

SOLVING BOTTLENECK AT PRODUCTION LINE THROUGH SIMULATION TO ENHANCE PRODUCTIVITY AT MANUFACTURING COMPANY



# BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

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# Faculty of Mechanical and Manufacturing Engineering Technology



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Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

#### SOLVING BOTTLENECK AT PRODUCTION LINE THROUGH SIMULATION TO ENHANCE PRODUCTIVITY AT MANUFACTURING COMPANY

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**Faculty of Mechanical and Manufacturing Engineering Technology** 

## UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

### DECLARATION

I declare that this Choose an item. entitled "Solving Bottleneck at Production Line Through Simulation to Enhance Productivity at Manufacturing Company" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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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.



## DEDICATION

Praise to God for the strength, guidance and knowledge that was given by God for me to

complete this study.

&



To all people who support me throughout my journey.

#### ABSTRACT

In Lean manufacturing, waiting waste is important to stream and indeed is probably the second most critical waste among all seven wastes. Line balancing is a technique implemented in the industry to eliminate wasteful waiting. Growing manufacturing companies have begun to incorporate lean manufacturing ideas into their organizations. It is important in industry to solve productivity problems in the production line. This research was conducted at PEPS-JV Sdn. Bhd .Currently, the case company discovered that they are lack of attention to the accuracy of cycle time and have unequal workload among the operator. Decisions will be made by using lean manufacturing techniques to solve this problem. In addition, lean tool line balancing is another tool to support researchers to solve bottlenecks in production lines. The aim of this study is to conduct a line balance study using Arena simulation software to improve the smoothness of the production line and thus increase productivity. Real-time data will be collected in case companies and shown in histograms. To move towards IR4.0, Arena simulation software is used to verify the productivity of the new workstation design. An Arena simulation model that can be used to make strategic decisions about process improvement will be built using bottlenecks as a basic step to solve problems in a productivity production line. This model can take advantage of the facts needed to make such a decision. The effect of using appropriate lean tools on a production line can be usefully analyzed through the use of simulation. The overall productivity produced by a manufacturing company's production line attempts to represent the manufacturing company's ideal future situation. As a result, the time study methodology used in this study to analyze the production line and provide it with a more effective selection tool. At the end of this study, a comparison of the results of the existing production line system and the new production line in the simulation model after the implementation of corrective actions shows that the productivity of product production has increased by 11.7% if reduced workstations and 2.5% increased if operator 2 does work on workstation 2. In this research, using the method of line balancing and Arena simulation is the best to solve the problem of bottlenecks issue that occurs in the production line. The proposed solution is a reduced workstation because the percentage productivity of product production is higher compared to the second one.

#### ABSTRAK

Dalam pembuatan Lean, sisa menunggu adalah penting untuk aliran dan sememangnya mungkin merupakan sisa kedua paling kritikal antara kesemua tujuh sisa. Pengimbangan talian adalah teknik yang dilaksanakan dalam industri untuk menghapuskan menunggu yang membazir. Syarikat perkilangan yang semakin berkembang telah mula memasukkan idea pembuatan tanpa lemak ke dalam organisasi mereka. Adalah penting dalam industri untuk menyelesaikan masalah produktiviti dalam barisan pengeluaran. Penyelidikan ini dijalankan di PEPS-JV Sdn. Bhd .Pada masa ini, syarikat kes mendapati bahawa mereka kurang mengambil berat tentang ketepatan masa kitaran dan mempunyai beban kerja yang tidak sama rata di kalangan pengendali. Keputusan akan dibuat dengan menggunakan teknik pembuatan kurus untuk menyelesaikan masalah ini. Di samping itu, pengimbangan garisan alat tanpa lemak ialah alat lain untuk menyokong penyelidik menyelesaikan kesesakan dalam barisan pengeluaran. Matlamat kajian ini adalah untuk menjalankan kajian imbangan garisan menggunakan perisian simulasi Arena bagi meningkatkan kelancaran barisan pengeluaran dan seterusnya meningkatkan produktiviti. Data masa nyata akan dikumpul dalam kes syarikat dan ditunjukkan dalam histogram. Untuk bergerak ke arah IR4.0, perisian simulasi Arena digunakan untuk mengesahkan produktiviti reka bentuk stesen kerja baharu. Model simulasi Arena yang boleh digunakan untuk membuat keputusan strategik tentang penambahbaikan proses akan dibina menggunakan kesesakan sebagai langkah asas untuk menyelesaikan masalah dalam barisan pengeluaran produktiviti. Model ini boleh mengambil kesempatan daripada fakta yang diperlukan untuk membuat keputusan sedemikian. Kesan penggunaan alat kurus yang sesuai pada barisan pengeluaran boleh dianalisis dengan berguna melalui penggunaan simulasi. Produktiviti keseluruhan yang dihasilkan oleh barisan pengeluaran syarikat pembuatan cuba mewakili situasi masa depan ideal syarikat pembuatan. Hasilnya, metodologi kajian masa yang digunakan dalam kajian ini untuk menganalisis barisan pengeluaran dan menyediakannya dengan alat pemilihan yang lebih berkesan. Di akhir kajian ini, perbandingan keputusan sistem barisan pengeluaran sedia ada dan barisan pengeluaran baharu dalam model simulasi selepas pelaksanaan tindakan pembetulan menunjukkan bahawa produktiviti pengeluaran produk telah meningkat sebanyak 11.7% jika stesen kerja berkurangan dan 2.5. % meningkat jika operator 2 melakukan kerja di stesen kerja 2. Dalam penyelidikan ini, menggunakan kaedah pengimbangan garisan dan simulasi Arena adalah yang terbaik untuk menyelesaikan masalah masalah kesesakan yang berlaku di barisan pengeluaran. Penyelesaian yang dicadangkan ialah stesen kerja yang dikurangkan kerana peratusan produktiviti pengeluaran produk adalah lebih tinggi berbanding dengan yang kedua.

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## LIST OF SYMBOLS AND ABBREVIATIONS

LM Lean Manufacturing \_ TPS Toyota Production System Value Stream Mapping VSM Just in Time JIT TPM **Total Productive Maintenance** \_ **Overall Equipment Effectiveness** OEE \_ TQM Total Quality Management \_ Key Performance Indicator KPI \_ Single-minute Exchange of Die **SMED PDCA** Plan Do Check Act



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#### **CHAPTER 1**

#### **INTRODUCTION**

The study's justification and overview were laid out in this chapter. The chapter begins with an introduction to the business and the theory behind the project. The next step is to talk about what you want to accomplish.

#### 1.1 Background

Digital industrial technology was referred to Industry 4.0, became widely accessible, manufacturing businesses immediately began experimenting with more efficient techniques of production. The companies operate within this sector are able to take action on management strategies that will enable to enhance the characteristics of their production and services, increase the quality, and decrease their costs of their product, all while improving their capital productivity and providing services to their customers. The fact that manufacturers have decided not only to fulfil the needs of domestic markets but also to provide a product of higher quality to international markets. As a result, to be taken in order to constantly enhance the manufacturing process and eliminate waste so that the product can be delivered.

In this work, lean tools is essential element of the lean manufacturing concept and principles that aim to increase the efficiency of the production line. Lean manufacturing is a tool that may be used to increase profits and to improve the efficiency of the system by reducing waste. This is due to the implementation of a bottleneck, which attempts to distribute work among all operators while reducing the number of workstations in the production line. In addition, most of the production lines does not apply simulation as their tools before real production started. It can be used to analyse a variety of scenarios, also known as simulation scenarios, in order to develop and improve processes. As a result, the decision was made to combine bottleneck study with Arena simulation in order to make that output a decision about how to increase productivity in the production line. In the real world, where every company wants to be successful in the long run on the global market, competition and excellence are very important.

#### **1.2 Problem Statement**

In the modern, global marketplace, manufacturer need to compete to each other to deliver the best service to their customer. As a result, a lot of businesses are constantly searching for innovative approaches to enhance the productivity of their production lines. Significant percentage of manufacturers does'nt have clear understanding on how to implement lean concepts into their operations. Many industries keep making same mistake of producing unnecessary waste or sacrificing productivity on the production line, resulting in customers not receiving their orders on time. The automotive business, PEPS-JV Sdn. Bhd, then, will serve as the primary target of this investigation.

By making suggestions for ways to improve the production line using other good methods, they require assistance from a good technique such as the bottleneck lean tool, which analyses the lean waste that occurs in the production line. The company's PEPS-JV Sdn. Bhd production system, it is important to make use of this method in order to identify the right reliability in the production line and the primary case of products in order to satisfy customers. The bottleneck, the problem that has to be solved, is a tool that can be used to increase profits in order to improve the efficiency of the system as a whole by decreasing or

eliminating waste (Bastos et al., 2018). Furthermore, the lean tool line balancing is another tool to support the research to solve the bottleneck.

Moreover, developments in information technology have increased manufacturers' potential, allowing them to achieve good financial performance while simultaneously improving product quality and reducing costs. As a result, by using Arena simulation software the validate the performance of the system and associate lean manufacturing with the idea of Industry 4.0. The bottleneck analysis and the Arena simulation are going to be combined as a result of a decision. The output of this combination will be a decision about how to improve productivity in the production line.

## 1.3 Research Objective

The objectives of this work included the following:

- 1) To proposed a combination between bottleneck and simulation in process improvement.
- 2) To validate the proposed methodology for bottleneck and simulation.
- 3) To suggest a improvement alternative through proposed methodology.

#### 1.4 Scope of Research

This research aims to identify the bottleneck lean tool and simulation activity in the manufacturing process and improve productivity as a result. To better understand and conceptualise the production process, the decision was made to revisit the production planning. Then, the findings of this study will show that the lean technique can be used to make improvements. The aims for this research are to provide smooth flow of production and the biggest possible productivity increase. This study will conduct by using the line

balancing method in PEPS-JV(M) Sdn Bhd. The line balancing method will be applied in production line 4 (3MO), which assembles the Frame Comp Rear RH LH by spot welding.

Additionally, simulation and bottleneck lean tools can also be used to analyse current processes and make suggestions for improvement to the management of a company. Arena is the software that will be used for simulation purposes. Research in this area uses the bottleneck lean tool in the Arena simulation to conceptualise current manufacturing processes. Next, a simulation model is used to examine the current stream of waste for lean waste. Many lean tools, like Kanban, the Pull System, Standard Work Tool and Line Balancing, can help shorten lead times and help management increase customer delivery rates.

#### 1.5 Summary

The project improvement research will be conducted based on the problem that has been identified and the advanced conceptual understanding of the project background. Within the scope of research, the study is also based on three main objectives. The process of studying will go smoothly and be clear if there are clear limits set in the scope of research.

#### **CHAPTER 2**

#### LITERATURE REVIEW

#### 2.1 Introduction

The main objective of a literature review is to evaluate and analyse what approved researchers have written on a given issue. This section aims to express information about bottlenecks and simulation ideas related to productivity improvement. The concept of bottlenecks and simulations, case studies of successful implementations of this approach will be highlighted. Then, this section includes case studies that demonstrate how Bottle-neck and simulation were used in a Lean Manufacturing Company. Furthermore, this section identifies gaps in previous research as well as what needs to be studied further about the use of the lean technique.

# اونيونرسيتي تيڪنيڪل مليسي Mistory of LM

#### UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A manufacturing practise known as Lean Manufacturing (LM), or simply Lean, considers any expenditure of resources other than the creation of value to be wasteful and thus a target for elimination. 'Value' is defined by a customer's willingness to pay for the product. The lean concept dates back to the end of the 19th century and the beginning of the 20th century, when Henry Ford and other manufacturers began developing production systems that were more efficient. Figure 2.1 depicts a high-level overview of the evolution of lean management over time. Eli Whitney, Taylor, Gilbreth, Henry Ford, Shingo, and Ohno all played significant roles in the evolution of the lean concept. (Krishnan et al., 2018)



Since the 1980s, many business models have been developed to teach and demonstrate business management. However, only a few of these models were long-term and secure. Japan was viewed as a model for a rising manufacturing nation in the late 1980s. It was not only in Japan that Toyota, Nissan, Sony and Honda began to establish market position. Other market participants, consultants, and academics were curious about how these companies designed, implemented, and operated their manufacturing systems. These procedures were to be called "lean production."

## 2.3 Lean Manufacturing

Productivity and waste reduction are the primary goals of the LM process. By reducing waste in organisations, the lean philosophy aims to maintain a steady flow of production. An important part of LM's creation process is empowering the flow system to attract customers from all over the organisation by using a variety of mechanical practises to identify value-adding processes. By eliminating all waste, Velmurugan et al. (2020) claim that lean is a method that aims to benefit the customer and society while also lowering costs and increasing quality.

The Toyota Production System (TPS), developed in Japan by Taichii Ohno's drives at Toyota Motor Company (Ohno, 1988), aims to reduce waste in a manufacturing operation. The two guiding principles of lean manufacturing are visualisation and "go to see," also known as "go to Gemba," which aim to reduce "Muda," or non-value-added activities. Most manufacturing companies have shifted their focus away from equipment and energy utilisation in order to reduce lead time and "Muda." A company can apply lean manufacturing techniques to a specific production process using a variety of lean techniques. Seven different types of waste are targeted by lean manufacturing, as are numerous tools and techniques that companies around the world have adopted.

## اويونرسيني تيڪنيڪل مليسيا ملاك 2.3.1 Types of Lean Waste UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The principle of LM states that customers don't pay for mistakes or waste; they only pay for the product's value. The term "waste" then refers to any flaws or errors that undermine customer loyalty (Yahya et al., 2019). Waste is defined as any activity that degrades product quality while adding no value to the product. Efforts should be made to identify the source of poor product quality and waste so that users in the production line can be improved. According to Ohno, waste includes transportation, inventory, motion, waiting, overproduction, overprocessing, and defects (1988). There are seven types of Lean waste developed and shown in Figure 2.2 that are commonly referred to in manufacturing as TIMWOOD wastes (Cawley et al., 2020).



Moving goods from one place to another is called transportation. Transportation waste is defined as the excessive or inefficient use of materials and components as a result of poor planning or ineffective Jobsite logistics. As a result, if the manufacturer reduces transportation waste, energy consumption and product costs can be reduced. Carrying a product over a long distance is an example of transportation waste (Abdalla et al., 2018). It's critical to keep transportation costs as low as possible because it adds no value to the product. For example, it could mean moving a production plant closer to another in the chain or reducing transportation costs by using more efficient procedures.

#### 2.3.1.2 Inventory

Unprocessed inventory waste is the waste that it generates. Storage waste, financing waste tied up in unprocessed stock, transportation waste, inventory containers, storage lighting, and so on are all examples. The most important thing to remember about inventory is that it includes both raw materials and finished goods (Chahala and Narwal, 2017).

Furthermore, having too much inventory can cause the original wastes associated with its creation to be redistributed. Inventory waste has environmental costs such as waste packaging, deterioration or effected work-in-process inventory, the need for more materials to replace damaged or obsolete inventory, as well as the energy required to light inventory space.

#### 2.3.1.3 Motion

An organization's motion waste can have both direct and indirect consequences. Motion waste reduces the efficiency of production. To plan more capable working environments, an ergonomics assessment of the workplace should be performed (Chahala and Narwal, 2017). Transportation between workstations takes a significant amount of time and effort in industry. Aside from that, motion can refer to anything from a worker bending down to pick something up on the factory floor to increased wear and tear on machines, which results in capital maintenance costs and the need to replace them. Due to a lack of system integration, manual intervention is required.

A variety of factors contribute to ineffective motion, including irregular work processes, inefficient plant layout, machine maintenance issues, a lack of a work method, and an absence of a well-documented and applied consistently standard of work.

#### 2.3.1.4 Waiting

During a manufacturing process, waiting refers to the time that is lost due to production being slowed or stopped while another step is being completed. Time is wasted when a procedure has to wait for another to finish before it can begin. Instead, the operation should be smooth and uninterrupted. The majority of a product's manufacturing time is spent waiting for things like a task plan, an order, or a machine part, according to some estimates (Chahala and Narwal, 2017).

Waiting for the next employee to finish a task can be a waste of time on a production line, for instance. Efforts must be made to reduce the time spent on the task, hire more workers, or better schedule the workflow in order to compensate for the lost time.

#### 2.3.1.5 Over-processing

Over-processing is a term used to describe any unnecessary steps in the production process. This includes things like enhancing an area that will never be seen or adding features that will never be utilised. When one process has to wait for another to complete before starting, time is wasted. Instead, the process must be smooth and continuous. In order to get the best results, this is a waste that typically necessitates additional processing, which can be quite costly. The entire system is frequently disrupted by this procedure, which takes place over a short period of time (Chahala and Narwal, 2017).

Furthermore, inefficient processing occurs as a result of tools and product design are poor, resulting in unnecessary motion and defects. Waste is produced when higher-quality products are provided than is required.

#### 2.3.1.6 Over-production

Overproduction is the most serious type of waste because it generates all other waste and excess inventory. Having a product on hand that is never going to be used costs money, space, and materials in the form of additional storage space and materials. According to Li et al. (2019) stated the advantages of not overproducing: reduced raw materials use, less energy consumption and no risk of excess inventory not being sold, as well as the proper disposal of excess inventory when overproduction is avoided.

Overproduction has been divided into two types such as early and quantitative (Shingo, 1989). The term "early overproduction" refers to the production of products before they are required. Quantitative overproduction is the production of more products than are required. For example, a company could produce a variety of products as compared to demand, or it may produce products too early before they are necessary. This increases the possibility of failure as well as the possibility of producing the invalid thing. It generally results in a long lead time and insufficient storage capacity.

# 2.3.1.7 Defects

The lack of acceptable quality is referred to as "defect waste." Poor equipment quality, insufficient qualification, or the use of non-standard techniques can all relate to this (Junior et al., 2020). Defective products can be the result of a naturally occurring defect, such as a knot in a wood product, or they can be the result of a manufacturing process defect. Whatever the cause of the defect, one of two things must occur: the part must be discarded and a new part must be created to replace the defective part, or the part must be sent back through all or part of the manufacturing process to fix the defect.

#### 2.3.2 Philosophy LM

A philosophy, because the more people who believe in it, the more improvements are possible, easing the implementation process. Furthermore, lean must be viewed as a journey; if viewed as a tactic or process, it may be assumed that it must only be used to achieve the end result. LM must be viewed as a mindset that governs how one approaches business or processes. According to Chiarini et al. (2018) the Toyota production system as practised by Toyota may be difficult to replicate by other organisations due to the variation in how some procedures are managed and the prevailing culture.

# 2.3.3 Principle LM

The five principles of lean manufacturing were established in 1997 by James P. Womack and Daniel T. Jones. This has been used to advise businesses on how to provide the most value to their customers while also maximising efficiency. It is useful throughout the manufacturing process, from research and development to packaging and delivery. This method can be used to improve a single product or an entire manufacturing line. It is flexible enough to be used on a small or large scale, making it useful to a wide range of organisations.



Figure 2.3 Principle of LM

Table 2.	1	Exp	lai	nati	on	of I	Prin	cple	LM	[

Principle	Details
Value	The value of a product is determined by the needs of its target market.
لا	Examples include the manufacturing schedule, delivery schedule, and price range.
Value Stream	It's easy to use and extremely informative, identifying every single step
	of any process that a product or service goes through. Design,
	manufacturing, logistics, human resources, and etc.
Flow	In order to ensure that the product or service is delivered smoothly to
	the customer, ensure that the value-creating steps take place
	sequentially.
Pull	This makes it easier to produce and deliver goods on time. When a
	customer needs your product, they can "pull" it from your hands (often
	in weeks, instead of months).
Perfection	The benefits of lean are undeniable, but keep in mind that it's not a
	one-size-fits-all system.

#### 2.3.4 LM Tools and Technique

LM implements attempted tools and techniques to systematically apply these LM principles. If these are used correctly, they will improve the final product's quality, cost, and delivery. These tools help in the implementation, monitoring, and analyzation of LM efforts and outcomes. From the other hand, if these are used inaccurately, they can have a negative impact on an organization's LM efforts.

According to current research, there are many lean tools and techniques that are widely used, depending on the size of the industries. In Malaysia, several studies have been discovered to be related to the adoption and implementation of lean production tools and techniques, especially in automotive, electrical and electronic, and food and beverage industries, to achieve higher performance improvement (Yahya et al., 2019).

Table 2.2 Description for Tools and Techniques

Types of Lean Tools	Details
and Techniques	اونىۋىرىسىتى تىكنىكل ملىر
5S	5S is generally applied to medium to large scale industries
UNIVERSI	T (Rizkya et al., 2019). ALAYSIA MELAKA
Just in Time (JIT)	Cusumano (1988) states that developments in the Japanese
	automotive industry and explores the impact of Process
	management on solidifying productivity gains.
Kaizen	Kaizen is a process-oriented improvement method to improve
	quality (Ma et al., 2017).
Kanban	Kanban is a pulling signal for a specific product's demand in
	specific quantities of components (Houti et al., 2017).
Poka Yoke	The main issue with an automobile production process was a
	destroyed plastic part capable of connecting to a vehicle's sun
	visor (Zvidzayi, 2020).
Jidoka	Ohno 1988, jidoka means "automation of quality control with
	a human touch," since this allows processes to be stopped in the

	incident of an anomaly, ensuring that no defective parts proceed to the next stage.
Heijunka	Heijunka is a adjusted production is required to keep the system stable and to keep inventory to a minimum (Elbadawi, 2018).
Hoshin Kanri	Throughout the Toyota organisation, there is a lack of understanding of the beneficial Hoshin Kanri process (Soliman, 2020).
Andon	Andon system to control cross LED lights on the production floor (Hirvonen, 2018).
Value Stream Mapping (VSM)	Value stream mapping can help with both product or market delivery flows (Shou et al., 2017).
Total Productive Maintenance (TPM)	Total Productive Maintenance ensures fewer failures, stops, and defects while lowering costs and engaging employees from the C-suite on down (Agustiady and Cudney, 2018).
Standardlized Work	Standardized performance is the main tool for establishing the best methods and sequence data for procedures as well as for each operator by reducing waste (Mor et al., 2019).
Six Big Losses	The performance rate TPM and OEE are commonly used to eliminate the Six Big Losses to determine the level of effectiveness of a machine with the availability of parameters (Dana Karningsih and Ko-Pembimbing Nani Kurniati, 1415).
Overall Equipment Effectiveness (OEE)	OEE means "a measure of production operations performance and productivity expressed as a percentage," and it "demonstrates the amount to which a manufacturing process" (Paul et al., 2020).
One -Piece Flows	Begin One Piece Flow by Kiichiro Toyoda 1934 that he used this method at a foundry and engine production with the concept of "confirming one, after the other" to save time and eliminate errors discovered mid-batch before they impacted the entire order.

Takt Time	Takt time is if you receive a new product order every two days,
	your team must complete a product in two days or less (Luca et
	al., 2021).
Total Quality	It is difficult to quantify TQM components such as top
Management (TQM)	management commitment and involvement in TQM (Aoun et
	al., 2018).
Gemba	Gemba Practices use the method of continuous improvement in
	all aspects, so that all workers, depending on the job position,
	participate in the process of improvement, and at all levels of
	administration, from top management to the cleaning agent in
	it (Al-rusheidi and Supian, 2021).
Key Performance	(KPI) enable HEP initiatives in generating long-needed data to
Indicator (KPI)	inform production quality, develop strong standards of conduct,
ST.	and ensure quality outcomes for students (Setijono and
R.M.	Dahlgaard, 2007).
Cellular Manufacturing	Greene and Sadowski (1984) define cellular manufacturing as
the second	a physical grouping of machines, or cells, each dedicated to the
AINO	production of a product family.
Continous Flow	Waiting time, transportation, inventory, and unnecessary
**	movement of people or machines are all reduced in a smooth
UNIVERSIT production cycle within the manufacturing process (Wiles and	
	Watts, 2012).
Single-minute Exchange	It is was first used in Japan in 1950 at Mazda, Hiroshima, an
of Die (SMED)	800-ton press where direct and indirect activities were
	separated.
Plan Do Check Act	According to Wani et al. (2019) the PDCA cycle give support
(PDCA)	in carrying out improvement in a systematic way.
SMART Goals	SMART goals allow companies to ensure that their goals and
	production targets are clearly defined and well-supported for
	production purposes (Lawlor, 2012).
Continous Improvement	According to Hasan et al. (2022) RMG manufacturers in
	general place a high value on producing high-quality goods.

#### 2.4 Bottleneck

A bottleneck is defined as any step along the production line where the number of tasks to be completed exceeds the maximum workload capacity. This issue frequently causes subsequent steps in the workflow to be delayed. Bottlenecks can be caused by an entire stage of work, a lack of employees, a lack of resources, or even computer problems. In a logistics system, a bottleneck (or constraint) is the resource that takes the longest to operate. A bottleneck in hiking, for example, is the slowest member of a hiking group. The speed of the entire group can be determined by that member. The same should be true for manufacturing processes. If one component of a supply chain is unnecessarily slow, the overall speed and efficiency of the manufacturing process suffer (Chen and Mandelbaum, 1991).

Based on specific research, a new concept of bottlenecks in the production system is developed and analyze. For example, a machine is defined as the bottleneck if the sensitivity of the system's performance measure to the machine's production capacity in isolation is the greatest. While this concept is appealing from a machine perspective, it has a flaw in that the sensitivities included cannot be estimated online or effectively determined disconnected. As a result of this issue, by investigating the links between the processing blockage and starvation of each machine, the bottleneck device in a sequential production process can be identified. This leads to a straightforward principle for locating bottlenecks. The fundamentals does not require the estimation of production rate sensitivities or the production rate itself. It appears that online measurements do not provide the probabilities of production blockages and starvation. Moreover, an analytical estimate may be used for bottleneck identification under certain conditions (Koh et al., 2020).

According to Siregar (2019) the adding of machines, equipment, or employees, the increase in quality of work methods, and the addition of overtime are all common methods

for dealing with bottleneck work stations in the manufacturing industry. However, these methods require a major investment and a longer time, which is not always possible.

As a result, an issue strategy is required, which includes optimising the factory's resources and helping to control the factory's constraints. The company produces instant noodles and has six work stations: sieving, mixing, dough forming, cooking, packaging, and packing. It is clear from observations that not all production flows are well-defined. Due to capacity differences between two work stations, one of the issues was the availability of bottlenecks on the production line, especially at the sieving and mixing work stations. Because of the capacity difference, the centrifuging work station has a higher production capacity than the mixing work station (Bastos et al., 2018).



Figure 2.4 Identifying Bottlenecks (Bastos et al., 2018)

## 2.4.1 Explanation of Identifying Bottlenecks

Process	Explanation
Identify	To improve production line efficiency, locating bottlenecks is critical.
	The machine or process with the longest queue is usually a
	bottleneck.
Consequences	Production bottlenecks can lead to production halts, supply overstock,
	employee dissatisfaction, and customer loss. Overloading a machine
	can damage or wear it out, resulting in extended downtime.
Manage	Provide a constant buffer stock upstream of the bottleneck, reduce
	setup and changeover time, and train more operators for the
	bottlenecked machines. A bottlenecked machine can also be made
S.	more efficient by scheduling production.
Prevent Future	Cross-trained employees will be more adaptable in the production
Bottlenecks	line, reducing future downtime. Retaining high-performing
Fer	employees reduces the risk of bottlenecks due to inefficient use of
×.	assigned machinery.
2.4.2 Example to	اونيوم سيتي تيڪنيڪا ملسيا م

Table 2.3 Explanation of Identifying Bottlenecks

## nle to conduct Bottleneck 2.4.2 Example to conduct Bottleneck

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According to Moran et al. (2017) the Process Bottleneck tool should be used when test data for a process does not perform as expected or when a process is unable to increase production. It can also be used when customer satisfaction surveys show a decrease in satisfaction or when employee complain about process-related issues increase. The following example demonstrates how to conduct a bottleneck.
Step	Description
Create a Process flow	Make the assumption a clinic process with five steps
	listed below when flow charted:
	1. Check-in client
	2. Pre-screening
	3. Determination of Eligibility
	4. Provided service Payment and exit are the final
	steps in the process.
Create a wide range of information	In this example, the time taken for each process step
by calculating average time for	is depicted in the figure below.
each process step.	25
ALAYSIA	20
Str. Mar	15
No.	10
۳	
Es,	
S AAINO	Step 1 Step 2 Step 3 Step 4 Step 5
shi li la	Figure 2.5 Example of the graft Time Taken
Set a target value for each step in the	A limitation period of 15 minutes has been set in this
process. To determine which	example. Exceeding this limit slows customer
process steps are experiencing	payments and exits from the system, as well as
bottlenecks, make a comparison this	preventing some patients from being seen at the end
target value to the current estimated	of the health centre day. All of the other steps are
duration for each process. As long as	working as they should.
the process steps are finished on	
schedule, no further action is	
required.	
Determine the effect, if any, of the	Following an examination of this clinic process, it was
bottleneck step on the process steps	discovered that a bottleneck in services provided (Step
preceding and following it, as well	4) When waiting time is required after determining
as its overall effect.	eligibility, some patients may not be seen on their
	appointment day.

Table 2.4	Example	conduct	Bottlenecks
-----------	---------	---------	-------------

Give a quantitative description of	"Waiting period has increased by 25% in last quarter,				
the bottleneck.	giving rise in 15% fewer clients seen per day," for				
	example. This system was built to handle 9 clients per				
	day during the 8 hours that they are open. Each client				
	should be able to finish the system in 54 minutes or				
	less (dividing 480 minutes per day by 9 clients to be				
	seen).				
Determine the cause of the	Create a Cause and Effect Diagram				
bottleneck and the actual cause that					
needs to be addressed.					
Simulation	The Arena simulation is being used in the simulation				
	process.				

## 2.5 Industry 4.0

The transformation of organisations to digital forms is referred to as Industry 4.0. It completely changes the way a company operates. All organisational functions undergo a sea change, from manufacturing to all other activities that occur within and outside of the industry (Sanghavi et al., 2019). There is academic debate over whether such organisational implementation can be referred to as Industry 4.0 (Alcácer et al., 2021). The concept was developed first in Germany and then spread to other countries. The main focus of Industry 4.0 is the development of cyber-physical systems (CPS), which are based on the incorporation of large amounts of diverse data and information.

### 2.6 Concept of Line Balancing

Recently (Chahala and Narwal, 2017) gave a comprehensive review of the definition of line balancing. Line Balancing is equalizing the workload among all the operation in a cell or value stream to eliminate bottlenecks and excess capacity. According to Hasan et al. (2022), the design of an assembly line balancing system for a production line not only included reduce the number of workstations but also need to consider on how to balance the workload among operators which assist the industry to manufacture the right amount of products to reach customer demand.

The information required for built-in line balancing included precedence network of time, tasks times, cycle time and a number of the workstation. The immediate precedence connection between the tasks of assembling a product is indicated by precedence network diagram. Meanwhile, the task time is the time needed for accomplishing of each task which either in deterministic or probabilistic. In the other hand, the cycle time is the maximum time allowed in each workstation. (Chahala and Narwal, 2017)

## 2.7 Simulation

Simulation techniques first appeared in the late 1950s and have since grown to become a valuable decision-making tool for a variety of institutions. Banks (1998) defines simulation as "the imitation of the operation of a real-world process or system over time." To improve and design processes, simulation can evaluate several alternatives, or so-called simulation situations, under a variety of conditions.

### 2.7.1 ARENA Simulation

According to Ito et al. (2020) the sector simulation model **is** employed within the manufacturing line of Uninterrupted Power Supply (UPS). This has wiped out some UPS manufacturing industries. The first goals of this model are to scale backflow time, improve design layout, and aim to maximize production rate. The merchandise output and average wait time are two of the foremost important performance measures for illustrating the system's performance. The simulation model was created using process-oriented simulation software and therefore the best Arena Input Analyzer for data analysis using standard stochastic distributions. This work is additionally statistically analyzed the data using the Microsoft Excel software package. To balance the UPS production flow line, where output may be a problem compared to input thanks to improper layout design and irregular load distribution to workers.

### 2.8 Benefits of Bottleneck and Simulation

There have been many changes over time in LM's approach to business improvement (along with a set of LM tools). Using this approach, you can make sure that your business is more focused on meeting the needs of your customers and less on creating unnecessary waste. There are numerous benefits to lean manufacturing and service industries equally. It all depends on where you start and what you put into it. However, with the right level of commitment and planning, you will see some of the benefits of lean production in a relatively short time. (Fang et al., 2020).



Figure 2.6 Benefits of Lean and Simulation (Fang et al., 2020)

#### • Improved Customer Service

According to Kim et al. (2003) to provide excellent customer service, the company must first understand its customers' needs, experiences, and pain points. For these, it must ensure that multiple channels for customers to provide feedback are available, while also delivering exactly what the customer wants, when they want it.

### • Improved Productivity

The study's tyre manufacturing company needs to reduce non-value-added activities, bottlenecks, processing time, and simulation (Krishnan et al., 2018).

### • Improved Quality

Defect and rework reductions when quality issues arise, problem-solving techniques are employed to determine the root cause of the issue. Following that, error proofing is implemented to strengthen the process and prevent frequency (Bongers and Torres, 2021).

## Reduced Waste

Before implementing robots into the real system, reduce waste by trying to minimise robot path, avoiding robot collision, shortening setup time, and minimising possible unexpected errors (Supsomboon and Varodhomwathana, 2017).

## 2.9 Application of Bottleneck and Simulation

The LM waste tools and simulation ideas have been extensively studied for their ability to increase productivity, quality, and other aspects of the manufacturing process. According to the case study, the performance of the process had improved LM waste tools and simulations in industry are explained in this part by the authors. Many researchers have

focused on problem-solving methods that have been found to be very effective across a wide range of industries.

Krishnan et al. (2018) noted the simulation determined bottleneck analysis, throughput, and makespan. The results matched the Pareto analysis, and improvements were offered. Fabric Calendering was identified as the bottleneck procedure. Using a four-roll calendering machine instead of the current three-roll calendering equipment will significantly increase production. Using a four-roll calendering device eliminated the need for a second pass, reducing calendering time. Automation of transport networks between operations can also boost productivity. It saves time and increases production.

According to Velumani and Tang (2017) suggest handle a moderately difficult batch processing with simulation of product and process variables. A thorough DES model is constructed to analyse serial re-entrant line production throughput with batch production and product/process variability. Process and production characteristics including bottlenecks, utilisation, and process time are compared to the priority on due date. To ensure that all machines run on time, the simulation logic checks the batch allocation for tardiness. The developing simulation outputs help discover production bottlenecks and priority with routing logics. The analytical results are in strong accord with floor observation, providing a good understanding of machine and buffer operations. the predicted reductions in bottleneck, tardiness, and production efficiency.

As a result, Subramaniyan et al. (2018) suggested an alternative to discrete event simulation-based modelling in bottleneck analysis, which is based on active period theory. The proposed algorithm can be automated to make real-time decisions. Engineers with practical experience in the production system can then analyse the diagnostic information and formulate appropriate bottleneck management solutions. Then, investigate connections between free and bottleneck workloads. Workload Control order release and drum buffer rope performance implications have been examined individually but not directly compared. In a job shop and a general flow shop with varied degrees of bottleneck severity, the performance of drum-buffer-rope and Workload Control release Workload Control release strategies for bottlenecks and non-bottlenecks are offered. If the bottleneck severity is mild, Workload Control release methods outperform drumbuffer-rope. Drum-bufferrope outperforms Workload Control and its bottleneck-oriented release methods if a strong bottleneck exists. Workload Control's unique load balancing capability helps it stand out in balanced shops (Thürer et al., 2017).

Lou et al. (2020) proposed that recent disruptions in the supply network caused by suppliers should put a greater emphasis on identifying bottleneck suppliers, i.e. those whose failure will result in significant losses for the whole supply chain. For supply network risk management, locating the bottleneck provider is critical. A MALNS-based approach is being considered for this purpose. In the suggested method, instead of using metrics to estimate the importance of a provider to supply network performance, MALNS is used to identify bottleneck suppliers.

After that, the lateness bottleneck is the constraint of just-in-time management and order delivery. Due to the dynamic nature of the manufacturing system, the bottleneck regularly shifts and affects production run stability. Predicting the bottleneck allows operators to plan ahead for a balanced line. For shifting bottleneck prediction, a unique Parallel gated recurrent units (PGRUs) network with main and auxiliary inputs is created (Fang et al., 2020).

Identifying system bottlenecks helps prioritise maintenance and improvement actions. Statistical methods are widely used to detect bottlenecks in machine data. These statistical approaches work best when the machine data distribution, correlations, and stationarity are known beforehand. Compiling statistical descriptors necessitate. If the machine data does not match these assumptions, the results may be disconnected from the actual production system dynamics. The result of carefully selecting ML techniques. It begins by generating a time series of the chosen bottleneck detection metric and then clustering the time series using a dynamic time-wrapping measure and a complete-linkage agglomerative hierarchical \sclustering technique (Subramaniyan et al., 2020).

According to Singroha and Malik (2020) used a bottleneck to identify the most productive workstations in a gear manufacturing line. Six workstations make up a multiproduct, multi-stage gear production line. The principle of queuing was applied in this investigation to determine how well each workstation performed. Using this queuing model, every station on the gear assembly line may increase its efficiency and performance. Improved workstation efficiency and performance contribute to increased productivity for the firm. Satnamia Gear Industries limited in Panipat performs this work. Drilling and slotting are bottleneck procedures, according to research. The setup time for keyway slotting is found to be more time-consuming. This study is highly beneficial to the firm since it provides the organisation's management with all the information they need to plan their future output more effectively.

A case study of a Saudi Arabian firm is used as an example of how to measure manufacturing plant performance and total productivity. Baseline productivity and the manufacturing plant performance index are used to measure productivity. Data from several manufacturing departments are gathered to conduct a thorough case study investigation. The manufacturing industry increased its performance in each manufacturing area by adopting the lean method. The overall manufacturing plant performance index to productivity. Resource utilisation, personnel

and materials flow, manufacturing bottlenecks, and rejection percentages are the subject of this case study (Ur Rehman et al., 2020).

Lean manufacturing is a new trend in Indian industry. Many small and medium-sized businesses in the country aspire to enhance customer happiness, cost, quality, process speed, and capital investment. Study of a food processing sector in south India, with emphasis on production and packaging procedures. SIPOC, VSM, ANOVA, and 5S methodologies were used to help identify and alleviate bottlenecks in these processes. Based on the study's findings, lean and six sigma initiatives were suggested to improve overall equipment efficiency, productivity, and eliminate production variations (Nandakumar et al., 2020).

A study compared two older researchers. Table below summarises study articles and case studies on the method and characterized by old researchers in manufacturing industry.



No	Author & Year	Method
1	(Krishnan et al., 2018)	The simulation determined bottleneck analysis and
		bottleneck present in the plant as calendaring process.
2	(Velumani and Tang,	The developing simulation outputs help discover
	2017)	production bottlenecks and priority with routing
		logics.
3	(Subramaniyan et al.,	An alternative to discrete event simulation-based
	2018)	modelling in bottleneck analysis and formulation of
		relevant bottleneck management solutions
4	(Thürer et al., 2017)	The performance of drum-buffer-rope and Workload
		Control release Workload Control release strategies
	MALAYS/4	for bottlenecks and non-bottlenecks
5	(Lou et al., 2020)	Identification of bottleneck supplier is significantly
		important for supply network risk management
6	(Fang et al., 2020)	The bottleneck regularly shifts and affects production
		run stability. Predicting the bottleneck allows
	ainn -	operators to plan ahead for a balanced line.
7	(Subramaniyan et al.,	Identifying system bottlenecks helps prioritise
	2020)	maintenance and improvement actions.
8	(Singroha and Malik,	Used bottleneck to identifying the most productive
	2020)	workstations in a gear manufacturing line
9	(Ur Rehman et al., 2020)	Resource utilisation, personnel and materials flow,
		manufacturing bottlenecks, and rejection percentages
		are the subject of this case study.
10	(Nandakumar et al., 2020)	5S methodologies were used to help identify and
		alleviate bottlenecks in these processes.

Table 2.5 The method used from old research

### 2.10 Summary

This review of the literature provides a summary of lean manufacturing systems. This fundamental concept provides a wealth of information on lean waste tools and techniques. This is to increase manufacturing process productivity while improving process outcomes by identifying and reducing loss rates. Furthermore, organizations frequently have had success by implementing this method into their system in order to increase productivity and produce the highest business. Many companies have successfully implemented this strategy on their systems in order to increase productivity and profits. This study's objective is to address problems, reduce waste and inefficiency, and improve conditions in order to better retain customers. Finally, this study proposed a method for conducting a bottleneck and simulation in order to improve productivity in LM. The details of the time study will be presented in the following chapter.

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#### **CHAPTER 3**

#### METHODOLOGY

#### 3.1 Introduction

Here, the methodology was described as a road map to ensure that each step of the research process is on course and leads to the desired result. Research methodology should be described following a theoretical analysis of the working method. Methodology flowcharts will be explained as a guide for conducting the study from start to finish and will be used as an example. Also, this chapter is mostly about how lean tools and techniques will be used to make sure the study is successful.

### 3.2 Planning Study

This section explains the study's methodology in detail. As a result, a flowchart is created to make the overall process more understandable. This research will take place for two semesters. Semester 1, also known as FYP 1, includes determining the title, literature review, problem statement, objective, and methodology. The identification of a potential company, data collection, analysis, problem solving, discussion, conclusion, and recommendation are included in FYP 2. Semester 2 is the deadline for completing this study's final report, including the work done in FYP 1 and FYP 2. Figure 3.1 is a flowchart of the overall planning process that was used to do the bottleneck, simulation, and productivity improvement studies.

## 3.2.1 Overall Planning Flowchart



Figure 3.1 Overall Planning Flowchart

#### 3.3 Research Phases

According to Figure 3.2, the researcher classified the scientific analysis into three important phases specific to the research objectives. These phases were focused on the research objectives mentioned in Chapter 1. The first phase (Phase 1), obtaining research data, is a literature review attempting to evaluate current LM decision-making. Following that, the limitations of LM implementation in the era of Industry 4.0 were identified and analysed. The research phase included the development of research as well as the justification of the LM concept, such as principles, philosophy, and tools. Following that, framework design for bottleneck and simulation is used to solve the study. In phase 2, semistructured interviews are used to assess the applicability of the bottleneck and Arena simulation frameworks on decision makers in case study organizations. Finally, in phase 3, following conduct, a decision was made to improve productivity in the production line based on output. The research used the techniques described below to examine the concepts of the study's impact,

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Figure 3.2 Research Phases

## 3.4 Research Methodology

The bottleneck and simulation will be used to carry out this project. Research shows that bottlenecks are one of the most commonly used lean manufacturing tools for improving productivity in a production line. As a result, the best approach to investigating ways to improve manufacturing performance is through simulation. This data will be created for the model and simulation verification and validation. Validated simulation model results can be used with lean tools to improve the future. Figure 3.2 shows the processes of step application, bottleneck, and simulation.





## **3.3.1** Defining the problem

The problem statement provides the necessary information and is understandable. The first steps in problem formulation are for company executives and project team members to talk about and agree on what the problem is.

### 3.3.2 Identifying project goals & developing a strategy

A problem statement serves as the basis for defining the simulation model's objectives. For the overall project plan, there is a description of the system to be evaluated, along with an explanation of how various alternatives will be evaluated. A Gantt Chart will be created for each step of the project's progress and its anticipated outcome. This chart will display the tasks that have been created throughout the project.

### 3.3.3 Model Building

When a model's complexity begins to rise, the information that's required can change. There must be an early start to the data collection process because it accounts for the majority of the time required to run a simulation. This frequently occurs during model creation.

#### 3.3.4 Data Collection

When creating a model, data storage and computation are required, so the model must be stored in a computer-readable format. Using the Arena Simulation, it will be able to create a simulation of the building.

#### 3.3.5 Verified

Verification is performed on the simulation model's computer software. To make sure that the modelling of products, materials, and process steps is correct, the data input must match the right process.

#### 3.3.6 Pilot Runs

To test the viability of a project idea, pilot projects are small-scale implementations. Before deploying the full application, an organisation can test its strategy with a pilot implementation. Using a pilot application that mimics production conditions can help prevent problems with the full application rollout.

#### 3.3.7 Validated

Model calibration is the process of figuring out if the accuracy of the model is good enough for the end users. The process of verifying that a model accurately 90% and above will be acceptable in a system is validated.

### 3.3.8 Simulation Investigation

The model uses simulations to predict how input variables in a given range will affect the outcome of a decision. Simulation analysis ensures a product meets operational requirements. It can also reveal needed changes and ensure proper real-world testing.

## **3.3.9** Modify the simulation configuration

Find the configurations that have been given for each baseline or alternative model of a different design.

### 3.3.10 Model Runs

The analyst can decide if new experiments need to be done and what design those new experiments should follow by looking at the results of runs that have already been done.

## 3.3.11 Select the scenario

A concise and easy-to-understand report may be required if the programme is to be reused by the same or different analysts or to suggest the best selected scenario.

## 3.3.12 Suggest improvement output based on simulation

Choose the best simulation for each station in order to increase production line productivity.



## 3.5 Gantt Chart

No	Teelr	Plan/	Week													
INO	1 ask	Actual	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		Plan														
1.	The Approval	Actual														
2	EVD 1 heisfing	Plan	6													
2.	F T P 1 briefing	Actual	5								-					
2	De ressauch ab aut Title	Plan	X								Μ					
3.	Do research about 11tie	Actual	Z								Ι					
4	Duofting Literature Device	Plan							0		D	1				
4.	Draiting Literature Review	Actual									Т					
5		Plan				1					Ε					
э.	Do correction Literature Review	Actual			~	1					R					
6	Identify Commons	Plan									Μ					
0.	Identify Company	Actual														
-	Identify the problem statement and	Plan		1		1					B					
/.	objective.	Actual			ž			3	2	وللمعا	R	20				
0	De correction of Chanton 1	Plan	0		- 10				5.	6	E	a. I				
0.	Do correction of Chapter 1	Actual							**		Α					
0	Mathadalaan IINIVEBS	Plan	EV	NIL	CA1	3.5	A.L	AV	CI A	D.U.	K	N IZ	Λ.			
9.	Methodology UNIVERS	Actual	Ľ	MIR	A.		X	AL	DIA	N		AN	ŕ			
10	De connection of Chanton 3	Plan														
10.	be correction of Chapter 5	Actual														
11	Submit full report FVD 1	Plan														
11.	Submit full report F Y F 1	Actual														
10	Presentation of EVD 1	Plan														
12.	<b>12.</b> Presentation of FYP 1															

## Table 3.1 Gantt Chart FYP 1

## **3.6 Gantt Chart**

No	Task Plan/				Week											
INO		Actual	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		Plan														
1.	visit Company	Actual														
2	The data collection	Plan	0													
4.	The data collection	Actual	5				-									
2	Conduct Dottlongely	Plan	X					_								
э.	Conduct Bottleneck	Actual	A							Μ						
4	Model building using ADENA	Plan								Ι		1				
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5	Submit the negate	Plan								Т						
5.	Sublint the results	Actual				/				Ε						
6	De discussion	Plan								R						
0.	Do discussion	Actual								Μ						
7	Do conclusion and recommendation	Plan		1		./		- 4.4								
/.	Do conclusion and recommendation	Actual			2	-	_	w	n	B	A	and.	9			
8	Submit discussion, conclusion and	Plan	0					- 10	5.	R	1	1	1			
0.	recommendation	Actual							1.4	E						
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9.	chapter 5	Actual	En		M	_ IV	IAL	AI	OIP	K		An	~			
10	10. Submit Full report of FYP 2	Plan														
10.		Actual														
11	Propaga for presentation of FVD ?	Plan														
11,	repare for presentation of FTT 2	Actual														
12	Prosontation for EVD ?	Plan														
14.	12. Presentation for FYP 2															

## Table 3.2 Gantt Chart FYP 2

### 3.7 Summary

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This chapter has been explained the whole method and process that has been proposed in conducting the study. The clear description about the project background and the scope will lead to produce a great solution towards the problem that has been state. By focusing in achieving the objectives, the data has been gathered and the flow of the process solution has been developed. All this part is to recognize at which process of workflow faced the problem. Final study will be end up by writing complete project report. The purpose of report writing is to convey the result and progress of the study to the others. It also acts as a prove that the study has been done. Thus, by preparing the systematic report will be a better way to track a study progress. The objectives will be review in the conclusion to determine the percentage of effectiveness regarding the research.

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#### **CHAPTER 4**

#### **RESULTS AND DISCUSSION**

#### 4.1 Introduction

This chapter discusses the data collection and processing time required for bottleneck process analysis and Arena simulation to improve production line productivity. To conduct a time study, all data from PEPS-JV Sdn Bhd has been gathered here, including product details, production process flow, downtime observation, overall workload calculation, and the ideal processing time for each workstation. After analysing the collected data, arena simulation software will be used to conduct an improvement solution. This section also includes information on employee happiness, productivity, and commitment.

## 4.2 Company Background

This study was carried out at PEPS-JV (M) Sdn Bhd, a subsidiary of EP Manufacturing Bhd located in Melaka (Pegoh Plant). The company primarily focuses on the automotive industry, where it supplies body components for Honda products. The company must be universally aggressive, personal, and forthright to survive. As a result, they have developed a workable governance framework that has made significant progress in ensuring that EPMB not only stays but also succeeds beyond the expectations of its founding members. Spot welding robots were used to assemble the company's product. Figure 4.1 depicts a spot welding machine (Robot). This study only looks at the assembly of the Honda CR-V, which will hit the market in 2023.



Figure 3.4 Spot Welding Robot

## 4.2.1 Product Description

This company's total number of production lines is 5, and this research focuses on production line 4 for model 3M0, 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 CR-V that will be released on the market in 2023. Figures 4.2 show frame comp rear RH (right side) and Figure 4.3 show frame comp rear LH (left side)



Figure 3.5 Frame Comp Rear RH (Right Side)



Figure 3.6 Frame Comp Rear LH (Left Side)

#### 4.2.2 Overall Process Description

Production line 4 has two operating lines running simultaneously to assemble Frame Comp Rear RH and Frame Comp Rear LH. Each operating line consists of four operators and one operator to build and inspect tasks at the inspection station. Instead, five spot welding robots run simultaneously for both sides.

Operators 1, 2, 3, 4, 5 and 6 will load and unload the child parts from the jig after the spot welding process by the robot. Operators 1 and 2 operate workstations one and two, while Operators 3 and 4 operate workstations 3. Operators 5 and 6 use workstation 4. When the children's section is unloaded from workstation station 5, operators 7 and 8 perform a manual inspection at each control inspection gate quality

Spot welding robots are programmed to operate on a first-come, first-served system. The first station that has finished loading the child parts into the jig station will undergo the welding procedure. The operator will press the green button to assign the next task to the robot. Robot 1 will install child parts S01, S02, S03 and S04 at workstation one, while Robot 2 will weld child parts S05 and S06 at workstation 2. Alternatively, Robot 3 handles child parts A10 and A20 at workstation 3. Then Robot 4 installs child parts position A30 at workstation four while robot 5 runs child parts A40 and A50 at workstation five without

manpower. Figure 4.4 shown the layout of the existing production line model 3M0 in production 4. The Frame Comp Rear RH is comprised of 27 child parts. The child part came from 5 workstations, including W1, W2, W3, W4, W5, and the QC Inspection station. The child parts will be assembled using a spot-welding robot. APPENDIX D shown the child parts of each workstation for the Frame Comp Rear RH. The Frame Comp Rear LH is comprised of 27 child parts. The child part came from 8 workstations including W1, W2, W3, W4, W5, W6, W7, W8 and QC Inspection station. The child parts of each workstation for the Frame Comp Rear ILH is comprised of 27 child parts. APPENDIX E shown the child parts of each workstation for the Frame Comp Rear ILH.





Figure 3.7 Layout of Existing Production Line Model 3M0

## 4.3 Data Collection

The time study is conducted at PEPS-JEV (M) Sdn. Bhd. After learning the workflow of Production Line 4 (Model 3MO), real-time data were collected show at APPENDIX F during a site visit to analyse potential sources of waste. All cycle times for all five stations, including the QC inspection station, were recorded. All of this information will aid in determining the demand for each activity at each workstation. All the collected data aims to improve the productivity of this production line.

#### 4.3.1 Target and Working Hour

Target of the company for production line 4 (Model 3MO) in 12 hours is 120 units of product. Production line 4 only has a single shift every day. Working shift from 8 a.m. until 8 p.m. All operators will have two fifteen-minute breaks during the twelve-hour shift and one forty-five-minute lunch break. Thus, the working hours are between ten hours and forty-five minutes every shift. Table 4.1 is shown the working hour for production line 4 (Model 3MO).

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Table 3.3 Working Hours Production Line 4

Product Demand = 120 units per day

Production time = 1 shift x 12 hours per day

Lunch Break per day = 45 minutes

Short Break per day = 2 x 15 minutes

### 4.3.2 Process Standard Time

After the cycle time is collected then the average time and range can be obtain. The performance rating will be given based on the observation of operator performance. The observer will rate 90% for the worker who work slower than normal, 100% for normal speed and 110% for the worker faster than normal. Next, the normal time and standard time for the workstation were calculated. In this case study, the fatigue allowance is 10% and personal allowance is 5% in the ten hours and thirty minutes working time per shift. The predetermined total assembly time for each products were determined. The formula of calculate the normal time (NT) and standard time (ST) as following:

Normal time (NT) = Average Time \* Rating Factor Standard Time (ST) = Normal Time \* (1+ Allowance Factor) = Normal Time \* 1.15

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Process :	Product : Frame Comp Rear RH and Frame Comp Rear LHObserver:Date :									
Spot Welding	Model : 3M0				Levynia Henry	27 September 2022				
Station	Average Time (s)	Range	Performance Rating	Rating Factor	Normal Time (s)	Standard Time (s)				
		MA	(%)							
S01, S02, S03, S04 RH	193	40	90	0.9	174	200				
S01, S02, S03, S04 LH	<b>1</b> 80	24	> 90	0.9	162	186				
S05, S06 RH	37	7	100	1.0	37	43				
S05, S06 LH	35	12	100	1.0	35	40				
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	UN 91 ERG	7	ERM100AL N	1.0	MEL91	105				
QC Checked	99	16	100	1.0	99	114				

## 4.3.3 Available Time

Information	Calculation
Product Demand = 120 units per day	Available Time = 12 hours*60 minutes * 60 seconds
Production time = 1 shift x 12 hours per day	= 43200 seconds
Lunch Break per day = $45 \text{ minutes } * 60$	Total Available Time = 43200 seconds - 2700 seconds - 1800seconds
seconds MALAYSIA	= 38700 seconds
= 2700 seconds Short Break per day = 2 x 15 minutes = 30 minutes * 60 seconds = 1800 seconds	TeM

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Takt time is the rate where production process require to be accomplish in order to

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achieve target. The total time available and the amount of customer demand is required to calculate cycle time.

	•	

Table 3.5 Calculation Cycle Time

Formula	Calculation
Cycle Time,C =	Cuele Time C - 38700 seconds
Production Time per day Required unit of production	Cycle Time, $C = \frac{1}{120 \text{ units per a day}}$
	= 322.5 @ 323 units/sec

<sup>4.3.4</sup> Process Cycle Time

### 4.3.5 Minimum Workstation

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

Formula	Calculation
Takt Time = Total task, 1204 sec Takt Time	$N_i = \frac{1204 \ sec}{323 \ sec}$
Cycle Time,C	= 3.72 = 4 Workstations

Table 3.6 Calculation Minimum Workstation

## 4.3.6 Existing Production Line

A graph is develop from the calculated standard time and takt time to manifest the in existing production line. Based on the graph, all the workstations is below the takt time. This indicate that all the workstations able to accomplish the task within specific time to achieve target.

However, this production line has a situation where unequal workload among operators happened at the inspection station. The standard time of workstation 2 that is S05, S06 RH LH are lower than other workstations. Figure 4.5 showed the existing of production line in Model 3M0.



Figure 3.8 Existing of Production Line

### 4.4 Model Simulation for Existing Production Line

The manufacturing system is modelled using model translation. As the simulation model's input data, the cycle time calculations for each product are necessary. To estimate how long it takes for a batch of components to arrive at the inspection station, we can use the same cycle time to produce a single unit of the final product. Model simulation shows the concept of the particular simulation model. The construction of a simulation model relies upon the system's complexity and accessible information. There will be two simulation models to be carried out in this study: a model for the existing inspection station and a model for the new layout design. This model will construct according to the existing production layout in production line Model 3MO.

### 4.4.1 Create Module

The Create Module will be first select for establish the simulation model. The Create Module can select from the Basic Process under Project Bar to allow the entities enter the model and begin the process flow. In this simulation, the Create Module are relies upon cycle time of each products. Figure 4.6 and Figure 4.7 shows the detail set in Create Module.



Figure 3.9 Module Create



## 4.4.2 Assign Module

The Assign Module will place after Create Module to add new value for the Entity Type, Entity Picture, Attributes and other variables. The Assign Module also can be select from the Basic Process under Project Bar. Figure 4.8 and Figure 4.9 shows the detail set in Assign Module.



Figure 3.11 Module Assign

Assign	?	×
Name: Assign RH ~ Assignments:		
Attribute, A part Type, 1 Entity Picture, RH <end list="" of=""></end>	Add Edit Delete	
Comment: OK Cance	I Hel	p

Figure 3.12 Module Assign Setting

### 4.4.3 Process Module

Every process has three modules which is seize, delay and release. Seize is the entity waits until a resources or server available. Delay is the amount of time an entity is held for processing at a resources or server. When a resources is on hold, it will not be available until it is released. The entity that has completed processing and is ready to proceed to the next station is known as a release. Figure 4.10 Figure 4.11 shows the detail set in Assign Module.

Seize /orkstation 1

Figure 3.13 Module Seize

Seize			?	×
Name: Seize Workstation 1 ~	Allocation: Other	Priority:		~
Resources: Resource, Operator 1, 1, <end list="" of=""></end>		Add Edit	d t ete	
Queue Type: Queue	Queue Name:	1.Queu 🗸		
Comment:				
	ОК	Cancel	He	elp

Figure 3.14 Module Seize Setting 55


# Figure 3.15 Module Delay

Delay				?	$\times$
Name:			Allocation:		
Delay Workstation 1		~	Value Added		$\sim$
Delay Time:			Units:		
NORM(373, 12.5)		~	Seconds		$\sim$
Comment:					
	ОК		Cancel	Help	



MALAYSIA	Figure	3.16 Mo	dule Delay	Setting	
ST	1101				
LEWIN	MKA	- Work	lease tstation ⊢ 1		
a/Nn	Fig	gure 3.17	Module R	lelease	
يسبيا ملاك	Refease	کنید	چې نيچ		اونيق
	Name:			**	
UNIVERSITI	Release Wor	kstation 1	/ALAYS	SIA M⊋I	
	Resources:				
	Resource, O	perator 1, 1		Add	
				Edit	
				Delete	
	Comment:				
		ОК	Cancel	Help	

Figure 3.18 Module Release Setting

## 4.4.4 Process Inspection

To identify errors early in production, which saves time and resources in the long run. They identify problems as they occur, then take corrective action, trace, and update the inspection process and ensure its accuracy.



Figure 3.19 Module Inspection



Figure 3.20 Module Inspection Setting

## 4.4.5 Decide

This module provides the system with the ability to make decisions. It enables decision-making on the basis of one or more conditions or probabilities. By this module the system decide 90% of precent of true.



Figure 3.21 Module Decide 57

Decide			?	×
Name:		Туре:		
Decide RH LH		✓ 2-way	by Chanc	ж ~
Percent True (0-100):				
90 ~ %				
Comment:				
	ОК	Cancel	Hel	p

Figure 3.22 Module Decide Setting

## 4.4.6 Dispose

In the new simulation model, two Dispose Model are utilize for collect the entities flow from 'True' and 'False' at the end of the production line.



UNIVERSI Figure 3.23 Module Dispose True and False

Dispose	?	×	Dispose	?	×
Name: Dispose Acceptable		~	Name: Dispose Failed		~
Record Entity Statistics Comment:			Record Entity Statistics Comment:		
OK Cancel	Help		OK Cancel	Help	

Figure 3.24 Module Dispose True and False Setting

# 4.4.7 Run Module

Before running the simulation model, need to fill up the replication parameter information at runsetup setting.

Run Setup				×
Run Speed Run Control Reports	Establish replication simulation replication simulation, warm-up replications.	-related options for the ns to be run, the length time length, time units,	e current model. Settings inc of the replication, the start d , and the type of initialization	lude the number of ate and time of the to be performed between
Project Parameters	Replication Parameter	ers		
Replication Parameters	Number of Replications:	1	]	
Array Sizes	Start Date and Time:	Tuesday , 3 January	, 2023 3:47:52 AM	
Arena Visual Designer	Wam-up Period:	0.0	Hours ~	
	Replication Length:	1	Days 🗸	
	Hours Per Day:	12	]	
	Teminating Condition:			
	Base Time Units	Country	1	
	base time onto.	Seconds V		
	Parallel Replications	i.		
	Run Replications in	Parallel		
	Number of Parallel Proce	esses: 4		
	Parallel Replication Input	t Data Files:		
	Data File		Add	Υ.
ALAYSIA				
Figu	re 3.25 R	eplicatior	n Parameter	Setting
N TEKUIT	A84		Te	M
مليسيا ملاك	ڪل	کنید	يتى تيە	اونيوس
			1.0	



Figure 3.26 Existing Simulation Model of Production Line

#### 4.4.8 Result of Simulation

The result is generated when the simulation model has been executed. The output from simulation is 116 units per day as shown in Figure 4.24. It has a 90% same to actual output from the actual production line produce product. As a result from this simulation, the existing production's capability and the current state of the production line are able to determined.



The simulation is checked by contrasting its process flow with an already established conceptual model. Additionally, the simulation model was fed information regarding process flow, cycle time, resources, and other factors from the model conceptualization.

### 4.4.10 Validation

4.4.9

Determine whether or not a model faithfully represents the system in question by going through the procedure of validation. When compared to the output of the production model, which is 160 units, the simulation's output is 90% consistent. The 12-hour shift on the assembly line managed to turn out 120 units.

#### 4.5 Disscussion of Result

Based on this chapter discusses the data collection and processing time required for bottleneck process analysis and Arena simulation to improve production line productivity. After analysing the collected data, arena simulation software will be used to conduct an improvement solution. The three main points need to be discussed in this section that is line balancing improvement, productivity improvement and application of Arena Simulation Software.

#### 4.5.1 Line Balancing Improvement

According to the data collected, there is a total of eleven stations in the production line Model 3M0. The histogram demonstrates the finding to analyse the production line's behaviour. According to the histogram shown in Figure 4.5 existing of the production line before improvement, it shows that workstation two that is stations S05 and S06 RH LH have the lowest cycle time compared to other workstations and stations. For this reason, workstation two, that is, station S05, S06 RH LH was suggested as a solution in order to reach optimum production line planning. Figure 4.25 below shows the production after improvement.

Based on the graph, the number of workstations reduced to five rather than nine stations. As a result, the cycle time for workstation 1, which is S01, S02, S03, S04, S05, S06 RH LH still higher than other workstations and does not balance S01, S02, S03, S04, S05, S06 RH LH. From this, the cycle time for workstation one is suggested to reduce as another solution. According to the graph, the number of cycle time workstation one reduced is shown in Figure 4.26 line balancing after improvement. The line efficiency becomes higher by

eliminating the number of workstations. Figure 4.27 shows the new layout after line balancing improvement.

In addition, the proposed proposal is also to change the operator. The actual production line, operator 1, does work in workstation 2. However, the proposed work in workstation 2 will be done by operator 3. Figure 4.28 shows the proposed new layout of the production line after changing the operator position.







Figure 3.29 Line Balancing After Improvement 63



Figure 3.30 Layout Production Line After Reduce Workstation



Figure 3.31 Layout Production Line After Improvement of Operator Position

#### 4.5.2 **Productivity Improvement**

Based on a simulation model for the existing production line, the output of the finished product is 116 products produced per shift. In the same way, the simulation results from the new simulation model for a redesigned number of workstations and reduced cycle time show that the total output for Frame Comp Rear RH LH is 134 products produced per shift.

Besides, the workstation and cycle time in the existing production line improved there were workstation and cycle time in the proposed solution. Moreover, the salary for an operator is around RM4 per hour, based on the information given by the company. The number of output products produced increased after improvement. In addition, if the output was increased, productivity was an improvement. Product production productivity is increased after reducing the workstation, which is 11.7%, and after changing the operator's position of an operator which is 2.5%. The table shows the difference in productivity improvement.

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

Table 3.7 Table Productivity Improvement

	Productivity	
Existing production	After Reduce Workstation	After Changed Operator Position
= $\frac{120  pieces}{RM4*12  hours*8  operators}$	= 134 pieces RM4*12 hours*8 operators	= 123 pieces RM4*12 hours*8 operators
= 0.31 pieces per RM	= 0.35 pieces per RM	= 0.32 pieces per RM

Table 3.8 Table Percentage	ge Increased Productivity

Reduce Workstation	Changed Operator Position		
Percentage Increased Productivity =	Percentage Increased Productivity =		
Existing output * 100%	Existing output * 100%		
$\frac{\frac{134  pieces - 120  pieces}{120  pieces} *  100\% = 11.7\%$	$\frac{123 \ pieces - 120 \ pieces}{120 \ pieces} * \ 100\% = 2.5\%$		

### 4.5.3 Arena Simulation Software Improvement

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The simulation model for the current 3M0 production line and the proposed solution are developed in Arena Simulation version 2020 for this research study. The transition to industry 4.0 relies heavily on simulation, which plays an increasingly important role as industrial technology progresses. The link between simulation technology and financial success is undeniably substantial. The company's performance and productivity were vastly improved thanks to the implementation of simulation technology. Utilizing Arena simulation software simplifies not only data collection but also production line planning.

The Arena software can be used to create and test prototypes of production line behaviours. Reducing the number of workstations and the cycle time in a production led to the following results. The statistical analysis of the results from the Arena simulation makes it easy for the engineer to see how chance operates in the production process. In order to better assess and make decisions, the production line can be designed to account for a wide variety of possible scenarios and conditions (104). To sum up, simulation tools are crucial for the company's advancement toward IR4.0, as they enable the company to meet customer demands in the shortest possible time at the lowest possible cost, thereby raising global intensity.

The result is generated when the simulation model has been executed. The output from the simulation after improvement is 134 pieces of products produced per day, as shown in Figure 4.29 for output after line balancing improvement. In comparison, the output from the simulation after changing the operator in the workstation is 123 pieces of products produced per day. Figure 4.30 shows the output for the proposed operator change position improvement. The Arena Simulation design is still the same as the existing just changed operator one into operator 2 in workstation 2. As a result of this simulation, the existing production capability and the current state of the production line can determine. Figure 4.31 shows the Arena Simulation design after line balancing improvement. Table 4.8 shows the difference between existing output and output after improvement.



Figure 3.32 Product Output After Improvement 1

Replications: 1	Time Units:	Seconds
	Key	Performance Indicators
System		Average
Number Out		123

Figure 3.33 Product Output After Improvement 2

Existing Output	Reduce Workstation Output	Changed Operator Position
120 pieces per day	134 pieces per day	123 pieces per day

# Table 3.9 Existing Output and Output After Improvement





## 4.5.4 Arena Module After Line Balancing Improvement

Figure 3.34 Arena Model After Improvement

### 4.6 Summary

This chapter has used the entire method and process proposed in the methodology to conduct the study. A clear description of the project's background and scope resulted in a great solution to the problem. Data has been collected by focusing on achieving objectives, and a flow of process solutions has been developed. A report presenting the results and progress of a complete project study has been written in this chapter. It also proves investigation has been done the way that was proposed. Therefore, the project study were better and easier to understand by preparing a great written report. The objective of this study is 90% effectiveness related to research. The researcher has been provided some suggestions and recommendations that can be improved for future studies.



#### **CHAPTER 5**

#### **CONCLUSION AND RECOMMENDATIONS**

#### 5.1 Introduction

In this chapter, the objective was to make a recommendation for increasing the productivity in manufacturing at the PEPS-JV Sdn.Bhd company. The result of managing the process that was generating bottlenecks, line balancing and applying Arena simulation has been discussed in this topic. The work will bring clarity to both of the situations. The outcomes of the objectives for this research project, which were defined at the beginning, are summarised in this chapter. The aims of this research study were defined at the beginning. In this chapter, there is also a suggestion for how the company in the scenario could improve its production process in the future.

# 5.2 Conclusion ERSITI TEKNIKAL MALAYSIA MELAKA

In conclusion, the expected result was successful due to the goals established to be achieved by proper planning of the study process. The researcher obtained a comprehensive understanding of the study and the answer to a difficulty that a previous researcher mentioned. Defining the scope of the problem and the complexity of the research is part of the process established to finish this study. The sequence of activities that make up the process and the details of the suggested solution have been developed. The goals for identifying the bottleneck process have been effectively achieved due to all of the parameters provided in the data-gathering subjects. After that, run an Arena simulation to check the accuracy of the results presented in this thesis. The choice to increase productivity in the production line was successful due to the combination of bottleneck analysis, line balancing and the Arena simulation.

The core target of this study is to eliminate the waste of waiting by implementing the line balancing technique and developing the simulation model using Arena simulation software to improve the smoothness of the production line. All the objectives of this study are achieved successfully. The first objective was completed by analyzing the behaviour of production line 3M0 through the line balancing method. The layout of the existing production line is illustrated in Figure 4.4, and the line balancing of the current production line is shown in Figure 4.27 and Figure 4.28. The second objective was achieved by validating the proposed methodology for bottleneck and simulation. The third objective was to develop the simulation model using Arena simulation software. Both models for the existing production line and the proposed solution were also created in Arena simulation software. After reducing the number of workstations and changing operator positions, productivity increased by 11.7% and 2.5%, respectively. In this study, line balancing and Arena simulation are the most effective methods for resolving the problem of production line bottlenecks. The proposed answer is a reduced workstation since the percentage productivity of product manufacturing is higher compared to the second one.

## 5.3 Recommendation

A few suggestions for this research that might be helpful to analyze for problems in the production line of PEPS-JV Sdn.Bhd company. According to this study, the idea is that the number of workstations is reduced to balance the production line and improve productivity. Based on the resulting attempt in this research, productivity increased by 11.7% after reducing the number of workstations. In a subsequent study, the simulation model might operate for a whole day's manufacturing. An Arena simulation model that can be used to make strategic decisions about process improvement will be built using bottlenecks as an essential step to solve problems in a productivity production line. This model can take advantage of the facts needed to make such a decision.

Moreover, the amount of time needed for the spot welding process to be completed by the welding robot can be shortened by increasing the speed of the welding robot in order to reduce the amount of time spent by the operator doing nothing. The manufacturing productivity of the PEPS-JV Sdn. Bhd company can be reached, and once it has been reached, it can be improved. It depends on the company whether they use the Arena simulation method in their production line. This study is only for suggestions to the management company 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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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# APPENDICES

Unnamed	Project							
Replications:	1	Time Units:	Seconds	3				
		Key	Perfo	rmance Ind	dicators			
Syster Numb	<b>n</b> er Out	-	Av	erage 116				
Unnamed	Project							
onnamed	Project							
Replications	s: 1	Time Units:	Second	s				
Entity	8	ALAYS/4		70.				
Time	KIIIE		SCI AKA					
VA Time	F	=	Average	Half Width	Minimum Value	Maximum Value		
Entity 1 Entity 2	L'SA A		1305.92 1301.89	(Insufficient) (Insufficient)	1258.26 1242.94	1351.92 1342.35		
NVA Time	chi	(	Average	Half Width	Minimum Value	Maximum Value	. • . 1	
Entity 1 Entity 2	200	s hund	0.00	(Insufficient) (Insufficient)	0.00	0.00	اويو	
Wait Time	UNIV	ERSITI	Average	NIK AL	A Minimum S	;   / Maximum   Value	AKA	
Entity 1			301.62	(Insufficient)	0.00	1324.63		
Entity 2			763.51	(Insufficient)	0.00	2355.74		
Transfer Tin	ne		Average	Half Width	Minimum Value	Maximum Value		
Entity 1			0.00	(Insufficient)	0.00	0.00		
Entity 2			0.00	(Insufficient)	0.00	0.00		
Other Time			Average	Half Width	Minimum Value	Maximum Value		
Entity 1			0.00	(Insufficient)	0.00	0.00		
Entity 2			0.00	(Insufficient)	0.00	0.00		
Total Time			Average	Half Width	Minimum Value	Maximum Value		
Entity 1			1607.54	(Insufficient)	1258.26	2630.33		
Entity 2			2065.40	(Insufficient)	1273.61	3666.80		
Other								

# APPENDIX A Arena Simulation of Existing Production Line



Unnamed Project					
Replications: 1 Time Units:	Second	IS			
Queue					
Time					
				1 - January	
Waiting Time	Average	Half Width	Value	Value	
Qc Checked.Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 1.Queue	102.55	(Insufficient)	0.00	876.52	
Seize Workstation 2.Queue	4.6990	(Insufficient)	0.00	70.0095	
Seize Workstation 3.Queue	354.39	(Insufficient)	0.00	2475.99	
Seize Workstation 4.Queue	123.46	(Insufficient)	0.00	1492.63	
Seize Workstation 5.Queue	0.00	(Insufficient)	0.00	0.00	
Other					
Number Waiting	Average	Half Width	Minimum Value	Maximum Value	
On Checked Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 1.Queue	0.2991	(Insufficient)	0.00	4.0000	
Seize Workstation 2.Queue 0.0	01370553	(Insufficient)	0.00	1.0000	
Seize Workstation 3.Queue	1.0879	(Insufficient)	0.00	6.0000	
Seize Workstation 4.Queue AY STA	0.3844	(Insufficient)	0.00	3.0000	
Seize Workstation 5.Queue		(Insufficient)	0.00	0.00	
S	20				
S.	Z				
X					_
		_	-		
Unnamed Project					
Unnamed Project				-11-	
Replications: Time Units:	Second				
Replications: Time Units:	Second	•			
Replications: Time Units:	Second	s			
Replications: Time Units: Resource	Second				
Replications: Time Units: Resource	Second		H Sti		اونو
Unnamed Project Replications:	Second کل ما	s S	م میں تیک	ى مىسىيتى	اونيۆ
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Unnamed Project Replications: Time Units: Resource Usage Instantaneous Utilization Inspector Inspector	Second	s		ی سیبی ای اسیبی Slavinum Slavinum 1.0000	اونيو ۸KA
Unnamed Project Replications: Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Docume 0	Second Average 0.2663 0.5625 0.2125	s	Minimum O.00 0.00	می سیدی Maximum SIAValaer 1.0000 1.0000	اونيو AKA
Unnamed Project Replications: Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3	Second Average 0.2663 0.5425 0.2125 0.2125	s	Minimum 0.00 0.00 0.00	می سیبی السیبی المح Maximum S <u>Maximum</u> 1.0000 1.0000 1.0000	اونيو AKA
Unnamed Project Replications: Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 3 Operator 4	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099	s	Minimum A Value 0.00 0.00 0.00 0.00 0.00 0.00	می تعدید Maximum S. <u>Avalue</u> 1.0000 1.0000 1.0000 1.0000	اونيو AKA
Unnamed Project Replications: Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 4 Operator 5	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911	s HarfWidth (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient)	Minimum A Use 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	Maximum Maximum S Maximum 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000	اونيو AKA
Unnamed Project Replications: Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 3 Operator 4 Operator 5	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911	s HaifWidth (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient)	Minimum 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0	Maximum Maximum Maximum 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000	اوينيو AKA
Unnamed Project Replications: 1 Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 3 Operator 4 Operator 5 Number Busy	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911	s HalfWidth (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient)	Minimum 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0	Maximum Maximum Maximum 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.000000 1.0000000000	او نيو AKA
Unnamed Project Replications: 1 Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 3 Operator 4 Operator 5 Number Busy	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663	s HalfWidth (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient)	Minimum A 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 Minimum Value 0.00	Maximum 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.0000000000	او نيو AKA
Unnamed Project Replications: Time Units: Resource Usage Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 5 Number Busy Inspector Operator 1	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663 1.0850	s HartWith (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient) (Insufficient)	Minimum Value 0.00 0.00 0.00 0.00 0.00 0.00 0.00 Minimum Value 0.00 0.00	Maximum 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000	اونيۇ AKA
Unnamed Project Replications: Time Units: Resource Usage Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 5 Number Busy Inspector Operator 1 Operator 1 Operator 2	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663 1.0850 0.2125	s	Minimum Value 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.	Maximum 1.0000 1.000	اونيۇ AKA
Unnamed Project Replications: Time Units: Resource Usage Usage Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 5 Number Busy Inspector Operator 1 Operator 1 Operator 2 Operator 3 Opera	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663 1.0850 0.2125 0.7788	s	Minimum Value 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.	Maximum 1.0000 1.000	اونيو AKA
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Unnamed Project Replications: 1 Time Units: Resource Usage Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 4 Operator 5 Number Busy Inspector Operator 1 Operator 1 Operator 2 Operator 3 Operator 4 Operator 5 Number Busy Inspector Operator 1 Operator 2 Operator 5 Number Busy Inspector Operator 1 Operator 2 Operator 3 Operator 4 Operator 5	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663 1.0850 0.2125 0.7788 0.8099 0.4911	s HalfWidth (Insufficient)	Minimum Value 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.	Maximum 1.0000 1.000	اونيۇ AKA
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Unnamed Project Replications: 1 Time Units: Resource Usage Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 4 Operator 5 Number Busy Inspector Operator 1 Operator 1 Operator 1 Operator 5 Number Busy Inspector Operator 1 Operator 5 Number Busy Inspector Operator 1 Operator 5 Number Scheduled	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663 1.0850 0.2125 0.7788 0.8099 0.4911 Average	s	Minimum 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0	Maximum Value 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000	او نيو AKA
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Unnamed Project Replications: 1 Time Units: Resource Usage Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 4 Operator 1 Operator 2 Operator 3 Operator 4 Operator 5 Number Scheduled Inspector Operator 1 Operator 5 Number Scheduled Inspector Operator 1 Operator 3 Operator 4 Operator 3 Operator 4 Operator 5 Number Scheduled Inspector Operator 1 Operator 1 Operator 2 Operator 3 Operator 3 Operator 4 Operator 3 Operator 4 Operator 1 Operator 3 Operator 4 Opera	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663 1.0850 0.2125 0.7788 0.8099 0.4911 Average 1.0850 0.2125 0.7788 0.8099 0.4911 Average 1.0000 1.0000 1.0000 1.0000 1.0000	s	Minimum           0.00           1.0000           1.0000           1.0000	Maximum Value 1.0000	او نيو AKA
Unnamed Project Replications: 1 Time Units: Resource Usage Instantaneous Utilization Inspector Operator 1 Operator 2 Operator 3 Operator 4 Operator 1 Operator 2 Operator 3 Operator 4 Operator 5 Number Scheduled Inspector Operator 5 Number Scheduled Inspector Operator 1 Operator 5 Number Scheduled Inspector Operator 1 Operator 5 Number Scheduled Inspector Operator 1 Operator 5 Number Scheduled	Second Average 0.2663 0.5425 0.2125 0.7788 0.8099 0.4911 Average 0.2663 1.0850 0.2125 0.7788 0.8099 0.4911 Average 1.0000 2.0000 1.0000 1.0000 1.0000 1.0000 1.0000	s	Minimum 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0	Maximum Value 1.0000	او نيو AKA



## APPENDIX B Arena Simulation for Proposed Solution 1

Unnamed Project								
Replications:	1	Time Units:	Seconds					
		Key	Performance Indicators					
System			Average					
Numbe	Number Out		134					



Linnamed D	Project					
Unnamed P	roject					
Replications:	1 Time Units:	Seconds	i			
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Other						
Number In						
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Entity 2		108.00				
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104.000						
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98.000						
96.000						
Number Out	ALAYSI.	Value				
Entity 1	No. 14	94,0000				
Entity 2	S.	40.0000				
WIP	3	E		Minimum	Maximum	
	·	Average	Half Width	Value	Value	
Entity 1	. =	3.4800	(Insufficient)	0.00	10.0000	
Enuty 2		21.1330	(Insuncient)	0.00	70.0000	
	Million	_				
Unnamed P	roject	_				
Replications:	Time Units:	Seconds	1:4		14 - 210	
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100033						
Time per E	intity/ERSITI	TEKN	IKAL M/	ALAYSIA	MELAKA	
VA Time Per E	ntity	Average	Half Width	Minimum Value	Maximum Value	
Qc Checked		98.9508	(Insufficient)	91.5137	108.49	
Wait Time Per	Entity	Average	Half Width	Minimum Value	Maximum Value	
Qc Checked		0.00	(Insufficient)	0.00	0.00	
Total Time Per	Entity	Average	Half Width	Minimum Value	Maximum Value	
Qc Checked		98.9508	(Insufficient)	91.5137	108.49	
Accumulat	ted Time					
Accum VA Time	8	Value				
Qc Checked		13259.41				
Accum Wait Tir	me	Value				
Qc Checked		0.00				
Other						
Number In		Maker				
Qc Checked		134.00				
Number Out						
On Checked		Value				
QC Checked		134.00				

Unnamed Project					
Replications: 1 Time Units:	Second	s			
Queue					
Time					
Time					
Waiting Time	Average	Half Width	Minimum	Maximum	
Oc Checked.Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 1.Queue	3789.06	(Insufficient)	0.00	34040.58	
Seize Workstation 2.Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 3.Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 4.Queue	0.00	(Insufficient)	0.00	0.00	
Other					
Number Waiting	Average	Half Width	Minimum Value	Maximum Value	
Qc Checked.Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 1.Queue	28.2922	(Correlated)	0.00	71.0000	
Seize Workstation 2.Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 3.Queue	0.00	(Insufficient)	0.00	0.00	
Seize Workstation 4.Queue	0.00	(Insufficient)	0.00	0.00	
S	100				
S'	- Ze				
Unnamed Project					
Replications: 1 Time Units:	Seconds	s			
Resource					
2161					
Linga Lilla	کا م	-	au in	1pupa, m	
Usage	0	10	. 0.	. 0	
Instantaneous Utilization			Minimum	Maximum	
UNIVERSITI	Average	HalfWidth	Qalue	A M Value A K.A	
Operator 1	1.0000	(Insufficient)	0.00	1.0000	
Operator 2	0.6315	(Insufficient)	0.00	1.0000	
Operator 3	0.6755	(Insufficient)	0.00	1.0000	
Operator 4	0.2232	(Insufficient)	0.00	1.0000	
Robot	0.4105	(Insufficient)	0.00	1.0000	
Number Busy	Austana	Half Width	Minimum	Maximum	
An ending 4	Average 4 0000	(In cufficient)	Value	Value	
Operator 1	1.0000	(Insufficient)	0.00	1.0000	
Operator 2	0.6755	(Insufficient)	0.00	1.0000	
Operator 5	0.0733	(Insufficient)	0.00	1.0000	
Coperator 4 Robot	0.4105	(Insufficient)	0.00	1 0000	
Nobol	0.4100	(moundarity	6.66	1.0000	
Number Scheduled	Average	Half Width	Minimum	Maximum	
Operator 1	1 0000	(Incufficient)	1 0000	1 0000	
Operator 2	1.0000	(Insufficient)	1.0000	1.0000	
Operator 2	1.0000	(Insufficient)	1.0000	1,0000	
Operator a	1.0000	(Insumolency	1.0000	1.0000	
Operator A	1 0000	( the exception of the	10 10 10 10 10 10 10 10 10 10 10 10 10 1	the second se	
Operator 4	1.0000	(Insufficient)	1.0000	1.0000	



Unnamed Project							
Replications:	1 Time Units:	Seconds	rmance Ir	dicators			
System Numbe	l er Out	Avi	erage 123				
Unnamed P	Project						
Replications:	1 Time Units:	Second	s				
Entity							
Time							
VA Time		Average	Half Width	Minimum Value	Maximum Value		
Entity 1		1303.91	(Insufficient)	1258.66	1349.55		
Entity 2	WALAYS/4	1299.67	(Insufficient)	1240.16	1346.30		
NVA Time	ST.	Average	Half Width	Minimum Vatue	Maximum Value		
Entity 1		0.00	(Insufficient)	0.00	0.00		
Entity 2		0.00	(Insufficient)	0.00	0.00		
Wait Time		Average	Half Width	Minimum Value	Maximum Value		
Entity 1	· · · · ·	1123.80	(Insufficient)	0.00	3112.95		
Entity 2	AINO	2040.64	(Insufficient)	0.00	4388.68		
Transfer Time	h l	Average	Half Width	Minimum Value	Maximum Value		
Entity 1	and and	0.00	(Insufficient)	0.00	0.00	~ 92 91	
Entity 2	4 <sup>8</sup> 4 <sup>8</sup>	0.00	(Insufficient)	0.00	· 0.00	and the second sec	
Other Time	NIVERSITI	Average	HalfWidth	Minimum Value	S A Value	ELAKA	
Entity 1		0.00	(Insufficient)	0.00	0.00		
Entity 2		0.00	(Insufficient)	0.00	0.00		
Total Time		Average	Half Width	Minimum Value	Maximum Value		
Entity 1		2427.71	(Insufficient)	1301.28	4422.20		
Entity 2		3340.31	(Insufficient)	1288.66	5691.47		
Other							

# APPENDIX C Arena Simulation for Proposed Solution 2

Unnamed F	Projec	t						
Replications:	1	Time Units:	Seconds	3				
Entity								
Other								
Number In			Value					
Entity 1			62.0000					
Entity 2			72.0000					
70.000								
68.000							Г	Entity 1
66.000							L	Entity 2
64.000				-				
62.000								
Number Out			Value					
Entity 1			58.0000					
Entity 2		LAYSIA	65.0000					
WIP			Average	Half Width	Minimum Value	Maximum Value		
Entity 1			3.1527	(Insufficient)	0.00	8.0000		
Entity 2			4.8244	(Insufficient)	0.00	9.0000		
1	_						V.	
Unnamed P	rojec	t						
Replications:	C. D.A.D.	Time Units:	Second	5				
Process		1 1	1		/ 0			
Time per E	Entity	und.	عل ما	- no	-20	رسيتي	اويبوم	
VA Time Per E	ntity	RSITI	Average	HalfWidth	Minimum Value	Maximum Value	LAKA	
Qc Checked			99.16	(Insufficient)	91.5263	108.49		
Wait Time Per	Entity		Average	Half Width	Minimum Value	Maximum Value		
Qc Checked			0.00	(Insufficient)	0.00	0.00		
Total Time Per	Entity		Average	Half Width	Minimum Value	Maximum Value		
Qc Checked			99.16	(Insufficient)	91.5263	108.49		
Accumula	ted II	me						
Accum VA Tim	е		Value					
Qc Checked			12196.30					
Accum Wait Ti	me		Value					
Qc Checked			0.00					
Other								
Number In			Value					
Qc Checked			124.00					
Number Out								
			Maker					
Replications: 1 Time U	nits: Second	s						
---------------------------	--------------	----------------	------------------	------------------	--			
Queue								
Time								
Waiting Time	Average	Half Width	Minimum Value	Maximum Value				
2c Checked.Queue	0.00	(Insufficient)	0.00	0.00				
Seize Workstation 1.Queue	98.3225	(Insufficient)	0.00	851.44				
Seize Workstation 2.Queue	856.96	(Insufficient)	0.00	3534.53				
Seize Workstation 3.Queue	627.66	(Insufficient)	0.00	2244.05				
Seize Workstation 4.Queue	30.9584	(Insufficient)	0.00	189.36				
eize Workstation 5.Queue	0.00	(Insufficient)	0.00	0.00				
Other								
Number Waiting	Average	Half Width	Minimum Value	Maximum Value				
Qc Checked.Queue	0.00	(Insufficient)	0.00	0.00				
Seize Workstation 1.Queue	0.2815	(Insufficient)	0.00	5.0000				
Seize Workstation 2.Queue	2.3689	(Insufficient)	0.00	9.0000				
eize Workstation 3.Queue	1.7068	(Insufficient)	0.00	8.0000				
Seize Workstation 4.Queue	0.08268801	(Insufficient)	0.00	1.0000				
Seize Workstation 5.Queue	0.00	(Insufficient)	0.00	0.00				
29/	5							
3	2							
Jnnamed Project	-							

· · · · · · · · · · · · · · · · · · ·					
Resource					
يسيبا ملاك Usage	كل ما	کنیک	ى تيە	ونيونرسي	91
Instantaneous Utilization	Average	Half Width	Minimum **	Maximum	
Increased UNIVERSITI	Average			A Value A K	<u>A</u>
Operator 1	0.201/	(Insufficient)	0.00	1,0000	AT 78
Operator 2	0.9462	(Insufficient)	0.00	1.0000	
Operator 3	0.7943	(Insufficient)	0.00	1 0000	
Robot	0.4833	(Insufficient)	0.00	1.0000	
	0.1000	(		1.0000	
Number Busy	Aug 200	Linif Width	Minimum	Maximum	
	Average	Hair width	Value	Value	
Inspector	0.2617	(Insufficient)	0.00	1.0000	
Operator 1	1.0515	(Insufficient)	0.00	2.0000	
Operator 2	0.9462	(Insufficient)	0.00	1.0000	
Operator 3	0.7943	(Insufficient)	0.00	1.0000	
Robot	0.4833	(Insufficient)	0.00	1.0000	
Number Scheduled	Average	Half Width	Minimum Value	Maximum Value	
Inspector	1.0000	(Insufficient)	1.0000	1.0000	
Operator 1	2.0000	(Insufficient)	2.0000	2.0000	
Operator 2	1.0000	(Insufficient)	1.0000	1.0000	
Operator 3	1.0000	(Insufficient)	1.0000	1.0000	
Robot	1.0000	(Insufficient)	1.0000	1.0000	



### APPENDIX D Child Part of Workstation for Frame Comp Rear RH

	Ρ	Part Name	Frame Comp Rear RH								
Work	station	ALAY:	Pari	t		Assembly Part					
W1	S01	and a	Sec.								
		Brkt R,Trg Arm Inn	Stiff R,Side Sill Extn			Assy S01 RH					
	S02			3 CELO							
		Extn R,Side Sill	Brkt R, Trg Arm Out	Patch R,Side Sill Extn	Stiff Lwr R S/Sill Extn	Assy SO2 RH					
	S03	and the second s	- Jale	بي تيڪنيا	ونيومرسيني						
		Sub Assy S01 RH	Sub Assy S03 RH	L MALAYS	IA MELAKA	Assy SO3 RH					
	S04										
		End Plate L,Side Sill RR	Patch L,Side Sill RR End Plate			Assy SO4 RH					

W2	S05					
		Stiff R,Spring Base	Base,Spring			Assy S05 RH
	S06	AY:	SIA ARE			
		Sub Assy S03 RH	N.K.			Assy SO6 RH
W3	A10		i i	a se l'	· · · · ·	
		Brkt L,Exh Pipe Mtg	Frame A R,RR	Frame B R	Stiff L,Rr Frame A	Assy A10 RH
	A20	بيا ي	alla		اونيۇم سىيې	A CONTRACT OF
		Sub Assy S05	Sub Assy A10 RH	Bhd,Rr Frame A	A MELAKA	Assy A20 RH
W4	A30	Site			Contraction of the second seco	A COMPANY
		Stiff R,Rr Frm B Out	Extn R,Rr Floor C/Mbr	Sub Assy S03	Sub Assy A20	Assy A30 RH



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA** 

# APPENDIX E Child Part of Workstation for Frame Comp Rear LH

	I	Part Name		Frame C	Comp Rear LH	
Works	station	- ALA)	Part			Assembly Part
W1	S01		The second secon			
		Brkt L, Trg Arm Inn	Stiff L,Side Sill Extn			Assy S01 RH
	S02			3 CELOS		
		Extn L,Side Sill	Brkt L, Trg Arm Out	Patch L, Side Sill Extn	Stiff Lwr L S/Sill Extn	Assy SO2 LH
	S03			ِي ٽيڪني L MALAYS	اونيوم سيې AMELAKA	
		SUD ASSY SUT LH	SUD ASSY SUS LIT			ASSY SUS LH
	S04		A. S.			
		End Plate L,Side Sill RR	Patch L,Side Sill RR End Plate			Assy SO4 LH

W2	S05					
		Stiff L,Spring Base	Base,Spring			Assy S05 LH
	S06	ALAI	SIA ME			
		Sub Assy S01 LH	R			Assy S06 LH
W3	A10				and the second	
		Brkt L,Exh Pipe Mtg	Frame A R,RR	Frame B L	Stiff L,RR Frame A	Assy A10 LH
	A20				اونيۇم سىخ	
		Sub Assy S05 LH	Sub Assy A10 LH	Bhd,Rr Frame A		Assy A20 LH
W4	A30	UNIVERS				A CHART
		Stiff R,RR Frm B Out	Extn R,RR Floor C/MBR	Sub Assy S03	Sub Assy A20 RH	Assy A30 LH



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA** 

APPENDIX F Cycle	e Time for Production	Line Model 3M0
2		

Process :	Produc	roduct : Frame Comp Rear RH and Frame Comp Rear LHObserver:Date :										
Spot Welding	Model	: 3M0	Levynia	27 September 2022								
			5 M (0)			Henry						
Station		MAL	AT SIA	140	Cycle Ti	me						
	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	<b>A</b> 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 I	RH = 674	40 sec						To	tal LH =	6692 sec	

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

Process :		Product :	Frame Co	mp Rear Rl	H and Fran			Observer:	Date :		
Spot Welding		Model : 3	M0							Levynia	27
			. h.r							Henry	September
		MAL	ATSIA A	h.							2022
Workstation	1. A	7		No.	Сус	le Time					
Workstation 1	KN	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	E		_								
S05, S06 RH LH	3	76	75	63	70	71	75	80	67	74	74
Workstation 3		AININ	-								
A10, A20 RH LH	de	268	275	260	279	279	308	274	282	280	286
Workstation 4	2	y all	und	0,10	Zu	9	w, cu	ورم	اوىر		1
A30 RH LH		317	309	281	293	281	296	286	315	306	295
Workstation 5	UN	IVER	SITI	<b>TEKN</b>	IKAL	MAL	AYSIA	MEL	AKA		
A40, A60 RH LH		182	177	182	184	182	181	183	181	188	183
QC Checked		102	104	95	97	108	94	92			
	Tota	ll Average	RH = 704	sec				Total A	Average LH	= 699  sec	



#### APPENDIX H Input Analyzer for Frame Comp Rear RH LH



Process :	Product	: Frame	Comp Re	Observer:	Date :							
Spot Welding	Model :	3M0		Levynia	27 September 2022							
			NY PO	Henry								
Station	4	MAL	- ora	Ma C	ycle Tim	e						
	1	2	3	4	5	6	7	8	9	10	Total	Average Time (s)
S01, S02, S03, S04,	226	244	243	215	218	230	270	235	235	235	2351	235
S05 S06 RH	TE									Vi		
S01, S02, S03, S04,S05	218	200	216	218	220	225	225	222	217	223	2184	218
S06 LH	100		_									
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	S <sup>90</sup>	-90	92	93	92	92	93	92	A 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 I Cycle Time of Station After Reduce Workstation

# APPENDIX J Cycle Time Station After Line Balancing Improvement

Process :	Product	: Frame	Comp Re		Observer:	Date :						
Spot Welding	Model :	3M0				Levynia	27 September 2022					
		MAL	AYSIA								Henry	
Station		1		Me C	ycle Tim	e						
	1	2	3	4	5	6	7	8	9	10	Total	Average Time (s)
S01, S02, S03, S04,	218	200	216	216	219	222	224	222	222	216	2175	218
S05 S06 RH	F		-							V1		
S01, S02, S03, S04,S05	218	200	216	218	220	225	225	222	217	223	2184	218
S06 LH		an-				-						
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	A 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

Process :	Product : Frame Co	omp Rear l	RH and Frame Comp R	Observer:	Date :	
Spot Welding	Model: 3M0				Levynia Henry	27 September 2022
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/Mn	29	100	1.0	141	162
A30 RH	145	20	100	1.0	145	167
A30LH	153	34	100	-1.0	153-0	176
A40, A60 RH	91	5	100	1.0	91	105
A40, A60 LH	UN <sup>9</sup> /ERS	<b>1</b> 77	EKNI100AL N	ALA'Y'SIA	MEL94KA	105
QC Checked	99	16	100	1.0	99	114

# APPENDIX K Standard Time After Line Balancing Improvement

# APPENDIX L Cycle Time After Line Balancing Improvement

Process :	Product :	Product : Frame Comp Rear RH and Frame Comp Rear LH								Date :
Spot Welding	Model : 3	Model: 3M0								27
										September
	MAL	MALATSIA 4								2022
Workstation	Y		R.	Сус	le Time	_	_			
Workstation 1	1	2	3	4	5	6	7	8	9	10
S01, S02, S03, S04, S05, S06	436	400	432	434	439	447	449	444	439	439
RH LH							-11			
Workstation 2	Sec.									
A10, A20 RH LH	268	275	260	279	279	308	274	282	280	286
Workstation 3	hi (	1	1/		/			• 1	·	
A30 RH LH	317	309	281	293	281	296	286	315	306	295
Workstation 4			-			~ ~ ~			·	
A40, A60 RH LH	182	S <sup>177</sup>	182	184	182	181	183	181	188	183
QC Checked	102	104	95	97	108	94	92			

APPENDIX M Picture Visited do Field in PEPS-JV Sdn Bhd Company

