing technique Efficiency and Productivity Improvement View project Fabrication and characteristics of Aluminium alloy-Rice husk ash hybrid composites, Collaborative Research Project of KUET and BAUST View project Bottleneck problem reduction of a garment manufacturing industry in Bangladesh by using line balancing technique. *International Journal of Research in Advanced Engineering and Technology 28 International Journal of Research in Advanced Engineering and Technology*, *4*(2), 28–32. https://doi.org/10.13140/RG.2.2.32627.84004

Thakur, A. (2016). A Review on Lean Manufacturing Implementation Techniques: A Conceptual Model of Lean Manufacturing Dimensions Optimization View project A Review on Lean Manufacturing Implementation Techniques: A Conceptual Model of Lean Manufacturing Dimensions. In *REST Journal on Emerging trends in Modelling and Manufacturing* (Vol. 2, Issue 3). www.restpublisher.com/journals/jemm

Womack, J. P., Jones, D. T., & Roos, D. (1990). The machine that changed the World. New York: Harper Perennial

Womack, J. P., & Jones, D. T. (1997). Lean Thinking—Banish Waste and Create Wealth in your Corporation. *Journal of the Operational Research Society*, *48*(11), 1148–1148. https://doi.org/10.1038/sj.jors.2600967

Womack, J. P., & Jones, D. T. (1997). Lean Thinking—Banish Waste and Create Wealth in your Corporation. *Journal of the Operational Research Society*, *48*(11), 1148–1148. https://doi.org/10.1038/sj.jors.2600967

Yasir, A. S. H. M., & Mohamed, N. M. Z. N. (2018). Assembly Line Efficiency Improvement by Using WITNESS Simulation Software. *IOP Conference Series: Materials Science and Engineering*, *319*(1). https://doi.org/10.1088/1757-899X/319/1/012004

Yusup, M.Z., Mahmood, W.H.W., Salleh, M.R., Yusof, A.S.M., 2015. Review the influence of Lean tools and its performance against the index of manufacturing sustainability. Int. J. Agil. Syst. Manag. 8, 116–131.

Yusoof, M. Y. M., Mohamed, N. M. Z. N., Nelfiyanti, & Hadi, M. Z. I. A. (2021). The effect of quick response manufacturing in factory layout: Assessment using Witness software. *IOP Conference Series: Materials Science and Engineering*, *1078*(1), 012027. https://doi.org/10.1088/1757-899x/1078/1/012027

APPENDICES

APPENDIX A Meeting with Company

APPENDIX B Part Assembly in Production Line 1

PEPS-JV (MELAKA)
STANDARD OPERATING PROCEDURE (SOP
Standard Operating လုပ်ထုံးလုပ်နည်း
CHILD PART #S02
PART 1
PART 2
PART 3
STIFF R, TRG ARM BRKT
65618-T9A-X000-H1
EXTN R, SIDE SILL
65614-T9A-T000-H1
BRKT R, TRG ARM OUT
65616-T9A-T000-H1
Letakkan part 1 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.

STANDARD OPERATING PROCEDURE (SOP)
Standard Operating လုပ်ထုံးလုပ်နည်း
PEPS-JV (MELAKA)
CHILD PART #S03
PART 1
PART 2
S01 ASSY R
S02 ASSY R


EPMB
PEPS-JV (MELAKA)
STANDARD OPERATING PROCEDURE (SOP)
Standard Operating လုပ်ထုံးလုပ်နည်း
PART NAME FRAME COMP R, REAR
PART NO.
VARIANT PETROL
LINE/STAGE
NO. ROBOT ROBOT 2
MODEL T00A
DOC NO.
REV. NO. 00
DATE 1-Jun-20
GUN TYPE X-GUN
CHILD PART #A10
FOLLOW SEQUENCE PART NO.
PART 1
PART 2
PART 3
PART 4
PART 5
PART 6
PREVIOUS QUALITY PROBLEM
MACHINE CHANGEOVER
1. CAP TIP CHANGING
MAINTENANCE CHECKING
PLEASE DO CHECKING ITEMS ON EARLY SHIFT REFERRING TO START UP CHECKSHEET
PERHATIAN!
PANGGIL LEADER JIKA ADA MASALAH
PERALATAN KESELAMATAN
5S's
PROCESS
Letakkan part 1 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
Letakkan part 2 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
Letakkan part 3 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
Letakkan part 4 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
MAKE SURE


VARIANT
EPMB
PEPS-JV (MELAKA)
STANDARD OPERATING PROCEDURE (SOP)
Standard Operating လုပ်ထုံးလုပ်နည်း
PART NAME
PART NO.
VARIANT
LINE/STAGE
NO. ROBOT
CHILD PART #S04
FOLLOW SEQUENCE PART NO.
PART 1
PART 2
PART 3
EXTN R, S/SILL RR ENG PLATE
65626-T00-T000-H1
END PLATE INN R, S/SILL RR
65622-T00-T000-H1
END PLATE OUT R, SIDE/SILL RR
65636-T00-T000-H1
N/A
1. CAP TIP CH
PROCESS
Letakkan part 1 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
Letakkan part 2 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.


EPMB
PEPS-JV (MELAKA)
STANDARD OPERATING PROCEDURE (SOP)
Standard Operating လုပ်ထုံးလုပ်နည်း
PART NAME
FRAME COMP R, REAR
PART NO.
65610-T0OA-T000-H1
VARIANT
PETROL
LINE/STAGE
LINE 2 / #A20RH
NO. ROBOT
ROBOT 3
PREVIOUS QUALITY PROBLEM
CP OVERLAP (PART 4)
PART 1
PART 2
PART 3
PART 4
PART 5
EXTN R, REAR FLOOR C/MBR
65628-T9A-T001-H1
S03 ASSY RH
A10 ASSY RH
FLG R, REAR FRAME END
65619-T00-T000-H1
GUSSET R, RR FRAME RR
65644-T9A-T001;H1
MACHINE CHANGEOVER
1. CAP TIP CHANGING
MAINTENANCE CHECKING
PLEASE DO CHECKING ITEMS
START UP CHECKSHEET
PROCESS
Letakkan part 1 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
Letakkan part 2 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
Letakkan part 3 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.


VARIANT:
EPMB
PEPS-JV (MELAKA)
Standard Operating လုပ်ထုံးလုပ်နည်း
PART NAME
PART NO.
VARIANT
LINE/STAGE
NO. ROBOT
CHILD PART #A30
FOLLOW SEQUENCE PART NO.
PART 1
PART 2
PART 3
PART 4
BRKT, ABS HORN
65643-T9A-X000-H1
A20 ASSY RH
S04 ASSY R
BHD R, RR FRAME
65637-T00-T000-H1
1. CAP TIP CHANG
PROCESS
Letakkan part 1 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.
Letakkan part 2 ke atas jig dan pastikan part masuk ke dalam pin sepenuhnya.

APPENDIX C Data from The PEPS-JV

PART NAME	ROBOT NO.	SIDE	STATION	TIME/STN	TOTAL 1 SIDE	UPH 1 SIDE	OUTPUT 1 SHIFT (8H)/SIDE	TOTAL ROBOT TIME
FRAME COMP REAR T00 4DR	ROBOT 1	RH	S01/S02	33	88	40	320	181
			S03	55				
		LH	S01/S02	35	93	38	304	
			S03	58				
	ROBOT 2	RH	S04	21	92	39	312	178
			A10	71				
		LH	S04	23	86	41	328	
			A10	63				
	ROBOT 3	RH	A20	54	85	42	336	175
			A30	31				
		LH	A20	57	90	40	320	
			A30	33				
	ROBOT 4 (HANDLING)	RH	A40	83		43	344	173
		LH	A40	90		40	320	

NO.	TIME		HOURS	OUTPUT (UPH) 18	OUTPUT (UPH) 19	OUTPUT (UPH) 22	OUTPUT (UPH) 23
1	08.00-09.00		0.50	9	10	11	12
2	09.00-10.00		1.00	18	19	22	23
3	10.00-11.00		0.50	9	10	11	12
4	11.00-12.00		1.00	18	19	22	23
5	12.00-1.00		1.00	18	19	22	23
6	1.00-2.00		0.00	0	0	0	0
7	2.00-3.00		1.00	18	19	22	23
8	3.00-4.00		0.50	9	10	11	12
9	4.00-5.00		1.00	18	19	22	23
10	5.00-6.00		0.50	9	10	11	12

STN			ROBOT TIME	ROBOT NO	TOTAL ROBOT TIME	LOADING	UNLOADING	TOTAL WORKING TIME	DIFF RBT VS MAN TIME
RH	MP1	S01/02	33	ROBOT 1	88	47	8	78	10
		S03	55			12	11		
LH	MP1	S01/02	35		93	43	12	80	13
		S03	58			15	10		
RH	MP2	S04	21	ROBOT 2	92	9	7	63	29
		A10	71			41	6		
LH	MP2	S04	23		86	11	4	59	27
		A10	63			35	9		
RH	MP3	A20	54	ROBOT 3	85	49	7	74	11
		A30	31			18			
LH	MP3	A20	57		90	44	5	71	19
		A30	33			22			

APPENDIX D Data of Assembly in Simulation

Witness

Part Statistics Report by On Shift Time

Name	SubCombA_R
No. Entered	357
No. Shipped	0
No. Scrapped	0
No. Assemble	355
No. Rejected	0
W.I.P.	2
Avg W.I.P.	1.61
Avg Time	137.61
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombB_R
No. Entered	365
No. Shipped	0
No. Scrapped	0
No. Assemble	335
No. Rejected	0
W.I.P.	30
Avg W.I.P.	29.30
Avg Time	2448.08
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombC_R
No. Entered	336
No. Shipped	0
No. Scrapped	0
No. Assemble	335
No. Rejected	0
W.I.P.	1
Avg W.I.P.	0.75
Avg Time	68.30
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombD_R
No. Entered	335
No. Shipped	0
No. Scrapped	0
No. Assemble	335
No. Rejected	0
W.I.P.	0
Avg W.I.P.	0.60
Avg Time	54.57
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombE_R
No. Entered	336
No. Shipped	0
No. Scrapped	0
No. Assemble	335
No. Rejected	0
W.I.P.	1
Avg W.I.P.	0.34
Avg Time	31.02
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombF_R
No. Entered	336
No. Shipped	0
No. Scrapped	0
No. Assemble	335
No. Rejected	0
W.I.P.	1
Avg W.I.P.	0.87
Avg Time	79.35
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombC_L
No. Entered	338
No. Shipped	0
No. Scrapped	0
No. Assemble	337
No. Rejected	0
W.I.P.	1
Avg W.I.P.	0.75
Avg Time	68.05
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombB_L
No. Entered	368
No. Shipped	0
No. Scrapped	0
No. Assemble	337
No. Rejected	0
W.I.P.	31
Avg W.I.P.	29.25
Avg Time	2424.55
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombA_L
No. Entered	390
No. Shipped	0
No. Scrapped	0
No. Assemble	359
No. Rejected	0
W.I.P.	31
Avg W.I.P.	26.17
Avg Time	2046.42
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombD_L
No. Entered	338
No. Shipped	0
No. Scrapped	0
No. Assemble	338
No. Rejected	0
W.I.P.	0
Avg W.I.P.	0.60
Avg Time	53.86
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombE_L
No. Entered	338
No. Shipped	0
No. Scrapped	0
No. Assemble	337
No. Rejected	0
W.I.P.	1
Avg W.I.P.	0.34
Avg Time	30.79
Sigma Rating	6.00

Witness

Part Statistics Report by On Shift Time

Name	SubCombF_L
No. Entered	338
No. Shipped	0
No. Scrapped	0
No. Assemble	338
No. Rejected	0
W.I.P.	0
Avg W.I.P.	0.87
Avg Time	78.51
Sigma Rating	6.00

APPENDIX E Thesis Status Verification Form

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **A Simulation Study to Improve Line Balancing in Manufacturing Production Line**

SESI PENGAJIAN: **2023/24 Semester 1**

Saya **AHMAD AIMAN HAZIQ BIN AHMAD SYAMSUL**

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

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2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

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☑ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:

33/R PERSADA JAYA, BANDAR ENSTEK, NILAI 71760, NEGERI SEMBILAN

Cop Rasmi:

TS. DR. MOHD SOUFHWEE BIN ABD RAHMAN
Ketua Jabatan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
Universiti Teknikal Malaysia Melaka

Tarikh: 8 JANUARY 2024

Tarikh: 24 JANUARY 2024

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

APPENDIX F Thesis Classification Letter

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76100 Durian Tunggal,
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Tel : +606 270 1184 | Faks : +606 270 1064

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Tuan

PENGKELASAN TESIS SEBAGAI TERHAD BAGI TESIS PROJEK SARJANA MUDA

Dengan segala hormatnya merujuk kepada perkara di atas.

2. Dengan ini, dimaklumkan permohonan pengkelasan tesis yang dilampirkan sebagai TERHAD untuk tempoh **LIMA** tahun dari tarikh surat ini. Butiran lanjut laporan PSM tersebut adalah seperti berikut:

Nama pelajar: AHMAD AIMAN HAZIQ BIN AHMAD SYAMSUL (B092010129)
Tajuk Tesis: A Simulation Study To Improve Line Balancing In Manufacturing Production Line.

3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULIT.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
"KOMPETENSI TERAS KEGEMILANGAN"

Saya yang menjalankan amanah,

TS. DR. MOHD SOUFHWEE BIN ABD RAHMAN
Ketua Jabatan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
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