REVIEW PRODUCTION CAPACITY THROUGH ASSEMBLY LINE BALANCING STUDY AT PRODUCTION LINE IN MANUFACTURING INDUSTRY

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DEDICATION

I dedicate this thesis to all of my relatives, but especially to my mother, my father, and my siblings, who serve as a tribute to love and generosity, as well as to my friends who have helped and supported me.

I then made a dedication to my supervisor, who had assisted and advised me during the completion of this thesis.

ABSTRACT

Current competitive environment in manufacturing industries has driven companies to adopt methods to improve their production capacity. Assembly Line Balancing (ALB) is an approach to improve production capacity and effectiveness in Assembly Line (AL) at industry. Next, the objectives of this research are (i) to identify the factor of unbalance AL, (ii) to implement ALB technique to improve capacity of current AL, (iii) to propose the improvement need to be taken to the current assembly by assigning a number of workstations need in the AL and determine the suitable processing time for the processes. This study is conducted thoroughly by referring to literature study. This study uses a case study approach to data collection that focuses on manufacturing industries. The researcher's goal is to thoroughly evaluate assembly line productivity and improve it by utilizing the ALB technique by combining qualitative and quantitative methods. The collected data then analyzed to propose improvement method by conducting time study methodology in ALB and determine the optimum number of workstations in the AL. A significant finding from this research is the effect of implementing ALB in AL, such as standard process time, process flow and optimum number of workstations to the assembly process. The outcome of this research will be presented to Company X, an automotive manufacturing company. This research improves productivity of AL and improve the working condition by assigning optimal task distribution in the workstation. The outcomes provide practical insights for professionals to optimize production capacity, streamline operations, and gain a competitive edge.

ABSTRAK

Keadaan persaingan semasa dalam industri pembuatan mendorong syarikat-syarikat untuk mengamalkan kaedah-kaedah untuk meningkatkan kapasiti pengeluaran mereka. Penyeimbangan Barisan Pemasangan atau “Assembly Line Balancing” (ALB) adalah satu pendekatan untuk meningkatkan kapasiti dan keberkesanan pengeluaran dalam Barisan Pemasangan atau “Assembly Line” (AL) di dalam industri. Seterusnya, objektif kajian ini adalah (i) untuk mengenal pasti faktor ketidakseimbangan didalam AL, (ii) untuk melaksanakan teknik ALB bagi meningkatkan kapasiti AL semasa, (iii) untuk mencadangkan penambahbaikan yang perlu diambil ke atas seluruh proses pemasangan semasa dengan menetapkan bilangan stesen kerja yang diperlukan dalam AL dan menentukan masa pemprosesan yang sesuai untuk proses-proses tersebut. Kajian ini dijalankan secara terperinci dengan merujuk kepada bahan kajian literatur. Kajian ini menggunakan pendekatan kajian kes untuk pengumpulan data yang memberi tumpuan didalam industri pembuatan. Matlamat penyelidik adalah untuk menilai dengan terperinci produktiviti barisan pemasangan dan meningkatkannya dengan menggunakan teknik ALB dengan menggabungkan kaedah kualitatif dan kuantitatif. Data yang dikumpulkan kemudiannya dianalisis dan seterusnya mencadangkan kaedah penambahbaikan dengan menjalankan metodologi kajian masa dalam ALB dan menentukan bilangan stesen kerja yang optimum bagi AL. Penemuan penting dari penyelidikan ini adalah kesan pelaksanaan ALB dalam AL yang teilit, seperti proses masa yang standard, aliran proses, dan bilangan stesen kerja yang optimum dalam proses pemasangan. Hasil daripada penyelidikan ini akan dibentangkan kepada Company X, sebuah industri pembuatan. Penyelidikan ini meningkatkan produktiviti AL dan memperbaiki keadaan kerja dengan menetapkan pengagihan tugas yang optimum di stesen kerja. Hasil kajian ini memberikan pandangan praktikal kepada profesional untuk mengoptimumkan kapasiti pengeluaran, menyelaraskan operasi, dan mendapatkan kelebihan bersaing.

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LIST OF SYMBOLS AND ABBREVIATIONS

AL	-	Assembly Line
ALB	-	Assembly Line Balancing
CI	-	Continuous Improvement
LM	-	Lean Manufacturing
JIT	-	Just In Time
TPS	-	Toyota Production System
VSM	-	Value Stream Mapping
TQM	-	Total Quality Management
TPM	-	Total Productive Maintenance
OEE	-	Overall Equipment Effectiveness
AI	-	Artificial Intelligence
CT	-	Cycle Time
TT	-	Takt Time
SALBP	-	Simple Assembly Line Balancing Problem
GALBP	-	General Assembly Line Balancing Problem
APL 6	-	Assembly Production Line 6

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CHAPTER 1

INTRODUCTION

1.1 Research Background

An assembly line (AL) consists of a series of workstations where specific tasks required to create a product are completed. The changes in AL for the past 20 years are influenced mostly by Lean Manufacturing (LM). In LM, the production will produce many types of waste. To reduce these wastes, several methods can be implemented and one of them is Assembly Line Balancing (ALB). ALB is a proven technique to increase line efficiency by minimizing workstations, Karatepe (2022) and Bongomin (2020). Many researchers have carried case studies and literature reviews for this technique. The current manufacturing system aims to balance the production line to maximize its efficiency toward balancing the loads Sivasankaran (2017).

ALB is a tool to minimize workstation and balance workload in the station. The approach is to make process time shorter, and all resources are use optimally. As mentioned by Chutima (2020) in AL, there are three main components, workstations, cycle time and precedence diagram. In ALB, these components are connected as pointed out by Jusop (2015) the manufacturing line consist of workstation in a flow and then the production time are assigned to the workstation with the precedence constraint of the process respected. ALB problem is categorized in to 2. i) Simple Assembly Line Balancing Problem (SALBP) and ii) General Assembly Line Balancing Problem (GALBP). Jusop (2015). Also mentioned in the research, SALBP is the standard type of AL in the industries. It is well use in the industries because it direct toward achieving it objective by using mathematical methods based on the parameter in the manufacturing line.

The problem in the AL must be identified first before we proceed to the solution. In this research we aim to find the bottleneck in the production line as it is a barrier for manufacturing line achieving it best capacity. From all parameter collected in the manufacturing line, we can balance cycle time of each workstation to be below the Takt Time of the production and balance workload using the approach of ALB. Then with the type of assembly line problem we can determine the number of workstations and arrange the workstation according to their precedence diagram. It is known as SALBP Type 1. The appropriate approach is determined by the number of products produce in the manufacturing line and the production capacity. Lastly, ALB's main objective is to prevent production bottleneck other than to maximize production efficiency.

1.2 Problem Statement

Many factors can affect the productivity in assembly line. Past study has found that the uneven workload and processing time in workstation can reduce production quality and productivity. In some studies, the unbalance task and processing time can cause to inefficient production lines. It causes too much waste created in the production line. The philosophy of Lean Manufacturing (LM) has created many problem-solving methods to create a better manufacturing line. One of the methods that taken from by Lean Thinking is Assembly Line Balancing.

To be able to adapt Assembly Line Balancing (ALB), many steps need to be carried out. The first step in ALB is to identify the factors of unbalance workload or time in the assembly line. This is known as the critical part of ALB, as time study and productivity of the need to be carried to detect the problem. After that, a suitable approach is needed because method of ALB has been highly developed since its early days. The approach depends on the type of production, production variation in assembly line and other constrains that can influence the result of ALB application in the AL.

Lastly, a suitable method to apply ALB in current AL is very critical to achieve a good result because ALB has many factors that need to be considered. It also has many types of approaches to solve the problem in AL. The changes that need to be implemented must consider the current AL's precedence flowand also, we need to consider the workforce and workstation in the current AL.

1.3 Research Question

Based on the problem statement, the research question is developed and stated as below:

RQ1: What are the factors that cause of unbalance processing time and task distribution in assembly line?

RQ2: What is the suitable technique to solves unbalance assembly lines?

RQ3 : How to enhance production capacity in the current assembly line?

1.4 Research Objective

The main objective of this study is to improve the productivity in an assembly line by performing the correct steps of ALB application such as time study, task distribution and identifying the cause of unbalance in the line. There are other objectives of this case study such as:

i. To identify the factors of unbalance time and task at production assembly.

ii. To conduct a suitable technique to solve unbalance assembly lines.

iii. To propose improvement to enhance production capacity through assembly line balancing study.

1.5 Research Scope

The main focus of this study is application of Assembly Line Balancing (ALB) in Assembly Line (AL). This is used by the tools and methods of ALB to optimize the processing time and improving the productivity of the production. The technique is put into practice after data from manufacturing company are gathered and analyze. It cover all the aspect and parameters that are need for this research data analysis. After that, the ALB is employed because it can reduce the number of workstations while enhancing the processing time and manufacturing process. Every measure needs to be taken to achieve the objective of this study. The detail of the research scope is show in K Chart to provide a better understanding.

1.6 Expected Result

The expected finding of this study is to identify the factor that causes the production assembly to work less efficiently. By identifying the problem, a suitable approach can be made, and then the proper improvement technique can be implemented. After that, by carrying out the time studies and determining the task distribution in workstation, the future results are used to suggest an improvement technique to improvise the current result to increase the productivity of the production line. Then, it can determine the processing time in each workstation and a number of workstations can be determined.

Lastly, from all the data and results of the time study in this research, the proper improvement method can be implemented in the assembly line. The optimum number of workstations can put in the Assembly Line (AL) and the cycle time can be balanced among the workstations. Upon completing the study, the AL is analyzed and can have lesser idle time and optimizing the use of resources. Thus, the research achieves to reach its objective to improve the current assembly line by practicing Assembly Line Balancing (ALB).

1.7 Thesis Frame

The first chapter of this research, it will outline the purpose of this case study. It begins with introducing this research and then to identifies the problem that is absent in the assembly line and ways to solve it. The research question developed from the problem statement to present the main problem that this research wants to tackle. After that, the objective of this research is produced to show what is the intention of this study. Then, the expected result can be written, and it indicates the possible outcome of the study.

Next, a literature review is carried out to gather data and information from the past study that have been carried out. In the literature review, there are explanations of the history of Assembly Line Balancing and also the method that past researchers have carried out. This chapter covers topics about Lean Manufacturing (LM), Waste in Lean Manufacturing and Tools in Lean Manufacturing. Other than that, in this chapter, there are comprehensive explanations about methodology of the Assembly Line Balancing (ALB) application.

Chapter 3 explains method how this research is conducted. In this section, the are tools such as time study, efficiency calculation and how to calculate the productivity. It also shows the strategies and decision taken regards the data that have been collected. In addition, this chapter shows the overall method taken to achieve the objective of this research.

In addition, the study's founding and analysis are shown in Chapter 4. The outcomes in this chapter will be produced using the above specified tools and procedures.

It will discuss the approach and different instruments used to collect data. The impact of employing the tools and methodologies for this study is discussed after the data has been collected and based on the findings.

At the last chapter, the conclusion of this study is stated. The overall result is explained in this section with the improvement method towards improving the assembly line’s production capacity. It also summarizes the key point of this study, such as introducing the new framework to improve the current assembly line. Lastly, this chapter discuss the problem and solution as the ALB is applied, and the finding can be compared for future enhancement.

CHAPTER 2

LITERATURE REVIEW

2.1 Preliminaries

In Manufacturing Industries, there are a lot of mechanisms and components that need to be taken care. One of the main aspects in manufacturing or production is production management. Production Management usually describes the organization’s ability to maximize production by using the optimum resources to avoid loss and overspending. This method has been implied in industries since the second industrial revolution, after the factories back in the day start to implement Assembly Line in their production. At that time, AL has brought much attention as the system had been proven to achieve higher production capacity and produce more quality products in a shorter time. AL is implemented for mass production capacity. After the introduction of the AL, there has been much of improvement by the player in the industry. From 1900 until today, the development of manufacturing technology has been tremendous. As we can see now, the production line has been implementing the IR4.0 technology. This technology consists of an automated conveyor, robotic arm and the internet and Artificial Intelligence (AI).

Assembly Lines need to evolve. To be evolve, continuous improvement needs to be applied. In this modern era, production achievement is improving towards method and analysis to reduce variance and waste. According to Inan (2021) this method is driven by Lean Manufacturing and another method. Similarly, Berhe (2023) stated that as competitiveness in manufacturing industries is increasing, many tools have been adopted such as Lean Manufacturing (LM), Lean Six Sigma (LSS), Total Quality Management

(TQM) and many more. Many researchers have found that Lean Manufacturing has brought many benefits in production. This method has been continuously applied in all manufacturing companies to create a better environment in the production system. One of method to improve manufacturing system is to review the production system and then, apply Assembly Line Balancing (ALB). ALB is a well-know method to increase the efficiency of production and to reduce waste.

2.2 Assembly Line

Before Assembly Line (AL) were invented, the production commonly held as a fixed layout. It is where workers usually do all the assembly processes in one place. Today, most of the AL are arrange for the flow of the process where task is distributed evenly through the whole assembly process. As mentioned by Cimen (2022), the Assembly Line work in a flowline assembly process to produce many consumer goods. Also written by Sordan (2021), an AL is a system where workstations are positioned simultaneously, and assembly procedures are carried out as the product is transferred from one workstation to the next without disregarding precedence rules. Initially, it was created to produce large volumes of goods at lower cost. AL use a transportation system such as conveyor to move the product. The idea of the continuous flow of assembly was brought when Henry Ford wanted to improve Ford Motor Company’s AL. As Goshime (2019) said in 1913, Henry Ford was the first to introduce the AL in the automotive industry and mass production. The purpose of this system is to reduce time, labor, cost, and material during production. This also benefits Ford Motor Company after the new assembly line run; it gives the company higher productivity as they can improve the lead time of the production. After that, the effect of the new system gives Ford Motor Company more significant profit margin. Assembly Line, as define in the Cambridge Dictionary: an arrangement of machines, workers, and equipment in a factory. The product is continuously flows moving while built or produced. Each worker and machine performs a task that must be finished before proceeding to the next task or process.

Today, with the development of technology in manufacturing, the assembly line has highly involved advance technology such as automated conveyors, robotics and significant data regarding the Industry Revolution 4.0 (IR4.0) Rahman (2020). Improvements in assembly lines are also growing as many techniques can be approach toward higher productivity in assembly lines. The current AL will have a subline where the products go through subassembly processes, an automated transportation system or automated guided vehicles and a smart machine that can reduce the usage of while increasing production quality and performance. This evolution has inspired the application of automated transportation in assembly lines.

Manufacturing industries are keen on to reducing waste in their production. One way to overcome the problem is Lean Manufacturing. Many companies have implemented the Lean philosophy to reduce the amount of waste in their company. Lean Manufacturing and I.R 4.0 has been combined to create a better workplace and help to achieve better goals in the manufacturing segment. Jayanth (2020) expressed the opinion that lean concepts and tools have aided manufacturing companies in achieving operational excellence and, in doing so, achieving both classic and modern organizational goals, including profitability, efficiency, responsiveness, quality, and customer happiness. Automation needs to be implemented in the AL for a manufacturing company to remain competitive. As Berhe (2023) identified, poor technology capability and development contribute to slow process time and low productivity. As in this study, it wants to focus on developing the current AL to improve the manufacturing capacity by adapting automation to create better working environment.

2.3 Lean Manufacturing

Lean manufacturing (LM) is a method in the industry to create a production line or manufacturing system with less waste produced during production. LM generic name is 'LM' for Lean Manufacturing as referred by Goshime (2019). This method ensure the production is efficient to produce the desired output with the optimum resources. It also works similarly to Just In Time (JIT) method. Both of this method is to meet customer demand and desired quality for the product. LM in the industry aims to create a production line that is ideal with the resources used efficiently, the time management in the production line is balanced and lastly, the production waste is minimal.

LM is developed from Toyota Production System or Just In Time (JIT) Production and Henry Ford's philosophy as claimed by Shi (2019). LM was first implement as Toyota Production System (TPS) in Japan, developed by Ohno in 1988. The idea was to eliminate waste in the production because back then an engineer at Toyota Company saw that there was overproduction in the production line, then, created waste that caused loss of material and resources. There are many background histories of the LM method. One situation that triggers the implementation is where Japan wants to recover their economy after World War 2. The Japanese company needs to have smaller company. However, they can produce a good quality product and reduce all the dependency on a big production layout that use much space and have optimum resources without neglecting their customer demand. After the Japanese recovered from the down time, the Western industry started to apply LM into their industries. According to Holweg (2007), Western industries were interested in the Japanese achievement after implementing Lean Manufacturing.

The evolution of LM comes with the recent Industry Revolution 4.0 (IR4.0). The continuous mechanization and automation of conventional manufacturing processes are known as IR 4.0, as referred to by Alnounou (2022). The recent development revolving around LM to reduce all the waste produced in the production. The waste must be identified in the production and management since it always happens between them. Those waste must be identified before implementing further action to improve the system. This method is also known as a management philosophy to improve productivity by implementing most minor task in the production including removing non-value-added Shi (2019) emphasized.

2.3.1 8 Waste of Lean Manufacturing

In Lean Manufacturing (LM), 8 types of waste have been recognized in the production. According to Goshime (2019) and Alkunsol (2017), Eight Waste in LM is i) Overproduction, ii) Idle Time, iii) Transportation, iv) Over-processing, v) Inventory, vi) Motion, vii) Defects, viii) Underutilized worker. The types of waste are described below:

i. Waste of overproduction (Overproduction)

Overproduction means the unused product that may results from from failing to meet customer demand. This can lead to extra costs for resources and materials. LMis growing pull techniques rather that push techniques. Production based on customer demand has been seen important as this method can prevail over losses and overproduction. Overproduction can lead to many other wastes, such as inventory and defects, referring to Chen (2019). Thus, the problem needs to be tackled because it will create many implications to the manufacturing line.

ii. Waste of time on hand (waiting / idle time)

Idle time in manufacturing needs to reduce to increase efficiency of the equipment. According Alnounou (2022), things such as material, equipment and labors are must be handle immediately. This type of waste can be seen in manufacturing as waiting time for the machine to start, waiting time of material to reach facilities and also, inefficient machinery. It also can be caused by an unbalanced workload at workstation.

iii. Waste of transportation (Transportation)

Waste of transportation means unnecessary movement of products, workers, equipment and inventory. This waste can lead to defects or product damage. As mentioned by Gupta (2020), transportation can be challenging at times due to travel distance, and many products suffer damage from improper treatment. The cost of the production also will increase as the movement of inventory increases.

iv. Waste of processing (Overprocessing)

Over processing is waste that can be reduced by having good design and planning. Waste of processing means the unwanted process is added to design process and causes many resources to go to waste, such as material and energy. Over processing happens because of poorly designed process. It can be such as overlapping process, human error, and need for more communication in the management. Also mentioned by Alnounou (2022), the error can be seen because non-valued task added to the process.

v. Waste of excess inventory (Inventory)

Excess inventory is number of unused product that are kept, it can be the material and unsold products that take up a large of space and slow the movement of the product. Alnounou (2022), describes it as unsold material waiting to be processed. It also means that waste of excess inventory can contribute to more enormous loss and resources wasted.

vi. Waste of movement (Motion)

In industries, motion is costly. For materials, its movement from the inventory go through processes and send to the customer use a lot of money. In human terms, movement or motion use energy, and excessive and extended motion can cause tiredness and sickness to the workers. The unneeded movement of workers and products is considered waste. The amount of motion needed in processing is 5%, Singh (2018). In LM, the goal is to save energy and cost in production. By applying one of the methods in LM, process mapping, we can plan and manage all the movement in the production line. When it has developed, we can utilize all the resources toward better quality production.

vii. Waste of making defective products (Defects)

Defects cost money, time, resources, and customer satisfaction. Defects are cause by improper process planning, poor design of the product, unsuitable work talent and machinery. In LM, to avoid this loss, proper work management needs to be implied in the working environment, focusing on quality check after and during processing and lastly, regular maintenance of the machine to avoid defect in the product and maintain production.

viii. Waste of underutilized worker

The eighth waste in LM is not using the full talent of the workers and it can cause a loss in the company. This means the unutillized talent from the workers may delay the solution or capabilities of solving the problems in an organization. Besides that, not utilizing the potential talent among workers can also hold up the organization’s development. To eliminate the waste, we can help the employers grow with experience and knowledge by providing training and creating a development process for the worker.

2.3.2 Tools of Lean Manufacturing

There are various of tools in Lean Manufacturing (LM). The purposes are to reduce waste and, at the same time to increase performance and quality in the manufacturing system. These tools are widely used around the globe as the approach of the philosophy can be suitable in any business and industry. The benefits of each tool are depend on the application and the problem.

Firstly, Value Stream Mapping (VSM) is a Lean Tool to reduce waste in production. VSM is a tool that draws a flowchart of the process. Referring to Hartini

(2020), VSM is a method to see the flow in production from the raw material until it becomes a finished product. By mapping the process flow, we can analyze and reduce the waste in the manufacturing system. Also mentioned by Hartini (2020), this tool has proven to be an action that can eliminate waste and deliver continuous improvement. The next tool in LM is 5S. 5S is stand for Sort, Set-in-order, Shine, Standardize and Sustain. A statement by Gupta (2020) stated that proper implementing the 5S tool could benefit to the workplace. This also means that by using 5S can create a safe working environment and help the worker's well being

The third tool in LM is Just-in-time (JIT) method. The following method is to avoid overproduction and overuse of spaces such as inventory to keep the excessive product. JIT is based on pull system where production is created based on customer demand. The system is reversed to the push system as the push system is a product produced by demand forecasting. This method depends on accurate forecasts to have minimal waste during production. JIT are known for being more efficient compared to traditional push systems. Besides that, Kanban is one of the tools useful for LM. Kanban is a just-in-time method that used for inventory. The Kanban system helps monitor production flow and replace material as soon as needed. This help to increase efficiency and reduce idle time at certain process.

The other tools in Lean Manufacturing are Total Quality Management (TQM) and Total Productive Maintenance (TPM). TQM is a concept on ensuring quality is at the highest level on a product or service. Since its implementation, this method focuses on the entire organization focusing on constant development. TPM is to avoid increasing downtime in the production. The machine management method can increase the productivity as the goal of LM. TPM also helps to care for the equipment. Other than that, we can estimate the down time of an equipment and avoid a more significant loss of time during production. Lastly, Kaizen leads to continuous improvement. Kaizen is the Japanese principle of continuous improvement in all part of our life, including at home, in working space and in the system. Continuous Improvement (CI) means an ongoing positive change to all areas of the organization and, when effectively applied, is a constant effort that changes how people work, think, and interact to enhance processes and strengthen capabilities across the organization.

All tools in LM need to be applied constantly from time to time. This process needs a period of implementation, relying on an organization's work culture and environment. This method has been proven to succeed in the industries. A citation from Ferrer (2022), The combination of LM and IR 4.0 had been achieved to reduce cost and improve efficiency. It shows that the implementation of both ideas creates a profitable step to be taken in the industries. To ensure the perfection of this methodology, we need to take steps to revise after certain period and continuously improve the organization. CI also also is constant development. This application can derive to better achievement as from the early of the introduction of LM methodology is to improve the process and product quality.

2.4 Continuous Improvement

Continuous Improvement (CI) has been in the industries for a long time. This methodology is brought as a technique to sustain achievement and especially to eliminate waste during the process and our management. Berhe (2023) defines that CI as a way to maintain reaching goals and help the growth of a manufacturing company other than eliminating waste during process. From the statement, by implementing CI we can maintain our discipline towards reaching goals and with ideal use of resources because overuse of any resources can lead to losses in the business. CI, in other words, means the application of a technique to increase achievement and decrease error that will lead to failure, according Inan (2021).

The first implementation of CI in the industries is believed to have started in 1800s Khan (2019). In that time, companies are focusing on achieving better achievements from time to time. They have taken steps to improve their worker’s skill and take into consideration of their creativity and ideas. The application of the technique has opened the eyes of Western Industries by observing the development in Japan after world war 2. With the same goals, it has been proven that this philosophy can increase the capacity and quality of the production.

Manufacturers must drive improvement by providing better quality products faster to their customers while reducing costs, increasing ROI, and maintaining a safe workplace. Manufacturers that are capable at concentrating with laser-like focus on creating and sustaining a solid continuous improvement process that includes a daily management system and genuinely engages people as "problem solvers" at all levels of organization retain their competitive edge in the industry. CI for manufacturers able to help them create a long-term succession and fill customer demand. Referring to Vo, B (2019), it is mentioned that Kaizen used Lean Manufacturing (LM) as it cores, as applying it can help for better production quality.

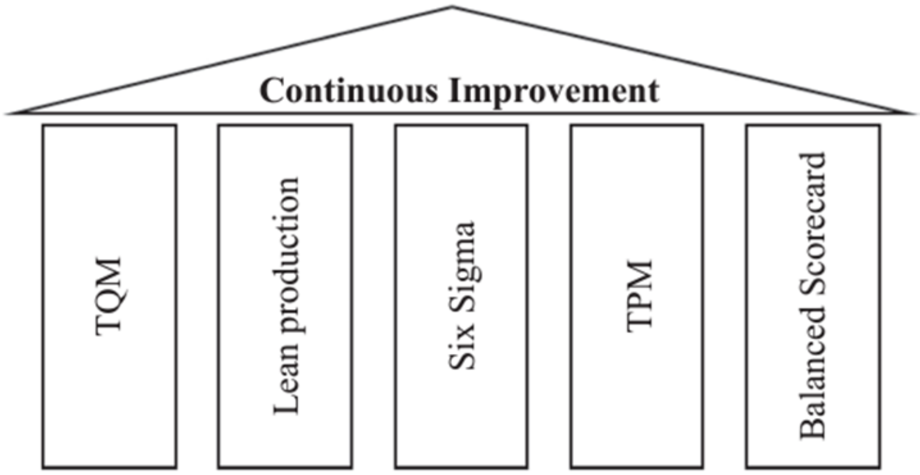

Figure 2.1 Foundation in Continuous Improvement. Inan (2021)

Continuous improvement is an essential component in management systems, including LM, Six Sigma, and Total Quality Management (TQM). TQM is a management philosophy that mainly focuses on CI by meeting customer demand, reducing overlapping work, long problem-soliving time, increasing worker involvement, reviewing process design and constant observation on the results, and maintaining a close connection with supplier. As defined by Kumar (2023), To ensure a smooth and continuous production flow, LM emphasizes minimizing the time and effort required to make a product and minimizing different types of waste. Based on the idea of Chen (2019), The methodology is focus on waste reduction and production planning. The method is also categorized as Overall Equipment Effectiveness (OEE), Kaizen, know as CI, and many other models. Six Sigma is a systematic method for process improvement and service development depending on statistics and analysis methods to reduce the defect on the product and product variation, Inan (2021).

The goals of implementing CI can be focus on the main component of the industry. The components are i) Efficiency and ii) Productivity. These two components are well connected to each other to achieve better productivity, we need higher efficiency. As well as these have been improved, the benefits that can be achieved is reducing use of resources and waste produced. After that we also can manage the production quality by reducing defects. Then we can increase worker interaction and contribution to the organization.

2.4.1 Efficiency

Efficiency is the highest perfomance level that uses the least amount of inputs that produce high-quality product. In other words, it means the ratio of output over input. In Manufacturing, it can be the least number of resources and workers with the least short production time and can produce a good quality product that meets customer demand. Because all inputs are limited in industries, efficiency is a crucial quality. Since resources like time, money, and raw material are finite, it is critical to preserve them while still producing work that reaches the quality required. By Raval (2020), Efficient use of resources is essential to manufacturing, such as machinery, worker and inventory, to manufacture their product. A process or system is considered efficient when achieving its intended result with a minor input or effort.

Efficiency is crucial in several disciplines, including engineering, management, and economics. Increasing efficiency, productivity, and effectiveness help company to remain competitive Vo (2019). Thus, a manufacturing company may strive to increase efficiency by optimizing its production processes to decrease waste and increase output. Increasing efficiency generally results in lower costs, more output, and better performance. It is a crucial factor in the manufacturing industry, as it directly affects the cost of production and the quality of the final product. Lean Manufacturing (LM), Quality Control and Automation are some applications that are driven by it.

To maintain efficiency, constant monitoring and analysis, if needed, to ensure all the resources are used optimally. As studied by James (2019), efficiency of machinery and performance can lead to high production output. To support that, Tortorella (2022), an implementation of LM can increase the level of efficiency in production process. It has been a critical part of identifying the level of efficiency in the production process. As for all, efficiency is a critical factor for manufacturing companies looking to stay competitive in today's global market. Equation 2.1 below shows the formula to calculate efficiency in the production line.

$$Efficiency = \frac{sum\ of\ task\ times\ (T)}{actual\ number\ of\ work\ stations\ (Na) * cycle\ time\ (Ct)} \qquad (2.1)$$

2.4.2 Productivity

Productivity refers to how effectively a machine, factory, or individual converts inputs into usable outputs. The basic formula is dividing the average production for a given period by the expenses incurred or the resources, such as staff used during the process period to determine productivity. It is the gauge of how effectively inputs are put to use to produce output. It is frequently used to evaluate how well a company, sector, or nation produces goods and services. Inputs such as labor, capital, materials and outputs such as goods and services can both be used to calculate productivity. The objective of productivity enhancement is to either maintain production while using fewer material or to increase output while using fewer inputs.

Numerous formulas can be used to calculate productivity, including those for labor, capital, total factor, and multifactor productivity. Shi (2019) identified that formula for productivity in manufacturing sectors is the ratio of input over output. For instance, capital productivity measures the amount of output produced per unit of capital input, whereas labor productivity gauges output produced per unit of labor input. Increasing the use of technology, enhancing procedures, and optimizing resource use are just a few ways that can be used to increase productivity. Tsarouhas (2019) asserts that by calculating the production of the product helps to recognize the problem in production. From that, organizations can boost their competitiveness, profitability, and capacity to generate value for their businesses by boosting productivity.

The first Industrial Revolution, which began in the 18th century in Britain, marked a significant shift in the way goods were produced. New technologies such as steam power and mechanization transformed manufacturing, leading to increased efficiency and productivity. Then, Henry Ford was a pioneer in the application of assembly-line manufacturing in the early 20th century. Ford was able to significantly boost productivity and efficiency by decomposing the manufacturing process into a series of routine actions. In recent years, the rise of digital technologies and the Internet of Things (IoT) has led to the development of Industry 4.0, which aims to create a "smart factory" that uses advanced technologies such as artificial intelligence and robotics to optimize manufacturing processes and increase efficiency.

There are many benefits to productivity improvement in manufacturing. A case study by Khan (2019) believed that implementing a Continuous Improvement (CI) method such as 5S could affect production performance. Here are some of the key advantages:

i. Increased efficiency: Improving productivity means reducing waste and optimizing resources, which can result in increased efficiency and reduced costs. Increasing efficiency is connected to increasing workers' productivity and production.

ii. Higher output: By improving productivity, manufacturers can produce more goods and services with the same amount of resources, increasing their overall output and revenue.

iii. Improved quality: Productivity improvements can also lead to improved quality of goods and services as processes become more streamlined and consistent.

iv. Better customer satisfaction: Improved quality and efficiency can lead to better customer satisfaction, as customers receive higher-quality goods and services more quickly and reliably.

v. Increased competitiveness: By improving productivity, manufacturers can become more competitive in the global market, as they are able to offer higher-quality goods and services at a lower cost.

vi. Greater innovation: Productivity improvements often involve the adoption of new technologies and processes, which can spur innovation and lead to the development of new products and services.

vii. Better working conditions: By streamlining processes and reducing waste, productivity improvements can also lead to better working conditions for employees, as they are able to work more efficiently and effectively. The Philosophy of 5S is able to create a conducive working environment and safe operating space. Khan (2019)

2.4.3 Bottleneck

A bottleneck is a point in a process or system where the flow of supplies, data, or other resources is constrained or slowed down, frequently leading to a backlog or delay. According to Abdullah (2022), the bottleneck will limit capacity and make it difficult for the production process to meet consumer demand. It can be compared to a constriction or narrow point that restricts resource flow and can result in a system backup. A supply chain, a computer system, a manufacturing process, and other settings can all experience bottlenecks. For instance, in manufacturing, a bottleneck may develop at a particular stage of production when the output rate is lower than the input rate, resulting in a backlog of inventory for work-in-progress. A bottleneck in the supply chain could happen at a certain node, like a transportation hub or warehouse, delaying the delivery of goods. To increase system effectiveness and cut out delays, bottlenecks must be found and eliminated. Process change, resource reallocation, or capacity addition may be necessary to remove the bottleneck.

Identifying bottleneck processes is an important part of improving system efficiency and reducing delays. Jamil (2016) highlights that by recognizing the bottleneck in the production process in the automotive interior manufacturing line. Once a bottleneck process has been identified, several strategies can be used to address it. There is need to highlight two techniques which are reviewing the production process and implementing new technology. Sometimes a bottleneck process can be improved by redesigning the process to eliminate unnecessary steps or improve the flow of resources, Song (2017). This may involve reorganizing the layout of the workspace, changing the sequence of operations, or automating specific tasks. Then, implementing new technology such as automation, robotics, or advanced analytics can help to improve the efficiency and productivity of a bottleneck process.

A few steps need to be applied to detect the bottleneck point in the manufacturing system.

i. Analyzing production flow: Analyze the flow of materials and information throughout the production process to identify stages where there are backlogs or delays. This can involve mapping the production process and looking for areas where work-in-progress inventory accumulates, Song (2017).

ii. Measuring cycle time: Measure the time it takes for a unit of product to move through each stage of the production process. Identify stages where cycle times are longer than the average, as this can indicate a bottleneck.

iii. Tracking inventory levels: Track inventory levels at each stage of the production process. Identify stages where inventory levels are higher than the average, which can indicate a backlog or bottleneck.

iv. Monitoring machine utilization: Monitor the utilization rates of machines or equipment at each stage of the production process. Identify stages where machines are underutilized or idle, as this can indicate a bottleneck.

v. Analyzing downtime: Analyze downtime data to identify stages where machines or equipment are experiencing the most downtime. This can indicate a bottleneck that is causing downtime and reducing productivity.

vi. Conducting simulations: Use simulation software to model the production process and identify areas where bottlenecks are likely to occur. This can help to identify potential bottlenecks before they become a problem.

2.5 Assembly Line Balancing

Assembly line balancing (ALB) is the process of maximizing the distribution of jobs or workstations in an Assembly Line (AL) in order to reduce idle time for employees and equipment, and guarantee that the output of production meets demand while keeping the required quality level. In AL, a product is moved from one workstation to the next until it is finished, with each workstation carrying out a distinct task. ALB involves allocating tasks to each workstation to reduces idle time and guarantees that each workstation's output rate corresponds to the assembly line's speed. Sanci (2017) ALB is a method to determine number of workstations according to the cycle time without any disrupting the process flow.

The AL was a series of workstations where workers performed specific tasks to assemble the car. Each worker was responsible for a specific task, and the product moved from one workstation to another until it was completed. The introduction of AL allowed Ford to increase production rates and reduce costs significantly. The assembly process did provide some difficulties, however. Managing the workload at each workstation become more challenging as production rates rose. Inequalities in workload led to bottlenecks and delays, which decreased production and efficiency.

F.W. Taylor initially discussed ALB in 1911's "The Principles of Scientific Management" book. Taylor, a pioneer in industrial engineering, pushed for applying time and motion studies to boost production productivity and effectiveness. The Ford Motor Company's Model T assembly line started in 191 and is home to one of the earliest instances of ALB. The line was made up of a number of workstations, each of which had a particular job to do, such mounting a wheel or fastening a fender. High levels of efficiency and production were possible because of the meticulous planning and organization of the duties, which ensured that there was an equal quantity of work for each workstation. After the 20th century, ALB has become increasingly sophisticated with the development of computer-based algorithms and optimization techniques. These tools allow manufacturers to more accurately balance assembly lines and minimize the amount of idle time and wasted resources. Today, ALB is used in a wide range of industries, from automotive manufacturing to electronics assembly. It plays a crucial role in the production of goods and services around the world.

2.5.1 Importanace of Assembly Line Balancing

The importance of Assembly Line Balancing (ALB) is to assign equal task distribution into each workstation in the process and to reduce idle time. This method can improve the productivity and quality of the final product. Sordan (2021), the technique balances workload in the workstation and optimizes Assembly Line (AL) productivity. Rahman (2020) expressed the opinion that balancing the assembly line aims at allocate tasks in a balanced manner to the workstations so that all workstations are equally loaded. By optimizing the allocation of tasks and minimizing idle time, assembly line balancing can increase the output of a production line while also reducing costs. This, in turn, can lead to increased profitability for manufacturers, which is particularly important in industries where profit margins are thin.

The central importance of ALB is to minimize process time and the in workstation. Referring to Sordan (2021), Line Balancing is to equal the Takt Time (TT), Cycle Time (CT) and number of workstations in an assembly line. From the reference, the application of ALB is by balancing the task time in each workstation. The word “Takt” defined to describe the outcome of dividing the amount of available working time by a unit of time and the consumer demand simultanieously to convey the idea of speed or rate of production. By finding the TT, we can identify the manufacturing process is able to fulfill customer demand by the time restriction and optimize use of resources. This as well can reduce production waste.

Next, ALB’s important in manufacturing to optimize the resources used by creating an even flow in AL. ALB is to eliminate bottlenecks and surplus capacity; line balancing equals the workload across all processes in a cell or value stream. When there is excess capacity, waiting for downstream activities causes a constraint, which slows the process and increase operational costs. The bottleneck in production will produce a loss for a manufacturing company. The bottleneck is a problem where high-flowing production turn slows and create problem in the process, such as delay and low quality of the final product. Detecting bottleneck in the production will help improve the productivity of a manufacturing system.

Lastly, the objective of ALB is to create higher profit margin and decrease the cost of resources and materials. This can be achieved as in ALB; the result of implementation has strongly suggested can achieve better efficiency of resources use and increasing production capacity. A study conducted by Shi (2018) shows that the application ALB in semi conducted industry can improve production productivity.

2.5.2 Critical Component in Assembly Line Balancing

To understand the application of Assembly Line Balancing (ALB), first, we need know the critical component of ALB. The components need to be understood is such as:

i. Workstation

A workstation is a designated area where one or more employees perform a specific activity or group of duties during a production process. Workstations usually set up in sequential order on an Assembly Line (AL), and each workstation carry out a particular task on the product as it moves down the line. Depending on the nature of the production process and the jobs being performed, workstations can differ greatly in size, layout, and complexity. For instance, a workstation at a car manufacturing facility might have several employees as well as specialized tools, like assembly jigs or robots, to do a broad range of activities.

ii. Process Cycle time

Cycle Ttime (CT), which is calculated from the beginning of the first task to the conclusion of the last task, is the actual amount of time spent working on creating an item or rendering a service. Both value-added and non-value-added time are included in cycle time. The essential term in the definition is "actual," as many businesses use "cycle time" to refer to the anticipated amount of time it will take to produce an item, even though these two timeframes are frequently not the same. Formula to calculate Cycle Time (CT) are shown as in Equation 2.2

$$cycle\ time = \frac{Net\ production\ time}{Number\ of\ units\ produced} \tag{2.2}$$

iii. Task Sequence

Task balancing and task sequence relationships depend strongly on one another. The order in which tasks must be completed is referred to as the task sequence. In other terminology, it also known as Precedence Diagram. A visual representation of any arrangement in which work pieces must be completed complete the product's overall assembly. The tasks' relationships of priority, which dictate that one task be processed before another, are not broken. The complexity of precedence restrictions affects the number of potential workstations.

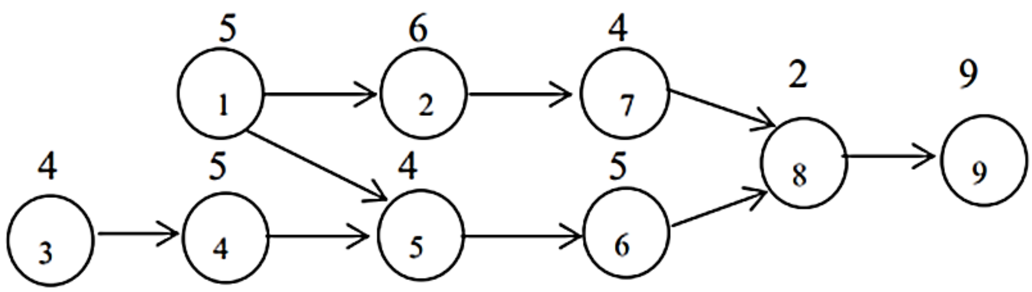

Figure 2.2 Example of Precedence Diagram

2.5.3 Steps of Improvement

Assembly Line Manufacturing is critical for effective and efficient manufacturing. The application of Assembly Line Balancing (ALB) is focuses on improving production capacity by streamlining production and eliminating inefficiencies; ALB can increase the overall output of the manufacturing process. This means manufacturers can produce more products in less time, increasing revenue and profits. Since the early days, Assembly Line has been introduced to increase capacity and improve production quality. The basic knowledge of Lean Manufacturing (LM) and Continuous Improvement (CI) have developed a better way of manufacturing according Khan (2019). As one of the important adaptations of LM, ALB is applied when there are several problems that need to be tackled in production. This methodology involves all resources and all level. In the industries, the number of competitors has risen, and to maintain competitive, ALB can be one way to sustain the company's production.

There are a few steps to implementing the method for ALB. This step determine wether the production line wants to be remodeled or the layout improved. Referring to Karatepe (2022), this following is the sequence of activities for the line balancing study after data collection. The first step before applying ALB is we need to create goals for our production line. This goal will be set and needs to be learned by entire organization. The objective is to set direction of the organization as in the industries to achieve productivity, process efficiency and improve quality. Then after goals have been created, the next step is to calculate the Takt Time of the production. TT is the tracking of time when available working time over customer demand. From Sordan (2021) and Chao (2022), To achieve a steady flow of production, it is essential to make sure that each process' cycle time is lower than the Takt Time (TT) and as consistent as possible. After that, the study of time needs to be carried out to establish the amount of time needed to execute each task throughout the production line. The time study will show the exact data of our production system and then analyze it using all the data gathered. Written by Sivasankaran (2017), determine task time and cycle time are steps to balance assembly line. Sordan (2021) wrote that the formula to calculate TT is as shown in Equation 2.3

$$Takt\ Time\ (TT) = \frac{Production\ Time\ Available}{Customer\ Demand} \qquad (2.3)$$

Next step is to identify the bottleneck points in our system. Identifying bottlenecks involves identifying the stage or process in a system where the maximum amount of time, effort, or resources are being consumed, resulting in a slowdown of the overall system's performance. Referring to Chao (2022), by eliminating bottlenecks can improve the productivity in production lines. When bottleneck point has been identified, the situation needs to be analyzed with different condition. This to test and make configurations to isolate the performance issues. After the bottleneck analysis has been identified, the next step is to optimize the point of the problem to improve the process flow. At this step, the process performance can be enhanced as the waste has been identified and can be improved. Then, from the identified data, we can determine the number of workstations needed for the whole manufacturing process. For the last steps, to make sure the goal is set in the earlier stage, a comparison needs to be made based on the result. The terminology here, by comparing the result, we can detect the problem happened in our production.

From all the steps of ALB, the tools of LM as the way to solve the problem are based on reviewing and analyzing the data collected in the production line.

2.5.4 Assembly Line Balancing Problem

Assembly Line Balancing Problems (ALBP) involve assigning tasks to a group of workstations that are arranged in a specific order so that each of the predetermined tasks is completed. To maximize a particular goal, the workstation's total task time must not exceed the Cycle Time (CT). An Assembly Line (AL) has a workstation, CT and jobs that are moving continuously in AL. Because of ALs are work in the flow process, the problem with its implementation is the change to the workstation or process can affect another process because of the continuous flow layout. The other constraint of Assembly Line Balancing (ALB) is some of the processes are important to the whole manufacturing. Thus, the process cannot be removed and need to be improved either its processing time or workload need to be reduced to avoid disturbance in the next process. In AL, many variables influence the output for a process, such as machine down time, and variation of task time and variance of customer demand. Furthermore, the ALBP involves distributing tasks to each workstation in a way that ensures that no precedence constraint is broken and that the total time spent on operations at each workstation does not exceed the permitted cycle time while optimizing some performance measure to ensure that the line runs as smoothly as possible.

In Assembly Line Balancing Problem (ALBP), its variants also are studied using several mathematical modeling techniques, exact algorithms, and heuristic approaches. Hueristic approach is a common method use in ALB. Refers to a method of problem-solving that is experience-based or intuitive, the most basic of which is trial and error. Becker (2006) have categorized ALBP into two main characteristics considering their constraint and purpose, which are Simple Assembly Line Balancing Problem (SALBP) and General Assembly Line Balancing Problem (GALBP).

2.5.4.1 Simple Assembly Line Balancing

The Simple Assembly Line Balancing Problem (SALBP) intends to determine how to allocate a set of tasks to a fixed number of workstations to minimizes the total time required to complete all tasks. SALBP is further divided into SALB-1, SALB-2, SALB-E, and SALB-F, where SALB-1 stands for reducing workstations, and SALB-2 stands for reducing cycle time, Yadav (2021). In this writing, it will be know as Type 1, Type 2, Type E and Type F. The standard type used in in research studies is Type 1 an and Type 2. It has direct method of solving the problem, although it has its own objective and constraints of its application.

i. Type 1- aims to minimize the number of workstations for a predetermined cycle time Yadav (2021). This approach is by determining the number of stations after the cycle time of each station is below takt time.

ii. Type 2- This method is reversed to the objective of Type 1. The processing time are changed due to the current number of stations throughou the whole process. As written in a study, it tries to minimize the cycle time for a predetermined number of workstations. Yadav (2021).

iii. Type E- Line productivity is increased by minimizing the number of workstations and the cycle time concurrently Cimen (2022). It also mentioned by Pinarbasi (2019) that Type E application is to maximize efficiency.

iv. Type F- Objective dependent problem, it is associated with the feasibility of line balance for a given combination of number of stations and cycle time written by Chutima (2020)

2.5.4.2 General Assembly Line Balancing

General Assembly Line are usually referred to Multi Model Assembly Line, U shape, Parallel Assembly Line and two-sided assembly lines, according to Chutima (2020). This problem approach method is for complex production systems such as multiple designs to produce and process variation. This method is suitable for company that have many customers demands. It also has been recognized to be adapted in industries to increase efficiency and reduced idle time by minimizing workload, number of workstations, and workspace. Becker (2006). Jusop (2015) Another problem that needs to comply to Simple Assembly Line Balancing are found to be General Assembly Line Balancing.

2.5.5 Assembly Line Balancing Model

There are three types of Assembly Line Balancing models that are used in the industries. The first model is Single Model Assembly Line. A Single Model Assembly Line is a single product manufactured in an assembly line. Provide advantage when the production does not have any variation in terms of process and design. The second model is the Mixed Model Assembly Line. This model is used for multiple flow processes and in a mixed-model assembly system, multiple unique products or models can be produced simultaneously while maintaining productivity, efficiency, and quality. In these settings, a single production line may have up to hundreds of thousands of different variations. The last model is Multi-Model Assembly Line. it is implemented to solve a problem that uses different product models or variations on a single assembly line.

i. Single Model Assembly Line.

The line continually produces a single identical product. Cimen (2022). It is mostly implemented in a company that only produce a single product and its benefits to mass production manufacturer. The example of Single Model Assembly Line is show in Figure 2.3.

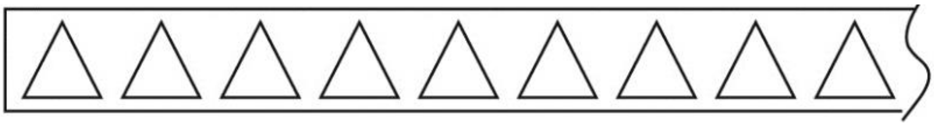

Figure 2.3 Single Model Assembly Line, Kumar (2013)

ii. Multi Model Assembly Line

This model is adequate for custom producion products in the automotive industry. Chao (2022), This type of model is able to handle many customers’ demands, such as a variation of parts and work processes. Since different models can be produced on the same production line without the need for separate lines, it increases production flexibility and efficiency. In this revolutionary era, the study has been developed as the competition in the industries is growing for variation in customer demand. The variation of inputs of Multi-Model Assembly Line are show in Figure 2.4.

Figure 2.4 Multi-Model Assembly Line, Kumar (2013)

iii. Mixed Model Assembly Line

In the job sequencing problem, batches of related goods are promoted since they can be produced consecutively with no setup, which cuts down on the total amount of preparation time needed for the production schedule. Sanci (2017) states that multi-model lines need additional lot sizing and job sequencing problem expansions. It is a production process that allows the production of multiple varied goods or models in a single step while maintaining productivity, effectiveness, and quality. This model helps to reduce operational costs as the multiple variation product is produced in a single line. It needs a highly skilled worker to operate the multiple tasks. The variation of inputs in Mixed Model Assembly Line is shown in Figure 2.5

Figure 2.5 Mixed Model Assembly Line, Kumar (2013)

2.6 Summary

Lean Manufacturing (LM) and Continuous Improvement (CI) philosophy have created Assembly Line Balancing (ALB) in the industries. The foundation of the methodology has brought significant improvement to the industries. It is proven since early 1900 that LM can help to reduce waste in production. Eight types of waste has been identified in LM, such as wastes of transportation, over-processing, waiting time, inventory, motion, excess production and underutilized talent for the human factor. By recognizing this waste, we can implement several suitable tools to reduce the waste. Examples of LM tools widely use in industries are Just in Time (JIT), Kanban, Total Quality Management (TQM) and Total Preventive Maintenance (TPM). Many studies show that these tools can improve productivity and quality. Researchers have stated that besides improving the production, it also can improve the working environment by setting a standardize working ethic in the organization. In addition, LM is the pillar of CI. The adaptation is to achieve maximum efficiency and higher profit margin in the business. Lastly, ALB is a method to apply statistical and analyzing method to detect unbalanced workloads and bottlenecks in the manufacturing system. The improvement is made to keep the assembly process in flow and take the benefits of modern technology meanwhile help to improve productivity. The model of Assembly Lines such as Single, Multi Model and Mixed Model Assembly lines, needs to be determine so the problem can be solved in an efficient way and the highest achievement can be achieved.

CHAPTER 3

METHODOLOGY

3.1 Preliminaries

The methodology section describes the approach and procedures used in conducting the research for the project. It includes details on the study's design, the methods used to collect and analyze data, and any specific techniques or tools employed. The flow of conducting this research is interpreted using flow chart, and the research method is explained in study's design. After that, the data collection process is performed in the real manufacturing case that is conducted through site visits. Then, the data will be analysed to reach the result and conclusion of this study. The purpose of this section is to provide enough information for others to understand and replicate the research, as well as to demonstrate the rigor of the study.

3.2 Design of Study

The design of a study is a structure or the collection of methods and techniques used to gather and examine information on the factors listed in a specific research subject. This section is important to the validity of method used during the research, and its shows the research variable and limitations that affect the research results. It can be used through two different types of methods such as Qualitative Research and Quantitative Research.

Qualitative research focuses on exploring and gathering data from a non-numerical study such as to understand claims supported by evidence such as journals, perspectives, theories, and personal experiences. This evidence can be collected through methods such as questionnaires, surveys, literature reviews and interviews with people involved in the research field.

On the other hand, Quantitative research takes more on statistical and numerical approach. The data is gathered, then measured and analyzed using variety of computation, formula, and calculation techniques. It allows for identifying the connection between collected data and the results using statistical measurement and analysis. Some studies provide a more comprehensive understanding when conducting the research.

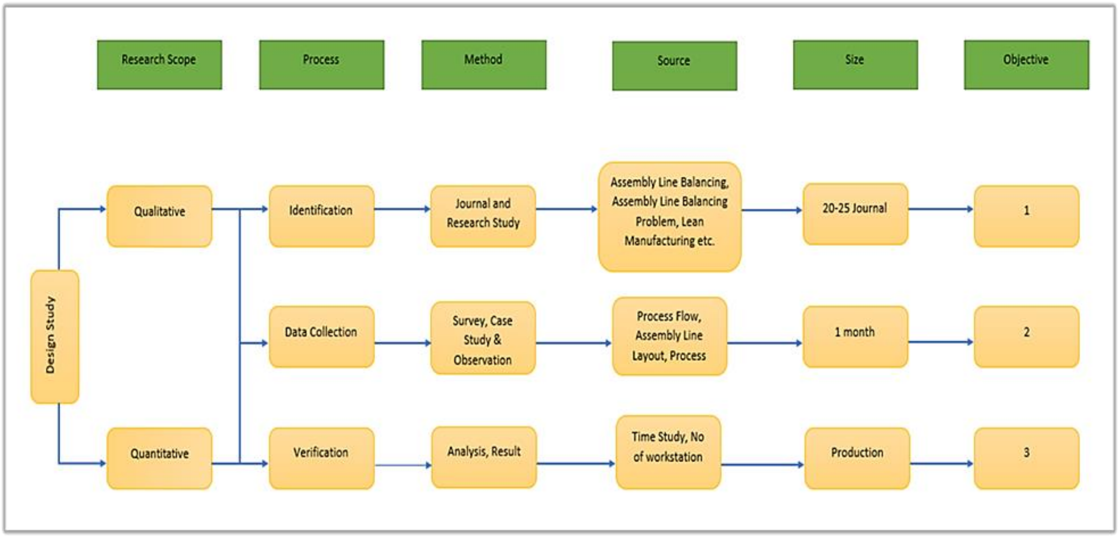

Figure 3.1 Design of Study

3.3 Flow Chart

A flowchart for research methodology is a visual representation of the steps involved in conducting a research study. It can be used to help researchers plan their studies, identify potential problems, and communicate their research process to others. The first step in research methodology is to define the research problem. This involves identifying the issue to investigate and developing a research question. The next step is to conduct a literature review. This involves reading and summarizing the existing research topic. The literature review will help you to understand the current state of knowledge on your topic and identify any gaps in the research. After defining the research problem and conducting a literature review, the process begins by developing a research design. This involves choosing a research method, collecting data, and analyzing data. The flowchart is just an overview of the steps involved in the research methodology. The specific steps involved will vary depending on the type of research study that is conducted. However, the flowchart can provide a useful starting point for planning and conducting the research.

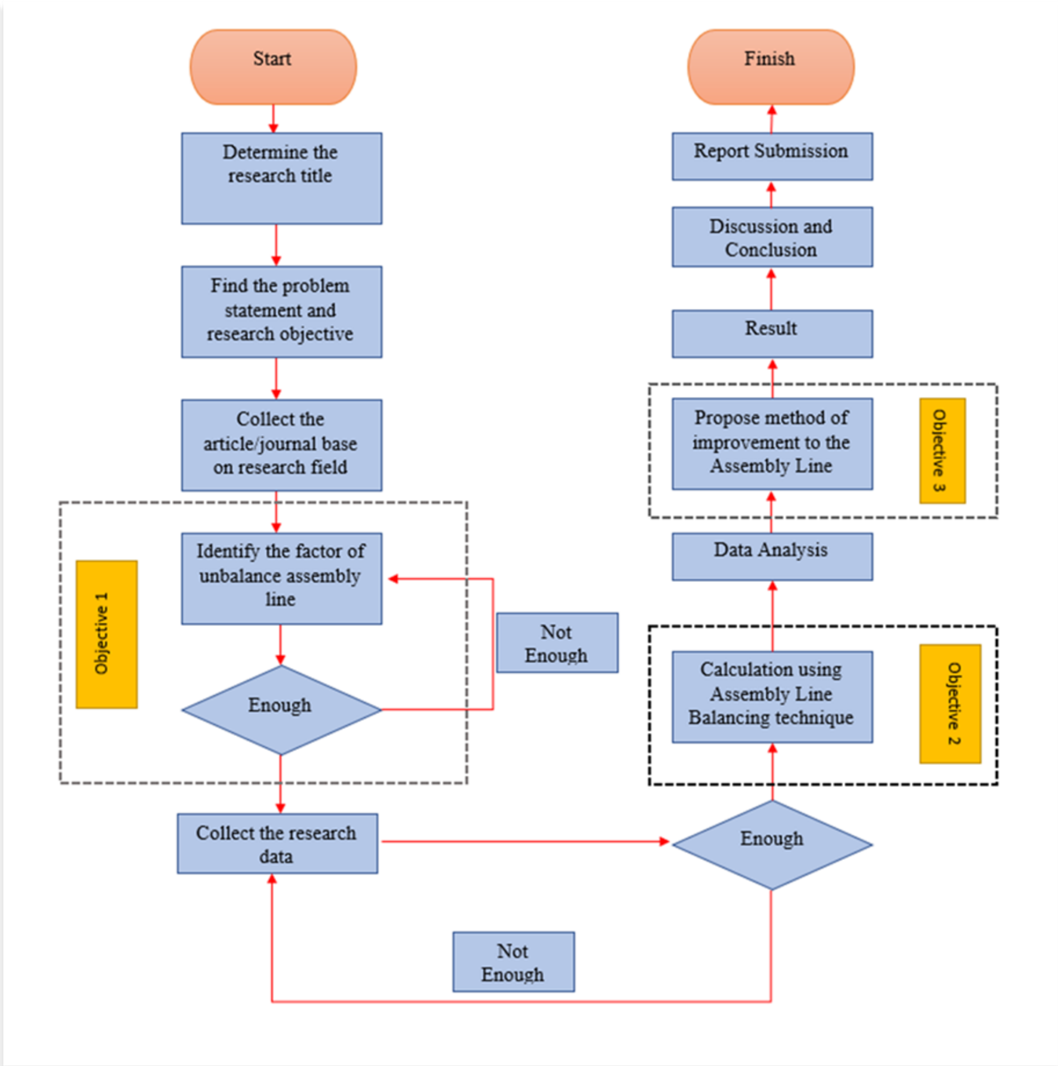

Figure 3.2 Flow Chart

3.3.1 Identify Research problem and Question

The first step that is taken in this research is to define the research problem and the objective of this research. Defining the research problem is a step to identify the difficulties in the industries and to highlight the issues in the area of study, mainly by investigating and requiring much information in the field of study. In this study, the main issues are from the assembly line in manufacturing industries. In an assembly line, the main problem is assigning a number of workers in the workstation and the skill level needed by the worker for doing the task. Other than that, the processing time is also a main problem that occurs in the industries. Creating a standard time for the whole process of assembly is a significant difficulty faced in industries as many factors influence the processing time, such as workers' capability, working process, and machine capability.

After the research problem is defined, the research question is created, aiming to be answered by this research study. The research question developed from the research problem and will set the methodology, and it will ensure the study is done systematically and thoroughly and that the findings are reliable and relevant.

3.3.2 Identify research scope and objective

The next step in the process to defining the research is to determine its scope and goals. The research scope is to set the parameters of this study and outlines the research's topic, intended audience, and methodology of this search. By identifying the research scope, it mentioned the field of this study, which is focus on manufacturing industries.

After that, identify the research objective is to create a specific goal through this study and define it base on the research problem. The research objective is important because it helps set the study track. The application of Assembly Line Balancing in the industries is mainly to create better working processes and create standard time in the assembly line. This research aims to review and improve the current assembly line in the transfomer manufacturing company. In addition, in this research, the objectives are categorize to three groups which are identification, data collection and analysis, and lastly, method of improvement. These objectives are defined as achievable, measurable and relevant to the research problem.

3.3.3 Literature Review

A literature review is used as a reference when conducting research. It is validated by earlier researchers in the field of studies. Then, it helps with data collection from a range of sources such as books, journals, and other suitable materials. The resources that are referred to in this study must have been published not more than five years ago before the year this research was written. It has been gathered, read, examined, filtered and summarized to make the resources helpful for this research. The ability to choose specific topics and fields allowed for the literature review to provide information for this research study. The collected information creates a strong foundation of knowledge use in this research.

The journal collected for this study is mainly focus on Assembly Line Balancing and Lean Manufacturing. Besides that, it covers the topic of efficiency, workstation, process flow and process time in the manufacturing industries. The literature review helps to identify the relevant formula needed and the proper method for analyzing the data to determine the number of workstations and standard time in the assembly line. Significantly, by referring to past studies will help to identify gaps and areas where the study can be carried out and provide good quality of this research.

3.4 Data Collection

Data collection step are crucial to make sure this research is conducted thoroughly. The data must be gathered from multiple resources aiming to answer the question of this research. These two methods are very common techniques used by past researchers, and they help to keep the research integrity. For this study, the data collected include the process time, production capacity and number of laborers assigned to each work station in the current assembly line. Accurate data is needed to make the research is valid. The validity of data depends on the method of collection; for example, to gather numerical data, the method of collection is the Qualitative method, and for description data are gathered from Quantitative method.

i. Qualitative Data

Qualitative data refers to non-numerical information that is collected through methods such as interviews, observations, or open-ended surveys. It involves recording individual opinions, ideas, and experiences in order to provide a rich and comprehensive understanding of a certain event or research topic. Qualitative information is frequently obtained as written or visual information, such as interview transcripts, field notes, or pictures. To find recurrent themes, patterns, and links within the data, researchers analyze it using methods like thematic analysis or content analysis. In this research, this method is used to gather data such as process flow of the assembly line and also its problem that conducted by interview and site visit at the manufacturing company.

ii. Quantitative Data

Quantitative data are numerical data that is gathered by measurements or assessments. It offers a precise and impartial data representation, enabling statistical and mathematical interpretations. Observations, surveys, experiments, and other methods can all yield quantitative data, frequently categorized or interval. Researchers can make hypotheses, reach meaningful findings, and promote evidence-based decision-making by using statistical approaches. For this study, this technique is used to collect data such as processing time, available production time, and the capacity of the current assembly line in the industry.

3.4.1 Interview

The purpose of interviews in research data collection is to gather information directly from individuals representative of the company. It belongs to qualitative method that allows us to explore more the experience, opinions and perspectives of someone who has been managing and working in the assembly line. This technique of data collection helps to get more clarification in the process of manufacturing and assists in getting more clarification of the detailed information for the working environment and work culture at the company. Data collection by interview is determined as Primary Data, and the validity of the data needs to be cross-referenced with another type of data collected with different method. It can be cross-referenced with surveys, document analysis and observation. The interview is conducted during site visitation at the manufacturing company, and the interviewee is a production manager, line supervisor and worker in the manufacturing line.

3.4.2 Observation

The observation technique is where data is gathered by observing the individual and situation that are happening in the field. This method is categorized as qualitative method. Using this technique helps to see the current manufacturing situation in their natural setting as this study is carried out based on actual data in the manufacturing industries. Other than that, observation help in noticing the problem in the current assembly line suitable to the objective of this research. Various techniques, including listening, reading, touching, and recording behaviour and phenomenon features, can be used to acquire data through observation.

3.4.3 Capturing Image

Another important method of data collecting is capturing images of the production line and the equipment that is being used. The main goal of taking the picture was to illustrate the study's primary objective, which to assess the manufacturing process at stations that might boost output. In conclusion, photographs serve as proof of the issues and make it simple to contrast the outcomes of the production process before and after using the Assembly Line Balancing method. Figure 3.3 show example of photograph taken during site visit at Company X.

Figure 3.3 Example of captured image

3.4.4 Document Analysis

Document analysis is qualitative research in which the researcher interprets materials to give context and meaning to a topic under review. Primary information, especially firsthand reports from persons who had firsthand experience in the industrial field, can be understood and classified with the aid of document analysis. Researchers in the past have built studies by gathering information and supporting data from trustworthy sources. This procedure enables a review of the documents used to assess their value and determine whether the data collected will be helpful for the studies. The procedure involves reviewing both electronic and paper documents in order to evaluate, comprehend, and build upon the information the document contains. This method is then are cross-referenced with other data collection methods to determine the similarities and differences.

3.4.5 Spreadsheet

The spreadsheet is a standard method of data collection used in the industries. Data that have been collected are then kept in the Spreadsheet software, and this research used Microsoft Excel. The spreadsheet also has many other functions, such as analyzing, categorizing and create data analysis diagrams, for example, tables and charts. This method also capable of holding big numbers of data and large data quantities.

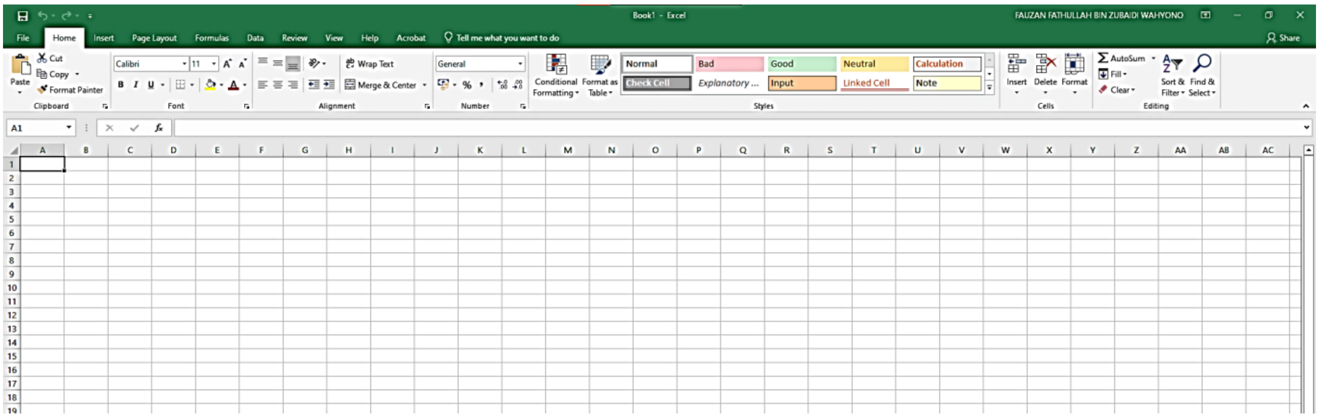

Figure 3.4 Homepage of Microsoft Excel

3.5 Data Analysis

A crucial step in the research technique process is data analysis. It is the process of analyzing data gathered during a research investigation using statistical and other methodologies. In order to find relevant information, support judgements, and support decision-making, data analysis is the process of analyzing, cleaning, transforming, and modelling data. Data analysis has many features and methods, incorporating various methodologies under various titles in various science and social research fields. Data analysis objectives are finding patterns in the data, testing hypotheses, and coming to conclusions regarding the study issue.

Data analysis is an essential part of the research process. It enables us to interpret the information gathered and make conclude the research question. Data analysis can be utilized to increase the effectiveness of the assembly line by determining the task precedence, process time, workstation capacity, and takt time. Then, data analysis also determine the optimal number of workstations and tasks that need to be assigned to the workstation. This help to increase production capacity, process efficiency and reduce idle time in the assembly line.

3.5.1 Cycle Time

Cycle time (CT), as used in manufacturing, is the time required to create one unit of a product. It considers the time invested in each stage of production, from the beginning preparation of raw materials to the last inspection and packaging. Calculation of CT is required desired production time divided by the available production time. CT is a crucial indicator for manufacturing companies since it can boost their productivity and profitability. The formula of calculating CT is show in Equation 3.1

$$Cycle\ time = \frac{Available\ time}{Desired\ Output} \tag{3.1}$$

3.5.2 Takt Time

Takt Time (TT) is the rate at which a product must be manufactured to satisfy consumer demand. It can be calculated by dividing the consumer demand by available production time. TT is vital for assembly line balancing because it ensures that the production line is moving at a pace that meets customer needs. Clients will face delays if the takt time is too quick because the production line will not be able to meet demand. The production line will be underutilized, and costs will rise if the takt time is too slow. The final product’s complexity, the production process’s effetiveness, and the workers' skill levels are the variables that might impact TT. Equation 3.2 shows how to calculate Takt Time.

$$Takt\ time = \frac{Total\ availabe\ production\ time}{Desired\ Output} \tag{3.2}$$

3.5.3 Number of Workstation

The number of workstations in Assembly Line Balancing (ALB) refers to the stations where work is done on a product as it passes down the line. ALB aims to produce a balanced line in which the amount of time needed to accomplish the task at each station is approximately equal. This guarantees that the line operates effectively and without any wasteful downtime. The least number of workstations that can finish all jobs in the specified period without going above the suitable production rate is the optimal number of workstations. The formula for number of workstations computations is shown in Equation 3.3 below.

$$Number\ of\ workstation = \frac{\sum Task\ Time}{Desired\ actual\ time} \tag{3.3}$$

3.5.4 Line Efficiency

After a fair task distribution, the next step is to assess the project's effectiveness. This approach can help find other areas that must be rebalanced and made more efficient. According to the equation , by enhancing machine time through balanced improvements and employee training, the cycle time can be reduced significantly. By reducing overall labour time, resizing line segments, such as increasing or decreasing the number of workstations in each sector, can also benefit a lean manufacturing approach. The formula for balancing efficiency in an assembly line is as shown in Equation 3.4.

$$Line\ efficiency = \frac{\sum Task\ Time}{Number\ of\ workstation \times Desired\ cycle\ time} \quad (3.4)$$

3.5.5 Identify the Root Cause of problem using Why-Why Analysis

The 5 Whys is a potent tool that may be applied to research as well as other contexts to determine the underlying causes of issues. The analysis can be done in an organized manner using a Five Whys template. To assist in determining the root causes of the current problem, templates frequently include some questions or prompts. This tradition is upheld by the 5 Whys technique, which works best when an individual provides the answers with first-hand knowledge of the process or issue in question. Example of Why-Why analysis method is shown as Table 3.1 below.

Main Factor	Problem	WHY 1	WHY 2	WHY 3	WHY 4	WHY 5	Root Cause

Table 3.1 Example of Why-Why Analysis Table

3.5.6 Identify issue using cause and effect diagram

A tool to find the source of a problem is a cause-and-effect diagram, commonly referred as a fishbone diagram. This approach enables a company to investigate several contributing factors to a problem. It demonstrates the underlying relationships between the problem and various factors. Using this method also aids in streamlining ideas and creating a thorough list of causes that could exist. This tool promotes collaboration and brainstorming, ensuring that a various viewpoints and thoughts are considered. The first step in drawing a cause-and-effect diagram is to decide which effect or problem you wish to address. Next, list the primary causes that potentially contribute to the issue. Once the reasons have been identified, a solution can be designed to eliminate or lessen the problem's primary cause.

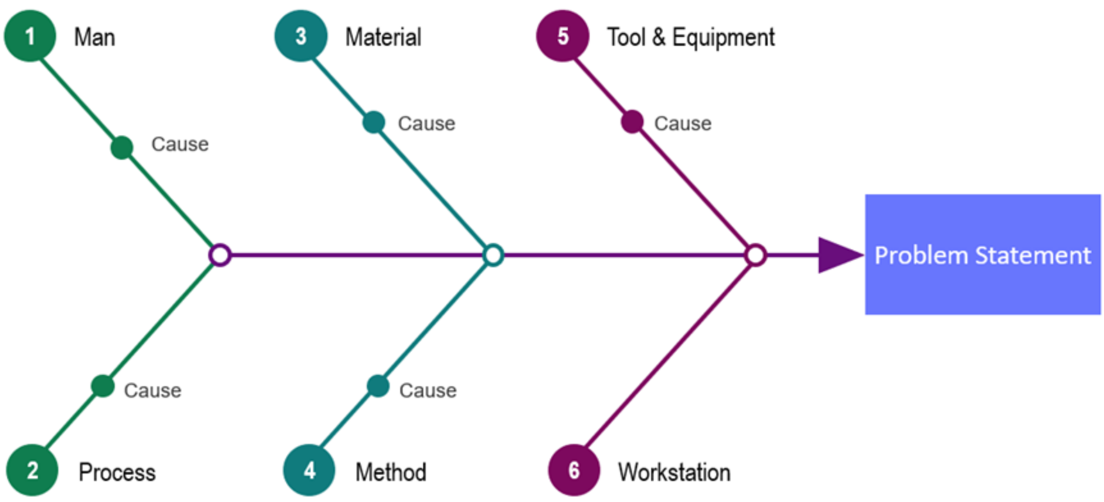

Figure 3.5 Example of a Fishbone Diagram.

3.6 Propose Improvement

To propose a method of improvement to the current assembly line is one of the process in this research flow. In this topic, ALB application can provide many advantages to the company but, the improvement method needs to be reliable and relevant to the current situation and environment. Organizations can improve their methods and get better results by implementing specific actions. First, a comprehensive study of the current methods must be done. This entails assessing the positives and negatives of the present strategy, locating inefficiencies or bottlenecks, and getting input from stakeholders. Organizations can identify particular areas for improvement and provide targeted solutions by recognizing the flaws in the current process. Mainly, this study's objective is to provide the option for improvement for the organization to be considered and implemented as the methodologies and the new results can obtained by this research.

3.6.1 Result and Dicussion

The result of this study is shown in this section. The final step of this study is to present a data collection that has been analyzed thoroughly by implementing ALB study. It will also show that this study can reach its objective in the first chapter. Furthermore, the results must be confront the research problem and be able to answer the proposed research question. As a result, applying an efficient assembly line balancing methodology can result in various positive outcomes, such as increased output, increased effectiveness, and better-quality goods. Organizations can increase manufacturing capacity, cut costs, and produce goods that meet or exceed customer expectations by optimizing job allocation and achieving a balanced workflow.

3.7 Summary

Finally, this chapter explains everything, from the flow chart to the conclusion and discussion. The first step is to create a flowchart that condenses the study's flow chart. Recording all relevant data is one of the most critical phases that must be concentrated on during the research process. The substance of the flowchart starts with the definition of the study problem.

The scope and objectives have been recognized using the flow chart as a guide. The mentioned challenges must be overcome is the goal. It will proceed to a literature review that has been read, analyzed, and summarized using the primary thesis of the study. The literature review resources depend on the research's goals, which are to identify the variables that affect manufacturing productivity and turnaround time. The data needed for the investigation is collected outside from that. There are two categories of data: quantitative and qualitative data. While qualitative data are captured photographs and discussions with factory workers, quantitative data are numerical data. Since these data may be statistically displayed, they are gathered, analyzed, and summarized in spreadsheets.

By using ALB technique, the data gathered are then analyzed with proper technique following all the rules and constrain of the method. Then, the outcomes of the data analysis will then be discussed in order to determine what changes need to be made. The data analysis will make the root of this research's issue clear. A presentation summarizing the results of the investigation will be made when these proposed revisions and reports have been submitted to the industrial panel.

CHAPTER 4

Result and Discussion

4.1 Preliminaries

This chapter is about the findings and presentation of data that have been collected during this study carried out at a manufacturing company, Company X. During this case study, the data were collected in real-time using the time study method, and some of it was provided by Company X workers. The data that have been gathered are then represented by using histogram, table and calculation by using the proper method of Assembly Line Balancing (ALB). In this research, the problem is identified by the Company X side and after that, the problem is assigned for this research suitable with this research title by using ALB tool.

In the ALB study, the information needed for the study is to determine the cycle time of an assembly process, the number of workers assigned to a workstation and the number of workstations in the current factory layout. This information then is analyzed and reconfigured with the knowledge of ALB. For this project, a manufacturing process to assemble part of the Honda Civic body frame as in Company X recognized model T20 and the part of the frame is Frame Comp Rear Right. The manufacturing process of this part contains spot welding and MIG welding. These manufacturing processes are held by robot and operated by humans. Although the process is semi-automated, the process is known to have the longest time cycle in the process of manufacturing T20 frame parts.

The data used in this research is gathered by using three methods consisting of interviews, real cycle time recording and observation of the assembly line. The data collected are then analyzed to get the solution for the problem that occurs in the manufacturing line. As in ALB the cycle time of the process is used in the calculation of Takt Time and to determine the optimum number of workstations for the assembly process. The data collected are verified and validated by Company X. The collected information needs to be sufficient and valid to provide a valid result for this study.

Lastly, after the analysis is completed, Company X is offered the improvement for the current assembly line. It was done to fulfill the third objective of this study. This is carried out after the cause-and-effect diagram and why-why analysis have been used to identify the root cause based on the affected region. Another technique utilized in the problem-solving process is DMAIC, which is well-known for being an efficient Lean Six Sigma tool.

4.2 Problem Definition

In Manufacturing, cycle time is defined as time duration of work in a station that can be done to produce a part. It is measured from the beginning until the completion of the part. In ALB, the measuring of cycle time is important as it will be used to calculate the Takt Time and the number of workstations needed for the process. During this process, the cycle time certainly will be affected by the workers' and machines' performance and also considering the delay caused by uncertain downtime during a process.

In this research, the problems that have been identified during the assembly of the Frame Comp Rear Right for the T20A model are the long cycle time and high number of workers assigned at the assembly line. This problem causes to increase in lead time and creates bottleneck in the T20A model assembly line. Product Lead Time is the sum of cycle time of a production process starting from the moment a customer places an order or request and ending with the product being delivered to the client. In the industry, when cycle time is high, it will affect the lead time to a product reaching the customer. The longer cycle time affects the efficiency of the process. Thus, it led to a decrease the productivity in the manufacturing process.

Lastly, the problem that is faced by this company is the difficulty in completing production demand within normal operation hours. Instead, the production demand is usually completed after its normal working hour which causes an increase in cost for the process especially in labor costs as to have workers working overtime, a higher wage is set to each operator and it is paid by hour.

4.3 Data Collection

During this process, all information is measured and gathered to perform the next step of this study. The data collection process is to gain knowledge and data of the current assembly line. It consists of company background, process flow and overall method of current situation at the company's assembly line. From the data that have been collected, then it will be able to analyze through calculation and method of Assembly Line Balancing (ALB). The data have to be reliable and backed by trusty evidence and eligible to be used to solve the research problem. Also, during this process, the method of data collection is one of the important aspects to make sure the data is valid. In this research, the data are split into two categories, Primary Data and Secondary Data. An appropriate data collection method reduces error in the result and minimizes error during decision-making.

In this case study, Company X is the manufacturing company where all the data are collected. Company X was founded in October 1990 and has been one of the big players in manufacturing automotive parts in Malaysia. Company X focuses on producing car frames for Honda Malaysia. This research focuses on the high cycle time of producing Honda Civic Frame Comp Rear Right in APL 6.

4.3.1 Primary Data

Primary Data is gathering the raw data from its source such as cycle time, idle time and the number of current workstations in the assembly line. This process involves interacting with workers, supervisors and visiting the assembly line. This is important because, for primary data, the data needed to have to be first-hand as it was not previously gathered or published anywhere and was specifically designed to meet the demands of the study. It gives more oversight and flexibility on the data collecting process and able to obtain information that is directly relevant to this research.

4.3.1.1 Assembly Line Layout

An Assembly Line (AL) is important for a mass production company. AL layout depends on the products that are being manufactured in the company. In the industry, there are many types of AL. There are Line layout, Process layout, Fixed Layout and Combination Layout. In this research, the AL Frame Rear Comp Right production is located at Assembly Production Line 6 (APL6) and in Company X (Pegoh Plant) the type of layout used is Line Layout. This type of layout is commonly used in the automotive industry as it helps in mass production.

Line Layout or Product Layout is where the machine and workstation are arranged according to the process of production. In this research, this type of layout is used in AL6 because the process of assembling the Rear Frame part is straightforward and the workstation is parallel. In AL6 there are 7 workstations where 2 tasks are held which are Spot Welding and MIG Welding. At the end of the AL, the finished product will go through a touch-up and finishing process.

Through this AL, there are 4 welding robot arms placed between 2 workstations. The robot arms are 3 spot welding robots and 1 MIG welding robot arm. Robotic arms were used to move with amazing consistency and precision. The robot and workstation layout are shown in Appendix D. The purpose of using the robot arm for the process is to assure standardization, accuracy, and compliance with standards, leading to high-quality welds on the chassis part.

4.3.1.2 Work Process Flow

In the field of manufacturing, work process flow means the order and procedures that go into making a product. It indicates the precise sequence in which duties, procedures, and phases are carried out while making a part and, in this study, it is the Frame Rear Comp for Honda Civic frame. In APL6 configuration, items move along the line in a predefined order, stopping at specified "work centers" to go through different procedures. The item may be moved using human work. Figure 4.1 shows the process flow of producing module Frame Comp Rear Right for model T20 at APL 6.

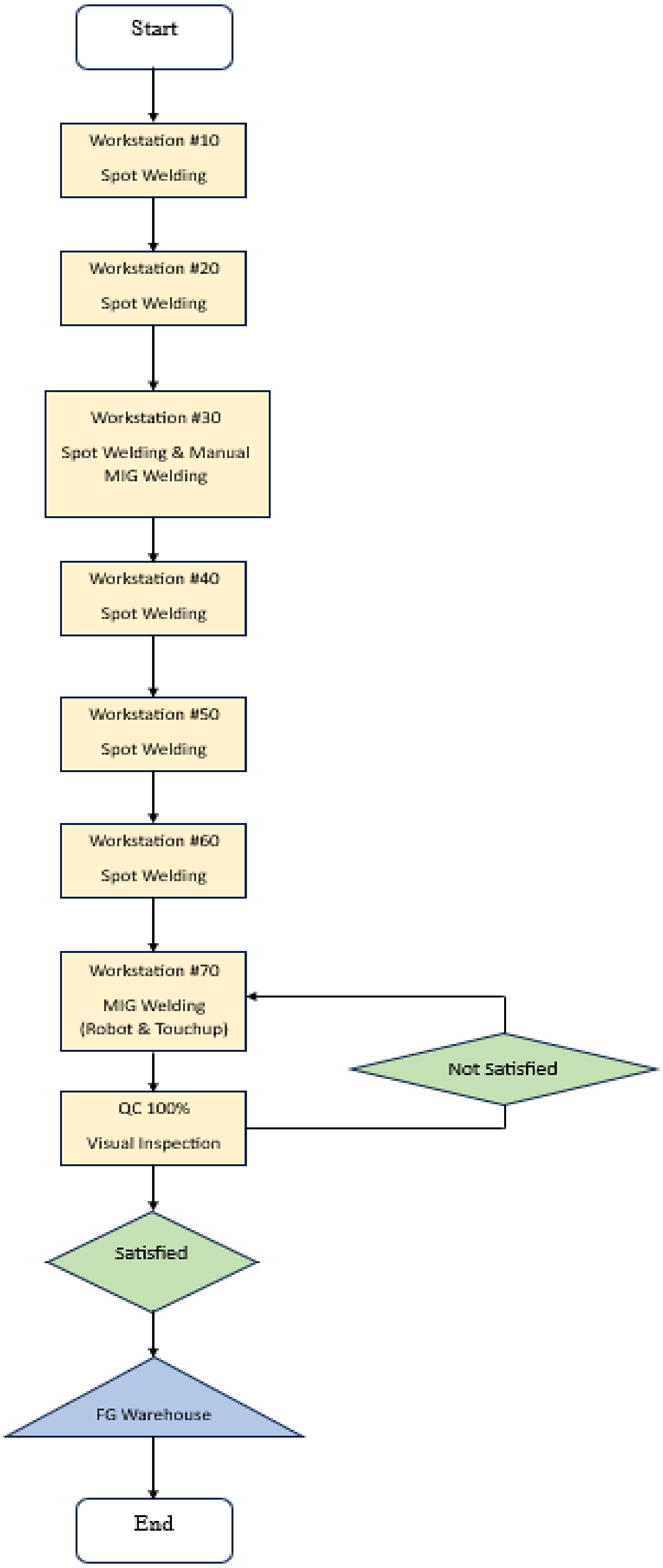

Figure 4.1 Process Flow Chart of Assembling Frame Comp Rear at APL 6

4.3.2 Secondary Data

Secondary Data is a type of data that has been collected, compiled and assembled by other parties. The use of this data is to support current research writing as this data contains the previous results. The advantage of using secondary data is it helps to gain more information about the research field. It also helps to identify the factors and problems in manufacturing and it helps to understand more about the field.

4.3.2.1 Time Study

A time study is a technique used in line balancing analysis to determine how long it takes to complete particular jobs or activities on a production line or during an assembly process. It involves monitoring and recording the time taken for employees to finish different jobs, taking into consideration all the steps needed, including gathering supplies, setting up tools, doing actual work, and taking breaks.

Cycle time is to measure the time taken for a unit of product to go through the whole process in the assembly line. For the Frame Comp Rear Right production, the cycle time is recorded from Workstation 1 until the end of the finishing process including the idle time. This cycle time recording purpose is to indicate the performance of the AL in producing a product. When task time is recorded, it also helps to detect to highest time consumption for the whole process and the bottleneck in the assembly line can be detect

Another component related to time study is recording the Idle Time in the production line. Idle time is an unproductive time when workers or machines are not doing any work inside the working hour. The purpose of recording Idle Time is to ensure the available production was used optimally and to help record the unproductivity factors inside the assembly line. As shown in Table 4.1, the table shows the time taken for the process in each workstation and the idle time of the part during the transition between processes.

Run		1	2	3	4	5	6	7	8	9	Average
Workstation											
#10 (Spot Welding)	Cycle Time	132	118	146	159	103	140	137	140	133	134.2
	Idle Time	66	71	75	76	79	56	55	61	65	67.1
#20 (Spot Welding)	Cycle Time	122	127	119	176	151	165	172	144	124	144.4
	Idle Time	48	69	61	32	55	50	45	33	42	48.3
#30 (Spot Welding / Mig Welding)	Cycle Time	140	159	152	140	116	120	115	157	155	139.3
	Idle Time	66	83	93	76	59	79	80	88	85	78.8
#40 (Spot Welding)	Cycle Time	116	132	151	145	156	124	151	141	139	139.4
	Idle Time	37	33	29	15	12	60	75	24	45	36.7
#50 (Spot Welding)	Cycle Time	114	113	215	92	106	135	104	100	122	122.3
	Idle Time	77	62	65	80	61	51	0	36	44	52.9
#60 (Spot Welding)	Cycle Time	130	127	131	150	154	156	145	139	190	146.9
	Idle Time	-	-	-	-	-	-	-	-	-	-
#70 (MIG Spot Welding & Touchup)	Cycle Time	150	140	127	90	116	105	116	82	125	116.8
	Idle Time	37	19	15	24	24	16	34	22	64	28.3
100% (QC)	Cycle Time	141	147	181	138	122	165	156	119	139	145.3
	Idle Time	-	-	-	-	-	-	-	-	-	-

Table 4.1 Recorded Cycle Time and Idle Time at APL 6.

4.3.2.2 Takt Time

Takt Time is a method of calculating the production demand over available hours in the production. Takt time is the rate at which a product or service needs to be produced or delivered to meet customer demand. The purpose of defining Takt Time is to set a benchmark for production to meet the demand. This is important as it can be used to eliminate waste in the current production line. Then after calculating the Takt Time, the line balancing method can be applied when the cycle time of each processing is rearranged to be under the Takt Time. Using a graph, when cycle time is managed to be under the Takt Time, the production will be able to meet the customer demand and also eliminate waste such as idle time.

During this study, the customer demand for the product Frame Comp Rear Right in November is 1410 units. For daily production for APL 6, Frame Comp Rear Right side is 150 which is planned for daily production when the production is running. After that, the available production hour is 8.25 hours and if needed, the available time for production Frame Comp Rear will have an additional 3 hours. This shows the calculation of Takt Time in APL 6 with the standard working hour in a day shift is 8.25 hours per shift.

$$Takt\ Time = \frac{(8.25\ x\ 60\ x\ 60)}{150}$$

$$= \frac{30300\ second}{150\ unit}$$

$$= 202\ second\ per\ unit$$

After the Takt Time has been calculated, a bar graph is used to show the distribution of the average cycle time and the Takt Time. In this case study, the Takt Time is set to get the performance of every workstation under the Takt Time line to meet the required production demand in a day. From Figure 4.1. the data shows that Workstation #30 has the highest cycle time and the bar graph is over the Takt Time. Because of this, it creates a bottleneck for the whole assembly line. In Figure 4.2, the standard cycle time at APL 6 shows that the workstation #30 is the bottleneck for Frame Comp Rear Right production.

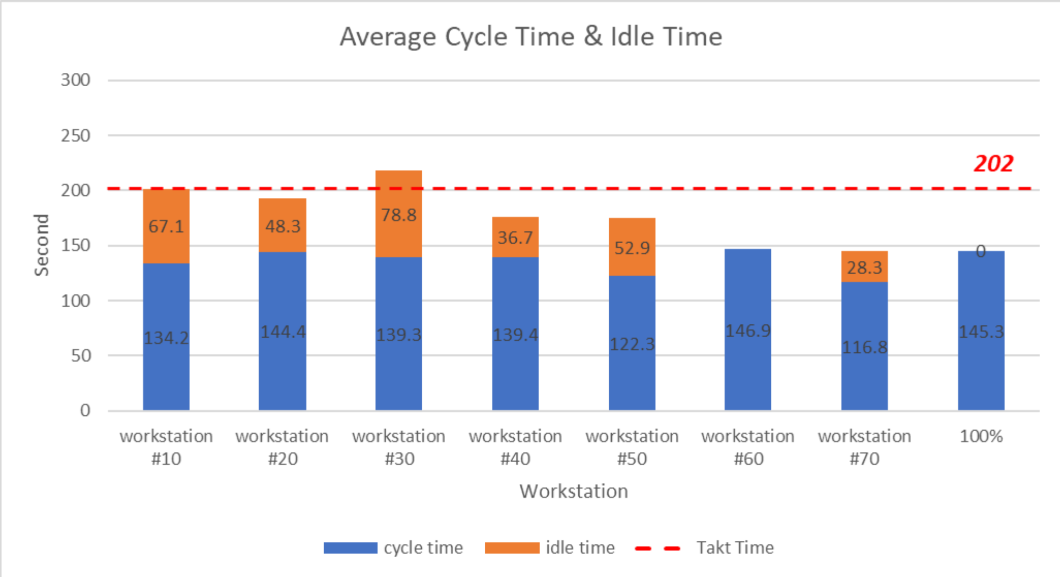

Figure 4.2 Takt Time set for every workstation.

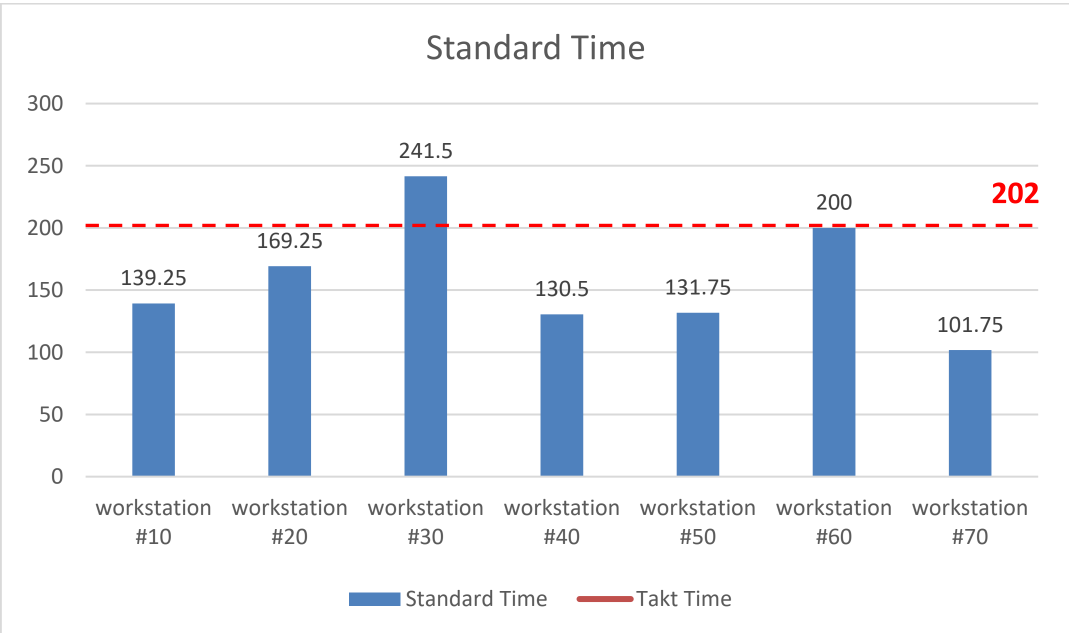

Figure 4.3 Standard Time for every workstation with Takt Time.

4.3.2.3 Number of Workstation

Total Cycle Time = 134.2+144.4+139.3+139.4+122.3+146.9+116.8+145.3

= 1088.6 seconds

$$= \frac{1088.6}{202}$$

= 5.3 $\approx$ 6 workstation

In APL 6 there are 7 workstations to carry out the assembly process of Frame Comp Rear. These workstations are arranged in a continuous flow where between 2 workstations is placed 1 W.I.P table where the part is waiting to be handled for the next process. Using Equation 3.3, the total processing time is divided by the takt time and the result shows the optimum number of workstations for the whole process is 6 workstations. Thus, the current workstation needs to be reduced to reduce waste of man and reduce cost.

4.3.2.4 Production Performance

An activity, task, or operation's performance is determined by how effectively it is executed. Performance can also be used to determine a product's or machine's capabilities under certain conditions. Production performance can be varied because there are many factors that can affect the randomness during the production such as human error and machine breakdown. These factors need to be taken into consideration because it will happen during production and will affect the production performance.

Available Working Hours in Production Line	
Working Days	5 Working Days
Shifts	2 Shifts
Working Hours/Shift	8.25 Hours (495 Minutes)
Breaks	1.08 Hours (65 Minutes)
Overtime	3 Hours
Machine Operating Hour	24 Hour (1440 Minutes)
1 Day Production	150 Unit
Product	Frame Comp Rear (T20A)

Table 4.2 Data of Available Hours at Company X.

4.3.2.5 Processing Requirement

In this part, it will determine the hours required during the month to produce 1410 units of product. From the data in Table 4.1, time needed to produce 1410 unit is 5758 minutes. Next, when 5758 is divided with time per shift 495 minutes, it resulting to 12 shift is needed to achieve customer demand. Then, with 245 seconds set to produce 1 unit in APL 6, a shift will produce approximately 112 units.

a) Standard Cycle Time per Unit set at Company X– 245 second per unit

b) Design capacity per hour with 100% performance

$$= \frac{60\ x\ 60}{245}$$

$$= \frac{3600}{245}$$

$$= 14.68 \approx 15 \text{ units per hours}$$

The standard capacity for APL 6 at Company X is 120. Thus, using the results of the design capacity per hour, to complete 120 units of product, it needed 8 hours of working hours. From the data that has been gathered at the company, for production demand per day

$$\frac{120\,units}{15} = 8 \text{ hours}$$

c) Actual Line Capacity

From the data that have been provided by Company X, the actual production of line APL 6 for production Frame Comp Rear is 15 per hour. Thus, the time needed to meet the production demand per shift is 10 hours. In spite of this, it needed extra 2.75 hours to complete the production demand per day. With 100%, the cycle time of every workstation as shown in Table 4.1 is, for a unit of Frame Comp Rear to complete the whole process is 1088.6 seconds.

4.3.2.6 Line Efficiency

To increase the production capacity, the assembly line needs to be efficient. For assembly line APL 6, the current production capacity is 150 units per shift with 8.25 working hours. To occupy monthly demand, assembly line APL 6 need to increase its capacity. The calculation is made to compare the efficiency by using the current cycle time of Company X and new cycle time that are set in the Time Study method. The line efficiency is related to the operator, machine and method. ALB help to increase the line efficiency by balancing the workload in workstation and reduce the downtime in workstation.

Calculation of line efficiency using current Cycle Time at Company X

$$Line\ Efficiency = \frac{1088.6}{7 \times 245}$$

$$= 0.63$$

$$0.63 \times 100\%$$

$$= 63\%$$

Calculation of line efficiency using New Cycle Time

$$Line\ Efficiency = \frac{1088.6}{6 \times 202}$$

= 0.89

$$0.89 \times 100\%$$

$$= 89\%$$

4.3.2.7 Production Yield

By measuring productivity of the production line, it helps to increase the efficiency. Productivity is affected when there is a bottleneck in the production line. When there is a bottleneck anywhere in the production line, the time constraint of producing the product demand for the day is high thus it reduces the efficiency of the production line. In the past research, the application of line balancing has been using calculation of the production productivity. For this study, the productivity is calculate using Formula 4.3.2.1. This formula is then use to calculate the AL6 productivity with the data that have been collected during the visit at Company X.

$$= \frac{150}{150}\ x\ 100\ \%$$

= 100 %

From the calculation, the output of current assembly line is 100 % with working hours of 8.25 hours and extra working hours for 3 hours. As planned, APL 6 of Company X need to produce 150 unit of Frame Comp Rear Right in a day. The actual output of APL 6 meets the required output per day with 3 hours of extra working hours

4.4 Data Analysis

4.4.1 Cause and Effect Diagram

Cause and Effect Diagram is a problem-solving method used to find and examine potential reasons for a particular issue. It is sometimes referred to as Ishikawa or Fishbone analysis. The Fishbone analysis, Figure 4.3 derives its name from the way it looks—it resembles a fish's skeleton. Man, Machine, Material, and Method, or the 4M factors, are relevant to production and manufacturing. It is taken into consideration when carrying out a Fishbone analysis.

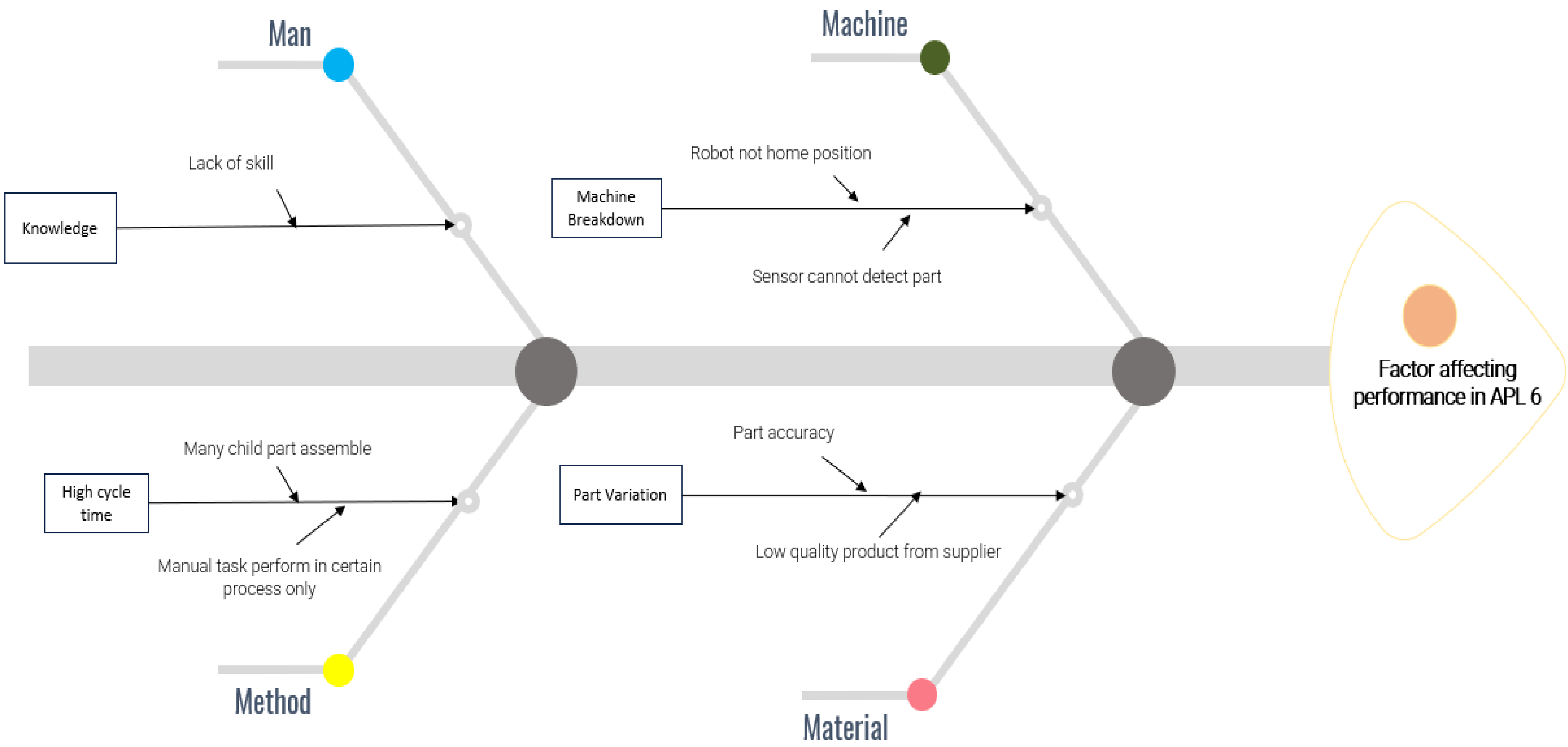

Figure 4.4 Cause and Effect Diagram of factor affecting performance at APL 6.

4.4.2 Why-Why Analysis

Why-Why Analysis is known as a tool to identify the root cause analysis. This method is used as problem problem-solving method in the Manufacturing Industry and any other field. The basic rule to implement Why-Why Analysis is to ask the “WHY?” question into the problem until it finds the root cause for the problem. For this research, the Why-Why analysis method is used after the problem is defined and after that by using Fish Bone diagram, the problem is expanded to help detect the root cause of the problem. The using of the method of Why-Why Analysis helps to resolve the underlying cause and aids in preventing the issue from recurring. Since the root cause can be identified, the proposal for improvement toward a more balanced production can be given to the manufacturing company. To sum up, this technique helps this research to able to solve the problem of the current issue of assembly line until it roots cause.

The factors that affect performance in current AL are Man, Machine, Material and Method. Firstly, the issue faced by the AL is when the machine stops during process usually during the cleaning of the tips. For this MIG Robot Welding Arm, after processing a unit of part, the rod needs to be cleaned at the dressing area. When the dressing area is not well maintained of its cleanliness, the tips usually will hang because of the dust collected at the tips. In the Why-Why Analysis Table 4.3, the root cause of the problem is referred to workers not following SOP in the workstation. For this reason, it also causes the jig to be jammed because of too much sputter collected at the sensor pin. When a workstation is finished a process, the part is removed and after that, the display monitor turns green signaling the jig is ready for the next part. In this case, after removing the part, the sensor stays red as the sensor detects the part is not removed after finishing the process. This happens because of too much sputter collected at the sensor tip.

After that, the Method factors that affect the performance is the presence of a bottleneck for the whole process. At workstation #30, there are manual MIG welding is held to combine a child part with the mother part. Then, the part will continue through the automated spot-welding process. With the Time Study result, workstation #30 and #40 have the highest cycle time and after finishing the process at workstation #30, the WIP part has the highest idle time. Because of this, the bottleneck occurs for ALP limiting the capacity of APL 6.

Lastly, the 4M factor that affects the performance is APL 6 is the Man issue. This issue is presence when there is a manual process is held in the semi-automated production line. Because of this, it increases the cycle time at the workstation thus creating a bottleneck in AL. Therefore, it influences the production yield of Frame Comp Rear production.

	Problem	Why 1	Why 2	Why 3	Why 4	Why 5	Root Cause
Machine	Machine breakdown	Sensor not detects part	Spatter collected at sensor	The area at the sensor is not properly clean	Workers not follow SOP		Improper step of process carried at workstation
		Robot not return to home position	Too many dirt at welding tip	Cleaning area is dirty	Cleanliness is not maintained regularly	Workers not follow SOP	Improper step of process carried in workstation
Method	Too many movements of worker in workstation	Many processes occur in workstation	Many steps feeding child part to machine	Child part not organized accordingly	Limited work space in workstation		Limited workspace to store child part that increase movement to worker
	Manual MIG welding is performed by worker	Robot arm unable to perform task	The angle and reachability of robot arm is limited	The dimension of part is too small			Limited task can be performed by robot arm

Material	Part Variation	High part variance	Poor part accuracy	Poor material handling			Inefficient material handling practices in warehouse
	Low quality parts supply	Inadequate quality assurances at warehouse	Lack of comprehensive inspection procedure	Personnel responsible for quality control lack proper training	Inadequate control of material and steps of material handling		No proper system of quality assurance for incoming parts at warehouse
Man	Poor of knowledge	Lack of welding skill	Shortage of welding training program	Constraint of tools for training and program	Lack of opportunities for advancement or career growth		Lack of emphasis on employee training and development for workers skill growth

Table 4.3 Table of Why-Why Analysis carried at APL 6

4.5 Process Improvement

Process improvement in the Assembly Line (AL) need to be implemented to increase the capacity of the assembly line. To solve the issue of the improper method of worker to follow the SOP, a clear and comprehensive training are needed to make sure the workers follow the SOP accordingly. By following the proper SOP, it can help to reduce the possibility of the robot arm and jig to be breakdown during the production.

According to Table 4.3, as stated in the first problem observed is improper step of following the Standard Operating Procedure (SOP) causes the machine to stop working because of maintenance that need to be carried during process. This problem can affect the performance of the AL. For improvement, a training need to be carried to make sure the workers are following the SOP. Company X can provide more comprehensive and understandably guide and SOP for workers so that they know how to do the task correctly and why it need to be followed. Furthermore, by reducing the repetition rate of the unexpected machine breakdown, it can increase the efficiency of the AL.

Secondly, after the time study carried out in the topic 4.3, the bottleneck for the whole process is identified. Afterward, to improve the current AL, the cycle time at station which have the bottleneck need to be reduce. Therefore, by reducing the cycle time at bottleneck station it can increase the whole operation. In APL 6, the highest cycle time is at workstation #30 and #40. Firstly, any non-value-added activities need to be minimized and equip highly efficient robot to reduce the cycle time. To be specific, the high cycle time at workstation #30 is because there is a manual MIG welding need to be carried out. Because of this, a highly skill worker is needed to perform the task. By increasing the ability of the workers to able perform the task, the company should increase the number of in-house trainings. It can help develop more of the employer skill and knowledge.

In addition to improve the method in APL 6, reducing the movement of workers can affect the performance of workers and AL. Through Assembly Line Balancing (ALB), one of the methods to improve the capacity of assembly line is to balance the workload of each workstation. With reference to Figure 4.1, it is possible to lower the cycle time at the workstation and set it below the Takt Time by transferring the task to other workstations and minimizing the cycle time at workstation #30. Based on ALB study, by setting the cycle time of workstation below the Takt Time, it can help the AL's capacity to meet the required production per day. Other than that, balancing activities in workstation and create ergonomic workspace can increase workers performance. Creating ergonomic working space is such as the part is put around the worker spot and increasing the reachability of workers toward the part. An ergonomic workspace can reduce fatigue and improve productivity of the workers

Then, to improve the material handling problem that occur at Company X. It should imply proper step of material handling during receiving the child part from vendor. This to make sure that the received child part is compatible and suitable to be process in the assembly line without other additional non-value-added activity later in the production line and can affect it production yield. To reduce the part variation, a standardize handling method should be implied during receiving and material handling when transfer parts to production trolley.

Table 4.4 shows the root cause and step of improvement proposed to Company X. It helps to overcome the issue that occur in APL 6.

Factor	Root Cause	Improvement
Machine	Improper step of process carried at workstation	- Provide clear and comprehensive training - Continually Examine and Strengthen SOPs
Method	Limited workspace to store child part that increase movement to worker	- Increase the ergonomic in the working space. - Review current layout and working area in workstation
	High cycle time at workstation	- Reduce manual welding point to reduce cycle time - Transfer activities to workstation in front to reduce process time and balance workload
Material	Inefficient material handling practices in warehouse	- Apply proper machinery to improve efficiency of material handling such as pallet jacks, trolley and ergonomic tools for material handling - Optimize workflow of material kitting upon receiving for better efficiency material handling
	No proper system of quality assurance for incoming parts at warehouse	- Create a proper system to make sure the quality of incoming parts is following the standard
Man	Lack of emphasis on employee training and development for workers skill growth	- Provide training and skill development program to skilled worker - Provide monitoring and performance feedback - Improve the condition and ergonomic in workstation

Table 4.4 Root Cause and Improvement

4.6 Control Improvement

On the last phase of practicing DMAIC is Control. This control phase is to sustain the improvement method that has been propose during the improvement phase. Base on the suggestion, to maintain the worker to comply the SOP is company can create more detail work process for every station stressing about maintaining the cleaning in the workspace as the sputter from the welding process and can slow the process in workstation. Another method to control the improvement method is to make a constant monitoring and measurement. For instance, to monitor the worker comply the SOP, a check sheet can be used and it can be used to monitor the frequency of the machine breakdown based on the problem mentioned such as the sputter problem and the welding tip at the MIG welding robot. The check sheet is used to monitor the downtime of the machine especially at workstation #50 and #70 where problem that causes by poor compliance of SOP occur.

Control charts and SPC software are examples of monitoring tools that function as watchful sentries, continuously tracking performance and warning the process of deviations. The strong walls are formed by standardized paperwork, which guarantees uniform execution by all. As knowledgeable intermediaries, regular training and communication keep everyone informed and involved. Root cause analysis turns into your creative engineer, plugging holes and fortifying protections. Combining these techniques enables the business to establish a long-lasting system that safeguards the methods of development and guarantees ongoing advancement in the manufacturing process.

4M	Propose Improvement	Control Method
Machine	- Provide clear and comprehensive training - Continually Examine and Strengthen SOPs	- Provide check sheet to monitor the downtime of the machine based on the problem occur. - Standardization of workflow in workstation that is to understand to follow.
Method	- Increase the ergonomic in the working space. - Review current layout and working area in workstation	- Use control chart to gain feedback on the changes that implemented for future assessment. - Implement 5S method to create standardization in work environment.
	- Reduce manual welding point to reduce cycle time - Transfer activities to workstation in front to reduce process time and balance workload	- Process monitoring system is a method to ensure the improvement steps such as Statistical Process Control (SPC) - Process audit using dashboard or software system.
Material	- Apply proper machinery to improve efficiency of material handling such as pallet jacks, trolley and ergonomic tools for material handling - Optimize workflow of material kitting upon receiving for better	- increase technology investments with technologies for higher process efficiency. - Foster a culture of continuous improvement by encouraging

	efficiency material handling	ongoing suggestions and experimentation with new techniques to further optimize the workflow
	- Create a proper system to make sure the quality of incoming parts is following the standard	- Install software that monitors production data automatically, including output quantities, cycle times, and scrap rates. For precision, this can be integrated with RFID tags or barcode scanners.
Man	- Provide training and skill development program to skilled worker - Provide monitoring and performance feedback - Improve the condition and ergonomic in workstation	- To see the key performance indicators (KPIs) associated with the improvement, use performance dashboards and reports. - Mapping the employers skill program for better skill development progress - Use ergonomic effect analysis to monitor the working condition in workstation.

Table 4.5 Control Method to sustain improvement in Assembly Line

4.7 Summary

For the summary, this chapter shows that the approach of Assembly Line Balancing (ALB) study to improve line capacity at Company X. The approach in this chapter is by using DMAIC method. In the early phase of DMAIC, the problem defined in APL 6 is the high cycle time and high number of workers assigned for the whole process in APL 6. After then, the next phase of DMAIC is to measure the current assembly line data in order to get information about the problem in the assembly line. The data measure is collected and categorized in two category, Primary Data and Secondary Data. From the data that have been collected, the bottleneck in the assembly line can be detect. Through ALB study, during the measure phase is where cycle time, Takt Time and number of workstations is determined.

Based on the finding in Measure phase, the problem and root cause are analyzed during Analyze phase. In this phase the method to find the root cause for the problem is Fishbone Diagram and Why Why Analysis. This method is then separated by using 4M which is Machine, Method, Material and Man. Hence, by using this technique it can help to locating bottlenecks and causes that affecting the productivity of in the current AL.

Finally, the root cause of each problem is proposed with improvement technique and the method to control the improvement method. These two steps are the last steps of DMAIC which are Improvement phase and Control phase these two is depending on each other. This proposal of improvement technique is to ensure that current AL can increase its capacity and help Company X gain more profit in the future.

CHAPTER 5

Conclusion

5.1 Conclusion

Assembly Line Balancing (ALB) is a well-known method to improve capacity and efficiency in assembly line. By implementing ALB in automotive industry, it benefits the entire production process. A balanced assembly line produces finish goods quickly by reducing idle time and assuring a constant workload across stations. Through ALB practice it enables each worker contribute to the maximum potential, resulting in a noticeable rise in output. As evidence, through ALB it helps APL 6 to reach planned production demand from 150 units per shift include with extra 3 working hours to 150 per shift without extra hours. By optimizing workflow and minimizing bottlenecks, balanced lines can readily accommodate changes in model variants and production schedules. Other than that, lean manufacturing is practice in assembly line by reducing the unnecessary movement and reduce idle time of man and material during process.

First objective of this research is achieved through measuring data at APL 6 at Company X. The study of past research and journal help to identify the factor of unbalance assembly line. Then, from the data collected, it is able to achieve the second objective. The data is collected categorized into Primary and Secondary data collection where the data is collected through interview, observation, time study, ALB calculation of Takt Time and calculation of optimum workstation in the assembly line. The process of identify the root cause is using DMAIC method, Why-Why Analysis and Fishbone Diagram. Subsequently, the final objective of is accomplish after the root cause is identify. The improvement method is proposed to each of the root cause. Emphasizing the method of DMAIC, after the data is measure and analyzed, the improvement phase is held towards the problem.

Finally, the control phase in DMAIC is a crucial stage. Its key goals are to keep up the progress made in earlier stages and avoid future problems. Regression is avoided and the continual viability of the improvements made during the Improve phase is guaranteed during the Control phase. This results in long-term cost reductions, improved quality, and optimized processes.

5.2 Contribution

Studies on assembly line balance take an active role in distributing work optimally to guarantee a smooth production process. These studies create balanced line configurations that reduce idle time, bottlenecks, and worker fatigue by examining task durations, precedence limitations, and worker skills. This study made a significant contribution to improve efficiency, productivity and capacity in manufacturing line.

Key areas where this research has impact is identify the problem that limit the capacity of current assembly line. Secondly, it helps to set a new standard task time in every workstation in order to increase the line capacity per shift. Moreover, this study has provided new data and improvement steps for assembly line to eliminate waste and preventing additional lost toward a manufacturing company. It is helpful to implement the right strategy that will produce high-quality products and to address the long-term problem of creating more things as a consequence of this research.

One must understand that the subject of assembly line research is always changing and that discoveries are being made regularly. We may anticipate even more creative solutions to arise as technology progresses, which will raise assembly lines' efficacy and efficiency even higher.

5.3 Improvement for Future Research

In future research, improvement can be made to study the implementation of method that have been proposed and following up the control process. The monitoring of the proposed improvement may help to produce more useful outcome of the research. A longer process of implementation can benefit to develop an adaptive line balancing method that can consider real-time monitoring of each worker's skills, preferences, and state of exhaustion helps to further optimize task allocation and employee well-being.

In addition, the future research can be conduct with more engaging with technology as the development of technology creating exciting opportunities to gain more data visualization tools. Other than that, technology can improve the method of data collection. Through this improvement, it creates more proactive research and solely focus on the essential aspect of the research study. The finding can produce new knowledge and solution to the problem occur in manufacturing field.

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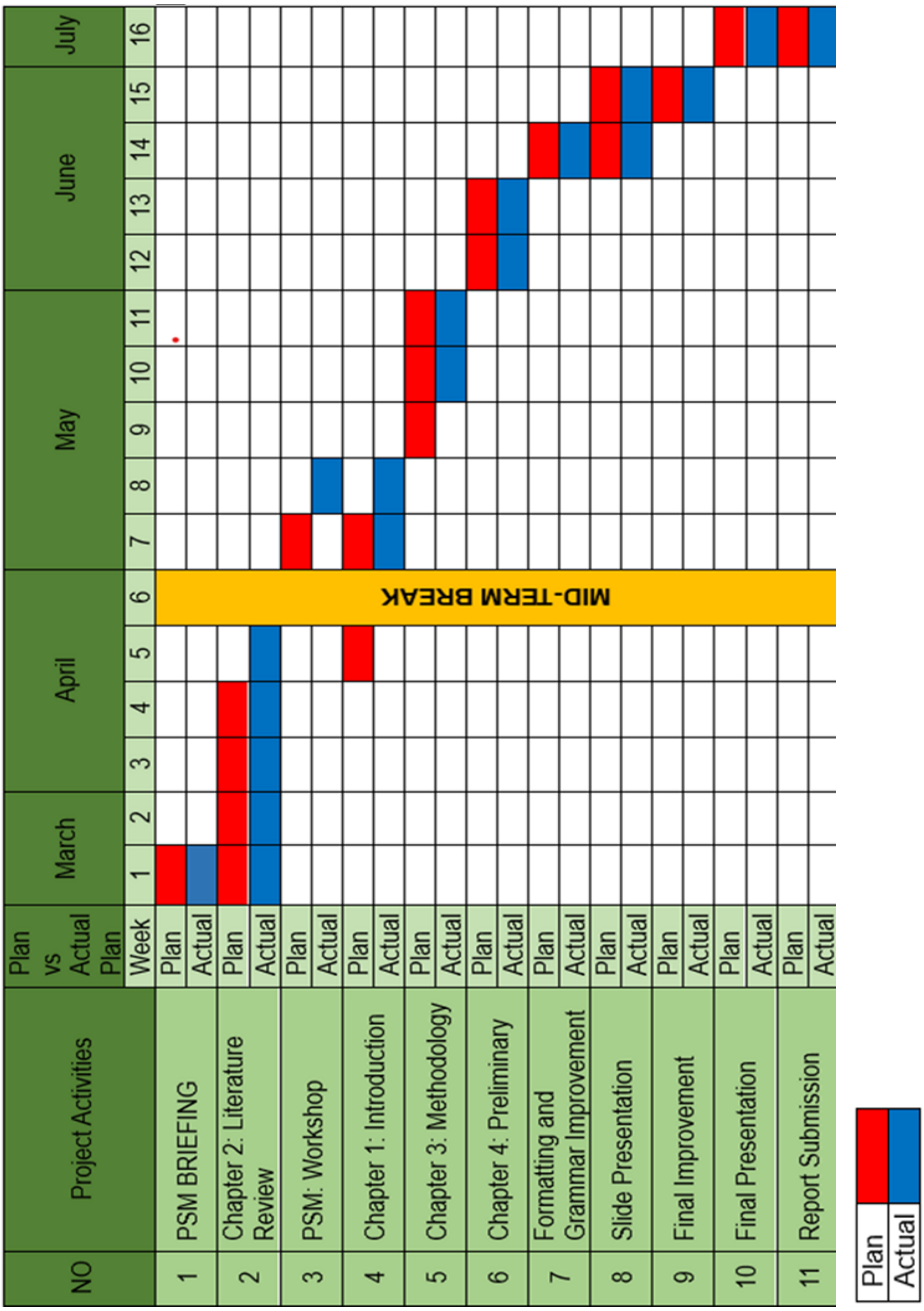
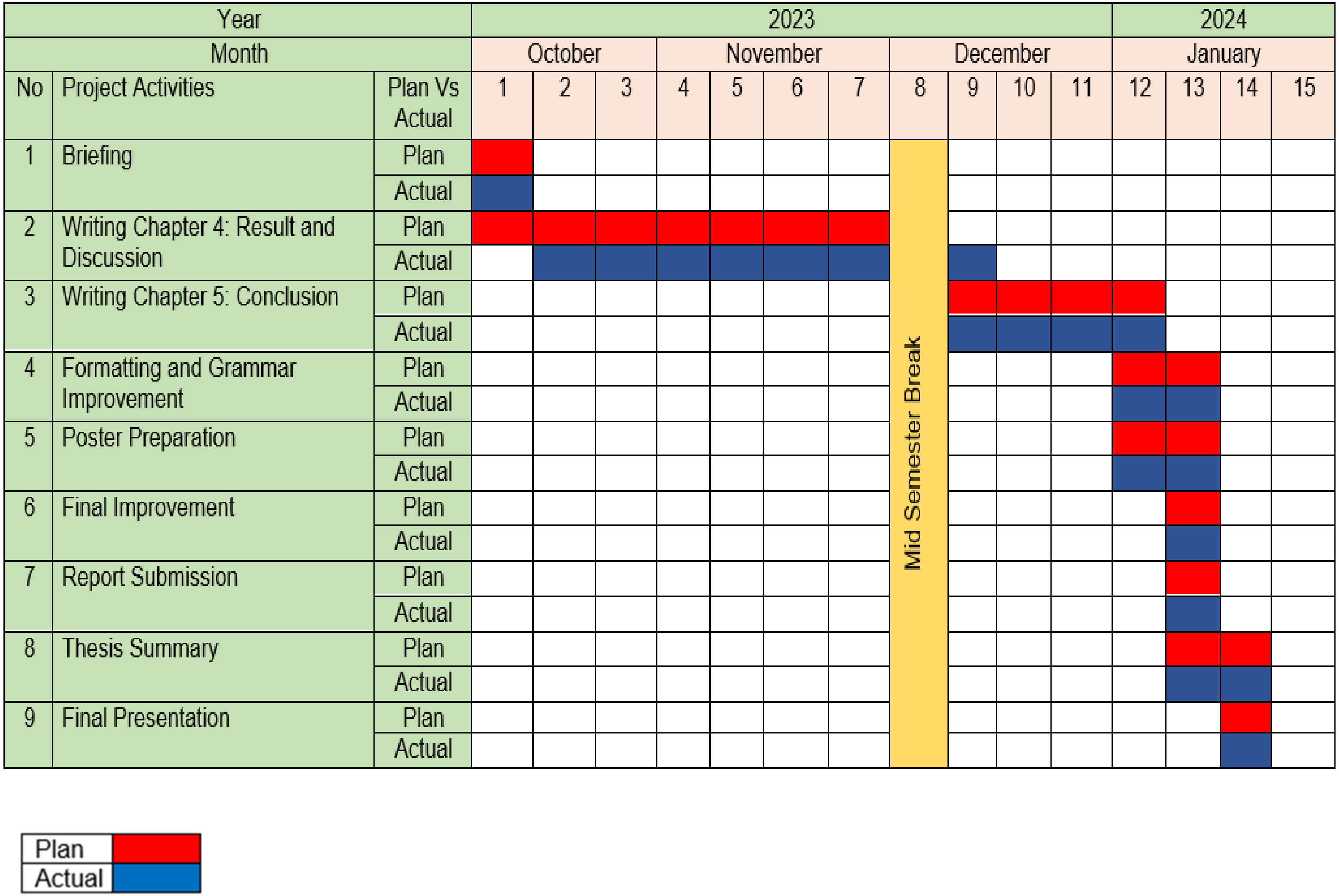
APPENDICES

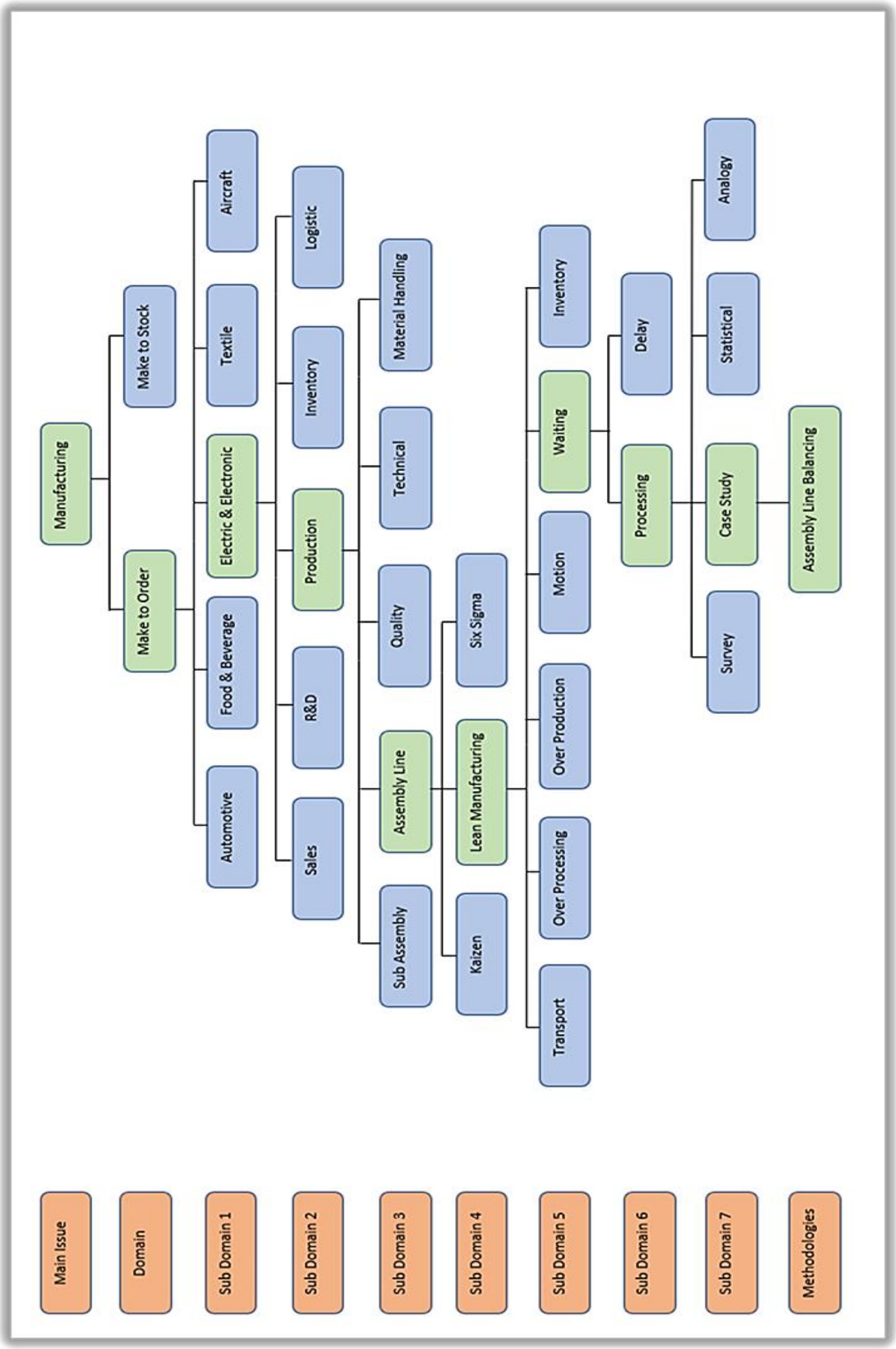
APPENDIX A PSM 1 Gantt Chart



APPENDIX B PSM 2 Gantt Chart



APPENDIX C   K Chart



APPENDIX D Plagiarism Report

ORIGINALITY REPORT

7%	4%	3%	3%
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APPENDIX E Company X Factory 1 Layout