IMPROVEMENT OF THE LINE BALANCING PERFORMANCE THROUGH SIMULATION APPROACH IN MANUFACTURING ASSEMBLY LINE

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Faculty of Industrial and Manufacturing Technology and Engineering

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DECLARATION

I declare that this thesis entitled "Improvement Of The Line Balancing Performance Through Simulation Approach In Manufacturing Assembly Line" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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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 (Process and Technology) with Honours.

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DEDICATION

Most notably, the highest gratitude and grateful to God. for His mercy and love. This thesis is dedicated to my parents, Muniady A/L Munusamy and M.Nalini A/P Marimuttu, who has always been supportive, encouraging, and wise. I am also extremely grateful to my thesis Supervisor, Ts. Dr. Mohd Soufhwee Bin Abd Rahman, Co-Supervisor Industry, En. Zulhelmi Bin Ismail for his essential advice, ongoing support, and patience during my thesis journey. Their vast expertise and experience have inspired me in my academic research and daily life. Remember the classmates and friends at Universiti Teknikal Malaysia Melaka (UTeM) who directly and indirectly assisted in this report. Last but not least, Thanks to the staff in EPMB Peps-Jv Melaka Sdn Bhd, who was involved in administering and providing information, advice, and giving helpful guidance.

ABSTRACT

This thesis delves into the realm of Lean Manufacturing (LM) and simulation techniques, focusing on improving line balancing in the automotive industry. The backdrop highlights the challenges faced by manufacturers in the competitive global market and underscores the significance of optimizing production processes for efficiency and cost reduction. Recognizing the limitations of traditional methods in addressing system variables, the research employs computer simulation, specifically Arena Simulation, to extend the exploration of line balancing in the apparel industry. The study emphasizes the pivotal role of LM in making manufacturing systems more productive and efficient. Lean principles, such as reducing waste, cycle times, and lead times, are identified as key drivers for improving productivity, cutting costs, and enhancing customer satisfaction. The project targets the implementation of Arena Simulation and Line Balancing (LB) as LM tools to address identified issues in the production system. The problem statement articulates challenges observed in an automotive company, PEPS-JV Sdn. Bhd, including the absence of standard time observation, a scattered and complicated workstation layout, and inefficiencies in the kitting process. The absence of a simulation model for measuring cycle time, process flow, and efficiency prompts the need for a new strategy to deal with product unpredictability. Line Balancing and Arena Simulation emerge as critical tools for analyzing LM waste and ensuring a smooth process flow in the production line. The research objectives outline the development of the production layout using Arena Simulation for data collection, the reduction of bottlenecks through a proposed methodology, and the suggestion of decision-making improvements. The scope encompasses the application of line balancing and simulation activities to identify LM waste and enhance productivity in manufacturing line 4 (3MOA) of PEPS-JV MELAKA SDN. BHD. In the pursuit of a smooth production flow and maximum productivity gains, the methodology involves employing line balancing approaches, simulation technologies, and LM tools such as Bottleneck analysis. The research aims to contribute valuable insights into decision-making after implementing improvements, including workstation reduction and changes in worker positions, to achieve optimal output and operational efficiency.

ABSTRAK

Tesis ini mendalami bidang Pembuatan Lean (LM) dan teknik simulasi, memfokuskan pada meningkatkan pengimbangan garisan dalam industri automotif. Latar belakang menonjolkan cabaran yang dihadapi oleh pengeluar dalam pasaran global yang kompetitif dan menekankan kepentingan mengoptimumkan proses pengeluaran untuk kecekapan dan pengurangan kos. Menyedari batasan kaedah tradisional dalam menangani pembolehubah sistem, penyelidikan menggunakan simulasi komputer, khususnya Simulasi Arena, untuk melanjutkan penerokaan pengimbangan garisan dalam industri pakaian. Kajian ini menekankan peranan penting LM dalam menjadikan sistem pembuatan lebih produktif dan cekap. Prinsip ramping, seperti mengurangkan pembaziran, masa kitaran dan masa pendahuluan, dikenal pasti sebagai pemacu utama untuk meningkatkan produktiviti, mengurangkan kos dan meningkatkan kepuasan pelanggan. Projek ini menyasarkan pelaksanaan Simulasi Arena dan Pengimbangan Talian (LB) sebagai alat LM untuk menangani isu yang dikenal pasti dalam sistem pengeluaran. Pernyataan masalah menyatakan cabaran yang diperhatikan dalam sebuah syarikat automotif, PEPS-JV Sdn. Bhd, termasuk ketiadaan pemerhatian masa standard, susun atur stesen kerja yang berselerak dan rumit, dan ketidakcekapan dalam proses kitting. Ketiadaan model simulasi untuk mengukur masa kitaran, aliran proses dan kecekapan mendorong keperluan untuk strategi baharu untuk menangani ketidakpastian produk. Pengimbangan Talian dan Simulasi Arena muncul sebagai alat kritikal untuk menganalisis sisa LM dan memastikan aliran proses yang lancar dalam barisan pengeluaran. Objektif penyelidikan menggariskan pembangunan susun atur pengeluaran menggunakan Simulasi Arena untuk pengumpulan data, pengurangan kesesakan melalui metodologi yang dicadangkan, dan cadangan penambahbaikan membuat keputusan. Skop ini merangkumi aplikasi pengimbangan garisan dan aktiviti simulasi untuk mengenal pasti sisa LM dan meningkatkan produktiviti dalam barisan pembuatan 4 (3MOA) PEPS-JV MELAKA SDN. BHD. Dalam mengejar aliran pengeluaran yang lancar dan keuntungan produktiviti maksimum, metodologi melibatkan penggunaan pendekatan pengimbangan talian, teknologi simulasi dan alatan LM seperti analisis Bottleneck. Penyelidikan ini bertujuan untuk menyumbangkan pandangan berharga dalam membuat keputusan selepas melaksanakan penambahbaikan, termasuk pengurangan stesen kerja dan perubahan dalam kedudukan pekerja, untuk mencapai output optimum dan kecekapan operasi.

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LIST OF SYMBOLS AND ABBREVIATIONS

LM	-	Lean Manufacturing
CP	-	Capacity Planning
ALBP	-	Assembly Line Balancing Problem
NVA	-	Non-Value Added
EPMB	-	EP Manufacturing Bhd
TPS	-	Toyota Production System
WIP	-	Work In Progress
VA	-	Value Added
LB	-	Line Balancing
APS	-	Advanced Planning System
DLL	-	Dynamic Link Library
OEM	-	Original Equipment Manufacturer
RH	-	Right Hand
LH	-	Left Hand

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CHAPTER 1

INTRODUCTION

This chapter elongates the study's background, problem statement, research objectives, the scope of this research and summary that related to the study. The key components of this report significantly explained the purpose and ideas to enhance the overall perceptions of the study outcome and results.

1.1 Background

In the manufacturing industry, optimizing production by balancing assembly lines is essential to increase efficiency and reduce costs. Various analytical and heuristic methods have been used for years to solve Assembly Line Balancing Problems (ALBP). However, in recent decades, computer simulation has gained interest among researchers as a new technique for line balancing. Unlike other methods, computer simulation can handle the random variables that affect the system. Moreover, there were several types of technique and methods used to identify the problem occur in manufacturing industry assembly line includes, Capacity Planning, Lean Manufacturing (LM) and Simulation. However, existing research has only considered a limited number of system variables. The purpose of this paper is to extend the use of computer simulation for line balancing in the apparel industry through further research.

Most businesses today face significant challenges in maintaining their position in this highly competitive global economy. To improve their chances of survival, manufacturers must meet customer demand with low-cost, high-quality products.

Customers have become the main focus of the industry. As a result, the industry has become more customer-centric and has made great efforts to reduce lead times. Businesses and organizations have found that 90% of existing activities are not necessary and can be removed to reduce lead times. Companies focus on cycle time as a measure of productivity to shorten delivery times, improve quality, and ultimately increase customer satisfaction.

Lean Manufacturing (LM) is a way for companies to stay ahead of the competition by making their manufacturing systems more productive and efficient. Industrial player strive to improve productivity and profits by reducing costs, waste, cycle times and lead times. LM improved employer and employee satisfaction. Employees love the sophisticated and efficient environment of a sophisticated workplace, and customers love the system. Additionally, LM requires administrative support, ongoing communication, and proper use of information technology to function. LM is a business strategy that reduces production waste without sacrificing productivity. These things also can change the corporate culture.

This project would be implemented the use of Arena Simulation and Line Balancing (LB) as the lean tool in order to achieve the problem stated. Line Balancing is a method that tries to optimise the manufacturing process by spreading workloads evenly across all workstations on a production line. Line balancing's purpose is to minimise idle time and maximise efficiency, which can lead to better production, lower costs, and higher quality.

Line balancing is the attempt of analyzing the manufacturing process to detect bottlenecks and inefficiencies. Most of the manufacturing applications represent how firms have adopted, developed, and applied in Lean principles. LM can focus on reducing production cycle time in order to respond to customer demand more quickly while utilising less resources and improving product quality and procedure.

1.2 Problem Statement

Manufacturers are struggling to compete in this highly competitive global market. Many firms are seeking for innovative methods to increase supplier quality and productivity. Productivity enhancement is always a top goal in business since it has a direct impact on a company's earnings. Total production costs are lowered when the LM approach is implemented to the manufacturing line.

After visiting and researching at the company, which is the automotive business, PEPS-JV Sdn. Bhd, there are few problems were identified in the production system, and can be improved. Firstly, there is no standard time observation to verify the cycle time. The work station layout is scattered and complicated. However, the cycle time observation at kitting process station were not properly taken and the processing time for the kitting process takes more time consumption to divide the parts into 30 set per to proceed for the next process in production line. When the manpower is idle or working slowly, the previous process is prevented from being completed. Next, another problem were stated during the discussion at the company which is, there is there is no any simulation model for the production line that measures cycle time, process flow and efficiency. This company intends to improve its production line with a new strategy for dealing with product unpredictability. Line Balancing and Arena Simulation is required to analyze the LM waste in the production line to ensure the customer satisfaction and also to ensure the smooth process flow in the production line.

1.3 Research Objective

The objectives of this work included in the following:

a) To develop the production layout using Arena simulation for the data collection.

b) To reduce bottlenecks using a proposed methodology for process improvement.

c) To suggest a development in decision-making by using the preferred methodology.

1.4 Scope of Research

This study seeks to identify the line balancing lean tool and simulation activities in the production process and, as a consequence, enhance productivity. The decision was made to enhance production planning in order to better comprehend and conceptualise the manufacturing process. The study's findings will then demonstrate that the lean approach may be applied to achieve changes. There are two key goals to strive which is a smooth flow of production and the greatest feasible gain in productivity. PEPS-JV MELAKA SDN. BHD will undertake this research utilising the line balancing approach. The line balancing approach will be used in manufacturing line 4 (3MOA), which will spot weld the Frame Comp Rear RH (Right Hand), LH (Left Hand). Furthermore, simulation and line balancing lean technologies may be used to examine present processes and give ideas for improvement to a company's management. Arena is the programme that will be used for simulation. The line balancing lean tool in the Arena simulation is used in this research to conceptualise contemporary manufacturing processes. Following that, a simulation model is utilised to assess the present waste stream for lean waste. Many lean techniques, including as Kanban, the Pull System, the Standard Work Tool, and Bottleneck, can assist management reduce lead times and boost customer delivery rates.

1.5 Summary

The project development study will be carried out based on the identified problem and the improved conceptual grasp of the project context. The study emphasizes the application of Lean Manufacturing (LM) principles, with a particular focus on line balancing, to enhance productivity, reduce waste, and meet customer demands. The engineers identified issues in the production system, including the absence of standard time observations, a scattered and complicated workstation layout, and inefficiencies in the kitting process leading to increased cycle time. To address these challenges, the study proposes the use of Arena Simulation and Line Balancing as tools to analyze and optimize the production line. The scope of the research involves identifying line balancing lean tools and simulation activities in the production process to enhance productivity. PEPS-JV Melaka Sdn. Bhd is chosen as the real case, with a focus on manufacturing line 4 (3MOA), specifically spot welding the Frame Comp Rear RH (Right Hand), LH (Left Hand). The methodology involves utilizing Arena Simulation for simulation activities, including the line balancing approach, to conceptualize contemporary manufacturing processes. The simulation model is then used to assess the present waste stream for lean waste. Various lean techniques, such as Line Balancing and Bottleneck analysis, are employed to reduce lead times and enhance customer delivery rates. In summary, the thesis integrates Lean Manufacturing principles, Arena Simulation, and line balancing techniques to address challenges in the automotive production line, aiming to optimize efficiency, reduce waste, and meet customer satisfaction. The research team's efforts are focused on implementing 2 practical improvements based on a comprehensive analysis of the manufacturing process at PEPS-JV Sdn. Bhd.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review aims to provide the information about the application of Lean Manufacturing (LM) and Capacity Planning (CP) on the Assembly Line Balancing in various industrial sectors. The concept of this study to verify the productiveness, impacts, and the outcomes after the implementation. Moreover, this chapter also defines all the history, philosophy, principle, technique, and tools used to reduce the Assembly Line Balancing Problem (ALBP). Arena simulation also used to verify that the simulation can increase manufacturing productivity.

2.2 Lean Manufacturing (LM) History

Lean Manufacturing (LM) is a systematic approach that used in manufacturing organizations that competitive advantage in the global market. According to Gupta and Jain (2013), the Japanese Toyota Motor Company pioneered his LM concept in the 1950s, which came to be known as the Toyota Production System 'TPS'. A primary goal of TPS was to reduce waste and non-value-added activities (NVA) to reduce costs and increase production. Over the past two decades, manufacturing companies operating in fast-changing and competitive markets have adopted the principles of LM thinking.

In recent years, there has been an increasing interest in applying lean manufacturing principles to service industries. According to a study by Radnor et al. (2016), lean thinking can be applied to service industries such as healthcare, banking, and government to improve efficiency and reduce waste. However, the authors point out that Lean implementation in service industries comes with special challenges of the need for more flexibility and the difficulty of measuring performance. Another area of interest in lean manufacturing research is the use of technology to support lean initiatives. A study by Kusi-Sarpong et al. (2018) found that the use of digital technologies such as sensors and analytics can help companies monitor production processes in real time and identify opportunities for improvement.

Referring to Leksic et al. (2020), TPS was created by Eiji Toyoda and Taiichi worked with Ohno on a new production system. By integrating this Japanese manufacturing approach into our manufacturing organization, were able to meet the expectations and demands of the customers with minimal resources, while also gaining the attention of the Western manufacturing competitors. A detailed history of LM prior to the 1950s (Ribeiro et al., 2019) is shown in Figure 2.1 below.

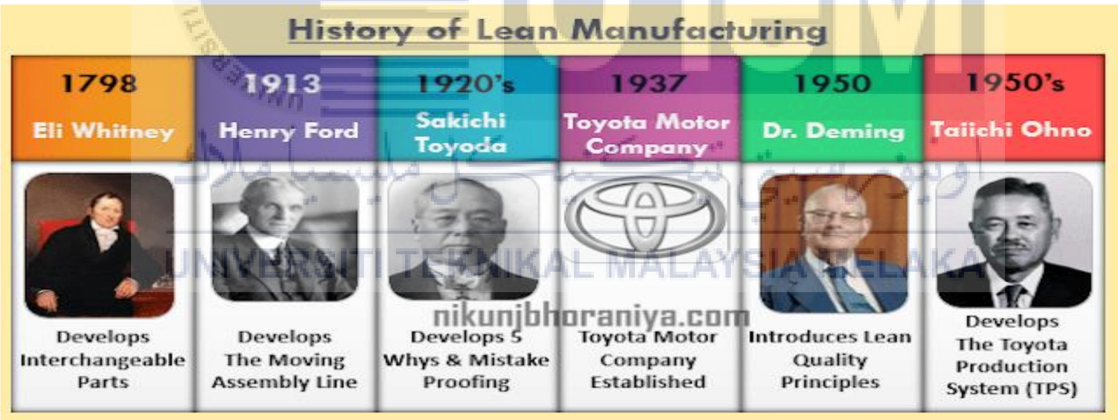


Figure 2.1 History of Lean Manufacturing

2.3 Lean Manufacturing (LM)

The technique of removing waste from a production system is known as lean manufacturing. Anything that does not add value to the final product is considered waste. At the same time, LM aspires to develop items that fulfil the demands of customers while decreasing Non-Value-Added (NVA) production practises. According to the LM principle, waste is defined as everything that does not bring value to the willingness of customers to pay for it (Sanders et al., 2017). LM seeks to generate the same amount of output with fewer inputs, such as less time, space, human labour, machinery, material, and cost (Abhishek Dixit et al., 2015). LM is categorization through three distinct lenses: (1) philosophy, (2) principles, and (3) tools and procedures.

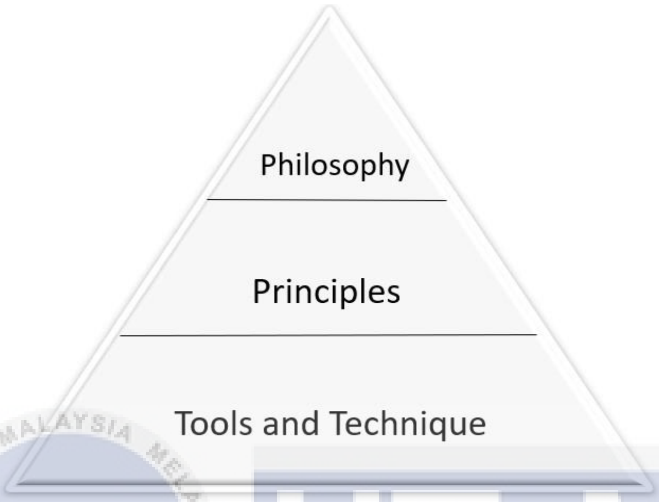


Figure 2.2 Categorization of LM in Production

2.3.1 Types of Lean Waste

In Lean Manufacturing, waste is defined as any action that consumes resources but adds no value to the final product. Overproduction, waiting, transportation, processing, motion, inventory, and defects are the seven categories of waste in Lean Manufacturing. Overproduction happens when more items are produced than the client requires. The time spent waiting for the next step in the manufacturing process is referred to as waiting. When items are carried from one site to another unnecessarily, transportation waste is created. Processing waste arises when superfluous stages in the manufacturing process are completed. Any needless movement of persons or equipment is referred to as motion waste. Inventory waste occurs when surplus inventory is kept on hand. Defects are any flaws or mistakes made throughout the manufacturing process. Defects refer to any errors or mistakes made during the production process that result in rework or scrap. (Ohno, 1988) as shown in Figure 2.3 below.

Figure 2.3 Types of Lean Waste

In between the seven categories of waste, overproduction is the most identified in production line. Table 2.1 below refers to the eight types of waste.

Table 2.1 Seven Types of LM waste

Types of LM Waste	Description
Transportation	The process of transporting something from one location to another is known as transportation. Transportation adds no value to the customer hence it should be avoided as much as feasible. This may be accomplished by bringing factories closer together and lowering transportation costs.
Inventory	This is the waste produced by unprocessed inventory. This includes waste capital locked up in extra stock, wasteful transportation needed to move the stock, lighting and heating used to store the capacity, and containers used to keep the surplus goods. Excess inventory might also conceal various types of inefficiencies caused by your present procedures.
Motion	Motion waste is any movement that might have been employed for anything else. This leads in waste since it is wasting energy and time. Wasted motion might range from a manufacturing worker leaning over to pick something up to a machine making an unnecessary trip.
Waiting	This includes any type of waiting required by either personnel or machinery to execute a task. This is common when a procedure in the production line runs longer than necessary, resulting in lost worker time. Employees might be paid even though they are not productive, and materials can deteriorate while waiting for manufacturing.
Overproduction	The most visible type of industry waste is overproduction. Not only does it result in exhausted raw resources, but it also results in underused storage and surplus money. The goal is to only produce what the consumer requests. Lean manufacturing is based on the 'just-in-time' idea, which means that your product should be made when it is needed, not before.
Overprocessing	Lean manufacturing is based on goods that provide value to the consumer while without over-engineering any product. Any effort that is unnecessary should be avoided. Over-processing is simply providing more value than the consumer requires.
Defects	Defects are defined as a product that does not satisfy the customer's expectations. Defects result in a significant loss of time, beginning with paperwork. The product must then be disposed of and recreated, which takes time and money.

Non-Utilized Talent	This type of manufacturing waste occurs when management in manufacturing environment fails to ensure that all their potential employee talent is being utilized. This waste was added to allow organizations to include the development of staff into the lean ecosystem. As a waste, it may result in assigning employees the wrong tasks or tasks for which they were never properly trained. It may also be the result of poor management of communication.

2.3.2 Philosophy of Lean Manufacturing

The lean manufacturing philosophy is a management style and philosophy that started in the manufacturing business but has subsequently been adapted to a variety of different industries. Its primary goal is to maximise customer value while minimising waste through continual improvement and the removal of non-value-adding operations. Lean manufacturing, at its foundation, seeks to build a more effective and streamlined production process by identifying and removing any activities or processes that do not directly contribute to the development of customer value. In this context, waste is defined as any resource or activity that consumes time, effort, or resources while contributing no value to the end output. The study by (Chiarini et al. 2018), the Toyota production method as used by Toyota may be difficult for other firms to imitate due to differences in how some operations are conducted and the underlying culture.

2.3.3 Principle of Lean Manufacturing

Lean Manufacturing ideas are still extremely applicable in today's sectors. Lean Manufacturing, often known as Lean Production or just Lean, is a method of reducing waste and increasing efficiency in manufacturing operations. The five principles of Lean Manufacturing were highly preferred by Murugesan et al. (2021) in various industry to provide the most value to their customers while maximizing efficiency. Table 2.2 provide the explanation of the five Lean Manufacturing principles.

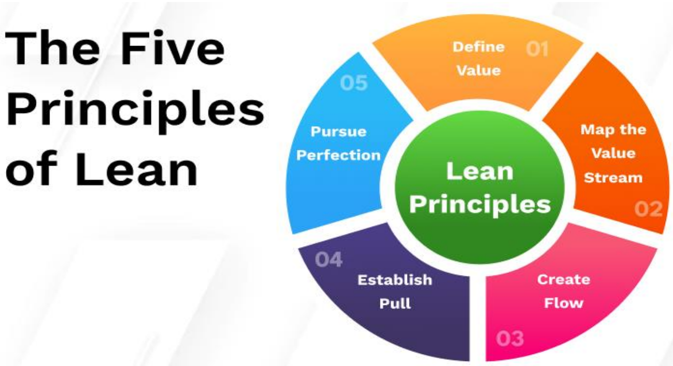


Figure 2.4 Principle of LM

Table 2.2 Five Principles of Lean Manufacturing

Principles of LM	Description
Value	The core goal of lean manufacturing is to understand and deliver value to the client. This entails determining the characteristics and quality that buyers are prepared to pay for and aligning manufacturing processes to fulfil those specifications.
Value Stream	Lean manufacturing highlights the importance of comprehending the full value stream, which includes all operations necessary to deliver a product or service to a consumer. Organisations can identify and reduce non-value-added activities or waste by mapping out the value stream.
Flow	Lean manufacturing promotes the production of a continuous and seamless flow of work across the value chain. This entails reducing interruptions, bottlenecks, and delays in order to produce a continuous and efficient manufacturing process.
Pull System	Instead of depending on forecasted output, lean manufacturing supports a "pull" system in which production is based on real consumer demand. This helps to avoid overproduction and the requirement for additional inventories.
Perfection	Lean manufacturing recognises that obtaining perfection is a continuous effort. It promotes organisations to aim for continuous improvement, remove waste, and foster a culture of continuous learning and problem-solving.

2.3.4 Lean Manufacturing Tools and Techniques

LM consists variety of LM tools to improve the quality, productivity, efficiency of the final products. Organisations may identify and remove tasks that do not provide value to the customer, streamline processes, and increase overall productivity by applying lean tools and approaches. These tools are intended to improve process flow, shorten lead times, increase quality, and promote continuous improvement. The use of lean manufacturing tools and processes is not restricted to a single industry or area. It may be used in a variety of industries, including automotive, aerospace, electronics, medicines, and consumer products. Furthermore, lean ideas may be extended to the service industry, healthcare, and administrative procedures. By conducting several studies in Malaysia, the implementation of lean production tools and techniques especially in automotive, electrical, and electrical industries gains the higher performance improvement (Yahya et al., 2019). These tools guides in implementation, monitoring, and analyzation of LM efforts and results. Table 2.3 allocates the explanation of LM tools and techniques.

Table 2.3 Explanation for Tools and Techniques of LM

LM Tools	Description
Kaizen	Kaizen is a type of techniques that targets on continuous process improvement. The Questions (4WH) Who, Where, When, Why and How were carried out in an organization (Oliveira et al., 2017).
5S	5S is a strategy for reducing waste and increasing productivity by keeping the workplace clean and employing visual signals to obtain more consistent operational results. Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke) are the 5S pillars. This approach helps employees to maintain a productive work environment (Ribeiro et al., 2019).

Standardized Work	Standardized work improves stability, reduces waste, boost uptime and efficiency, and can lead to higher worker and supervisor satisfaction. The Standard operation’s goal is to make sure the work standard and regulating in Quality, Cost, Output, and WIP (Nunees Mariz et al., 2019).
TQM	Total Quality Management seeks quality at the point of production and holds employees accountable for their own job and the production process. It strives to decrease quality flaws through statistical quality control, internal quality audits, teamwork, quality standards, and partnership with suppliers and consumers to ensure that the final product meets all requirements. Organizations can prefer these tools to identify methods, concept, data, and cause-and-effect contents (Chiarini and Baccarani, 2016).
KPI	Key Performance Indicators (KPIs) in Lean Manufacturing are focused on enhancing production efficiency and decreasing waste across the supply chain. KPIs also assist to reduce waste drivers such as breakdowns, long cycle times, production rejects, and quality control flaws (Helleno et al., 2017).
VSM	Value Stream Mapping (VSM) is a lean manufacturing approach for analysing, designing, and managing the flow of materials and information needed to deliver a product to a client (Gunduz and Naser, 2017). Production flow analysis via value stream mapping begins with the basic concept, progresses through various phases of manufacturing and production, and concludes with delivery and customer service.
Just In Time	Just in time (JIT) manufacturing is a workflow structure that aims to reduce flow times inside production systems as well as supplier and customer reaction times. JIT also exhibits the trend of having just in time rather than on time (Palange and Dhatrak, 2021).
OEE	Overall Equipment Effectiveness (OEE) is a "best practise" a metric that determines the proportion of scheduled production time that is genuinely productive. An OEE score of 100% represents suitable production: producing only good components as quickly as possible with no downtime. The OEE calculation is performed using the data from the six significant losses of machines and process (Chiarini, 2015)
Kanban	Kanban is a method of visibly managing an organization's work flow. Kanban makes it simpler to maintain efficiency and swiftly detect (and address) issues in the work flow. Using Kanban probably can stay efficient and aids in the rapid

	identification and resolution of problems in the workflow (Liang and Landeghem, 2020).
Hoshin Kanri	Hoshin Kanri (also known as Policy Deployment) is a method for ensuring that the company's long-term objectives drive progress and action at all levels. This strategy avoids waste caused by inconsistency in instructions and poor communication. Larger organizations with multiple of management can use the Hoshin Kanri strategic planning method (Nicholas, 2016).
Heijunka	Heijunka is a Lean approach for eliminating unevenness in a production process and limiting the possibility of overburdening. Heijunka is a Japanese word that literally means "levelling". Also uses to reduce manufacturing waste and match irregular customer demand (Ribeiro et al., 2019).
Bottleneck	Bottlenecks are procedures or activities with restricted capacity that reduce the overall capacity of the production chain. They can determine the production delays and identify which process area were causing the workflow to get backed up than it should be (Helleno et al., 2017).
Gemba	Gemba is a Japanese term that meaning "true place." When used to manufacturing, it refers to the area of the plant where things happen. Used to signify that persons whose job it is to produce are in an excellent position to enhance the process.
Poka Yoke	Poka-yoke is a lean manufacturing tool that refers to “mistake-proofing” or “error-proofing” a process. A poka-yoke device is anything that avoids a mistake in the production process or makes flaws easily observable, which is essential in maintaining to lean manufacturing principles (Leksic et al., 2020).
Jidoka	Jidoka is a Lean manufacturing concept that strives to design processes with self-sufficient, built-in quality controls. Essentially, Jidoka ensures that machines and their operators can stop a process when an abnormality is discovered. .Jidoka uses machinery and operators to ensure that quality is embedded into the manufacturing process(Sivaraman et al., 2020).
TPM	Total Productive Maintenance (TPM) aims to involve all levels and functions in an organisation in order to maximise the overall effectiveness of manufacturing equipment. This strategy improves existing processes and equipment by eliminating errors and mishaps. The purpose is to reduce the downtime as much as possible to make sure the improvement of the productivity (Rewers et al., 2016).

PDCA Cycle	The PDCA cycle is an iterative process that is used to continuously improve goods, people, and services. It became an essential component of what is now known as Lean management. The Plan-Do-Check-Act paradigm incorporates solution testing, data analysis, and process improvement. Before updating procedure and working practices, the model can be used to test improvement measures on a small scale (Chong and Perumal, 2020).
Line Balancing	Line balancing is a production approach that involves matching the production rate to the takt time by balancing human and machine time. Takt time refers to the rate at which components or goods must be manufactured to fulfil consumer demand. Using these tools helped company to develop process with cycle time within the takt time associated with building the product (Rathod and Balaji at al., 2016).
Takt Time	Takt Time is if the company receives the new product order every two days, the team must complete a product in two days or less (Luca et al., 2021).

2.4 Line Balancing (LB)

Line balancing is an important aspect of production planning and control, aimed at optimizing the distribution of work among different workstations within a production line. The aims of line balancing is to minimize idle time, reduce congestion, and improve productivity. In recent years, several studies have been conducted on line tuning, focusing on various aspects such as mathematical models, algorithms, case studies, and applications. These technologies enable real-time monitoring and control of the production process, improving the efficiency and effectiveness of line balancing.

In a study by (Kusiak et al., 2018) proposed a hybrid approach combining genetic algorithms and machine learning for line balancing in flexible manufacturing systems. The proposed approach was shown to outperform conventional methods in terms of productivity and efficiency. Another recent study by (Wang et al., 2019) proposed a new line balancing method based on the virtual station concept. A case study conducted in a semiconductor manufacturing facility showed that the proposed method reduces idle time and improves productivity. In addition, some of the research papers on line balancing have been published to improve the efficiency of productivity. These include multi-objective optimization (Gao et al., 2017), fuzzy logic-based approaches (Kumar et al., 2016), simulation-based methods (Chen et al., 2015), and lean manufacturing principles (Rahman et al., 2014).

2.5 Step of Line Balancing (LB)

To accomplish the performance benefits, the production line must be designed in such a way that it allows for a streamlined movement of materials and parts from one workstation to the next. A workstation is any location on the assembly line where operators perform a task on a produced component. The cycle time is the amount of time required to execute each workstation task. An optimal production rate is one in which each product is completed within the time limit specified. Experts agree that optimising scheduling is a near-impossible endeavour. Manual computations are sometimes time-consuming and labor-intensive. Each workstation's processing time should be balanced. Figure 2.5 shows the five steps in solving line balancing that described by (G. Andrew, 2006).

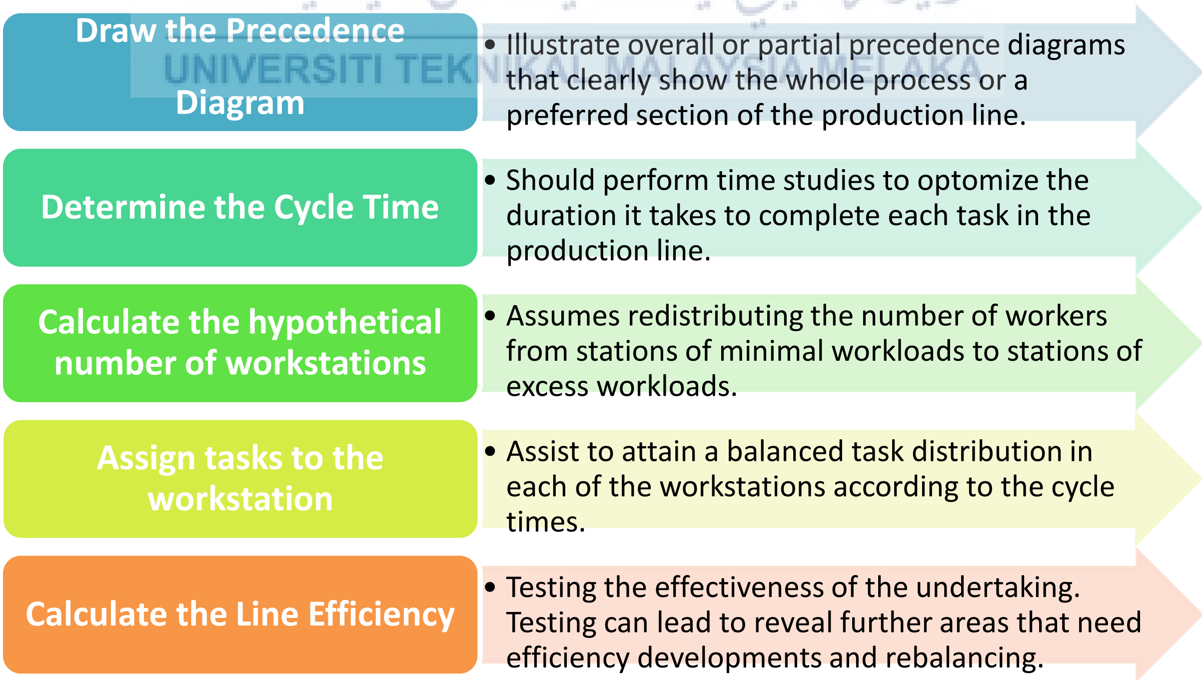
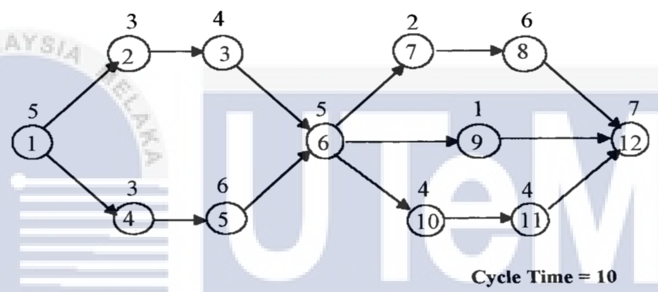


Figure 2.5 Basic steps of Line Balancing (LB)

2.5.1 Draw the Precedence Diagram

The Precedence Diagram is the first stage in Line Balancing. A precedence diagram, represented by nodes or a graph, must be built to explain the task link across workstations by demonstrating the sequence in which tasks are carried out. The product should not be transported to the next station until the previous station has been completed. This method entails breaking down the whole manufacturing process into successive steps. A product cannot move from one segment to the next unless the task at each workstation is completed. The Figure 2.6 below illustrates the Precedence Diagram for the Line Balancing (LB).



Task No.	Task Time	Immediate predecessor tasks	Task No.	Task Time	Immediate predecessor tasks
1	5	------	7	2	6
2	3	1	8	6	7
3	4	2	9	1	6
4	3	1	10	4	6
5	6	4	11	4	10
6	5	3, 5	12	7	8, 9, 11

Figure 2.6 Precedence Diagram of Line Balancing

2.5.2 Determine the Cycle Time

The cycle time is the maximum amount of time permitted at each station. Cycle time may be calculated by dividing the necessary units by the available production time each day. This is the duration in minutes between two concurrent goods exiting the end of the production line. It serves as an indicator of how the line is set up to run at that time, taking into consideration the total output amounts. Cycle time may be stated numerically as the Formula 2.1 below follows:

$$\text{Cycle time} = \frac{\text{Available time}}{\text{Desired output}} \tag{2.1}$$

2.5.3 Calculate the hypothetical number of workstations

Distribute tasks to workstation after completing a time cycle in the order of longest task times. This calculation will help to attain a balanced task distribution in each of the workstations based on the cycle times. Basically, from this calculation the organization can arrive at the number of workstations by their need by dividing the sum of your task times by the desired actual times. The Formula 2.2 shows the calculation of workstation.

$$\text{Number of work Stations} = \frac{\sum \text{Task Time}}{\text{Desired Actual Time}} \tag{2.2}$$

2.5.4 Assign tasks to the workstation

Continue to rearrange the jobs to decrease excess capacity and production bottlenecks. This entails moving the number of employees from stations with low workloads to stations with high workloads. This procedure contributes to shorter wait times in stations with extra capacity. Attempt to intelligently divide the quantity of work among the number of operators in a queue, with the goal of maximising machine utilisation. For synchrony, each task should take the same amount of time. The Takt time is the amount of time it takes a competent person or an unmanned machine to complete a task. It may risk overproduction and waste if the organization execute keg line balancing to the point where production exceeds takt time. However, producing slower than takt time can lead to delays, idle time, and frustrated clients. Formula 2.3 shows the calculation for Takt Time.

$$\text{Takt time} = \frac{\text{Total Available Production Time}}{\text{Average Customer Demand}} \qquad (2.3)$$

2.5.5 Calculate the Line Efficiency

Cycle time may be greatly reduced by improving machine time through balanced improvements and worker training. Resizing line segments (raising or decreasing the number of workstations in each division) can also help to a lean manufacturing approach by lowering total work time. Following a balanced job allocation, the next stage is to evaluate the project's effectiveness. Testing might assist to identify other areas that require efficiency improvements and rebalancing. The following Formula 2.4 is the assembly line efficiency formula:

$$\textbf{Line Efficiency} = \frac{\textbf{Sum of task times}}{\textbf{Number of workstation X Desired cycle time}} \qquad (2.4)$$

2.6 Capacity Planning (CP)

Manufacturing capacity planning is a process for determining the highest production rate feasible at a facility or on a manufacturing line, comparing this rate to client orders and predicted demand, and developing a strategy that maximizes actual output. This strategy is also known as "finite capacity planning" since it assists manufacturers in taking into consideration the actual constraints of current production resources when developing production plans and schedules. Manufacturing capacity planning serves one purpose: it ensures that production plans and schedules are realistic and do not exceed available capacity or violate any production regulations or limits. Working within maximum capacity constraints, producers avoid situations that result in rushed scheduling, extra in-process inventory, missed delivery dates, and dissatisfied customers.

Another goal of industrial capacity planning is to improve production efficiency. Capacity analysis and planning not only helps companies in avoiding overcapacity concerns, but they also assist in minimizing under capacity circumstances. Manufacturing capacity planning, in other words, may be used to optimize production plans and schedules in order to reduce waste associated with idle machinery and staff. Manufacturing capacity planning necessitates data from all parts of a manufacturing operation, including supply chain capacity, stocks, employee qualifications, availability, production capacity, and maintenance schedules for each manufacturing machine or workstation, among other things.

2.6.1 Types of Capacity Planning (CP) Strategies

There are three methodologies behind capacity planning. In order to choose the right strategy, the organizations need to consider the type of business they run, the level of risk that they can safely assume, and the lifecycle of the products. Figure 2.7 illustrates the types of Capacity Planning Strategies.

Figure 2.7 Types of Capacity Planning Strategies

2.6.1.1 Lead Strategy

Lead Strategy - The lead strategy is to prepare for adequate resources to satisfy the demand estimates. The lead strategy involves higher risk than the lag strategy. For example, if the company recruit new staff and do not get the orders company expected, they may end up paying them to sit around. The main advantage of this technique is that if there is a sudden increase in orders, company will most likely be able to keep all your clients satisfied and fulfil deadlines.

2.6.1.2 Lag Strategy

Lag Strategy - The lag strategy intends to have adequate resources to satisfy actual demand (rather than predicted demand). The lag strategy is a cautious approach to capacity planning that keeps your expenses as low as feasible. The possible disadvantage of this technique is that it may cause a lag in the delivery of items or services to clients, thus the term. If you see a sudden rush in orders or sign a significant new client that requires quick response times, your lag strategy may prohibit you from fulfilling deadlines.

2.6.1.3 Match Strategy

Match Strategy - Match strategy is a compromise between lag and lead strategies. Companies undertake strategic capacity planning more regularly while use match strategy. True demand, predicted demand, and market shifts/trends are all actively monitored. They change the ability of management to meet demand in increments based on this information. This technique provides the most flexibility with the least risk than the lead strategy, but it scales better than the lag strategy.

2.6.2 2 Key Capabilities of Manufacturing Capacity Planning

Manufacturing capacity planning, as a collection of functions inside advanced planning and scheduling software, includes the following capabilities:

i. Analytical modelling - Advanced algorithms are used in manufacturing capacity analysis to properly track order and production factors and assess the impact of changes on capacity planning.

ii. Simulation modelling - The capacity to run "what if" scenarios is a tool that allows factory planners to estimate the impact on workflow and productivity of changes in resource allocation, distribution, or order sequencing, among other things.

iii. Including real capacity - Initial capacity analysis yields relatively accurate capacity estimates that take into consideration not only the nameplate capacity but also setup time, maintenance downtime, changeovers, cleaning activities, and other aspects. It also takes into consideration structural difficulties, such as how long it takes a work in progress to travel from one processing station to the next. Variation owing to human variables, such as differences in the time it takes various operators to complete a set of operations, must also be considered. Advanced Planning System (APS)-based capacity planning updates these estimations with real values as production happens. This characteristic becomes increasingly crucial as the manufacturing cycle grows more complicated. Estimates that are incorrect by a few percentage points can disrupt synchronization and cause serious problems between production processes.

iv. Identifying Bottlenecks - APS-based manufacturing capacity planning detects production bottlenecks by allowing planners to visualize a production cycle and observe where work-in-progress is piling up or where workstations are waiting to conduct their activities. The system takes such bottlenecks into account in planning and timetables, then adapts when the manufacturer reallocates (or invests in new) resources to alleviate each bottleneck.

2.6.3 Capacity Planning (CP) Process

The capacity planning process typically includes four steps; determine current capacity, forecast future demand, identify gaps, develop plans to address those gaps and implementation of the plan. Extensive research has been done on the capacity planning process. One focus is the uncertainty involved in the planning process. Researchers have developed various models and techniques to account for uncertainties in demand forecasts and resource availability. One such model is that of (Zhang et al., 2012), proposed probabilistic capacity planning model. This model uses a simulation-based approach to incorporate uncertainty into the capacity planning process. The authors demonstrate the effectiveness of the model using a case study of a semiconductor manufacturing facility.

Another area of research was the inclusion of sustainability aspects in the capacity planning process. (Kuo et al., 2017) propose a sustainable capacity planning framework that considers both economic and environmental factors. The authors demonstrate the effectiveness of the framework using a case study in a solar module manufacturing facility. In addition to these specific models and frameworks, best practices for the capacity planning process were also considered. For example, (Sridharan et al., 2013) identify several critical success factors for effective capacity planning, including cross-functional collaboration, data accuracy, and flexibility of the planning process. Capacity planning is used by operations managers to estimate future demand for a company's products or services and guarantee that the appropriate resources are available when demand grows. Figure 2.8 and Table 2.4 below briefly explain about the five steps of capacity planning process.

Figure 2.8 The basic five steps of Capacity Planning Process

Table 2.4 Explanation of Capacity Planning Process steps

Capacity Planning (CP) Process	Description
Determine Current Capacity	The first stage is to assess the company's present resource capacity. It is a calculation of how much production the firm can currently create with its current resources. Current capacity will be influenced by factors such as personnel count, available space, and equipment type.
Forecast Future Demand	The following phase is to anticipate future demand for the company's goods or services. This involves forecasting how much demand will rise in the future and determining what new items or services will be required to fulfil this need.
Identify Gaps in Capacity	The next stage is to identify any capacity gaps. It entails identifying any areas where the company's resources will be insufficient to satisfy future demand. The gaps might be caused by a shortage of workers, space, or equipment. Capacity planning allows operations managers to identify and fix these shortcomings.
Develop a Plan to Fill the Gaps	The fourth phase is to devise a strategy for filling capacity shortfalls. It includes recruiting new workers, renting more space, or acquiring new equipment. Operations managers may guarantee that the firm is prepared for future demand by developing a strategy to handle the company's capacity needs.
Implement the Plan	The final stage is to put the capacity planning strategy into action. It implements the strategy and ensures that all essential resources are available. Operations managers may guarantee that their organization is ready for future expansion by following the capacity planning procedure.

2.7 Capacity Planning and Line Balancing

Capacity planning and line balancing are two important aspects of production line management and are closely related. Capacity planning is determining the production capacity required to meet demand for a product or service. This includes analysis of historical data, market trends and other factors to forecast future demand and plan production accordingly. Line balancing, on the other hand, is the process of optimizing the assignment of workstations and tasks on a production line so that each workstation operates at maximum efficiency.

Several studies have been conducted in the last decade to investigate the relationship between capacity planning and line balancing in production lines. One such study by Zhang et al. (2012) investigated the impact of capacity planning on line balancing in semiconductor manufacturing facilities. The study found that effective capacity planning can significantly improve circuit distribution by reducing idle time and increasing throughput.

Another study by Kusiak et al. (2014) focused on developing mathematical models for concurrent capacity planning and line balancing in flexible manufacturing systems. In this study, an optimization algorithm was proposed that considers both capacity planning and line balancing goals to achieve optimal results.

In a recent study, Wang et al. (2019) investigated the use of simulation-based optimization for capacity planning and line balancing in PCB assembly lines. In this study, we found that simulation-based optimization can effectively distribute the workload across multiple workstations and improve overall production efficiency. Taken together, these studies demonstrate the importance of considering both capacity planning and line balancing when managing production lines. Effective capacity planning helps optimize production capacity, and line balancing can ensure that this capacity is used efficiently.

2.8 Simulation

In the manufacturing industry, simulation has become an essential tool for improving production processes, reducing costs and increasing efficiency. One of the most common uses of simulation in the manufacturing industry is process improvement. Simulation can be used to identify bottlenecks, optimize production lines and reduce cycle times. According to a study by (Li et al., 2019) simulation-based optimization can improve production efficiency by up to 30%. Another study by (Wang et al., 2018) used simulation to optimize a material handling system and found that cycle times could be reduced by 20%. By simulating the manufacturing process, manufacturers can identify potential defects and take corrective action before they occur. A study by (Zhang et al., 2017) found that simulation-based quality control can reduce error rates by up to 50%.

In addition to process improvement and quality control, simulation can also be used for employee training and development. Simulating the production process gives workers hands-on experience without risking damage to equipment or products. A study by (Wang et al., 2019) found that simulation-based training can improve worker performance by up to 25%. Another area where the use of simulation is increasing is supply chain management. Through simulation, you can model complex supply chain networks and identify potential risks and opportunities. A study by (Gao et al., 2018) found that simulation-based supply chain management can reduce lead times by up to 40%. Overall, simulation has become an essential tool in the manufacturing industry to improve manufacturing processes, reduce costs, and increase efficiency. Latest research shows that simulation-based optimization improves production efficiency by up to 30%, simulation-based quality control reduces error rates by up to 50%, and simulation-based training improves employee performance by up to 25% is shown. Simulation can increase simulation efficiency by up to 30% and base supply the chain management can reduce lead times by up to 40%.

2.8.1 Simulation and Line Balancing

Simulation and line balancing are two significant concepts in the field of operations management. Simulation is the process of creating a model of a real system or process and using it to test different scenarios and predict how the system will behave under different conditions. Line balancing, on the other hand, is the process of optimizing the distribution of work between different workstations on a production line to minimize idle time and maximize efficiency. Applying simulation to line balancing helps companies optimize their output processes by distinguish potential bottlenecks, reducing idle time and improving overall efficiency. By creating a simulated model of the production line, managers can test different scenarios and adjust the distribution of work across different workstations to find the best balance. A key benefit of line balancing simulation is that it allows managers to test different scenarios without interrupting real production. This minimizes downtime and reduces the risk of errors and accidents that can occur during actual production. Additionally, simulations help administrators spot potential problems before they occur, allowing them to take proactive steps to prevent problems from occurring.

Another advantage of line levelling simulation is that it allows administrators to assess the impact of changes in real time. For example, when a new machine is added to a production line, managers can use simulation to test how it affects the efficiency of the entire line and customize as needed. increase. Overall, applying simulation to line balancing helps companies optimize their production processes and improve overall efficiency. By using simulations to test different scenarios and make real-time adjustments, administrators can identify potential problems before they occur and take proactive steps to prevent problems from occurring.

2.9 Arena Simulation

Arena Simulation is user-friendly software. Arena features interchangeable graphics simulation modeling and analysis module templates for creating various simulation models. Modules are typically organized into panels to access different modeling structures. It works by switching panels. In general, modules on different boards are compatible using the same simulation model. This study relied on arena simulation software of arena is a software program that provides an integrated framework for creating simulations models for different applications. Arena is a software product that provides integrated deployment a framework for creating simulation models in multiple applications. The software requires the simulation modeling, animation, model validation, analysis of input/output data and analysis results (Bait et al., 2020).

2.9.1 Module

A module in Arena Simulation is a pre-built collection of logic and functionality that can be added to a simulation model. Modules are created to carry out specific duties or operations within the simulation, such as producing arrivals, processing entities, or gathering data. Modules can be built by the user or bought from third-party vendors. They are usually distributed as Dynamic Link Library (DLL) files that may be simply inserted into the simulation model. Modules can be modified and modified after imported to match the unique demands of the simulation.

The Process module is one of the most often used modules in Arena Simulation. In the simulation model, this module represents a work station or process and is used to specify the processing logic for things that pass through it. The Create module, which produces new things in the simulation, and the Dispose module, which removes entities from the simulation, are two more often used modules. Overall, modules are an important part of

Arena Simulation because they enable users to rapidly and easily add complicated functionality to their models. The data modules are used to define parameters for model elements such as resources, entities, and queues (Gunduz and Naser., 2017). Table 2.5 and 2.6 shows the flowcharts and also data modules in basic process panel of Arena Simulation.

Table 2.5 Flowchart Module of Arena Simulation.

Name	Description
Create	Entities enters the simulation.
Seize	Entity responsible for availability of resources of servers.
Delay	Holding of an any entity for processing by a server or resources.
Release	Entity that has completed processing.
Process	Performed by one or more resources.
Decide	A branch in entity flow but only one branch is taken.
Dispose	Entities are removed from the simulation.

Table 2.6 Data Module of Arena Simulation.

Name	Description
Entity	Explain the different entity types and its initial image values.
Resources	Explain the system’s resources, including cost and availability.
Queue	Explain the queues that are present in the system.
Schedule	Define an operating schedule for a resource or define an arrival.
Attribute	Explain the attributes of the entity such as types, dimensions, and initial.
Variable	Explain the variables that will be used by the model’s modules.

2.10 Discrete Event Simulation (DES)

Companies clearly require simulation approaches for a variety of reasons. To begin with, processes feature variations, which indicates that a change can occur anywhere in the process, whether it is predicted or not. Take, for example, a manufacturing process. If it is necessary to raise or reduce the overall number of workers in a process, or the distance between processes, the production rate may be affected. Second, processes are linked together. In most circumstances, each component may be said to interact with others. Similarly, to the previous example, if they improve the capacity of one of the machines in an assembly process, they will most likely be preoccupied with finding a solution to a bottleneck soon after that machine. Another cause might be the intricacy of procedures. Consider a supply chain process. There will be a supplier, a wholesaler, and a customer. The consumer orders some items from the wholesaler based on demand. At that time, a little fluctuation in demand between wholesaler and client will also impact the supplier's production rate (Robinson 2003).

Considering customer demand is always changing, a flexible, high-performance, and cost-effective manufacturing system is essential. Both to suit the requirements of customers and to acquire a competitive edge. One of the methods used to achieve these goals is DES modelling. A solid DES model's strength is its ability to mimic a system's behavior in detail and hence give meaningful decision-making insights. Nonetheless, a simulation model gives a hint and should not be relied blindly, necessitating virtual faith. To build a realistic simulation model, the process data must be as accurate as feasible. This information might be derived from how the system performed in the past, present, or what you want it to do. In other words, the simulation model is defined by the process data, and if that data is erroneous, so is the model. This critique is something that should be considered while utilizing this approach to guarantee that the simulation model's output is valid in the future.

2.10.1 Discrete Event Simulation Applications

DES may be used in a wide range of applications. The applications of developing DES models make them extensively used in a variety of sectors and fields. Manufacturing, education, healthcare, economics, logistics, and, not least, the autonomous sector are all areas where DES is extensively employed. A full-scale simulation project's level of execution is closely related to its usage of undertaking management. Everything from identifying the goal and scope to prioritizing time and money lays the groundwork for a successful project. Before effectively constructing a simulation model, DES projects must go through many steps. They are as follows:

i. Building a process map (also called formalized scheme) of the system.

ii. Building a conceptual model.

iii. Manage data gathering.

2.10.1.1 Building a process map

Creating a process map is an excellent way for comprehending, representing, and analyzing how processes work. Direct observation of a process is insufficient to comprehend the whole link between work items in various stages of production; this may be grasped by developing a process map. When a process map is created, it may be used to analyze future improvements and optimizations in the organization, or, in the case of this project, it can be utilized to develop the simulation model. As a result, a third-party reader will have a greater understanding of how the various processes function as well as how the simulation model works.

2.10.1.2 Building a conceptual model

Conceptual modelling is a popular approach in simulation-related work. Conceptual modelling is the process of abstracting a model from a real-world system. This is generally regarded to be the most difficult, least understood, and most important aspect of the entire simulation effort. The significance of a conceptual modelling phase is that the abstraction is carried out at the appropriate degree of detail. This is also the stage at which decisions on what to simulate or not are made in order to achieve the required level of complexity in the shortest time feasible. A typical error is to create an overly complicated model for a purpose that has already been met. This then affects resource allocation, resulting in a greater economic cost.

2.10.1.3 Manage data gathering

To be able to develop a model that matches reality, DES operations frequently rely largely on high input data and data management. As a result, the data collection step is critical and time demanding. A general problem is how time intensive the data collection step frequently becomes. According to empirical research, this phase accounts for around one-third of the total project duration. A study on DES scheduling proposes a way for handling input data. The study's goal was to make DES exhibits more time-efficient by giving a structured methodology for dealing with incoming data.

2.10.2 What-If-Analysis

A what-if analysis is a technique used to assess how changes in the assumptions on which forecasts are based influence expected performance. What-if analysis is used to analyze several scenarios and their potential results in the face of changing situations. The goal of a what-if analysis is to identify the impact of these outcomes in a statistical model while also assessing risk. Sensitivity analysis approaches include scenario-management tools, brainstorming strategies, and modelling and simulation techniques. Researchers, analysts, scientists, and investors regularly employ what-if analysis. It is also known as sensitivity analysis.

Its primary goal is to assess the robustness of a model or system's outcomes in the face of uncertainty in order to better understand the linkages between input and output variables in a system or model. What-if analysis looks for faults in the model by examining unusual relationships between inputs and outputs. It is used in model simplification to fix model inputs that have no effect on the output and to detect and remove unnecessary model structure.

What-if analysis is an Excel method in which we work with tabular data. In the What-if analysis, several variables were entered into the cell of the excel sheet to see the results in multiple ways without having to create separate sheets. What-if analysis has three tools:

i. Goal seek - Goal seeking is a broad word that refers to the act of determining your input value based on an already known outcome value. A specific operator is used in a formula that can be calculated using computer software.

ii. Scenario manager - Scenario manager is an Excel-based what-if analysis tool that works with many situations. It employs a set of ranges that influence an individual output. As a result, users may utilize it to generate distinct situations, such as poor and medium, based on the numbers in the range that determine the outcome.

iii. Data table - Data tables are part of a set of commands known as What-If analysis tools in Microsoft Excel. What-if analysis occurs when you create and analyze data tables. What-if analysis is the process of changing the values in cells to observe how such changes affect the results of worksheet calculations.

2.11 Benefits of LM and CP

Capacity planning and lean manufacturing are critical ideas in production management. Capacity planning is evaluating an organization's production capacity required to meet demand for its products or services. In contrast, lean manufacturing is a systematic strategy to detecting and removing waste in the manufacturing process. The combination of these two principles has the potential to significantly increase line balancing performance, which is essential for attaining efficient and effective output.

The primary benefit of capacity planning is that it assists organisations in optimising their resources. Organisations may prevent overproduction or underproduction, which can result in wasted resources and lost income, by assessing the production capacity required to fulfil demand. Capacity Planning also helps businesses to anticipate possible bottlenecks in the manufacturing process and take proactive steps to address them before they become an issue. Moreover, Lean Manufacturing focuses on removing all types of waste from the manufacturing process. This involves decreasing surplus inventory, reducing faults, and optimising procedures to shorten cycle times. Organisations may increase their efficiency and save costs by using lean manufacturing concepts while maintaining or enhancing product quality. Organisations may improve their line balancing performance and gain improved efficiency and productivity by modelling various situations.

2.12 Applications of Line Balancing and Simulation

A lot of researchers was published on the basic applications of Line Balancing and Simulation in many studies. The LM tools and simulation ideas have been widely studied for their ability to improve productivity, quality, and other aspects of manufacturing process. Based on the case study, the performance of the process had improved LM tools and simulations in industry was explained in this part by the authors.

Chen, J. (2021) research focuses on optimizing line balancing and worker scheduling in automotive assembly lines using a simulation-based approach. The study aims to improve productivity and efficiency by considering worker skill levels and task allocation. By integrating line balancing and simulation techniques, the research demonstrates how lean manufacturing principles can be implemented in automotive assembly lines. The study highlights the importance of considering worker skill levels in line balancing decisions. By assigning tasks based on worker capabilities, the research aims to minimize idle time and maximize productivity. The simulation-based approach allows for the evaluation of different line balancing strategies and worker schedules, enabling manufacturers to identify the most efficient configuration.

According to Wang, Y. (2019), the study focuses on line balancing in a mixed- model assembly line using separate- event simulation. The study explores the impact of different line balancing strategies on productivity, resource application, and product inflexibility. The study provides precious perceptivity for manufacturers seeking to optimize their mixed-model assembly lines, enabling them to make informed opinions to ameliorate productivity and rigidity.

Moreover, in the study of Gupta, S. (2018), provides a comprehensive review of line balancing styles for effective resource application in manufacturing systems. The study evaluates effective ways, including simulation- grounded approaches, and provides recommendations for opting suitable strategies grounded on assiduity-specific conditions. The study evaluates different line balancing styles, similar as the ranked positional weight system and the largest seeker rule, and provides perceptivity into their effectiveness in different manufacturing systems.

The study conducted by Lee, (2022), focuses on the operation of line balancing and simulation for spare manufacturing implementation in a semiconductor factory. The exploration presents a case study that demonstrates how the integration of line balancing and simulation ways can upgrade process effectiveness, reduce waste, and enhance overall productivity in a complex manufacturing environment. Line balancing refers to the distribution of tasks among workstations in a way that minimizes idle time and maximizes productivity. By achieving a balanced workload across workstations, manufacturers can exclude backups and insure smooth product inflow. By using simulation, experimenters can test and upgrade line balancing strategies before enforcing them in the actual product environment.

By the study of Zhang, L. (2023), exploration proposes a simulation- grounded optimization frame for assembly line balancing considering worker variability. The study highlights the significance of incorporating mortal factors into line balancing processes and demonstrates how simulation ways can regard for worker skill variations and ameliorate overall system performance. The simulation- grounded optimization frame allows for the evaluation of different line balancing strategies and worker assignments, enabling manufacturers to identify the most effective configuration. The study showcases the benefits of incorporating worker variability into assembly line balancing. By optimizing line balancing considering worker skill variations, manufacturers can ameliorate productivity, reduce idle time, and enhance overall system performance.

After that, the study of Li, Q. (2021) exploration focuses on simulation- grounded optimization of product line balancing with multiple objects. The study explores the trade-offs between clashing objects similar as productivity, cost, and quality. By exercising simulation ways, the exploration provides decision- makers with perceptivity into opting an optimal line balancing strategy that considers multiple objects. The study highlights the significance of considering multiple objects in line balancing, as optimizing a single ideal may lead to sour overall performance. By using simulation- grounded optimization, manufacturers can estimate different line balancing strategies and their impact on various performance criteria. This allows decision- makers to make informed opinions that strike a balance between different objects and achieve better overall performance.

Based on the study of Kim, M. (2020), the study focuses on the operation of simulation and line balancing ways in a healthcare product assembly line. The exploration highlights the eventuality of these styles to optimize workflow, ameliorate effectiveness, and reduce backups in healthcare product assembly processes. By exercising simulation ways, the study allows for the evaluation of different line balancing strategies and their impact on effectiveness and resource application. This enables manufacturers in the healthcare assiduity to identify and apply advancements in their assembly line operations, leading to enhanced productivity and quality.

Tan, Z. (2019) also presents a simulation- based optimization approach for mixed-model assembly line balancing. The exploration investigates the impact of different line balancing algorithms on product effectiveness, resource application, and client satisfaction in a mixed- model product terrain. By exercising simulation ways, the study provides perceptivity into optimizing line balancing strategies in mixed- model assembly lines. This allows manufacturers to achieve better product effectiveness, reduce backups, and enhance client satisfaction. The exploration highlights the significance of considering the specific characteristics of mixed- model product when designing line balancing strategies.

Huang, G. (2018) exploration explores the integration of line balancing and simulation ways for resource- constrained product systems. The study demonstrates how combining these approaches can help optimize product processes in resource- constrained surroundings. By exercising simulation ways, the exploration allows for the evaluation of different line balancing strategies and their impact on resource application and product effectiveness. This enables decision- makers to identify the most effective line balancing approach in resource-constrained settings, leading to bettered productivity and resource allocation.

In addition, Zhang, L. (2023) proposes a simulation- based optimization frame for assembly line balancing considering worker variability. The study emphasizes the significance of incorporating human factors into line balancing processes, pressing how simulation ways can regard for worker skill variations and ameliorate overall system performance. By considering worker variability, the exploration provides perceptivity into optimizing line balancing strategies to achieve better productivity and worker satisfaction in assembly line operations. The study showcases the benefits of incorporating worker skill situations into the line balancing process, allowing for further effective task assessment and minimizing the impact of skill differences on productivity. Table 2.7 below summarizes study articles and methods conducted by old researches in manufacturing industry.

Table 2.7 The method used by the old research

Author, Year, Publisher	Finding
Chen, J. (2021)	"A simulation-based approach for optimizing line balancing and worker scheduling in automotive assembly lines." International Journal of Production Research.
Lee, S. (2022)	"Application of line balancing and simulation for lean manufacturing implementation: A case study in a semiconductor plant." Journal of Manufacturing Systems.
Wang, Y. (2019)	"Line balancing in a mixed-model assembly line using discrete-event simulation." International Journal of Production Economics.
Gupta, S. (2018)	"A review of line balancing methods for effective resource utilization in manufacturing systems." Journal of Industrial Engineering and Management.
Zhang, L. (2023)	"Simulation-based optimization of assembly line balancing considering worker variability." Computers & Industrial Engineering.
Li, Q. (2021)	"Simulation-based optimization of production line balancing with multiple objectives." Journal of Manufacturing Processes.
Kim, M. (2020)	"Application of simulation and line balancing for improving efficiency in a healthcare product assembly line." International Journal of Precision Engineering and Manufacturing-Green Technology.

Tan, J. (2019)	"Simulation-based optimization of mixed-model assembly line balancing." The International Journal of Advanced Manufacturing Technology.
Huang, G. (2018)	"Integration of line balancing and simulation for resource-constrained production systems." International Journal of Production Research.
Park, J. (2022)	"A systematic review of line balancing in the era of Industry 4.0: Challenges and opportunities." International Journal of Production Research.

2.13 Summary

This review of the literature provides a summary of lean manufacturing systems. This fundamental conception provides a wealth of information on spare waste tools and ways. This is to increase manufacturing process productivity while perfecting process issues by relating and reducing loss rates. likewise, associations constantly have had success by enforcing this system into their system in order to increase productivity and produce the highest business. numerous companies have successfully enforced this strategy on their systems in order to increase productivity and earnings. This study's ideal is to address problems, reduce waste and inefficiency, and improve conditions in order to more retain guests. Eventually, this study proposed a system for conducting a line balancing and simulation in order to improve productivity in LM. The details of the time study will be presented in the following chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Line balancing is a technique used in production and manufacturing to optimize the efficiency of assembly lines by ensuring that the workload is evenly distributed among workstations. The aim of this research is to minimize idle time, reduce bottlenecks, and provide a smooth workflow. An effective approach to analyzing and improving line conditioning is using simulation models. Arena, a popular simulation software, provides a powerful platform for creating and evaluating assembly line models. The purpose of this methodology is to introduce the process of line balancing using an arena simulation model. Learn the key steps in assembly line design, simulation, and analysis to achieve optimal balance and efficiency. Arena Simulation approaches and creates a virtual representation of the assembly line, simulate the production process, and collect valuable data for performance evaluation.

3.2 Research Design

The research design of this study uses a quantitative approach and specifically employs simulation-based experiments. The research design is based on a single-group pre-test and post-test design, using an arena simulation model to evaluate line balancing performance on an assembly line before and after implementation of different line balancing strategies.

Arena simulation software was selected as the primary tool for conducting these experiments because it can model complex assembly line systems, simulate different line balancing strategies, and evaluate performance metrics. The selection of the arena simulation model was based on its widespread use in the industry and its ability to realistically represent assembly line work. Flow chart was drawn for the better understanding to show the progress through this research. Figure 3.1 illustrates the progress of project planning.

3.2.1 Project Planning Flowchart

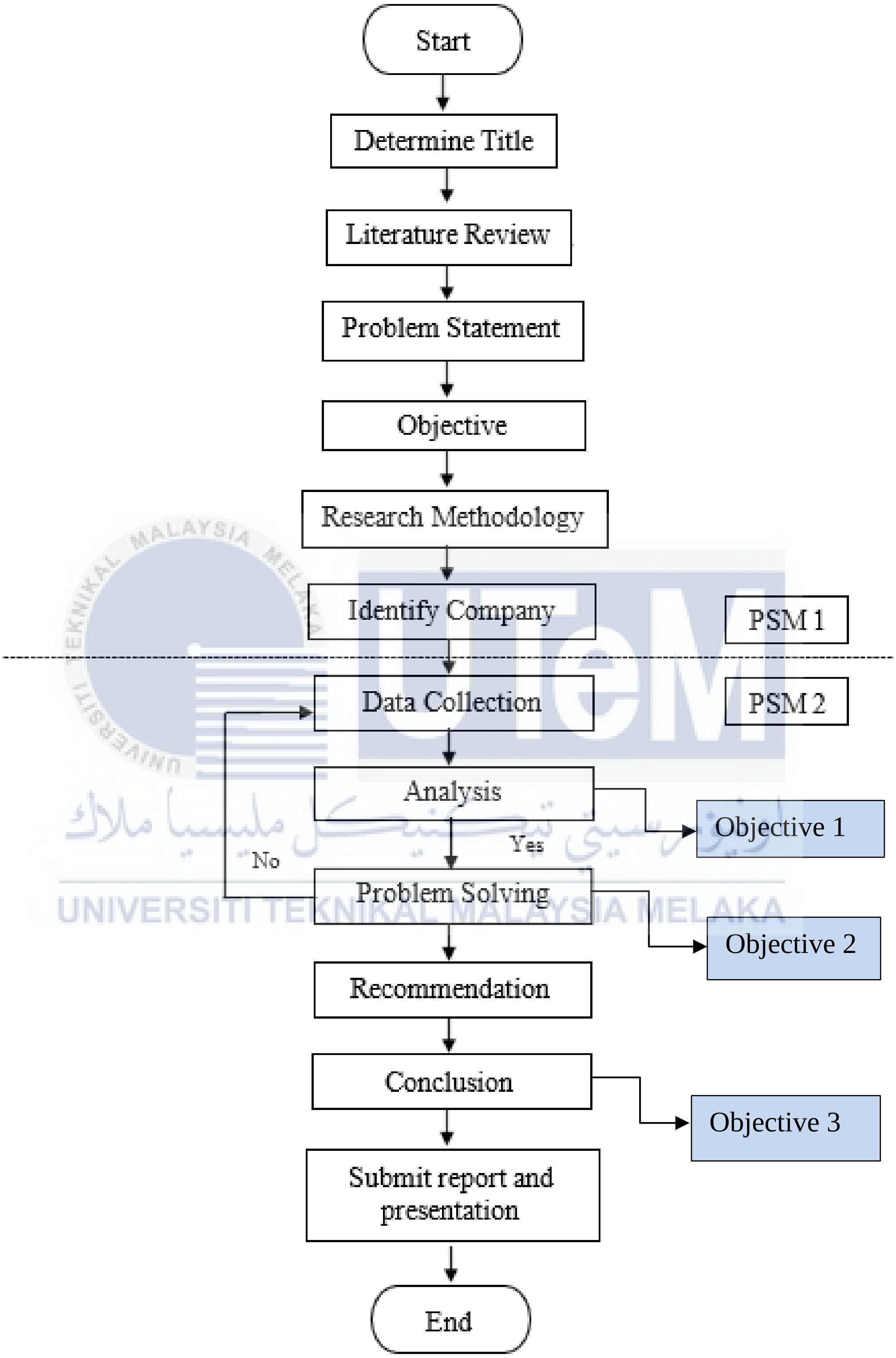


Figure 3.1 Overall Project Planning Flow Chart

3.3 Research Phase

Based on the Figure below, this research was categorized the technological analysis into three main phases according to the research objectives. The first stage was focused on the research objectives that mentioned in Chapter 1. The first phase (Phase 1 – Data Collection), following with the second phase (Phase 2 - Communication), and the third phase (Phase 3 - Implementation) clearly defined in the Figure 3.2.

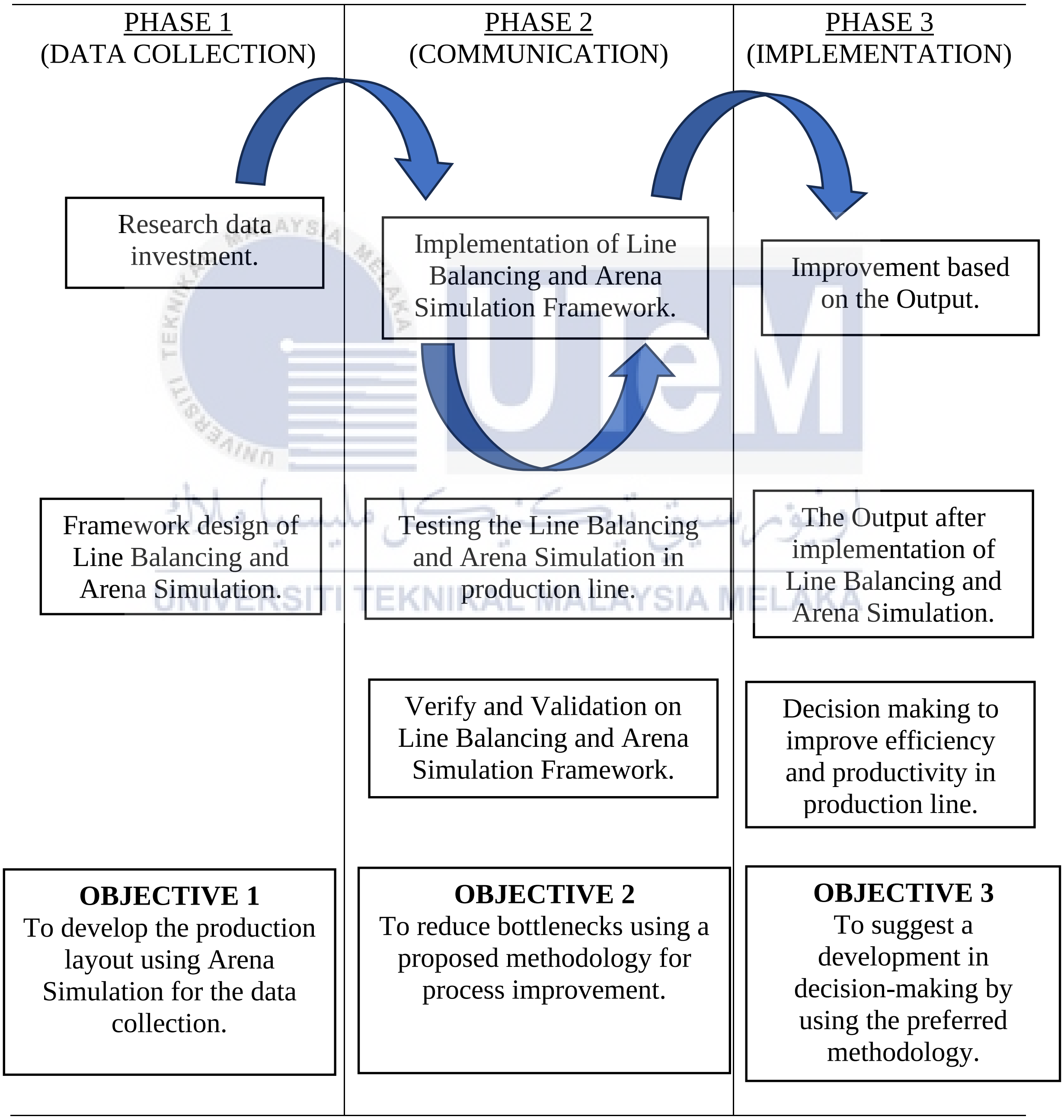
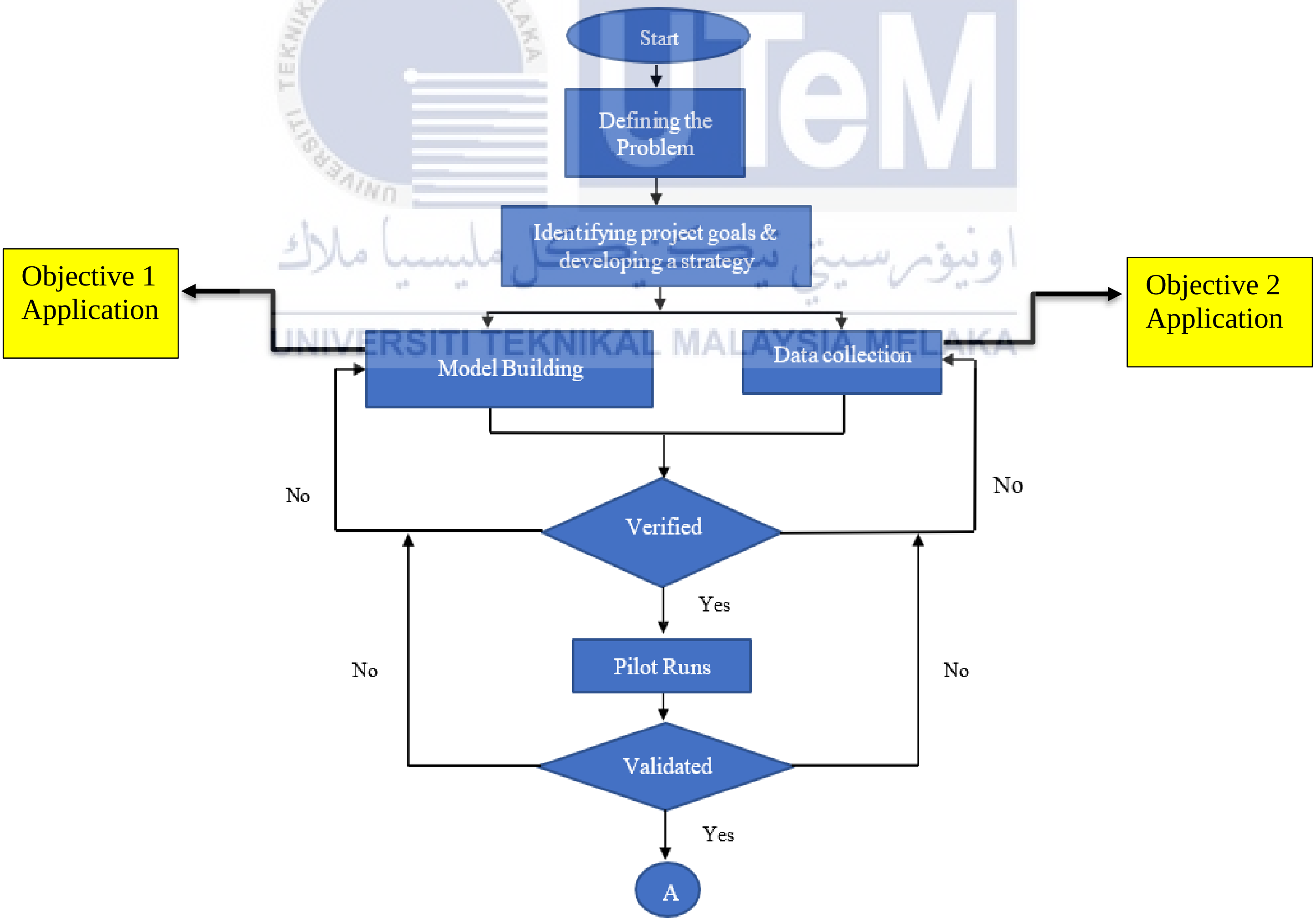


Figure 3.2 Research Phase

3.4 Proposed Methodology

The variables to be manipulated in the experiments will include task allocation methods, such as precedence-based, heuristic-based, and mathematical optimization algorithms. The controlled variables will include cycle times, worker skill levels, and assembly line configurations. Figure 3.3 depicts the proposed methodology that used in this research for further improvement. The experiments will be conducted multiple times to ensure statistical significance and reliability of the results. The Gantt Chart for PSM 1 and PSM 2 shows the planning versus actual work carried out along this research to accomplish the mentioned problem stated for improvement in line balancing.

Simulation Modeling:



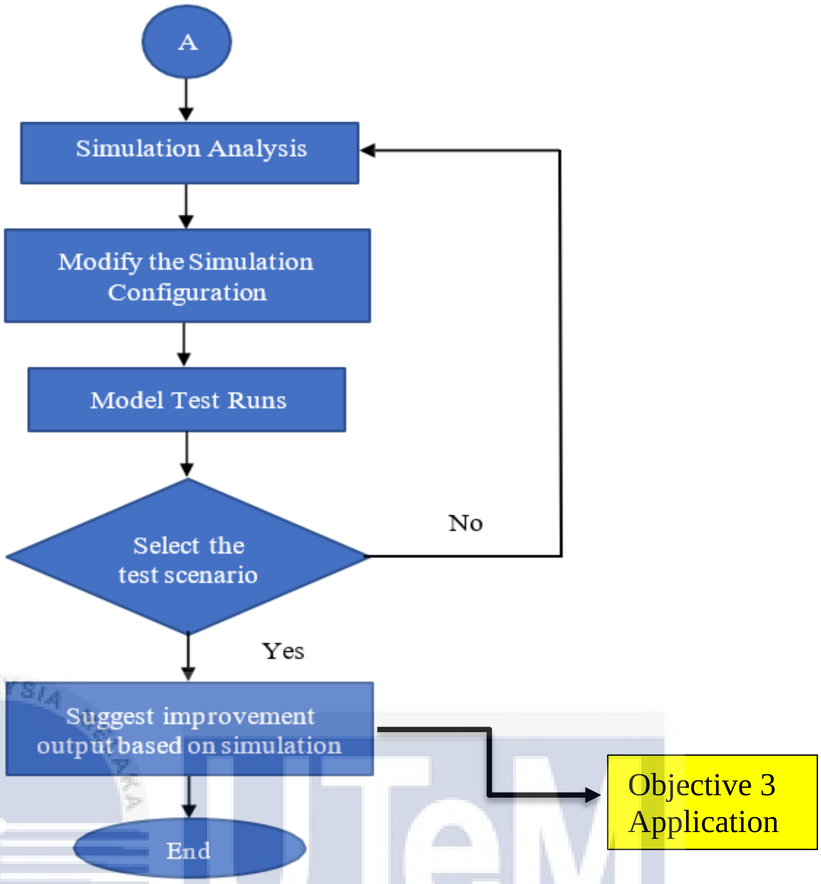


Figure 3.3 The proposed Methodology

3.4.1 Defining The Problem

Clearly define the goals of the line balancing project. Identify production targets, minimize cycle time, reduce workstation idle time, or maximize throughput. Determine desired output metrics and key performance indicators used to evaluate line balancing efforts.

3.4.2 Identifying Project Goals and Developing a Strategy

Plan the entire production process and identify each task or operation required to complete the assembly. The goals of the simulation model are defined using the problem statement as a structure. A description of the system to be evaluated and an explanation of how different alternatives will be examined are included in the overall project plan. Every stage of the project's development and its expected conclusion will have a Gantt chart developed for them. The tasks that have been produced over the course of the project will be shown in this chart.

3.4.3 Model Building

Create a virtual model of an assembly line using Arena software. Create graphic representations of workstations, conveyors, and material handling systems. As a model gets more complicated, several types of information may be needed. Since much of the time needed to run a simulation is spent to gathering data, it is important that this process begin early. This often happens when creating a model.

3.4.4 Data Collection

A computer-readable format for the model is necessary since constructing a model requires data storage and computation. It will be able to generate a simulation of the building using the Arena Simulation. During the company visit, a comprehensive collection of relevant information and data is essential for assessing Lean Manufacturing waste in the production line. To enhance efficiency using Arena Simulation, crucial data points such as workstation details, the number of operators, process flow, standard time, process cycle time, operating hours, and customer demand will be gathered. The identification of the system's bottleneck will be a pivotal aspect, highlights the operation with the longest cycle time. Subsequent to the completion of data collection, the focus will shift to evaluating necessary improvements to streamline procedures. To boost the productivity of the production line, targeted methods will be implemented to address inefficiencies and optimize workflow dynamics as shown in Table 3.1.

Table 3.1 The Methods Used For Improvement

NO	METHODS	FORMULA
1.	CYCLE TIME, C	The run time in production line.
2.	TAKT TIME	$\frac{Total\ available\ working\ minutes\ per\ day}{Daily\ quantity\ required}$
3.	NORMAL TIME	Average time X Rating factor
4.	STANDARD TIME	Normal time * (1 + Allowance factor)
5.	MINIMUM WORKSTATION	$\frac{Total\ Standard\ Time}{Takt\ Time}$
6.	PRODUCTIVITY	$\frac{Output}{salary\ hour\ X\ number\ of\ workstation}$
7.	LINE BALANCING EFFICIENCY	$\frac{Total\ Cycle\ Time}{Manpower\ X\ Takt\ Time} X\ 100\%$

3.4.5 Verified

The computer program for the simulation model is verified. The data input needs to match the appropriate process in order to provide accurate modelling of products, materials, and process steps.

3.4.6 Pilot Runs

Run the simulation model multiple times with different scenarios and input parameters. Consider different line balancing strategies by changing workstation assignments, task duration, or other factors. Collect data on cycle times, workstation utilization and other relevant performance indicators.

3.4.7 Validated

Before running a simulation, cross-check input parameters, task duration, and other variables to validate that the model is correct. Validate the model by comparing the output to historical data or observations from the actual production line. If necessary, adjust the model to ensure accuracy.

3.4.8 Simulation Investigation

The model makes predictions about how input factors within a specified range will impact a decision's result through simulations. An operational requirement-compliant product is guaranteed via simulation analysis. It can also guarantee proper real-world testing and highlight adjustments that need to be made.

3.4.9 Modify The Simulation Configuration

Identify the settings provided for every alternate model or baseline model of a different design.

3.4.10 Model Runs

Use the analysis results to identify improvement opportunities on the assembly line. Try different layouts, task assignments, or workflows to achieve a better balance. Run the simulation again with the changed parameters and compare the results. Repeat this process until you get the best line balance.

3.4.11 Select The Scenario

Analyze the simulation output data to evaluate the performance of each scenario. Compare results to defined targets and key performance indicators.

Identify bottlenecks, idle time, or other line inefficiencies. Should use statistical analysis techniques to determine the optimal balance and identify potential improvements to suggest the best selected scenario.

3.4.12 Suggest Improvement Output Based on Simulation

To improve production line productivity, select the most appropriate simulation for every station.

3.5 Limitation of Proposed Methodology

Using arena simulation to model and analyze assembly line systems is a powerful tool, but it also has some limitations. Here are some limitations to assure:

i. Simplified representation: Arena simulation software is based on simplified representations of real systems. Must make assumptions and approximations that may not accurately capture all the intricate details and intricacies of the assembly line. This simplification can lead to a gap between the simulation results and the actual performance of the system.

ii. Validation and validation: To ensure the reliability of a simulation model, it is important to verify and validate its accuracy. Collecting real-world data and comparing it to simulation results can be challenging, especially when dealing with complex assembly line systems. Misleading results can occur if the model is not properly validated.

iii. Assumptions and parameters: Developing an accurate simulation model requires defining various assumptions and parameters, such as processing time, machine failure rates, and worker behavior. The accuracy of these assumptions directly affects the reliability of simulation results. Inaccurate or outdated assumptions can lead to incorrect conclusions and ineffective decisions.

iv. Dynamic change: Assembly lines often undergo dynamic changes such as varying product demand, machine failures, or changes in production processes. Incorporating these dynamic changes into a simulation model can be difficult and time consuming. Failure to accurately capture and model these changes can undermine the usefulness of simulation for decision making.

v. Human factor: Assembly line systems require human operators to interact with machines, tools, and processes. Human factors such as fatigue, learning curves, and skill level differences can have a significant impact on system performance. Accurately capturing and modeling these human factors in simulation can be difficult and can lead to unrealistic results.

vi. Cost and time limits: Building a comprehensive assembly line simulation model can be a time-consuming and costly process. Collecting data, configuring simulations, validating models, and analyzing results require significant resources and expertise. Developing and maintaining robust simulation models can be challenging for organizations with time and budget constraints.

Despite these limitations, arena simulations provide valuable insight and help optimize assembly line systems. However, it is important to carefully approach simulation results, validate models, and consider limitations in order to make informed decisions based on simulation results.

3.6 Gantt Chart

Table 3.2 The Gantt Chart for PSM 1

NO	TASK OF PROJECT	PLAN VS ACTUAL	WEEK													
		WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	PSM 1 BRIEFING	PLAN															
		ACTUAL															
2	MEETING WITH SV	PLAN															
		ACTUAL						M									
3	PSM WORKSHOP	PLAN						I									
		ACTUAL						D									
4	WRITE LITERATURE REVIEW	PLAN						T									
		ACTUAL						E									
5	RESEARCH ON METHODOLOGY	PLAN						R									
		ACTUAL						M									
6	FINDING OBJECTIVE	PLAN															
		ACTUAL															
7	IDENTIFY PROBLEM STATEMENT	PLAN															
		ACTUAL															
8	FORMATTING AND GRAMMAR IMPROVEMENT	PLAN															
		ACTUAL															
9	CONSTRUCT MILESTONE	PLAN						B									
		ACTUAL						R									
10	IDENTIFY COMPANY	PLAN						E									
		ACTUAL						A									
11	DATA COLLECTION AND ANALYSIS	PLAN						K									
		ACTUAL															
12	SUBMISSION REPORT PSM 1	PLAN															
		ACTUAL															
13	PRESENTATION AND EVALUATION	PLAN															
		ACTUAL															

Table 3.3 The Gantt Chart For PSM 2

NO	TASK OF PROJECT	PLAN VS ACTUAL	WEEK													
		WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	VISIT COMPANY	PLAN														
		ACTUAL														
2	THE DATA COLLECTION	PLAN														
		ACTUAL								M						
3	CONDUCTING BOTTLENECK	PLAN								I						
		ACTUAL								D						
4	CREATING MODEL USING ARENA	PLAN								T						
		ACTUAL								E						
5	RESULTS SUBMISSION	PLAN								R						
		ACTUAL								M						
6	DISCUSSION DRAFTING	PLAN														
		ACTUAL														
7	CONCLUSION AND RECOMMENDATION DRAFTING	PLAN														
		ACTUAL														
8	SUBMIT DISCUSSION, CONCLUSION AND RECOMMENDATON	PLAN														
		ACTUAL														
9	SUBMIT DISCUSSION, CONCLUSION AND RECOMMENDATON	PLAN								B						
		ACTUAL								R						
10	CORRECTION FOR CHAPTER 4 AND CHAPTER 5	PLAN								E						
		ACTUAL								A						
11	SUBMIT FULL REPORT OF PSM 2	PLAN								K						
		ACTUAL														
12	PREPARE FOR PRESENTATION PSM 2	PLAN														
		ACTUAL														
13	PRESENTATION AND EVALUATION PSM 2	PLAN														
		ACTUAL														

3.7 Summary

In summary, using the arena simulation model provides a comprehensive and visual approach to line balancing. By following this methodology, manufacturers can optimize assembly lines, improve productivity, and make informed decisions based on accurate simulation results. This project used Arena simulation software to model and analyze an assembly line system. An assembly line represents a complex production process involving multiple workstations and a variety of interrelated tasks. The purpose of the simulations was to evaluate and improve system performance by identifying potential bottlenecks, optimizing resource allocation, and improving overall productivity. A simulation model consists of several main components such as, workstations, operators, material handling equipment and product flow control systems. Each workstation was responsible for a specific task, and operators performed their work based on predefined work instructions. Material handling devices such as conveyor belts and robotic arms facilitate the movement of materials between workstations. The simulation allowed to collect comprehensive data on a variety of key performance indicators such as throughput, cycle time, utilization, and queue lengths at various stages of the assembly line. Analyzing this data provided valuable insight into system behavior and identified areas for improvement and optimization. In simulation experiments, parameters such as workstation capacity, operator skill level, and material flow rate were manipulated to test different scenarios. This allowed to assess the impact of these variables on overall system performance and identify the optimal settings to maximize productivity and minimize bottlenecks. Based on the simulation results, the implementation of some improvements to increase the efficiency of the assembly line. For example, adjusting the staffing of certain workstations to better distribute the workload and prevent operator overload. Optimizing the material flow and routing strategy to reduce congestion and minimize idle time.

In addition, simulations allow to perform “what if” analyzes to explore alternative configurations and potential process changes. Evaluate the feasibility of introducing new equipment, changing workstations, or implementing other production workflows so that the manufacturers can make informed decisions about potential changes before implementing them.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter explains the data collection progress needed to recognize the productivity developments when applying Line Balancing with Arena Simulation software and concentrated on accomplishing productivity developments on the manufacturing production line. This chapter would conquer over the manufacturing process flow of automotive components that focused at EPMB PEPS-JV MELAKA SDN. BHD (PEGOH PLANT). Differentiation will be launch between the current Line Balancing and the future Line Balancing simulation model to reduce the cycle time in order to achieve great efficiency. Following the analysis of gathered data, the arena simulation software will be employed to implement an enhancement solution. This segment additionally encompasses details concerning employee satisfaction, efficiency, and dedication.

4.2 Research Company Background

The EPMB is a Malaysian investment holding company that mostly operates in the automobile sector. The firm specialist in selling a wide range of automotive parts, such as body component subframes, bumper assemblies, and light assemblies. The EPMB now has four production facilities. Metal items are manufactured at Batang Kali, while composite and plastic products are manufactured in Shah Alam's Hicom-Glenmarie Industrial Park. Furthermore, EPMB's operations in Melaka and Kedah make metal components for Honda and Mazda. EPMB's facilities and plants are strategically located near its original equipment manufacturer (OEM) clients, allowing the firm to provide efficient technical support, manufacturing help, and prompt delivery. Spot welding robots were used to assemble the company's product. The figure 4.1 shows the entrance of the company and Figure 4.2 shows the spot welding used in production line.

Figure 4.1 The Entrance of EPMB PEPS-JV MELAKA SDN. BHD

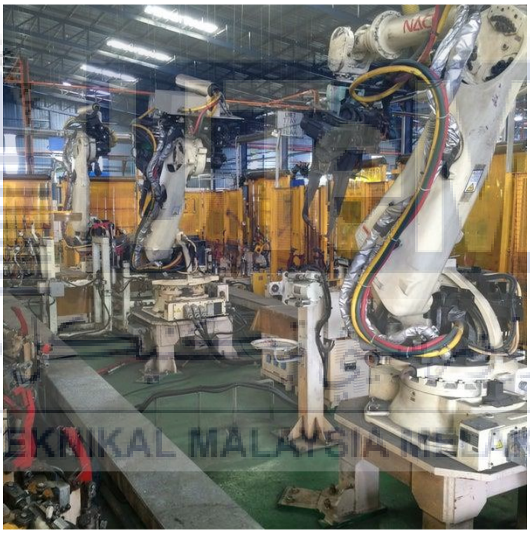


Figure 4.2 Spot Welding used in Production Line

This study was carried out at PEPS-JV (M) Sdn Bhd, a subsidiary of EP Manufacturing Bhd based in Melaka at the Pegoh Plant. PEPS-JV primarily serves the automobile sector and specialist in delivering body components for Honda vehicles. To survive in a highly competitive sector, the organization takes an aggressive, personal, and frank approach across the board. They have created an excellent governance system that has played a critical role in assuring EPMB's long-term success, beyond its founder’s initial expectations.

4.2.1 The Production Flow of PEPS-JV MELAKA SDN. BHD

EPMB Peps-Jv Melaka Sdn Bhd operates five manufacturing lines at its Melaka Plant, popularly known as the Pegoh Plant. Lines 3 and 4 of these production lines were not active on Thursdays and Fridays. Following careful consideration, the EPMB team decided to put Line 4 into service. This specific production line was chosen because its present output falls short of the company's goals. The 3MOA and TOO 5DR are shared models manufactured by Line 4. The figure 4.3 below illustrates the production flow of EPMB PEPS-JV MELAKA SDN. BHD.

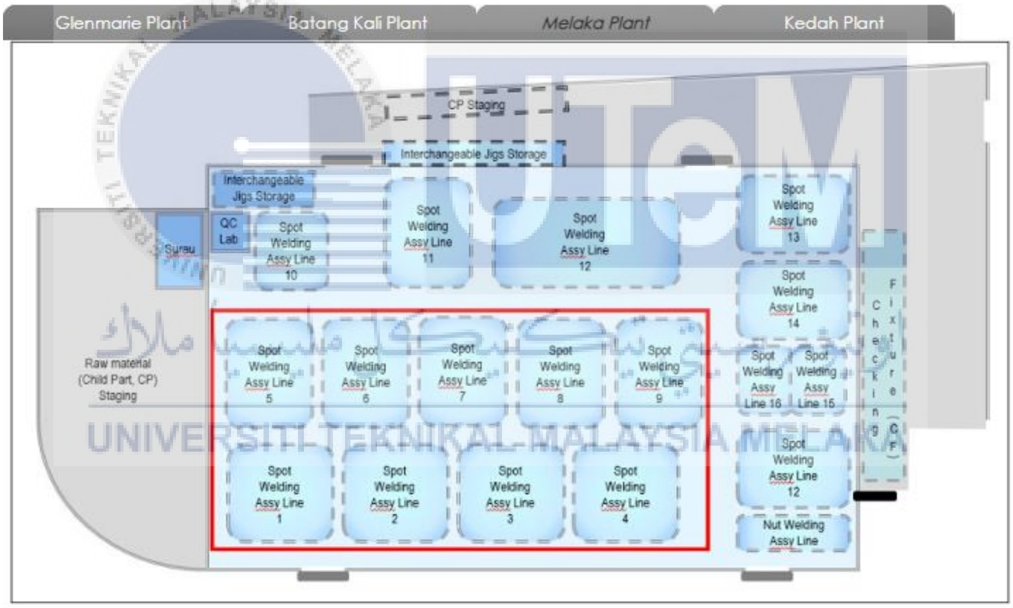


Figure 4.3 EPMB PEPS-JV MELAKA Plant (Pegoh Plant)

By the applications of the Line Balancing and Arena Simulation tools, EPMB PEPS-JV MELAKA SDN. BHD can optimize the performance among its five production lines. The Line Balancing technique was used to identify the unsolved problem in order to verify specifically into the causes of Line 4's problem. Line balancing ensures that each workstation in the production line has an equal quantity of work to accomplish. This means that the workload is uniformly spread across all workstations, with no bottlenecks or idle stations. By reaching this balance, the manufacturing production line may run at peak efficiency with little downtime and waste. It can aids in the acceleration of the production process and the reduction of the time required to make each parts. The layout and configuration of the EPMB Melaka Plant (Pegoh Plant) including the designated Line 3 also shown graphically in Figure 4.3 above.

4.2.2 Product Description In Production Line 4

This company's total number of production lines is 5, and this research focuses on production line 4 for model 3M0A, on which they make frame comp rear RH (right side) and frame comp rear LH (left side). The child parts will be assembled from workstation 1 to workstation 6 (quality checked). This model was built using five spot-welding robots on this production line. This research is only focused on the assembly part of the Honda HR-V that will be released on the market in 2023. Figures 4.2 show frame comp rear RH (right hand) and Figure 4.3 show frame comp rear LH (left hand).

Figure 4.4 Frame Comp Rear RH (Right Hand)

Figure 4.5 Frame Comp Rear LH (Left Hand)

4.2.3 Production Flow of Line 4

Production line 4 features two parallel operating lines that construct 3MOA HR-V Frame Comp Rear RH and Frame Comp Rear LH. To build and inspect jobs, each operation line consists of three operators (OP1, OP2, OP3) at eight workstations and one operator (OP QC) at an inspection station. Meanwhile, the five spot-welding robots work on both sides (RH and LH). The spot-welding robot is set up to work on a first-come, first-served basis. The welding operation will begin when the first station has done putting kid pieces into the jigs station. The 5 robots are shared by both sides of the production lines. To give the next duty to the robot, the operator will press the green button. Figure 4.4 and Figure 4.5 illustrates the layout of the production line 4.

Production Line 4: Line RH and Line LH			
Workstation	**Child Parts**	**Operator**	**Robot**
W1	S01, S02 RH	OP1	R1
	S01, S02 LH		
W2	S03, S04 RH		
	S03, S04 LH		
W3	S05, S06 RH		R2
	S05, S06 LH		
W4	A10 RH	OP2	R3
	A10 LH		
W5	A20 RH		
	A20 LH		
W6	A30 RH	OP3	R4
	A30 LH		
W7	A40 RH		
	A40 LH		
W8	A60 RH	-	R5
	A60 LH		
QC	Final Assembly	OP QC	-

Figure 4.6 The production line 4 of PEPS-JV MELAKA SDN. BHD

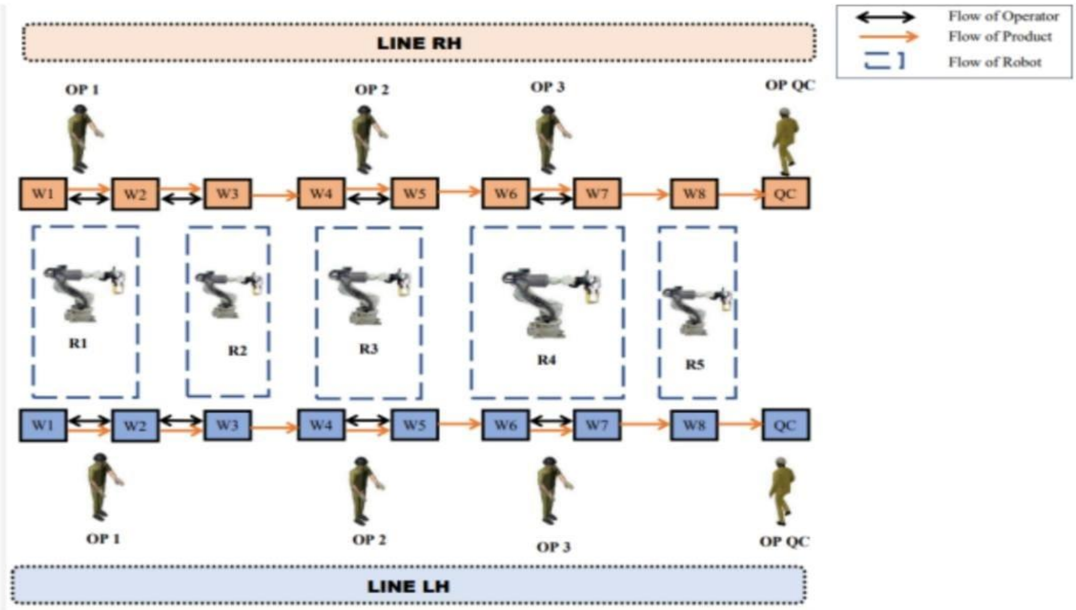


Figure 4.7 The layout of production line 4 of PEPS-JV MELAKA SDN. BHD

There are five spot welding robots and eight manned positions in the arrangement of Production Line 4 at Peps-Jv Melaka. The assembly process is handled by spot welding robots, while the manned positions are in charge of various jobs along the manufacturing line. Material handling, quality control, machine operation, and other manual processes essential for the manufacturing process are examples of these duties. The positioning of the spot welding robots and personnel is intended to optimize workflow and ensure efficient operations throughout the production line.

4.3 Process Description of Assembly Line 4

Production Line 4 operates with two concurrent lines dedicated to assembling 3MOA HR-V Frame Comp Rear RH and Frame Comp Rear LH. Each line is staffed by four operators, with an additional operator responsible for building and inspecting tasks at the inspection station. In contrast, both sides are served by five spot welding robots operating simultaneously.

Operators 1, 2, 3, 4, 5, and 6 handle the loading and unloading of child parts from the jig after the spot welding process performed by the robots. Operators 1 and 2 manage workstations one and two, Operators 3 and 4 handle workstation 3, and Operators 5 and 6 operate workstation 4. Upon unloading from workstation 5, manual inspection is conducted by operators 7 and 8 at each quality control inspection gate.

Spot welding robots follow based on first-come, first-served system, with the initial station completing the loading of child parts initiating the welding process. The robot is triggered by the operator pressing the green button to commence the next task. For instance, Robot 1 weld the child parts S01, S02, S03, and S04 at workstation one, while Robot 2 weld the child parts S05 and S06 at workstation 2 by using CO2 MIG welding. Meanwhile, Robot 3 handles child parts A10 and A20 at workstation 3, and Robot 4 welds the child parts position A30 at workstation four. Robot 5 manages child parts A40 and A50 at workstation five without requiring manpower.

Figure 4.8 illustrates the layout of the existing production line model 3M0A in production 4. The Frame Comp Rear RH comprises 27 child parts sourced from 5 workstations (W1, W2, W3, W4, W5), including the QC Inspection station, and assembled using a spot-welding robot. Appendix D provides details on the child parts at each workstation for the Frame Comp Rear RH. Similarly, the Frame Comp Rear LH consists of 27 child parts obtained from 8 workstations (W1, W2, W3, W4, W5, W6, W7, W8) and the QC Inspection station, with assembly facilitated by a spot-welding robot. Appendix E outlines the child parts at each workstation for the Frame Comp Rear LH.

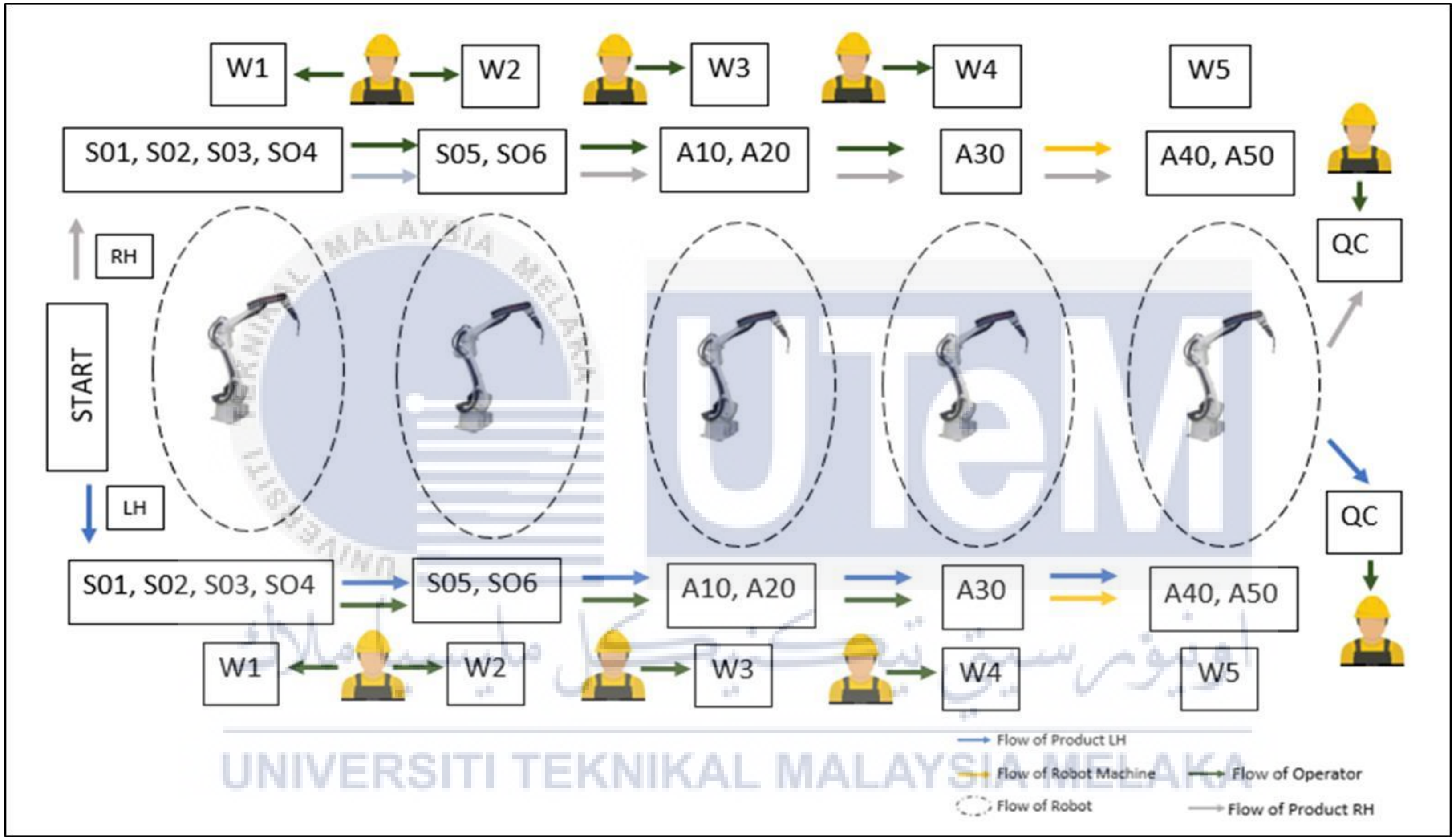


Figure 4.8 Layout of Existing Production Line Model 3M0A

4.4 Data Collection

The location of the time study is PEPS-JEV (M) Sdn. Bhd. Upon getting themselves with the Production Line 4 (Model 3MOA) workflow, real-time data was gathered and presented at APPENDIX F during a site visit aimed at analysing possible waste causes. Every cycle time for each of the five stations which included the QC inspection station was noted. Determining the demand for each activity at each workstation will be made easier with the help of all this information. The goal of all the data gathered is to raise this production line's efficiency.

4.4.1 Operating Hours and Product Demand Targets

Overall target production for the company's production line 4 (Model 3MOA) within a 12-hour shift is 120 units of product demand. The line operates with a single working shift every day, running from 8 a.m. to 8 p.m. During this time, operators are allowed two 15-minute breaks and a 45-minute lunch break, which adds up to a total of ten hours and forty-five minutes of working hours. The information about the working hours for production line 4 (Model 3MOA) is documented in Table 4.1.

In order to ensure the well-being and productivity of the operators on production line 4 (Model 3MOA), the company has implemented break and lunch time policies. Operators are given two 15-minute breaks and one 45-minute lunch break during their 12-hour shift. These breaks are essential for maintaining the mental and physical health of the workers, as well as optimizing their performance throughout the shift.

Table 4.1 Illustrates the breakdown of working hours for production line 4 (Model 3MOA).

Product Demand = 120 units per day	
Time	**Activity**
8:00 am	Shift starts
10:00 am	First fifteen-minute break
12:00 pm	Lunch break
12:45 pm	Shift resumes
3:00 pm	Second fifteen-minute break
8:00 pm	Shift ends

4.4.2 Standard Time of Process for Production Line 4

After recording the cycle time, the average time and range can be determined. Performance evaluation is based on observations of operator performance. Observers give a score of 90% for a worker working slower than normal, 100% for a worker working at normal speed, and 110% for a worker working faster than normal. Next, we calculated regular time and work standard time. In this case study, the fatigue allowance is 10% and the personal allowance is 5% for 10 hours and 30 minutes worked per shift. The total assembly time specified is determined for each product. The standard time for the process calculated by using the formula for calculating normal time (NT) and standard time (ST) is as follows:

Normal time (NT) = Average Time * Rating Factor

Standard Time (ST) = Normal Time * (1+ Allowance Factor)

= Normal Time * 1.15

Table 4.2 Standard Time Table of Production Line Model 3M0A

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp LH Model: 3MOA				Observer: Murali	Date: 11 December 2023
Station	Average Time (s)	Range	Rating Factor	Performance Rating (%)	Normal Time (s)	Standard Time (s)
(S01, S02, S03, S04) RH	193	40	0.9	90	174	200
(S01, S02, S03, S04) LH	180	24	0.9	90	162	186
(S05, S06) RH	37	7	1.0	100	37	43
(S05, S06) LH	35	12	1.0	100	35	40
(A10, A20) RH	138	24	1.0	100	138	159
(A10, A20) LH	141	29	1.0	100	141	162
(A30) RH	145	20	1.0	100	145	167
(A30) LH	153	34	1.0	100	153	176
(A40, A60) RH	91	5	1.0	100	91	105
(A40, A60) LH	91	7	1.0	100	91	105
QC CHECK	99	16	1.0	100	99	114

4.4.3 Available Time of Process for Production Line 4

The term "available time" usually describes the amount of time that a machine, workstation, or system is running and ready for use in productive tasks. It is an essential idea in use analysis and capacity planning. The amount of time that a resource or facility has to carry out its intended tasks without any disruptions, malfunctions, or planned downtime is known as available time. Table 4.3 simply shows the calculation of available time of process for Production Line 4.

Table 4.3 Available Time

<table>
<tr><th>Information</th><th>Calculation</th></tr>
<tr><td>Product Demand = 120 units per day</td><td rowspan="2">Available Time = (12 hours x 60 minutes x 60 seconds)
= 43200 seconds</td></tr>
<tr><td>Production time = 1 shift x 12 hours per day</td></tr>
<tr><td>Lunch Break per day = 45 minutes x 60 seconds
= 2700 seconds</td><td rowspan="2">Total Available Time = (43200 seconds - 2700 seconds - 1800seconds)
= 38700 seconds</td></tr>
<tr><td>Short Break per day = 2 x 15 minutes
= 30 minutes x 60 seconds
= 1800 seconds</td></tr>
</table>

4.4.4 Takt Time of Process for Production Line 4

Takt time would be the rate at which the production process must be completed in order to meet the goal. Takt time must be calculated using the total time available and the quantity of consumer demand as stated in Table 4.4.

Table 4.4 Takt Time

Formula	Calculation
Takt Time = $\frac{Production\ Time\ per\ day}{Required\ unit\ of\ production}$	Takt Time = $\frac{38700\ seconds}{120\ units\ per\ day}$ = 322.5 @ 323 units/sec

4.4.5 Minimum Workstation Required for The Operation

The exact number of workstations needed for this procedure is known as the minimum workstation. The minimum number of workstations can only be calculated by considering the cycle time and takt time as shown in Table 4.5 below.

Table 4.5 Minimum Workstation

Number of Workstation = $\frac{Sum\ Total\ Of\ Task\ Time}{Cycle\ Time,C}$	
Formula	Calculation
Takt Time = Total task, 1303sec $\frac{Takt\ Time}{Cycle\ Time,C}$	$N_i = \frac{1303\ sec}{323\ sec}$ = 4.03 = 4 Workstations

4.4.6 Bottleneck in Existing Production Line 4

In order to represent the current production line, a graph is developed using the calculated standard time and takt time. Every workstation is below the takt time, as shown by the graph. This shows that every workstation was able to complete the assignment in the time allocated to meet the goal. On this production line, however, there is a circumstance where an imbalance workload among operators occurs at the inspection station. Workstation 2's normal time, which is workstation S05, S06 RH LH, is shorter than those of the other workstations. A procedure that has the highest processing time or the lowest capacity in relation to other processes is known as a bottleneck. The production line's current bottleneck is showed in Figure 4.9 below.

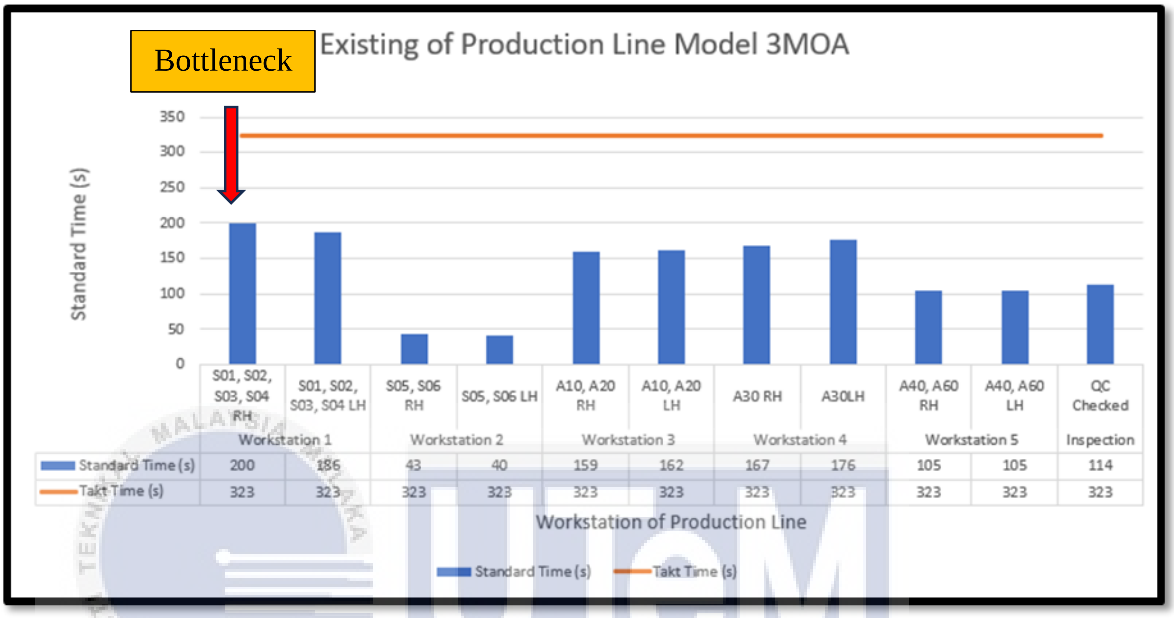


Figure 4.9 Bottleneck in Existing Production Line 4

4.5 Simulation Model for Existing Production Line 4

Model translation is employed to shows the manufacturing system, requiring cycle time calculations for individual products as input data in the simulation model. To estimate the arrival time of a batch of components at the inspection station, the cycle time for producing a single unit of the final product is utilized. The simulation model illustrates the concept of the specific manufacturing system. The complexity of the system and available information guide the construction of the simulation model. To accomplish successful line balancing in the assembly line, the Arena simulation model must closely replicate the actual layout, with at least a 90% similarity. This high degree of similarity is critical for the accuracy of the simulation results and subsequent improvement attempts. This approach includes careful attention to input data accuracy, validation against real-world observations, and ongoing refinement based on actual production system feedback, ensuring that the simulation serves as a robust tool for optimising the assembly line's efficiency and overall performance. Two simulation models will be executed in this study: one for the existing production layout design and another for the newly proposed layout design. This model will be developed based on the existing production layout in production line Model 3M0A as shown in Figure 4.10.

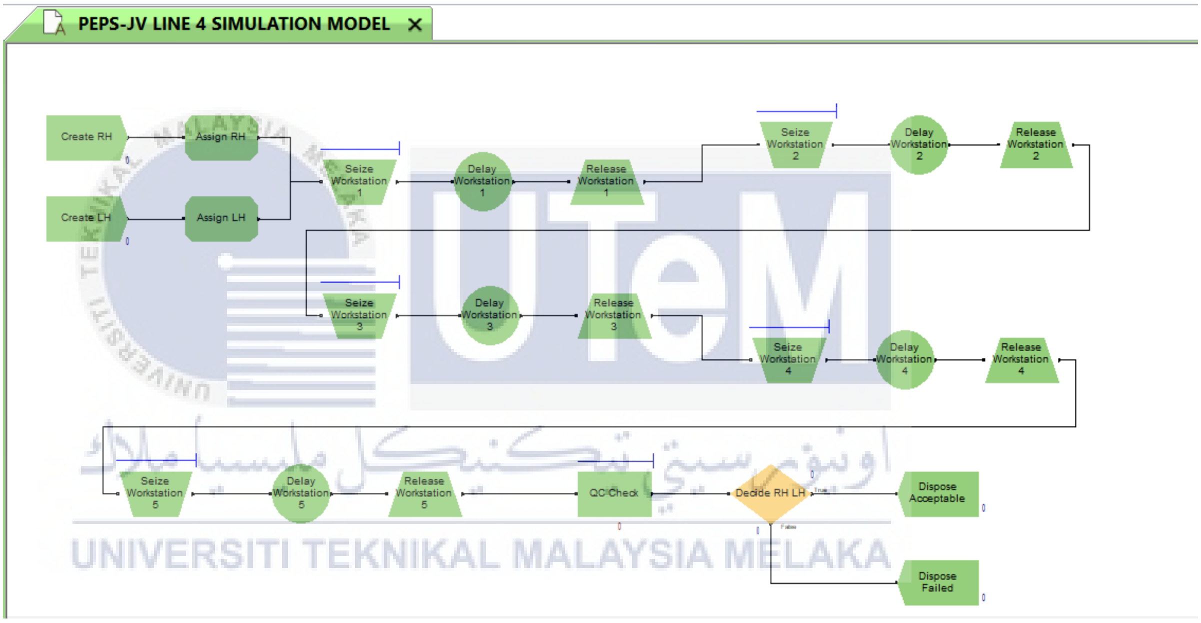


Figure 4.10 Simulation Model of Existing Production Line 4

4.5.1 Input Analyzer Data of Existing Production Line 4

The input data in W1, W2, W3, W4, W5, QC Check station which the type of data that analyzed by using the input analyzer in Arena Simulation as Appendix H. The results show the type of data according to its specification which is (NORMAL, TRIANGULAR, BETA). The input data of the simulation must be clarify according to the specifications in Arena Simulation. The Input Analyzer would detect the types of input data to insert in module for simulation. So, the user can identify which data would matches the simulation to begins the simulation process.

4.5.2 Create Module

The beginning steps for the simulation model is to create the Create Module. To let the entities into the model and start the process flow, the Create Module can choose the Basic Process option under the Project Bar. The Create Module in this simulation depends on each product's cycle time. The detail set in the Create Module is displayed in Figures 4.11.

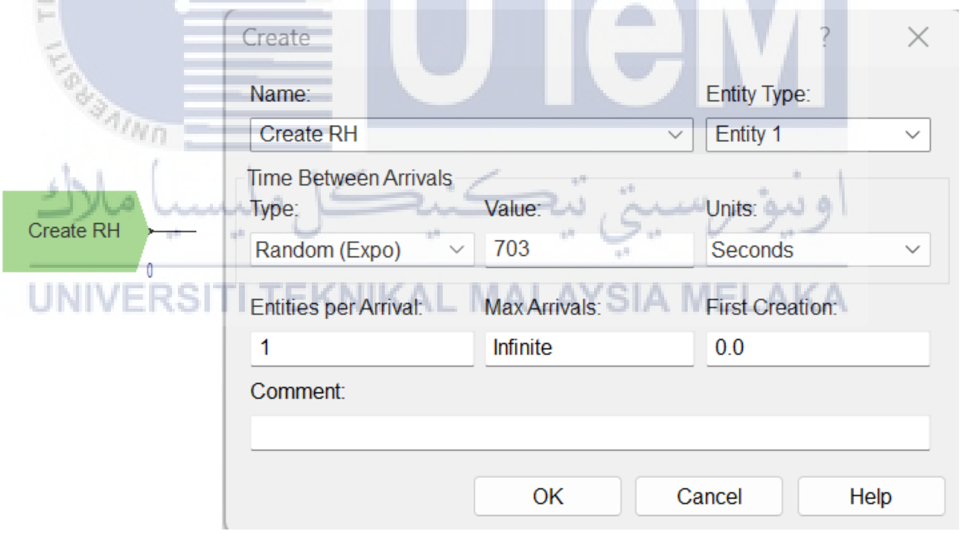


Figure 4.11 The Create Module and Parameter Setting

4.5.3 Assign Module

Further process of creating the simulation model is to Assign Module. In order to add new values for the Entity Type, Entity Picture, Attributes, and other variables, the

Assign Module will be placed after the Create Module. Users can also choose the Assign Module from the Basic Process menu below the Project Bar. The detail set within the Assign Module is displayed in Figures 4.12.

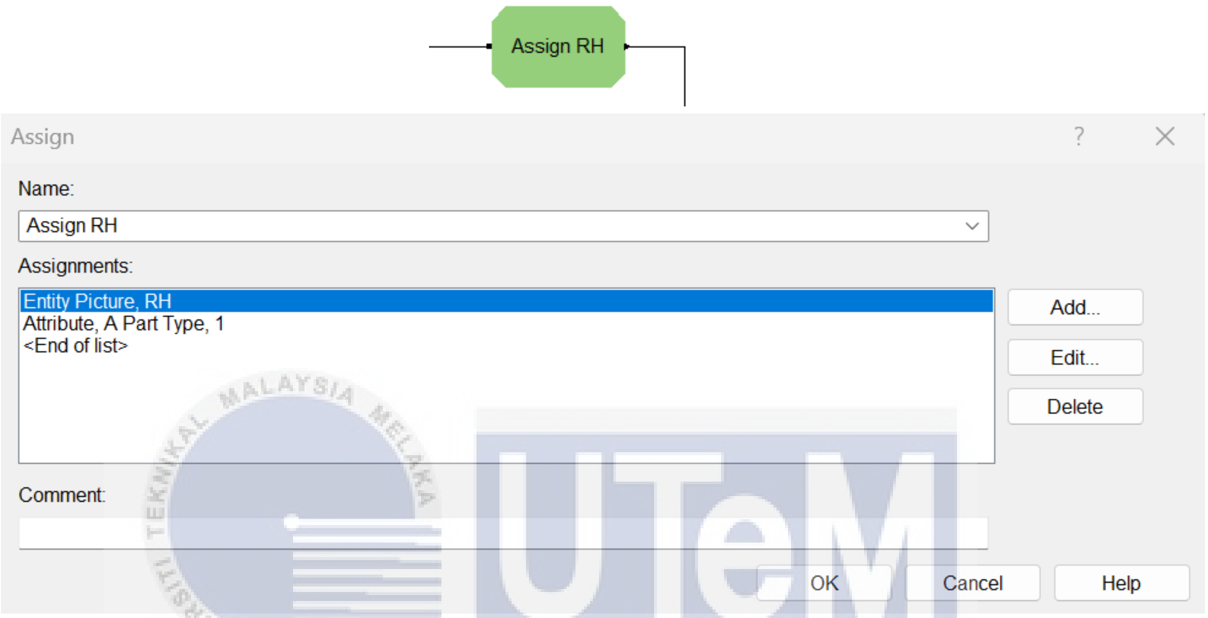
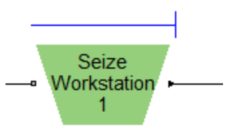


Figure 4.12 The Assign Module and Parameter Setting

4.5.4 Process Module

The Simulation Model must undergo the process flow by construct the Process Module to divide the process. There are three components in every process which is release, delay, and seize. When an entity is seize, it waits for a server or resource to become available. The length of time an entity is kept waiting to be processed at a resource or server is called a delay. A resource that is placed on hold won't become available until it is unlocked. A release is an entity that has finished processing and is prepared to go on to the next station. Assign Module's detail set is displayed in Figure 4.13, 4.14, 4.15.



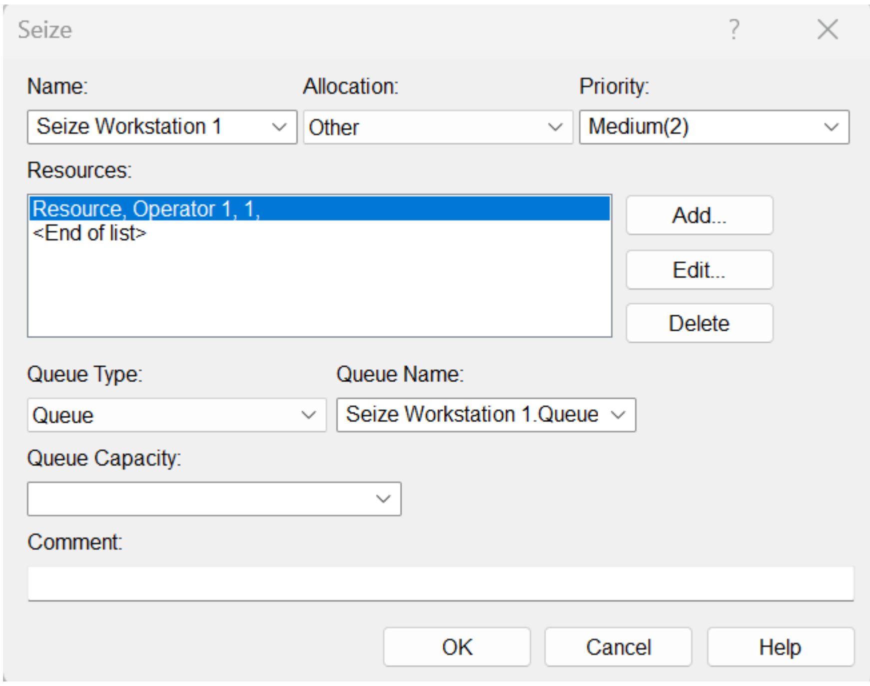


Figure 4.13 The Module Seize and Parameter Setting

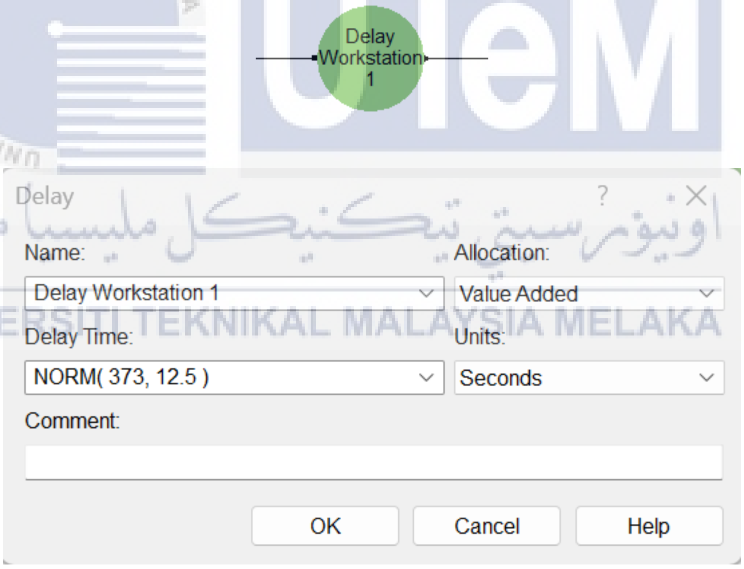


Figure 4.14 The Delay Module and Parameter Setting

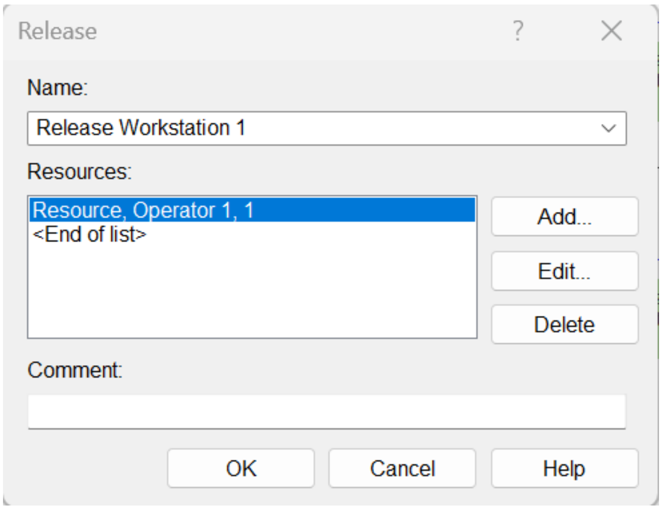
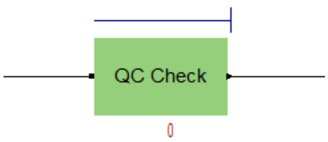


Figure 4.15 The Release Module and Parameter Setting

4.5.5 Inspection Process Module

Inspection process is the most important task where the all the unit produced undergo the inspection process to ensure that the manufactured products meet certain standards and specifications. Also, to find mistakes at an early stage of production, thus saving time and costs. As issues arise, they pinpoint the source, address them, maintain the inspection process, and make sure it is accurate as stated in Figure 4.16.



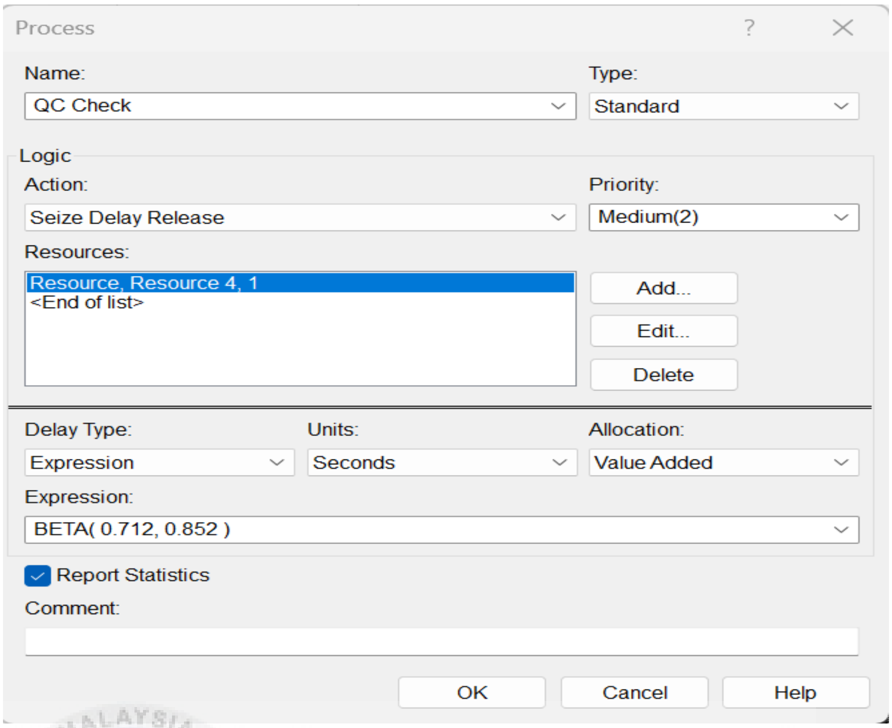
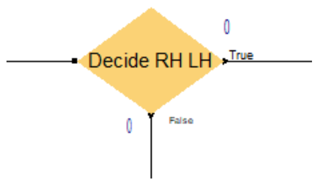


Figure 4.16 The Inspection Process Module and Parameter Setting

4.5.6 Decide Module

The system gains decision-making capabilities from this module. Making decisions based on one or more conditions or probabilities is made possible by it. The system determines that 90% of the percentage is true due primarily to this module as stated in Figure 4.17.



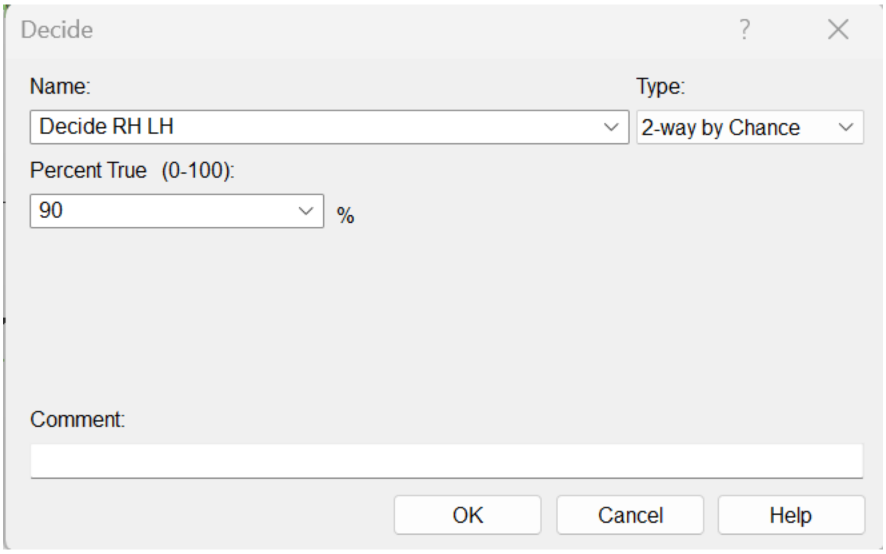
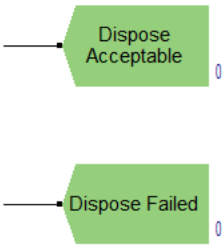


Figure 4.17 Decide Module and Parameter Setting

4.5.7 Dispose Module

The Dispose module is the method used in Arena to model the departure of entities from the system. This module is the method used in Arena to model the departure of entities from the system. It requires no parameters and simply removes an entity from the model, destroying the contents of its attributes in the process. Figure 4.18 provides the Dispose Module and during construct the new simulation model, two Dispose Module are utilize for collect the entities flow from 'True' and 'False' at the end of the production line.



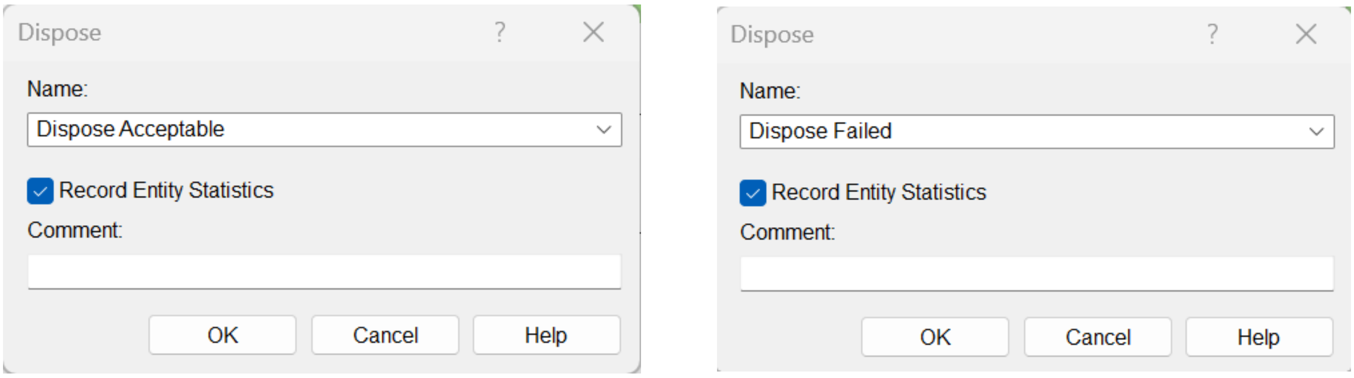


Figure 4.18 Dispose Module and Parameter Setting

4.5.8 Run Module Setup

The Run Setup dialog box helps build in end events so that Arena won't run off to infinity. It also helps ensure that Arena runs for a certain amount of time and then comes back with some results. The main parameter set in the Run Setup dialog window is the replication length, which is the simulation period. Before running the simulation model, need to fill up the replication parameter information at run setup setting as follows the Figure 4.19.

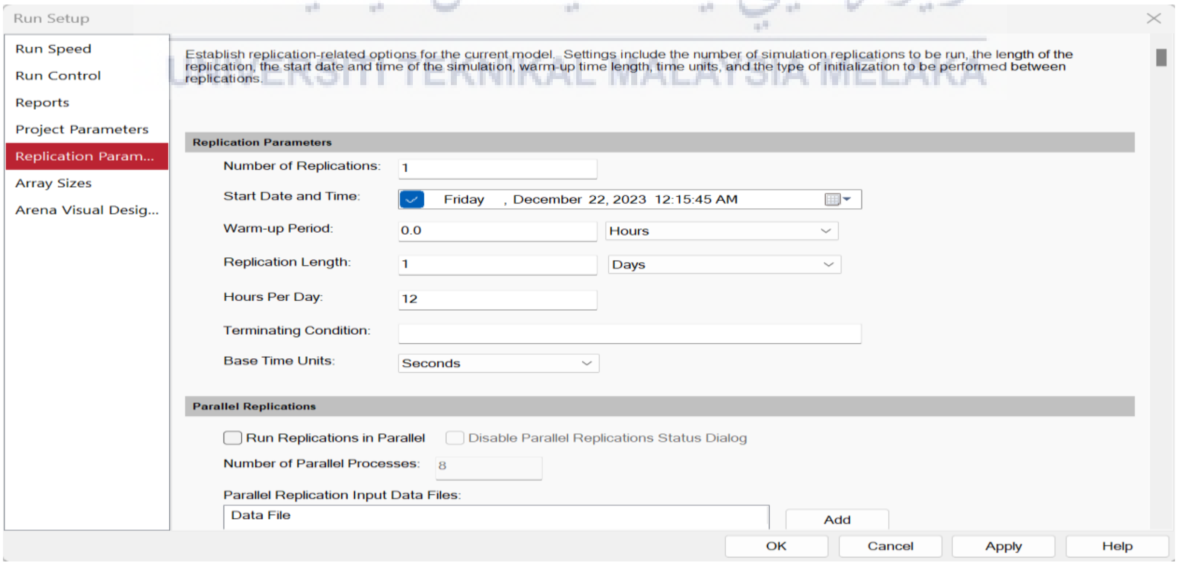


Figure 4.19 Run Setup Replication Parameter Setting

4.5.9 Results of Existing Simulation Model

After the simulation model has been run, the outcome is produced and then the report automatically converted to Microsoft Excel. Figure 4.20 illustrates the simulation's output in Microsoft Excel, which is 114 units per day. It produces a product with a 95% similarity to the actual output from the production line. This simulation allows for the determination of the production line's current condition and the capacity of the current output.

Output Statistics (Reports End of Replication Value)

Project Name	Name	Type	Source	Average Across Replications	Half-Width	Overall StDev Across Replications	Min Replication Value	Max Replication Value
Unnamed Project	Operator 1.NumberSeized	Total Numb	Resource	116	NoCalc	0	116	116
	Operator 1.ScheduledUtili:	Scheduled U	Resource	1	NoCalc	0	1	1
	System.NumberOut	Number Ou	System	114	NoCalc	0	114	114
	Entity 1.NumberIn	Number In	Entity	80	NoCalc	0	80	80
	Entity 1.NumberOut	Number Ou	Entity	58	NoCalc	0	58	58
	Entity 2.NumberIn	Number In	Entity	68	NoCalc	0	68	68
	Entity 2.NumberOut	Number Ou	Entity	56	NoCalc	0	56	56
	Resource 2.NumberSeized	Total Numb	Resource	115	NoCalc	0	115	115
	Resource 2.ScheduledUtili:	Scheduled U	Resource	0.192645564	NoCalc	0	0.192645564	0.192645564
	Resource 3.NumberSeized	Total Numb	Resource	115	NoCalc	0	115	115
	Resource 3.ScheduledUtili:	Scheduled U	Resource	0.745954303	NoCalc	0	0.745954303	0.745954303
	Resource 4.NumberSeized	Total Numb	Resource	344	NoCalc	0	344	344
	Resource 4.ScheduledUtili:	Scheduled U	Resource	0.482091572	NoCalc	0	0.482091572	0.482091572

Figure 4.20 Output Rate of Existing Simulation Model

4.5.10 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 input into the simulation model concerning process flow, cycle time, resources, and other elements.

4.5.11 Validated

Through the validation process, determine whether a model accurately represents the system under consideration. The result of the simulation is 95% consistent with the output of the actual production model, which is 114 units. On the assembly line, a 12-hour shift produced 120 units according to the simulation.

4.6 Discussion of The Exisiting Simulation Result For Production Line 4

The data collecting and processing time needed for bottleneck process analysis and Arena simulation to increase production line productivity are covered in this chapter. Software for arena 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 arena simulation software, productivity improvement, and line balancing improvement.

4.6.1 Improvement of Line Balancing Using Existing Simulation

Based on the data gathered, there are eleven stations in the Model 3M0A production line. The histogram depicts the discovery used to study the behaviour of the production line. According to the histogram in Figure 4.2 of the present production line before improvement, workstation two, stations S05 and S06 RH LH, has the lowest cycle time when compared to other workstations and stations. As a result, workstation two, namely stations S05, S06 RH LH, was proposed as a way to achieve optimal production line planning. Figure 4.21 demonstrates the production rate after improvement.

According to the graph, the number of workstations was lowered to five rather than nine. As a result, workstation 1, which is S01, S02, S03, S04, S05, S06 RH LH, has a longer cycle time than the other workstations and does not balance S01, S02, S03, S04, S05, S06 RH LH. As a result, it is advised that the cycle time for workstation one be reduced as another approach. Figure 4.22 line balancing after improvement shows the amount of cycle times reduced at workstation one. By reducing the number of workstations, the line's efficiency improves. Figure 4.23 exhibits the new layout following improved line balance.

Furthermore, the planned suggestion is to modify the operator. Operator 1 of the real manufacturing line works in workstation 2. Operator 2 will takeover and complete the proposed task on workstation 2 and workstation 3. Figure 4.24 depicts the planned new layout of the manufacturing line after the operator position has been changed.

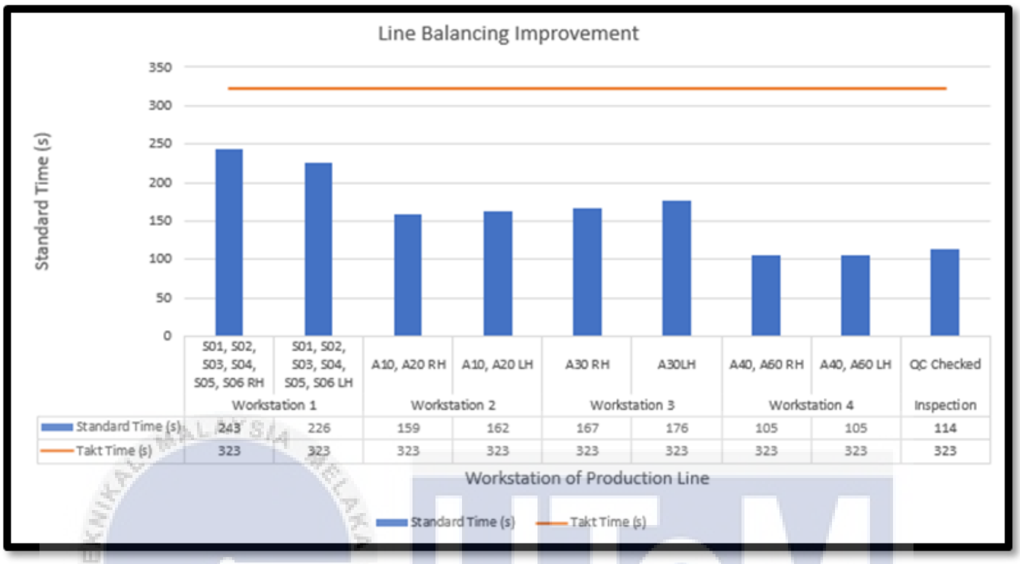


Figure 4.21 Line Balancing After Improvement 1

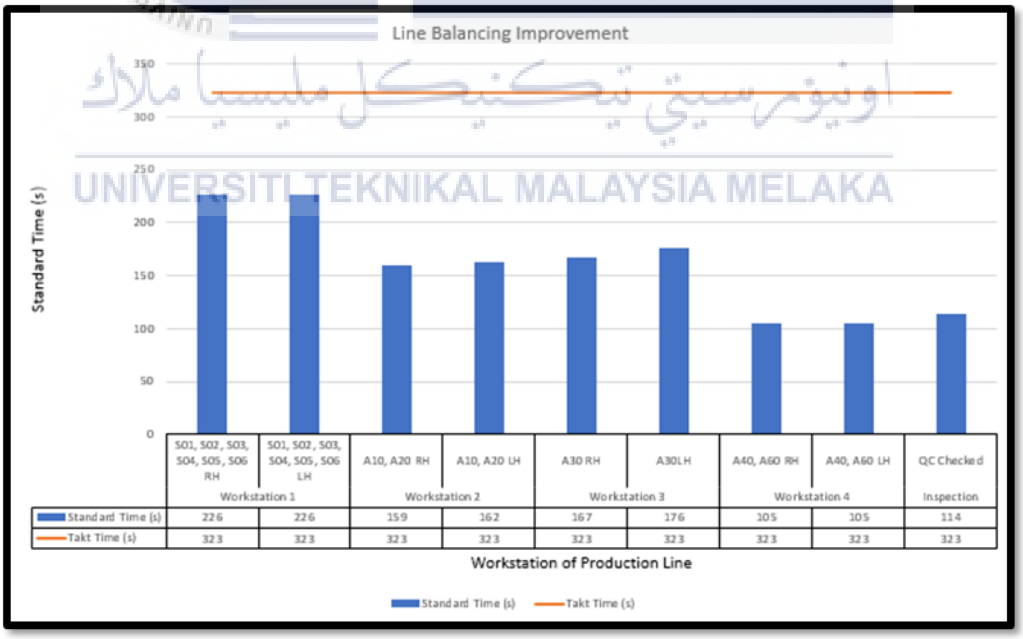


Figure 4.22 Line Balancing After Improvement 2

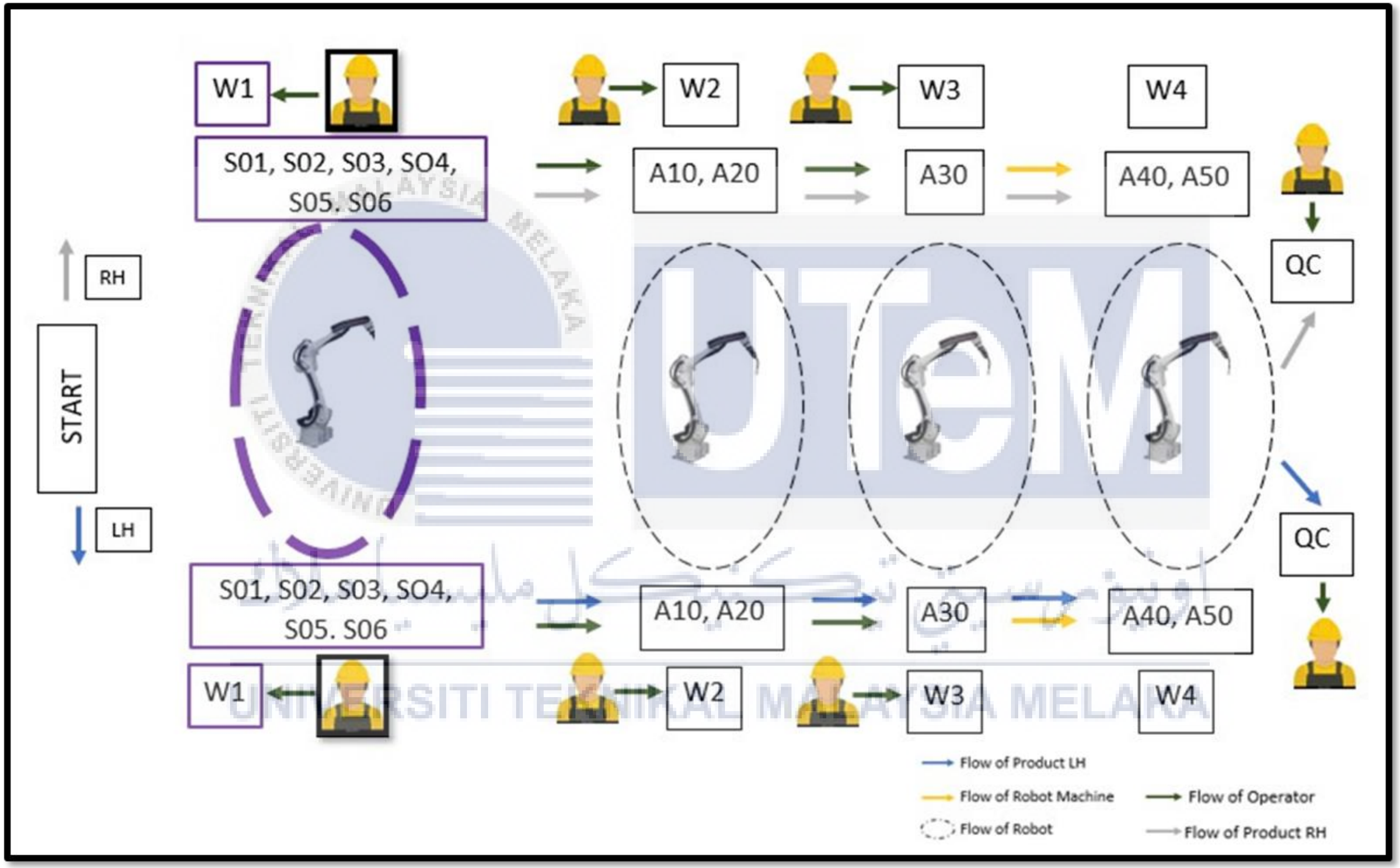


Figure 4.23 New Layout Production Line After Reduce Workstation (Improvement 1)

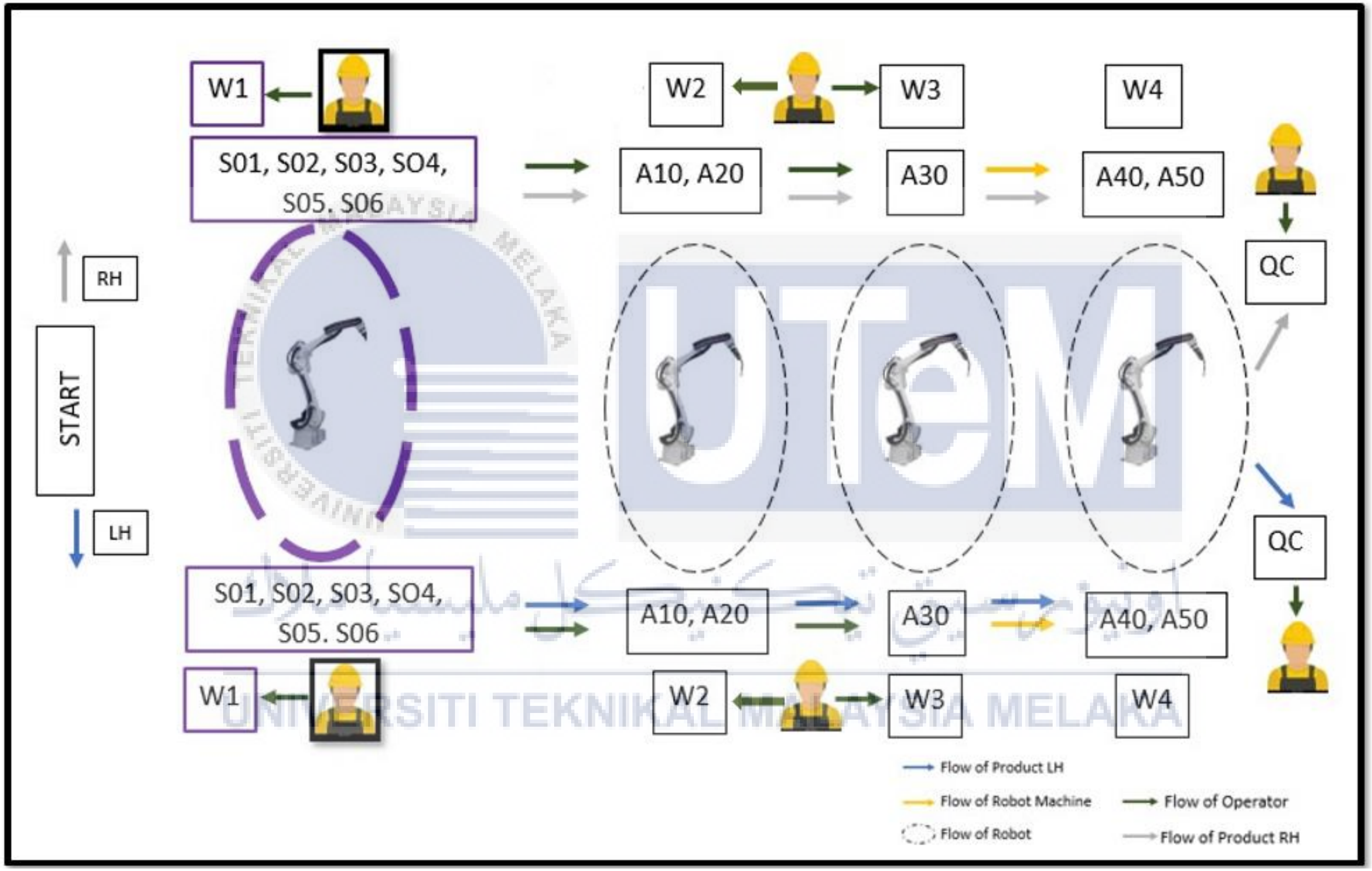


Figure 4.24 New Layout Production Line After Change Operator Position (Improvement 2)

4.6.2 The Improvement in Productivity After Proposed Solution

The output of the final product is 114 items produced each shift based on a simulation model for the current production line. Similarly, the improved simulation model's simulation results with a reduced workstation quantity and decreased cycle time indicate that 133 products are produced overall for Frame Comp Rear RH LH in a shift and after second improvement the product produced is 124 units.

In addition, the suggested solution included a workstation and cycle time that were better than those in the current manufacturing line. Furthermore, the company's research shows that an operator's hourly wage is approximately RM13.00. After improvement, more output goods were created. Furthermore, productivity was an improvement if output increased. Reducing the workstation 10.8% and shifting the operator's position 3.33% both result in higher product production productivity. The difference in productivity improvement is displayed in the table.

Formula pieces per RM productivity = $\frac{Output}{salary\ hour*number\ of\ operator}$

Table 4.6 Productivity Improvement Table

Productivity		
Existing production	After Reduce Workstation (Improvement 1)	After Changed Operator Position (Improvement 2)
$= \frac{120\ pieces}{RM13*12\ hours*8\ operators}$ = 0.11 pieces per RM	$= \frac{133\ pieces}{RM13*12\ hours*8\ operators}$ = 0.10 pieces per RM	$= \frac{124\ pieces}{RM13*12\ hours*6\ operators}$ = 0.13 pieces per RM

Table 4.7 Increased Productivity Percentage Table

Reduce Workstation	Changed Operator Position
Increased Productivity Percentage = $\frac{Proposed\ output - Existing\ output}{Existing\ output} * 100\%$ $\frac{133\ pieces - 120\ pieces}{120\ pieces} * 100\% = 10.8\%$	Increased Productivity Percentage = $\frac{Proposed\ output - Existing\ output}{Existing\ output} * 100\%$ $\frac{124\ pieces - 120\ pieces}{120\ pieces} * 100\% = 3.33\%$

4.6.3 Improvement in Arena Simulation

Arena Simulation version 2022 is used to construct the simulation model for the current 3M0A production line as well as the suggested solution for this research study. There is no denying the strong correlation between financial performance and simulation technologies. The use of simulation technologies significantly increased the organization's output and performance. Planning the manufacturing line and gathering data are made easier by using Arena simulation software.

It would be possible to develop and evaluate production line behaviour prototypes using the Arena software. The following outcomes were obtained in a production by decreasing the number of workstations and the cycle time. The engineer can easily see how chance functions in the manufacturing process thanks to the statistical analysis of the Arena simulation data. The manufacturing line can be built to take into consideration a wide range of potential scenarios and variables in order to more effectively assess and make decisions (104). In summary, simulation tools are critical to the growth of the company since they allow it to meet consumer demands in the quickest amount of time at the lowest cost, increasing global intensity.

After the simulation model has been run, the outcome is produced. Figure 4.25 displays the output after line balance improvement, which indicates that 133 pieces of items are generated daily from the simulation after improvement. In contrast, 124 pieces of goods are created daily as a result of the simulation's output once the position of operator in the workstation is changed. The output for the suggested operator changed position improvement is displayed in Figure 4.26. The design of the arena simulation remains the same; workstation 2's operator one has simply been replaced with operator 2 whom operates at workstation 3 in improvement 1. This simulation can ascertain the production line's present status and its current production capability. The design of the Arena Simulation after line balance was improved is shown in Figure 4.27. As the Table 4.8 shows the difference between existing output and output after improvement.

Output Statistics (Reports End of Replication Value)

Project Name	Name	Type	Source	Average Across Replications	Half-Width	Overall StDev Across Replications	Min Replication Value	Max Replication Value
Unnamed Project	Operator 1.NumberSeized	Total Numb	Resource	136	NoCalc	0	136	136
	Operator 1.ScheduledUtili:	Scheduled U	Resource	0.001340772	NoCalc	0	0.001340772	0.001340772
	Operator 2.NumberSeized	Total Numb	Resource	135	NoCalc	0	135	135
	Operator 2.ScheduledUtili:	Scheduled U	Resource	0.867303876	NoCalc	0	0.867303876	0.867303876
	Operator 3.NumberSeized	Total Numb	Resource	134	NoCalc	0	134	134
	Operator 3.ScheduledUtili:	Scheduled U	Resource	0.001400377	NoCalc	0	0.001400377	0.001400377
	Operator 4.NumberSeized	Total Numb	Resource	133	NoCalc	0	133	133
	Operator 4.ScheduledUtili:	Scheduled U	Resource	0.305357031	NoCalc	0	0.305357031	0.305357031
	System.NumberOut	Number Ou	System	133	NoCalc	0	133	133
	Entity 1.NumberIn	Number In	Entity	71	NoCalc	0	71	71
	Entity 1.NumberOut	Number Ou	Entity	70	NoCalc	0	70	70
	Entity 2.NumberIn	Number In	Entity	65	NoCalc	0	65	65
	Entity 2.NumberOut	Number Ou	Entity	63	NoCalc	0	63	63
	Robot.NumberSeized	Total Numb	Resource	134	NoCalc	0	134	134
	Robot.ScheduledUtilizatio	Scheduled U	Resource	0.560532434	NoCalc	0	0.560532434	0.560532434

Figure 4.25 Output Rate of Product After Improvement 1

Output Statistics (Reports End of Replication Value)

Project Name	Name	Type	Source	Average Across Replications	Half-Width	Overall StDev Across Replications	Min Replication Value	Max Replication Value
Unnamed Project	Operator 1.NumberSeized	Total Numb	Resource	130	NoCalc	0	130	130
	Operator 1.ScheduledUtili:	Scheduled U	Resource	0.001143832	NoCalc	0	0.001143832	0.001143832
	Operator 2.NumberSeized	Total Numb	Resource	251	NoCalc	0	251	251
	Operator 2.ScheduledUtili:	Scheduled U	Resource	0.812306356	NoCalc	0	0.812306356	0.812306356
	Operator 3.NumberSeized	Total Numb	Resource	124	NoCalc	0	124	124
	Operator 3.ScheduledUtili:	Scheduled U	Resource	0.285152791	NoCalc	0	0.285152791	0.285152791
	System.NumberOut	Number Ou	System	124	NoCalc	0	124	124
	Entity 1.NumberIn	Number In	Entity	66	NoCalc	0	66	66
	Entity 1.NumberOut	Number Ou	Entity	63	NoCalc	0	63	63
	Entity 2.NumberIn	Number In	Entity	64	NoCalc	0	64	64
	Entity 2.NumberOut	Number Ou	Entity	61	NoCalc	0	61	61
	Robot.NumberSeized	Total Numb	Resource	124	NoCalc	0	124	124
	Robot.ScheduledUtilizatio	Scheduled U	Resource	0.522281796	NoCalc	0	0.522281796	0.522281796

Figure 4.26 Output Rate of Product After Improvement 2

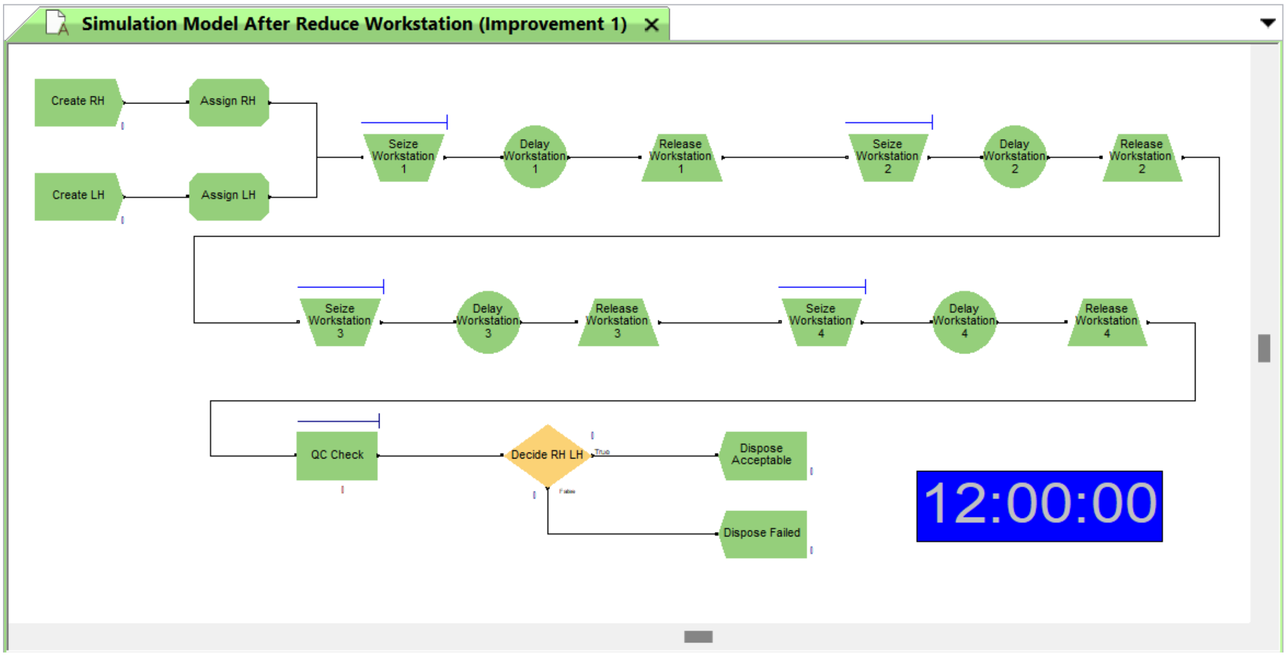


Figure 4.27 Arena Simulation Model After Improvement

Table 4.8 Existing Output and Output After Improvement

Existing Output	Reduce Workstation Output (Improvement 1)	Changed Operator Position Output (Improvement 2)
120 pieces per day	133 pieces per day	124 pieces per day

4.7 Line Efficiency After Improvement

Line efficiency is a measure of how well a production line performs in terms of output, quality, and cost. A higher line efficiency means the production line is performing better. After a balanced task distribution, the next step is testing the effectiveness of the undertaking. Testing can help to reveal further areas that need efficiency improvements and rebalancing by using the assembly line efficiency formula as shown in Table 4.9:

Table 4.9 Line Efficiency of Overall Production

Line Efficiency = $\frac{Total\ Cycle\ Time}{Manpower\ X\ Takt\ Time}$ x 100%	
Model	Calculation
Existing Production Line	Line Efficiency = $\frac{1403\ sec}{8\ x\ 323}$ x 100% = 54.29%
Production Line After Improvement 1	Line Efficiency = $\frac{1393\ sec}{8\ x\ 323}$ x 100% = 53.90%
Production Line After Improvement 2	Line Efficiency = $\frac{1410\ sec}{6\ x\ 323}$ x 100% = 72.75%

4.8 Summary

The approach in its whole has been implemented in this chapter to achieve the research objectives. An excellent answer to the issue was achieved by a thorough explanation of the project's history and scope. By concentrating on reaching objectives, data has been gathered, and a flow of process solutions has been created. This chapter is a report detailing the outcomes and development of a full project study. It also demonstrates that the inquiry was conducted in the suggested manner. As a result, by creating an excellent written report, the project research will be improved and made easier to understand. This study aims to achieve 90% efficiency in research-related studies. The researcher will offer some recommendations and ideas that can be improved for future studies. By conducting this research, the overall line efficiency can be obtained to what the line is designed to produce under optimal conditions.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The goal of this chapter was to offer suggestions for improving the PEPS-JV Sdn. Bhd. company's production productivity. This research study will discuss the outcome of implementing Arena simulation, line balancing, and managing the process that was producing bottlenecks. Clarity will be restored to both circumstances by doing this. This chapter provides an overview of the results of the study initial planning set of objectives. The research study's objectives were established at the beginning. Additionally, a recommendation for future production process enhancements that the company in the scenario could implement is included in this chapter.

5.2 Conclusion

In conclusion, the goals set out by careful study process planning allowed for the successful achievement of the proposed objectives. This researcher gained a thorough comprehension of the investigation and the resolution to a challenge that an earlier researcher had mentioned. Part of the procedure designed to complete this study includes defining the problem's scope and the research's complexity. Both the steps in the process that make up the recommended solution and its specifics have been developed. According to the factors included in the data-gathering subjects, the objectives for reducing the bottleneck process have been successfully met. The Arena Simulation would be run to verify the accuracy of the findings reported in this thesis. Bottleneck analysis, line balance, and the Arena Simulation worked together to make the decision to improve production line productivity successful.

In order to determine which improvement is the best in terms of decision making, we need to consider various factors such as production output, efficiency, and productivity percentage. The production output after the first improvement, which involved reducing the workstation from 6 to 5, was 133 units per day. On the other hand, the production output after the second improvement, which involved changing the operator position from 8 to 6, was 124 units per day. Based on this metric alone, the first improvement resulted in a higher production output. Although, the efficiency for the first improvement was calculated to be 53.90%, while the efficiency for the second improvement was 72.75%. This indicates that the second improvement led to a slightly higher efficiency in the manufacturing process. Behalf of this, the productivity percentage for the first improvement was 10.8%, whereas for the second improvement it was 3.33%. This shows that the first improvement resulted in a significantly higher increase in productivity compared to the second improvement. Based on the Table 5.2, it can be concluded that the first improvement, which involved reducing the number of workstations, is the better choice in terms of decision making. This is supported by the higher production output achieved with this improvement compared to the second one. Additionally, although the efficiency for both improvements is relatively close, the first improvement still outperforms the second one in terms of both production output and productivity.

Table 5.1 Overall Summary for Decision-Making

Model	Productivity %	Efficiency %	Output	Productivity Cost (RM)	Decision-Making
Model 1 (Existing)	1	54.29	120	0.11 pcs	-
Model 2 (Improvement 1)	10.8	53.90	133	0.10 pcs	√
Model 3 (Improvement 2)	3.33	72.75	124	0.13 pcs	-

This study's main goal is to reduce bottlenecks by applying the line balancing technique into strategy and creating a simulation model with Arena simulation software to increase the manufacturing line's smoothness. This study's goals have all been successfully achieved. By referring the objective which is to develop the production layout using Arena Simulation for the data collection of manufacturing line 3M0A, the first objective was achieved. Figure 4.1 shows the current production line's layout, Figures 4.15 and 4.16 show the line balancing of the current production line. By reduce bottlenecks using a proposed methodology for process improvement, the second goal was achieved. The third objective goal was to suggest a development in decision-making by using the preferred methodology. After reducing the number of workstations and changing operator positions, productivity increased by 10.8% and 3.33%, respectively. According to this study, the best solutions for attempting to deal with production line bottlenecks are Arena Simulation and line balancing. Since the percentage productivity of product manufacturing for first improvement is higher than the second option, reducing the number of workstation is the suggested solution.

5.3 Recommendation

Here are some study suggestions that could be useful in identifying any issues with PEPS-JV Sdn.Bhd company's production line. The theory behind this study is that fewer workstations are needed to balance the manufacturing line and boost output. Reducing the number of workstations resulted in a 10.8% improvement in production, according to the research that was conducted. The simulation model might run for an entire manufacturing day in a later investigation. Bottlenecks will be employed as a crucial first step in solving issues in a productive production line in order to build an Arena simulation model that can be used to make strategic decisions about process optimization. This model can benefit from the information required to reach that conclusion. Furthermore, by speeding up the welding robot, the operator can spend less time doing nothing and lessen the time it takes the welding robot to finish the spot welding procedure. The PEPS-JV Sdn. Bhd company has the potential to increase its manufacturing productivity and even beyond its current level. Whether an organization uses the Arena simulation method in their production line is up to them. The management organization is the only party receiving suggestions and recommendations from this study because they do not have the right to force the company to make an improvement in productivity in their production line.

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APPENDICES

APPENDIX A Arena Simulation of Existing Production Line

ProjectName	Project RunDateTime	Replication	Name	Type	Source	RecordedValue	IsPeriodic	GroupByKey	RepsRequested	Average	Sta
Unnamed Project	2024-01-07 02:02:06	1	Entity 1.NumberIn	Number In	Entity	141	0	Unnamed ProjectEntity 1.NumberInNumber InEntity	1	141	
Unnamed Project	2024-01-07 02:02:06	1	Entity 1.NumberOut	Number Out	Entity	114	0	Unnamed ProjectEntity 1.NumberOutNumber OutEntity	1	114	
Unnamed Project	2024-01-07 02:02:06	1	Operator 1.NumberSeized	Total Number Seized	Resource	116	0	Unnamed ProjectOperator 1.NumberSeizedTotal Number SeizedResource	1	116	
Unnamed Project	2024-01-07 02:02:06	1	Operator 1.ScheduledUtilization	Scheduled Utilization	Resource	1	0	Unnamed ProjectOperator 1.ScheduledUtilizationScheduled UtilizationResource	1	1	
Unnamed Project	2024-01-07 02:02:06	1	Operator 2.NumberSeized	Total Number Seized	Resource	115	0	Unnamed ProjectOperator 2.NumberSeizedTotal Number SeizedResource	1	115	
Unnamed Project	2024-01-07 02:02:06	1	Operator 2.ScheduledUtilization	Scheduled Utilization	Resource	0.192442795	0	Unnamed ProjectOperator 2.ScheduledUtilizationScheduled UtilizationResource	1	0.192442795	
Unnamed Project	2024-01-07 02:02:06	1	Operator 3.NumberSeized	Total Number Seized	Resource	115	0	Unnamed ProjectOperator 3.NumberSeizedTotal Number SeizedResource	1	115	
Unnamed Project	2024-01-07 02:02:06	1	Operator 3.ScheduledUtilization	Scheduled Utilization	Resource	0.742540572	0	Unnamed ProjectOperator 3.ScheduledUtilizationScheduled UtilizationResource	1	0.742540572	
Unnamed Project	2024-01-07 02:02:06	1	Operator 4.NumberSeized	Total Number Seized	Resource	114	0	Unnamed ProjectOperator 4.NumberSeizedTotal Number SeizedResource	1	114	
Unnamed Project	2024-01-07 02:02:06	1	Operator 4.ScheduledUtilization	Scheduled Utilization	Resource	0.001340827	0	Unnamed ProjectOperator 4.ScheduledUtilizationScheduled UtilizationResource	1	0.001340827	
Unnamed Project	2024-01-07 02:02:06	1	Operator 5.NumberSeized	Total Number Seized	Resource	114	0	Unnamed ProjectOperator 5.NumberSeizedTotal Number SeizedResource	1	114	
Unnamed Project	2024-01-07 02:02:06	1	Operator 5.ScheduledUtilization	Scheduled Utilization	Resource	0.001263933	0	Unnamed ProjectOperator 5.ScheduledUtilizationScheduled UtilizationResource	1	0.001263933	
Unnamed Project	2024-01-07 02:02:06	1	Robot.NumberSeized	Total Number Seized	Resource	114	0	Unnamed ProjectRobot.NumberSeizedTotal Number SeizedResource	1	114	
Unnamed Project	2024-01-07 02:02:06	1	Robot.ScheduledUtilization	Scheduled Utilization	Resource	0.479353872	0	Unnamed ProjectRobot.ScheduledUtilizationScheduled UtilizationResource	1	0.479353872	
Unnamed Project	2024-01-07 02:02:06	1	System.NumberOut	Number Out	System	114	0	Unnamed ProjectSystem.NumberOutNumber OutSystem	1	114	

Output Statistics (Reports End of Replication Value)

Project Name	Name	Type	Source	Average Across Replications	Half-Width	Overall StDev Across Replications	Min Replication Value	Max Replication Value
Unnamed Project	Operator 1.NumberSeized	Total Numb	Resource	116	NoCalc	0	116	116
	Operator 1.ScheduledUtili	Scheduled	Resource	1	NoCalc	0	1	1
	Operator 2.NumberSeized	Total Numb	Resource	115	NoCalc	0	115	115
	Operator 2.ScheduledUtili	Scheduled	Resource	0.192442795	NoCalc	0	0.192442795	0.192442795
	Operator 3.NumberSeized	Total Numb	Resource	115	NoCalc	0	115	115
	Operator 3.ScheduledUtili	Scheduled	Resource	0.742540572	NoCalc	0	0.742540572	0.742540572
	Operator 4.NumberSeized	Total Numb	Resource	114	NoCalc	0	114	114
	Operator 4.ScheduledUtili	Scheduled	Resource	0.001340827	NoCalc	0	0.001340827	0.001340827
	System.NumberOut	Number Ou	System	114	NoCalc	0	114	114
	Entity 1.NumberIn	Number In	Entity	141	NoCalc	0	141	141
	Entity 1.NumberOut	Number Ou	Entity	114	NoCalc	0	114	114
	Operator 5.NumberSeized	Total Numb	Resource	114	NoCalc	0	114	114
	Operator 5.ScheduledUtili	Scheduled	Resource	0.001263933	NoCalc	0	0.001263933	0.001263933
	Robot.NumberSeized	Total Numb	Resource	114	NoCalc	0	114	114
	Robot.ScheduledUtilizatio	Scheduled	Resource	0.479353872	NoCalc	0	0.479353872	0.479353872

APPENDIX B Arena Simulation for Proposed Solution 1

ProjectName	Project RunDateTime	Replication	Name	Type	Source	RecordedValue	IsPeriodic	GroupByKey	RepsRequested	Average
Unnamed Project	2024-01-07 16:55:29	1	Entity 1.NumberIn	Number In	Entity	71	0	Unnamed ProjectEntity 1.NumberInNumber InEntity	1	71
Unnamed Project	2024-01-07 16:55:29	1	Entity 1.NumberOut	Number Out	Entity	70	0	Unnamed ProjectEntity 1.NumberOutNumber OutEntity	1	70
Unnamed Project	2024-01-07 16:55:29	1	Entity 2.NumberIn	Number In	Entity	65	0	Unnamed ProjectEntity 2.NumberInNumber InEntity	1	65
Unnamed Project	2024-01-07 16:55:29	1	Entity 2.NumberOut	Number Out	Entity	63	0	Unnamed ProjectEntity 2.NumberOutNumber OutEntity	1	63
Unnamed Project	2024-01-07 16:55:29	1	Operator 1.NumberSeized	Total Number Seized	Resource	136	0	Unnamed ProjectOperator 1.NumberSeizedTotal Number SeizedResource	1	136
Unnamed Project	2024-01-07 16:55:29	1	Operator 1.ScheduledUtilization	Scheduled Utilization	Resource	0.001340772	0	Unnamed ProjectOperator 1.ScheduledUtilizationScheduled UtilizationResource	1	0.001340772
Unnamed Project	2024-01-07 16:55:29	1	Operator 2.NumberSeized	Total Number Seized	Resource	135	0	Unnamed ProjectOperator 2.NumberSeizedTotal Number SeizedResource	1	135
Unnamed Project	2024-01-07 16:55:29	1	Operator 2.ScheduledUtilization	Scheduled Utilization	Resource	0.867303876	0	Unnamed ProjectOperator 2.ScheduledUtilizationScheduled UtilizationResource	1	0.867303876
Unnamed Project	2024-01-07 16:55:29	1	Operator 3.NumberSeized	Total Number Seized	Resource	134	0	Unnamed ProjectOperator 3.NumberSeizedTotal Number SeizedResource	1	134
Unnamed Project	2024-01-07 16:55:29	1	Operator 3.ScheduledUtilization	Scheduled Utilization	Resource	0.001400377	0	Unnamed ProjectOperator 3.ScheduledUtilizationScheduled UtilizationResource	1	0.001400377
Unnamed Project	2024-01-07 16:55:29	1	Operator 4.NumberSeized	Total Number Seized	Resource	133	0	Unnamed ProjectOperator 4.NumberSeizedTotal Number SeizedResource	1	133
Unnamed Project	2024-01-07 16:55:29	1	Operator 4.ScheduledUtilization	Scheduled Utilization	Resource	0.305357031	0	Unnamed ProjectOperator 4.ScheduledUtilizationScheduled UtilizationResource	1	0.305357031
Unnamed Project	2024-01-07 16:55:29	1	Robot.NumberSeized	Total Number Seized	Resource	134	0	Unnamed ProjectRobot.NumberSeizedTotal Number SeizedResource	1	134
Unnamed Project	2024-01-07 16:55:29	1	Robot.ScheduledUtilization	Scheduled Utilization	Resource	0.560532434	0	Unnamed ProjectRobot.ScheduledUtilizationScheduled UtilizationResource	1	0.560532434
Unnamed Project	2024-01-07 16:55:29	1	System.NumberOut	Number Out	System	133	0	Unnamed ProjectSystem.NumberOutNumber OutSystem	1	133

Project Name	Name	Type	Source	Average Across Replications	Half-Width	Overall StDev Across Replications	Min Replication Value	Max Replication Value
Unnamed Project	Operator 1.NumberSeized	Total Numb	Resource	136	NoCalc	0	136	136
	Operator 1.ScheduledUtili	Scheduled	Resource	0.001340772	NoCalc	0	0.001340772	0.001340772
	Operator 2.NumberSeized	Total Numb	Resource	135	NoCalc	0	135	135
	Operator 2.ScheduledUtili	Scheduled	Resource	0.867303876	NoCalc	0	0.867303876	0.867303876
	Operator 3.NumberSeized	Total Numb	Resource	134	NoCalc	0	134	134
	Operator 3.ScheduledUtili	Scheduled	Resource	0.001400377	NoCalc	0	0.001400377	0.001400377
	Operator 4.NumberSeized	Total Numb	Resource	133	NoCalc	0	133	133
	Operator 4.ScheduledUtili	Scheduled	Resource	0.305357031	NoCalc	0	0.305357031	0.305357031
	System.NumberOut	Number Ou	System	133	NoCalc	0	133	133
	Entity 1.NumberIn	Number In	Entity	71	NoCalc	0	71	71
	Entity 1.NumberOut	Number Ou	Entity	70	NoCalc	0	70	70
	Entity 2.NumberIn	Number In	Entity	65	NoCalc	0	65	65
	Entity 2.NumberOut	Number Ou	Entity	63	NoCalc	0	63	63
	Robot.NumberSeized	Total Numb	Resource	134	NoCalc	0	134	134
	Robot.ScheduledUtilizatio	Scheduled	Resource	0.560532434	NoCalc	0	0.560532434	0.560532434

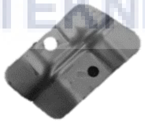
APPENDIX C Arena Simulation for Proposed Solution 2

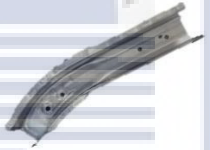
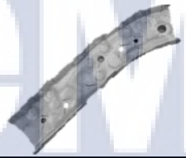
ProjectName	Project RunDateTime	Replication	Name	Type	Source	RecordedValue	IsPeriodic	GroupByKey	RepsRequested	Average	S
Unnamed Project	2024-01-07 19:47:21	1	Entity 1.NumberIn	Number In	Entity	66	0	Unnamed ProjectEntity 1.NumberInNumber InEntity	1	66	
Unnamed Project	2024-01-07 19:47:21	1	Entity 1.NumberOut	Number Out	Entity	63	0	Unnamed ProjectEntity 1.NumberOutNumber OutEntity	1	63	
Unnamed Project	2024-01-07 19:47:21	1	Entity 2.NumberIn	Number In	Entity	64	0	Unnamed ProjectEntity 2.NumberInNumber InEntity	1	64	
Unnamed Project	2024-01-07 19:47:21	1	Entity 2.NumberOut	Number Out	Entity	61	0	Unnamed ProjectEntity 2.NumberOutNumber OutEntity	1	61	
Unnamed Project	2024-01-07 19:47:21	1	Operator 1.NumberSeized	Total Number Seized	Resource	130	0	Unnamed ProjectOperator 1.NumberSeizedTotal Number SeizedResource	1	130	
Unnamed Project	2024-01-07 19:47:21	1	Operator 1.ScheduledUtilization	Scheduled Utilization	Resource	0.001143832	0	Unnamed ProjectOperator 1.ScheduledUtilizationScheduled UtilizationResource	1	0.001143832	
Unnamed Project	2024-01-07 19:47:21	1	Operator 2.NumberSeized	Total Number Seized	Resource	251	0	Unnamed ProjectOperator 2.NumberSeizedTotal Number SeizedResource	1	251	
Unnamed Project	2024-01-07 19:47:21	1	Operator 2.ScheduledUtilization	Scheduled Utilization	Resource	0.812306356	0	Unnamed ProjectOperator 2.ScheduledUtilizationScheduled UtilizationResource	1	0.812306356	
Unnamed Project	2024-01-07 19:47:21	1	Operator 3.NumberSeized	Total Number Seized	Resource	124	0	Unnamed ProjectOperator 3.NumberSeizedTotal Number SeizedResource	1	124	
Unnamed Project	2024-01-07 19:47:21	1	Operator 3.ScheduledUtilization	Scheduled Utilization	Resource	0.285152791	0	Unnamed ProjectOperator 3.ScheduledUtilizationScheduled UtilizationResource	1	0.285152791	
Unnamed Project	2024-01-07 19:47:21	1	Robot.NumberSeized	Total Number Seized	Resource	124	0	Unnamed ProjectRobot.NumberSeizedTotal Number SeizedResource	1	124	
Unnamed Project	2024-01-07 19:47:21	1	Robot.ScheduledUtilization	Scheduled Utilization	Resource	0.522281796	0	Unnamed ProjectRobot.ScheduledUtilizationScheduled UtilizationResource	1	0.522281796	
Unnamed Project	2024-01-07 19:47:21	1	System.NumberOut	Number Out	System	124	0	Unnamed ProjectSystem.NumberOutNumber OutSystem	1	124	

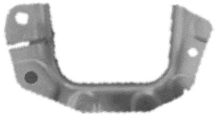
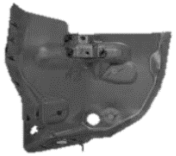
Output Statistics (Reports End of Replication Value)

Project Name	Name	Type	Source	Average Across Replications	Half-Width	Overall StDev Across Replications	Min Replication Value	Max Replication Value
⊟ Unnamed Project	⊟ Operator 1.NumberSeized	⊟ Total Numb	Resource	130	NoCalc	0	130	130
	⊟ Operator 1.ScheduledUtili	⊟ Scheduled U	Resource	0.001143832	NoCalc	0	0.001143832	0.001143832
	⊟ Operator 2.NumberSeized	⊟ Total Numb	Resource	251	NoCalc	0	251	251
	⊟ Operator 2.ScheduledUtili	⊟ Scheduled U	Resource	0.812306356	NoCalc	0	0.812306356	0.812306356
	⊟ Operator 3.NumberSeized	⊟ Total Numb	Resource	124	NoCalc	0	124	124
	⊟ Operator 3.ScheduledUtili	⊟ Scheduled U	Resource	0.285152791	NoCalc	0	0.285152791	0.285152791
	⊟ System.NumberOut	⊟ Number Ou	System	124	NoCalc	0	124	124
	⊟ Entity 1.NumberIn	⊟ Number In	Entity	66	NoCalc	0	66	66
	⊟ Entity 1.NumberOut	⊟ Number Ou	Entity	63	NoCalc	0	63	63
	⊟ Entity 2.NumberIn	⊟ Number In	Entity	64	NoCalc	0	64	64
	⊟ Entity 2.NumberOut	⊟ Number Ou	Entity	61	NoCalc	0	61	61
	⊟ Robot.NumberSeized	⊟ Total Numb	Resource	124	NoCalc	0	124	124
	⊟ Robot.ScheduledUtilizatio	⊟ Scheduled U	Resource	0.522281796	NoCalc	0	0.522281796	0.522281796

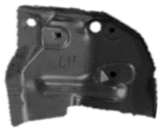
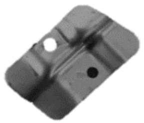
APPENDIX D Child Part of Workstation for Frame Comp Rear RH

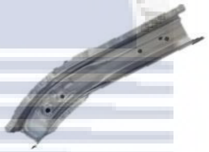
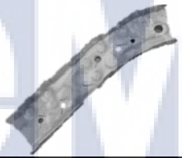
Part Name		Frame Comp Rear RH				
Workstation		Part				Assembly Part
W1	S01					
		Brkt R,Trg Arm Inn	Stiff R,Side Sill Extn			Assy S01 RH
	S02					
		Extn R,Side Sill	Brkt R, Trg Arm Out	Patch R,Side Sill Extn	Stiff Lwr R S/Sill Extn	Assy S02 RH
	S03					
		Sub Assy S01 RH	Sub Assy S03 RH			Assy S03 RH
	S04					
		End Plate L,Side Sill RR	Patch L,Side Sill RR End Plate			Assy S04 RH

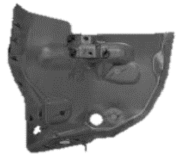
W2	S05					
		Stiff R,Spring Base	Base,Spring			Assy S05 RH
	S06					
		Sub Assy S03 RH				Assy S06 RH
W3	A10					
		Brkt L,Exh Pipe Mtg	Frame A R,RR	Frame B R	Stiff L,Rr Frame A	Assy A10 RH
	A20					
		Sub Assy S05	Sub Assy A10 RH	Bhd,Rr Frame A		Assy A20 RH
W4	A30					
		Stiff R,Rr Frm B Out	Extn R,Rr Floor C/Mbr	Sub Assy S03	Sub Assy A20	Assy A30 RH

W5	A40					
			Sub Assy A30	Sub Assy S04		Assy A40 RH
	A50					
		Final assembly of Frame Comp Rear RH				

APPENDIX E Child Part of Workstation for Frame Comp Rear LH

Part Name		Frame Comp Rear LH				
Workstation		Part				Assembly Part
W1	S01					
		Brkt L,Trg Arm Inn	Stiff L,Side Sill Extn			Assy S01 RH
	S02					
		Extn L,Side Sill	Brkt L, Trg Arm Out	Patch L, Side Sill Extn	Stiff Lwr L S/Sill Extn	Assy S02 LH
	S03					
		Sub Assy S01 LH	Sub Assy S03 LH			Assy S03 LH
	S04					
		End Plate L,Side Sill RR	Patch L,Side Sill RR End Plate			Assy S04 LH

W2	S05					
		Stiff L,Spring Base	Base,Spring			Assy S05 LH
	S06					
		Sub Assy S01 LH				Assy S06 LH
W3	A10					
		Brkt L,Exh Pipe Mtg	Frame A R,RR	Frame B L	Stiff L,RR Frame A	Assy A10 LH
	A20					
		Sub Assy S05 LH	Sub Assy A10 LH	Bhd,Rr Frame A		Assy A20 LH
W4	A30					
		Stiff R,RR Frm B Out	Extn R,RR Floor C/MBR	Sub Assy S03	Sub Assy A20 RH	Assy A30 LH

W5	A40					
		Flg L,Rear Frame End	Sub Assy A30	Sub Assy S04		Assy A40 LH
	A50					
		Final assembly of Frame Comp Rear LH				

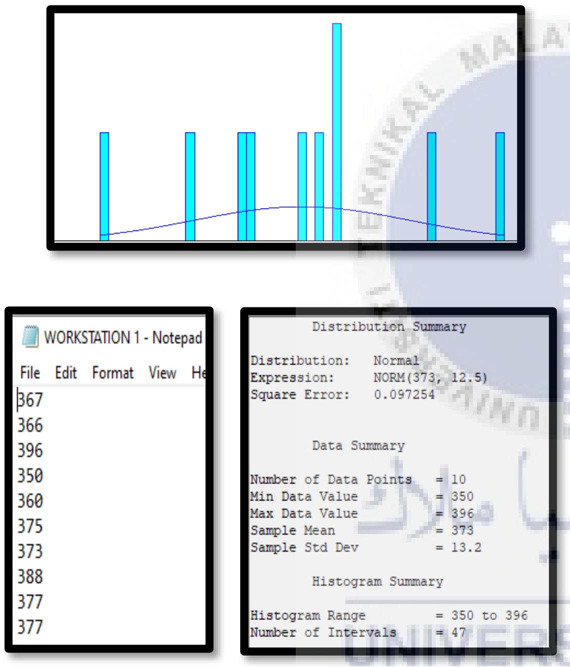
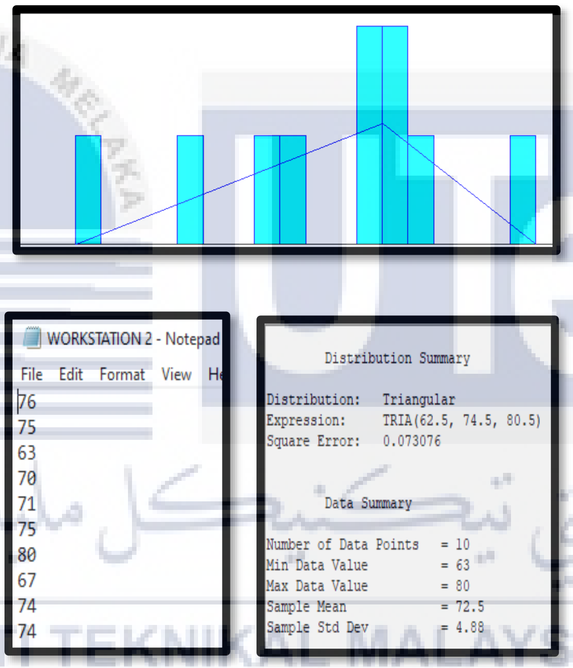
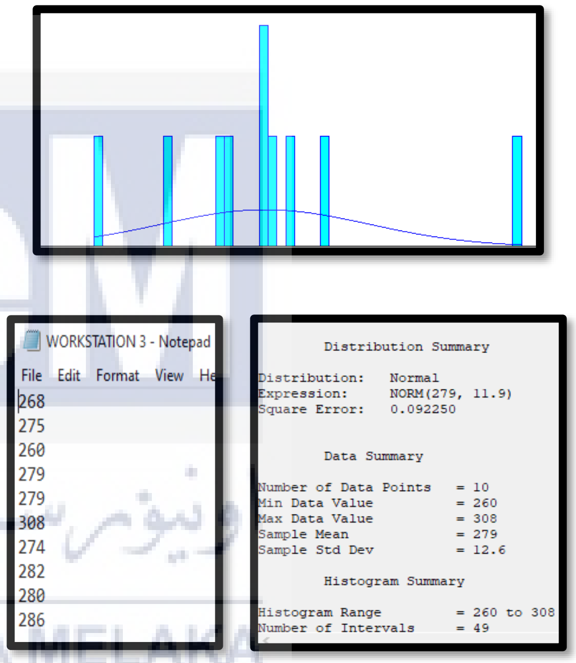
APPENDIX F Cycle Time for Production Line Model 3M0A

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A										Observer: Murali	Date: 11 December 2023
Station	Cycle Time											
	1	2	3	4	5	6	7	8	9	10	Total	Average Time (s)
S01, S02, S03, S04 RH	183	203	210	170	173	193	188	210	197	198	1925	193
S01, S02, S03, S04 LH	184	163	186	180	187	182	185	178	180	179	1804	180
S05, S06 RH	38	40	33	37	38	37	38	37	37	37	372	37
S05, S06 LH	38	35	30	33	33	38	42	30	37	37	353	35
A10, A20 RH	123	127	128	145	143	147	136	141	145	147	1382	138
A10, A20 LH	145	148	132	134	136	161	138	141	135	139	1409	141
A30 RH	160	154	140	143	140	143	145	140	145	143	1457	145
A30LH	157	155	141	150	141	153	141	175	161	152	1526	153
A40, A60 RH	90	88	90	90	92	93	92	92	93	92	912	91
A40, A60 LH	92	89	92	94	90	88	91	89	95	91	911	91
QC Checked	102	104	95	97	108	94	92				692	99
Total RH = 6740 sec							Total LH = 6692 sec					

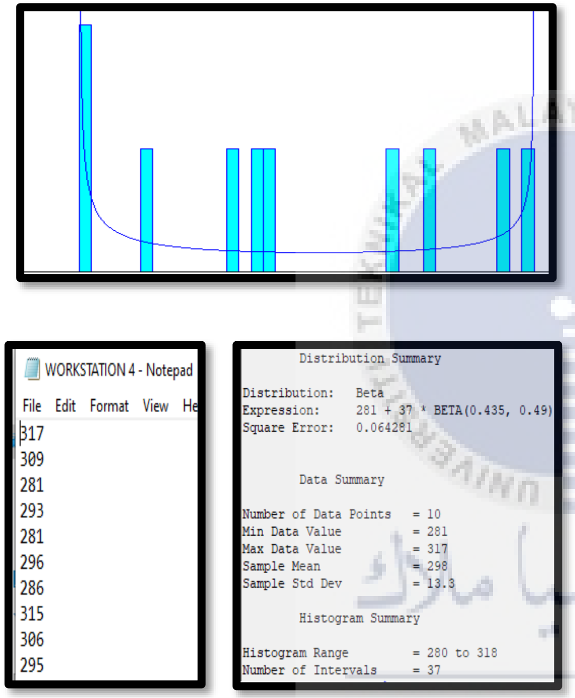
APPENDIX G Time Study of Workstation for Frame Comp Rear RH LH

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A								Observer: Murali	Date: 11 December 2023
Workstation	Cycle Time									
Workstation 1	1	2	3	4	5	6	7	8	9	10
S01, S02, S03, S04 RH LH	367	366	396	350	360	375	373	388	377	377
Workstation 2										
S05, S06 RH LH	76	75	63	70	71	75	80	67	74	74
Workstation 3										
A10, A20 RH LH	268	275	260	279	279	308	274	282	280	286
Workstation 4										
A30 RH LH	317	309	281	293	281	296	286	315	306	295
Workstation 5										
A40, A60 RH LH	182	177	182	184	182	181	183	181	188	183
QC Checked	102	104	95	97	108	94	92			
Total Average RH = 704 sec						Total Average LH = 699 sec				

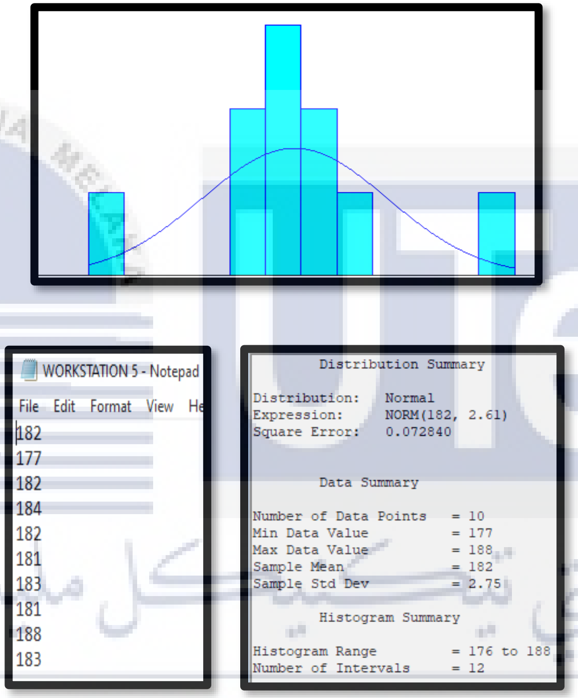
APPENDIX H Input Analyzer for Frame Comp Rear RH LH

WORKSTATION 1	WORKSTATION 2	WORKSTATION 3
		

WORKSTATION 4



WORKSTATION 5



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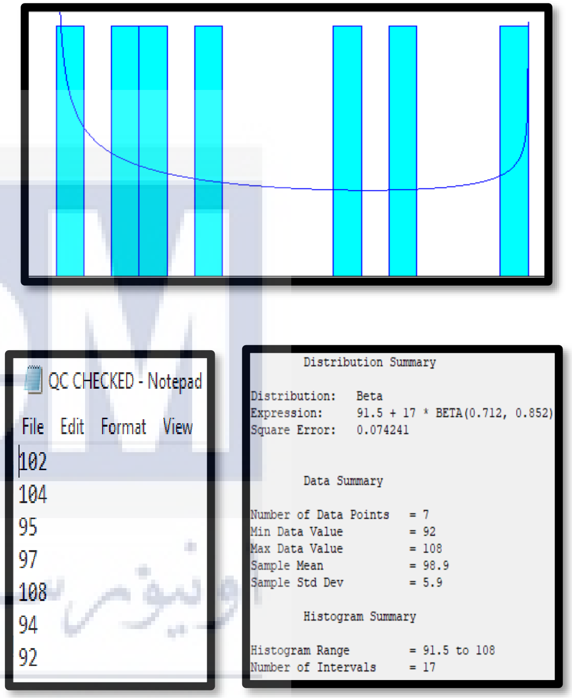


APPENDIX I Cycle Time of Station After Reduce Workstation

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A										Observer: Murali	Date: 11 December 2023
Station	Cycle Time											
	1	2	3	4	5	6	7	8	9	10	Total	Average Time (s)
S01, S02, S03, S04, S05 S06 RH	226	244	243	215	218	230	270	235	235	235	2351	235
S01, S02, S03, S04, S05 S06 LH	218	200	216	218	220	225	225	222	217	223	2184	218
A10, A20 RH	123	127	128	145	143	147	136	141	145	147	1382	138
A10, A20 LH	145	148	132	134	136	161	138	141	135	139	1409	141
A30 RH	160	154	140	143	140	143	145	140	145	143	1457	145
A30LH	157	155	141	150	141	153	141	175	161	152	1526	153
A40, A60 RH	90	88	90	90	92	93	92	92	93	92	912	91
A40, A60 LH	92	89	92	94	90	88	91	89	95	91	911	91
QC Checked	102	104	95	97	108	94	92				692	99

APPENDIX J Standard Time After Reduce Workstation

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A				Observer: Murali	Date: 11 December 2023
Station	Average Time (s)	Range	Performance Rating (%)	Rating Factor	Normal Time (s)	Standard Time (s)
S01, S02, S03, S04, S05, S06 RH	235	55	90	0.9	212	234
S01, S02, S03, S04, S05, S06 LH	218	25	90	0.9	196	225
A10, A20 RH	138	24	100	1.0	138	159
A10, A20 LH	141	29	100	1.0	141	162
A30 RH	145	20	100	1.0	145	167
A30LH	153	34	100	1.0	153	176
A40, A60 RH	91	5	100	1.0	91	105
A40, A60 LH	91	7	100	1.0	91	105
QC Checked	99	16	100	1.0	99	114

APPENDIX K Cycle Time After Reduce Workstation

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A								Observer: Murali	Date: 11 December 2023
Workstation	Cycle Time									
Workstation 1	1	2	3	4	5	6	7	8	9	10
S01, S02, S03, S04, S05, S06 RH LH	444	444	459	433	438	455	495	457	452	458
Workstation 2										
A10, A20 RH LH	268	275	260	279	279	308	274	282	280	286
Workstation 3										
A30 RH LH	317	309	281	293	281	296	286	315	306	295
Workstation 4										
A40, A60 RH LH	182	177	182	184	182	181	183	181	188	183
QC Checked	102	104	95	97	108	94	92			

APPENDIX L Cycle Time Station After Line Balancing Improvement

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A										Observer: Murali	Date: 11 December 2023
Station	Cycle Time											
	1	2	3	4	5	6	7	8	9	10	Total	Average Time (s)
S01, S02, S03, S04, S05 S06 RH	218	200	216	216	219	222	224	222	222	216	2175	218
S01, S02, S03, S04, S05 S06 LH	218	200	216	218	220	225	225	222	217	223	2184	218
A10, A20 RH	123	127	128	145	143	147	136	141	145	147	1382	138
A10, A20 LH	145	148	132	134	136	161	138	141	135	139	1409	141
A30 RH	160	154	140	143	140	143	145	140	145	143	1457	145
A30LH	157	155	141	150	141	153	141	175	161	152	1526	153
A40, A60 RH	90	88	90	90	92	93	92	92	93	92	912	91
A40, A60 LH	92	89	92	94	90	88	91	89	95	91	911	91
QC Checked	102	104	95	97	108	94	92				692	99

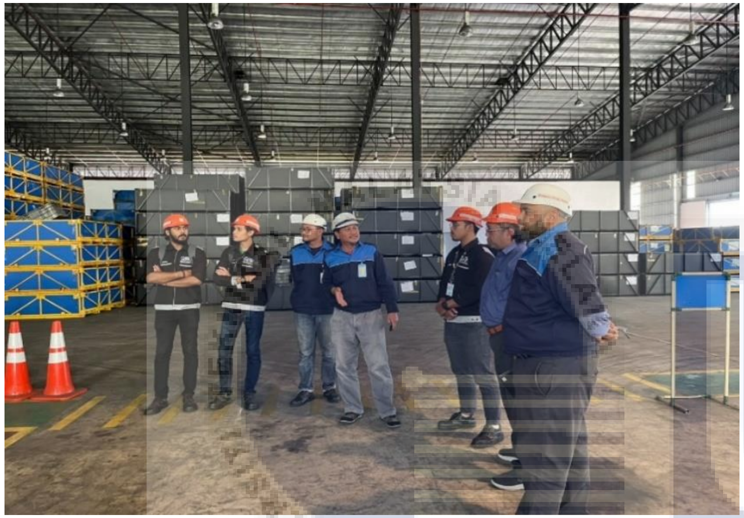
APPENDIX M Standard Time After Line Balancing Improvement

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A				Observer: Murali	Date: 11 December 2023
Station	Average Time (s)	Range	Performance Rating (%)	Rating Factor	Normal Time (s)	Standard Time (s)
S01, S02, S03, S04, S05, S06 RH	218	40	90	0.9	194	226
S01, S02, S03, S04, S05, S06 LH	218	12	90	0.9	194	226
A10, A20 RH	138	24	100	1.0	138	159
A10, A20 LH	141	29	100	1.0	141	162
A30 RH	145	20	100	1.0	145	167
A30LH	153	34	100	1.0	153	176
A40, A60 RH	91	5	100	1.0	91	105
A40, A60 LH	91	7	100	1.0	91	105
QC Checked	99	16	100	1.0	99	114

APPENDIX N Cycle Time After Line Balancing Improvement

Process: Spot Welding	Product: Frame Comp Rear RH and Frame Comp Rear LH Model: 3M0A							Observer: Murali	Date: 11 December 2023
Workstation	Cycle Time								
Workstation 1	1	2	3	4	5	6	7	8	9	10
S01, S02, S03, S04, S05, S06 RH LH	436	400	432	434	439	447	449	444	439	439
Workstation 2										
A10, A20 RH LH	268	275	260	279	279	308	274	282	280	286
Workstation 3										
A30 RH LH	317	309	281	293	281	296	286	315	306	295
Workstation 4										
A40, A60 RH LH	182	177	182	184	182	181	183	181	188	183
QC Checked	102	104	95	97	108	94	92			

APPENDIX O Site Visit For Data Collection EPMB PEPS-JV MELAKA SDN. BHD.



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