IMPLEMENTATION OF KAIZEN AT TEXTILE MANUFACTURING COMPANY

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

IMPLEMENTATION OF KAIZEN AT TEXTILE MANUFACTURING COMPANY

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Industrial Engineering (Hons.)

by

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FACULTY OF INDUSTRIAL AND MANUFACTURING TECHNOLOGY AND ENGINEERING

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Sesi Pengajian: **2023/2024 Semester 1**

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APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirement for a Degree in Industrial Engineering. The members of the supervisory committee are as follows:

……………………………………………………

(**Prof Ts Dr. Effendi B Mohamad**)

ABSTRAK

Penggunaan Kaizen di Syarikat Pembuatan Tekstil adalah topik utama kajian ini. Kaizen ialah metodologi penambahbaikan berterusan yang cuba meningkatkan produktiviti dan kecekapan dalam sesebuah organisasi. Penyataan masalah dalam kajian ini memfokuskan kepada penambahbaikan masa kitaran jarum pengisi dalam proses majalah di Syarikat Pembuatan Tekstil, yang pada masa ini adalah 2.6 minit dan mungkin melambatkan proses pembungkusan. Matlamat kajian ini adalah untuk menilai sejauh mana pelaksanaan Kaizen dapat meningkatkan masa kitaran proses kerja Syarikat Pembuat Tekstil. Kajian itu memerlukan pemeriksaan menyeluruh terhadap aliran kerja sedia ada dan menentukan peluang untuk menambah baik jarum pembungkusan di bahagian majalah di Syarikat Pembuatan Tekstil. Tahap prestasi semasa diukur dengan mengumpul maklumat menggunakan ukuran masa, temu bual dan pemerhatian. Selepas itu, data kemudiannya diperiksa untuk mencari sebarang ketidakcekapan, kesesakan, dan kawasan yang boleh dibuat penambahbaikan. Pendekatan Kaizen digunakan untuk menganalisis proses kerja, menyingkirkan tugas yang tidak perlu, dan meningkatkan produktiviti keseluruhan akibat peningkatan masa kitaran. Keberkesanan strategi yang dilaksanakan dipastikan dengan mengukur dan menilai kesan pengubahsuaian yang telah dilaksanakan terhadap masa kitaran semasa. Penemuan kajian ini termasuk pengenalpastian punca utama impak berdasarkan rpn tertinggi dalam FMEA dan punca dari rajah Ishikawa. Hasil kajian ini adalah peningkatan masa kitaran proses kerja sebanyak 39.36%.

ABSTRACT

The use of Kaizen at Textile Manufacturing Company is the main topic of this study. Kaizen is a continuous improvement methodology that attempts to improve productivity and efficiency within an organization. The problem statement in this study focuses on the improvement of the cycle time of the filling needles in the magazine process at Textile Manufacturing Company, which is currently 2.6 minutes and might slow down the packaging process. This study's goal is to evaluate how well Kaizen implementations can improve Textile Manufacturing Company's work process cycle time. The study entails a comprehensive examination of the existing workflows and pinpointing opportunities for enhancement of the packaging needles in the magazine section at the Textile Manufacturing Company. Current performance levels are measured by gathering information using time measurements, interviews, and observations. After that, the data is then examined to find any inefficiencies, bottlenecks, and areas where improvement could be made. Kaizen approaches is used to analyzed the work processes, get rid of unnecessary tasks, and raise overall productivity due to cycle time improvement. The efficacy of the implemented strategies is ascertained by measuring and assessing the impact of the modifications that have been put into place to the current cycle time. The findings of this study include the identification of the primary cause of impact based on the highest rpn in the FMEA and the root cause from the Ishikawa diagram. The result of this study is an improvement of the work process cycle time by 39.36%.

DEDICATION

My beloved father, Mohd Taib B
Katap

My appreciative mother, Mawar
Bt Saleh
My project supervisor, Prof Ts Dr. Effendi B
Mohamad my lecturers and friends for
for always helping, believing in me and continuously giving positive
motivation throughoutthis project.
Thank You So Much & Heartfelt Love from Me

ACKNOWLEDGEMENT

I praise Allah, the Most Gracious and Merciful, for the utmost honor for enabling me to effectively and effortlessly finish my final year project.

It gives me great pleasure to convey my sincere gratitude to Prof Ts Dr. Effendi B Mohamad, my project supervisor, for the excellent mentoring I received during the project. Throughout my study, I was exposed to valuable experiences thanks to her supervision, guidance, and counsel. She also made a point of giving me insightful advice and information to help me finish the report and presentation.

In addition, I would like to express my gratitude to my cherished parents, Mohd Taib B Katap and Mawar Bt Saleh, for their unwavering support and for constantly inspiring me to put out my best effort in finishing this project and report. In addition, I am grateful to my friends for their unwavering support and ideas during this effort.

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LIST OF ABBREVIATIONS

Pcs	-	Pieces
Kg	-	kilogram
SMED	-	Single Minutes Exchange Dies
PDCA	-	Plan, Do, Check, and Action
rpn	-	Risk Priority Number
FMEA	-	Failure Mode Error Analysis
CT	-	Cycle Time

CHAPTER 1

INTRODUCTION

In the introduction, the study's main section gives readers a general idea of the topic of the investigation. To address the current issues that the manufacturing industry is facing, this chapter provides an overview of the study's background. After the industry's issues are examined, their significance and veracity are made clear. It then continues to tell the readers the goals that have been defined and the extent of the study, with a focus on the specific workflow of the filling needles into the magazine process and the workstation layout of the operator. The study's results and conclusions are consistent with the study objectives that were specified. Finally, the study's significance is also discussed.

1.1 Study Background

The global economy depends heavily on manufacturing which holds approximately 16 percent of global GDP and 14 percent of employment in the ever-changing world of today (Iyer, 2018). It includes a broad range of businesses and procedures, including those in the food, pharmaceutical, and automotive industries. Manufacturing is the process of converting raw materials into completed goods using a variety of manufacturing methods and technological advancements (Kenton, 2024). This study offers a broad overview of manufacturing in the modern era, stressing its importance, major developments, and difficulties.

Nowadays, the manufacturing industries have to go through fierce competition globally to adapt and keep up with the changes in market demand (Alaloul et al., 2020). Along with the advancement and emergence of new technologies, the manufacturing industries also have to integrate the latest technologies and systems into their process to have a place in the market competition (Araliz et al., 2024). History of the Industrial Revolution already showed us how technologies had changed the pace of producing a product and the impact it had on the majority of every person related to the manufacturing industry (Nurdiana and Pandin, 2021). Every industrial revolution has similarities in showing how humankind came together to provide a way of reducing the cycle time in order to enhance productivity due to the fast-growing market demand.

In the fiercely competitive global market of today, producers are constantly under pressure to offer goods more quickly and for less money (Dabade, 2021). Cycle time is essential to achieving these goals. This pressure all of the manufacturers around the world including Malaysia. Manufacturers can attain a faster time-to-market by decreasing cycle time, which allows them to react promptly to evolving market trends and client preferences (Cohen et al., 1996). Shorter cycle times also enable better inventory control, which lowers carrying costs and eliminates the need for surplus stock. Cycle time optimization is now strategically necessary for enterprises to maintain their agility and competitiveness in the current industrial environment. This also applied to the Textile Manufacturing Company that the study was conducted on.

It is anticipated that a new wave of global customer class will appear soon, with developed economies experiencing the majority of the demand, especially in the Asia region, including Malaysia (Seong et al., 2023). That will provide the company with abundant new opportunities. As a result, manufacturers need to increase productivity to address the problems. Improving the manufacturing process cycle time can boost productivity, which will increase productivity.

A study collaboration between a textile manufacturing company where this company runs the needles manufacturing industry and Universiti Teknikal Malaysia Melaka was made. Textile manufacturing company's products are crucial to the sewing needlework industries all over the world, thanks to the global network of production facilities, a centralized quality management program, and outstanding attention to detail that the textile manufacturing company had. The points of this study are to study the current cycle time of the factory and propose a kaizen methodology that can improve the cycle time of the company by at least 20%.

1.2 Problem Statement

Work completion has been delayed as a result of the company's recent spate of cycle time process problems. Cycle time typically has an impact on the operator's working hours since it requires the operator to put in more effort and extend the process working time to meet the day's production demands. This is because, during the work process of filling needles into the magazine, the operator has to repeatedly make an unnecessary and repetitive motion which then results in an increment in cycle time.

Cycle Time = Actual working times / Unit produced Equation 1.1

From the observation that had been made, the cycle time of the filling needles into the magazine process is too long which is 2.61 minutes, and might slow down the process of packaging. Based on the calculation that had been made using equation 1.1, the cycle time of the process should be 2.27 minutes. Even though the production is keeping up with the shop order, it is still seen to be an ineffective way of working and producing that results in the loss amount of money which can be converted into profit for the company. The problem during the observation included no past data recorded to check the cycle time of the work process since it is a new work process in the production line.

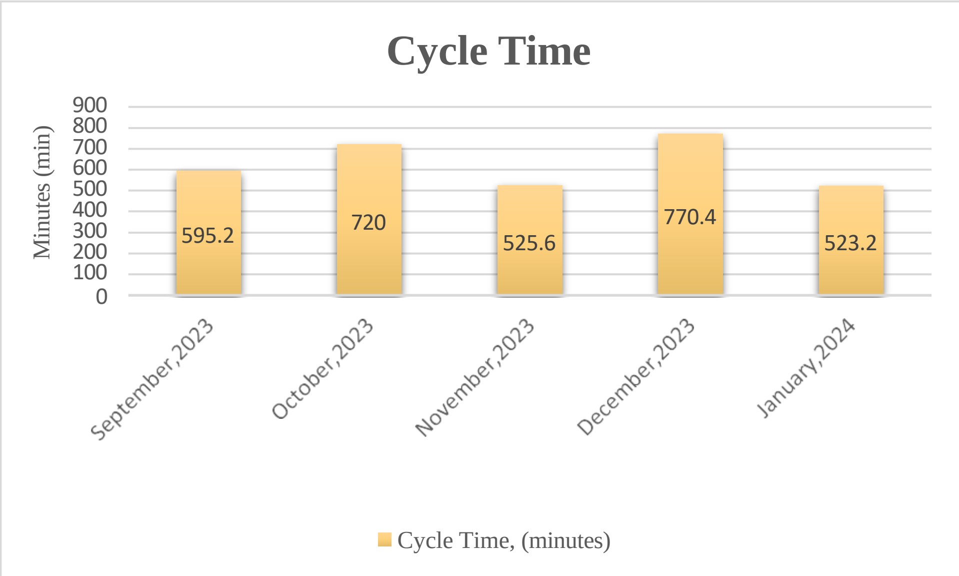

Figure 1.0: Time taken to completely package 40 magazines of needles

Figure 1.0 above clearly shows that some of the process exceed the actual working hours, which is 600 minutes a day during 5 months of data collection. The average working hours of the operator to fill needles into 40 magazines per day is 626.4 minutes. Since every needle needs to be separated into 500 pcs (pieces) per magazine, the operator will need to repeat the packaging process 6 times to complete the work process, which results in an average of 2.61 minutes per process based on the average current working hours.

The actual time measurement method is the main point in observing the operator's performance, primarily when some of the losses are incurred by the unnecessary motion time, and it is undeniable that the calculation of cycle time success depends on the ability to collect data correctly by taking into account of every step of the operator's work. If the data collected differs, the computed cycle time will not reflect the actual performance of the operators.

Other than an efficient way of completing a manufacturing process, the layout of the workstation also plays a significant role in eliminating waste since a proper design of the workstation might reduce the motion time of the process from one process to another process (Gay, 2023). Figure 1.2 and Figure 1.3 illustrate an example where a material needs to go through a process of weighing needles after the sorting process, where the needles are taken from a big box on the floor. From this sequence of operation, the most appropriate layout design for the workplace section is to put the needle’s box at the level where the operator does not need to bend and pick the needle from the box on the floor. With this type of arrangement, there will be no bend movement, and the time taken to move the workpiece from one section to another section is reduced compared to an unorganized layout may result in a longer time taken to transport the workpiece.

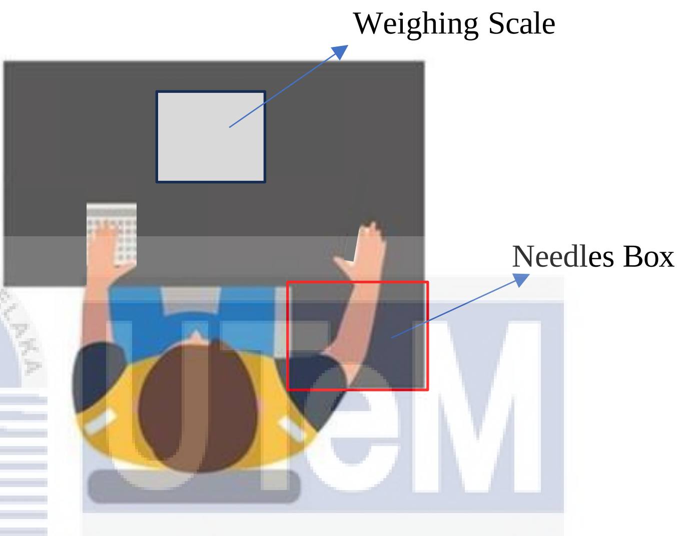

Figure 1.2: Top view of the current workstation

Figure 1.3: Side view of the current workstation

Longer waiting times are also one of the significant issues that usually occur in most of the industry including textile manufacturing companies. The time taken to complete a manufacturing process is critical since the demand from the customer is always high and needs to be produced in significant quantities. Longer waiting issues can happen due to the internal issue in the industry itself or from the external issue which is mainly from the supplier. The internal issue is usually due to a delay in the previous section which then results in less or no workpiece sent for the following process. For the external issue, the long waiting time is because of the delay from the supplier, which will hinder the manufacturing process because there is no material to be processed. This issue can be critical, especially to an industry that only has one supplier and is entirely dependent on the material from the supplier.

In this study, I had been given the trust of the company to investigate the possible way that may be implemented to reduce the current cycle time of the work process. The task is related to weighing a bundle of needles according to the weight the company wants. The task's main focus is to pack a magazine of needles, which is 3000 pieces of needles in quantity, but the needle is to be in a smaller packet of 500 in a magazine. To determine the amount of 500 needles, the company uses the weighing system (quantity per kg). I put the focus on improvement in the weighing process to the packaging process. However, since the work process is new, there needs to be proper tools provided to the operator to complete the work efficiently. The current work process was also unergonomic and might bring harm to the worker. The long working process was also an effect of the need for more tools provided.

1.3 Objectives

The objectives of this study are as follows:

I. To investigate the current performance of the actual cycle time of the process through the time study study.

II. To propose proper tools for the problems by implementing kaizen to eliminate waste and improve the cycle time of the filling needles in the magazine process.

III. To check the level of the suggestion's effectiveness to be implemented in the industry.

1.4 Study Scopes

This project's main focus is to investigate and identify the problems that lead to the increase in filling needles in the magazine process's cycle time. The study will be conducted in the packaging department at the Prym Consumer Malaysia Sdn Bhd factory. The study's scope also focuses only on 7 types of needles which are Chenille 18 1.2x50 Nickel, Darners 1/0(18) 1.2x60 Nickel, Doll Needle 4" 1.2x102 Nickel, Doll Needle 5"1.2x127 Nickel, Tapestry 18 1.2x50 Nickel, Upholstery Ndl 2 (2 1/2") 1.2x64 Nickel, and Upholstery Needle 3 (3") 1.2x76 Nickel.

The problems are then will be analyzed using analyzing methods such as why-why analysis, Ishikawa diagram, and value stream mapping. All of the investigation data will be observed during the actual working situation of the industry to get the most accurate data. Some surveys and interviews with the operator might take place to have a whole understanding problem that the operator had in completing the task at hand.

1.5 Significance of Study

The significance of the study is as follows:

1. When LM tools are integrated into the work process, inserting needles into the magazine process may help reach the ideal cycle time. Therefore, the purpose of this study is to evaluate whether the kaizen methodology can reduce cycle time.
2. To produce data through comprehension of the function of kaizen methodology. After that, valuable insights from the cycle time process can be obtained.
3. To advance the Prym Consumer Malaysia Sdn Bhd sector and learn new insights from the experimental study by improving cycle time.
4. To reduce the manpower by reviewing cycle time.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the literature review was produced by taking secondary data from the previous studies as it references. The studies that had been made consisted of determining and collecting data on a process cycle time at the packaging workstation. The cycle time of the process before implementing lean management is taken and will be compared to the cycle time of the improved process by implementing a lean manufacturing system. Based on the previous study that had been done, the study will focus on kaizen and time study to improve the cycle time.

2.1 Type of Waste

Muda, which translates to "waste" in Japanese, is a phrase used in Lean Management and Operational Excellence to characterize operations that use resources and cost money but don't create value. Toyota Production System creator Taiichi Ohno was the first to explain several kinds of waste. All non-value-added, wasteful activities need to be removed or drastically reduced in order to achieve sustainable, efficient production. Figure 2.0 illustrates the seven waste types/areas that Ohno describes (Ng et al., 2013)

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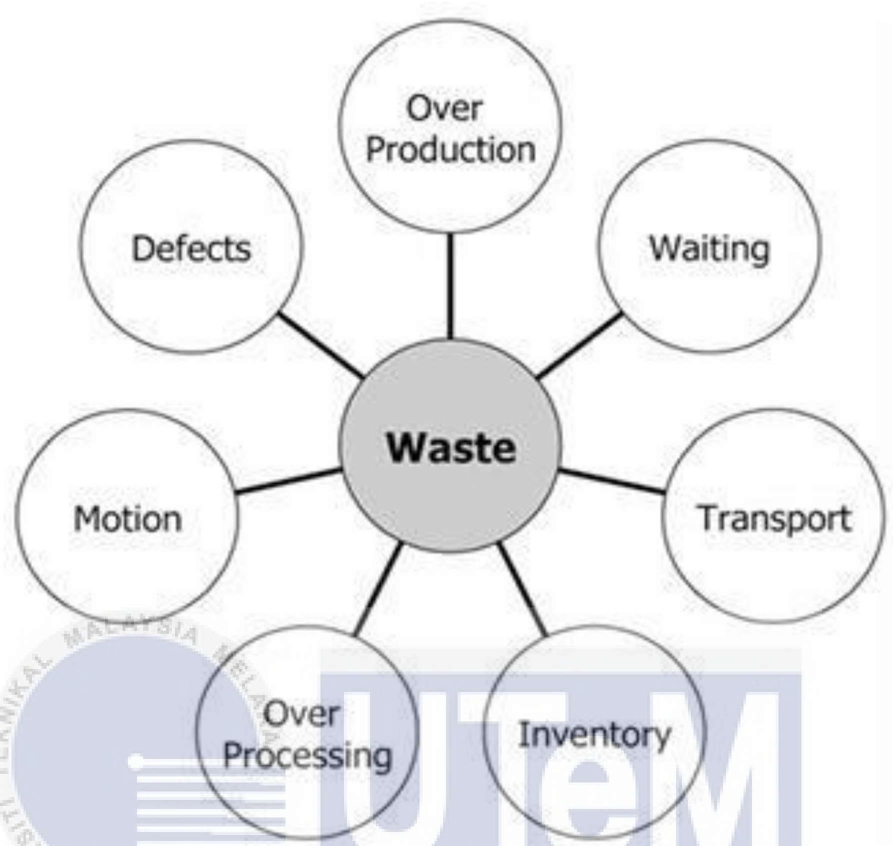

Figure 2.0: Type of waste (Melton, 2005)

2.1.1 Inventory

The inventory leads to the unnecessary accumulation of materials at each stage of production, involving massive engagement of funds without the knowledge as to when this investment will be encashable (Gupta et al., 2012). Holding "just in case" inventories by a business frequently leads to excess inventory. In these situations, companies overstock to cover unforeseen demand and guard against poor quality, manufacturing delays, and other issues. Nevertheless, these overstocks frequently fail to satisfy customers' needs and provide no value. All they do is raise the expense of depreciation and storage.

2.1.2 Waiting

Between each transformation step in any process is a period in which the item being produced must wait, which results in product waiting time (Nordgren, 2022). This waste is most likely the easiest to identify. The "waiting waste" happens whenever items or tasks are not in motion. Since lost time is the most visible symptom, it is simple to identify. As an illustration, consider items that are awaiting delivery, equipment that has to be fixed, or a document that needs executive approval.

2.1.3 Defects

Defects refer to any activity that was not done as per the required standard (Bharsakade et al., 2021). Errors may result in more work or, in the worst-case scenario, scrap. Defective work typically needs to be put back into production, which takes time. Additionally, there are situations where a second reworking space is required, resulting in further labor and tool exploitation.

2.1.4 Overproduction

In a manufacturing system, overproduction refers to producing more products than is required by the following process, producing earlier than is needed for the subsequent process, or producing faster than expected (Bharsakade et al., 2021). Recalling that waste encompasses anything for which the consumer refuses to pay; it becomes apparent why the excessive output is detrimental to Muda. Producing more entails exceeding consumer demand, which raises expenses. In actuality, the other six wastes arise as a result of overproduction. The rationale is that too many goods or jobs necessitate more transportation, too much movement, longer wait times, etc. Additionally, if a flaw does occasionally surface during overproduction, more units will need to be reworked by your team.

2.1.5 Motion

This type of waste comprises labor-intensive and needless transfers of workers or equipment. They may result in extra production time, injuries, and other issues. Put another way, take whatever steps are required to set up a procedure that requires employees to do the least amount of labor to complete their tasks.

2.1.6 Transportation

In order for the benefits of Lean to be fully realized, transportation management needs to integrate into the Lean implementation (Taylor & Martichenko, 2006). When resources (materials) are moved without adding value to the final product, it is considered waste. Moving things around a lot might be expensive for your company and lower the quality. You may frequently have to spend more on time, space, and equipment when using transportation.

2.1.7 Over-processing

The over-processing form of waste refers to the non-value added itself (Bharsakade et al., 2021). Bharsakade et al., (2021) also stated that usually, miscommunication inside the organization itself is the leading cause of over-processing. This kind of waste typically arises from performing tasks that either contribute no value at all or provide more value than is necessary which mean that the process need to be done once but done more than once which is unnecessary. These things can include giving a product more features that no one will use, yet they raise the expenses of running your firm. For instance, it's unlikely that anyone will use or value a TV screen that a car manufacturer decides to install in the rear trunk of a car. Furthermore, it will need resources and raise the product's final price for something that buyers will not buy.

2.2 Cycle Time

Cycle time is a metric borrowed from the lean manufacturing domain. The time required to execute a certain task from beginning to end is known as the cycle time. It can be conceptualized as the duration required to manufacture a single unit or item from start to finish (Boogaard, 2022). This can apply to software development cycles, customer support operations, manufacturing processes, etc. Cycle times are important for process optimization since cycle time show how quickly a process moves along and helps determine when adjustments should be made. Cycle times can be shortened to promote overall efficiency and prevent expensive mistakes (Pannell, 2023).

In the Lean methodology, cycle time and lead time are two crucial measures. However, cycle time is different from lead time. Figure 2.1 shows cycle time is the total amount of time an individual or team works on a task until it is prepared for delivery, while the lead time is the duration of time between the request for a new work item and its completion(Verma, 2023). A better understanding of how work advances over time can be achieved by measuring a process's cycle and lead times. The study can identify process flaws and suggest ways to fix them so that final customers receive goods and services on schedule.

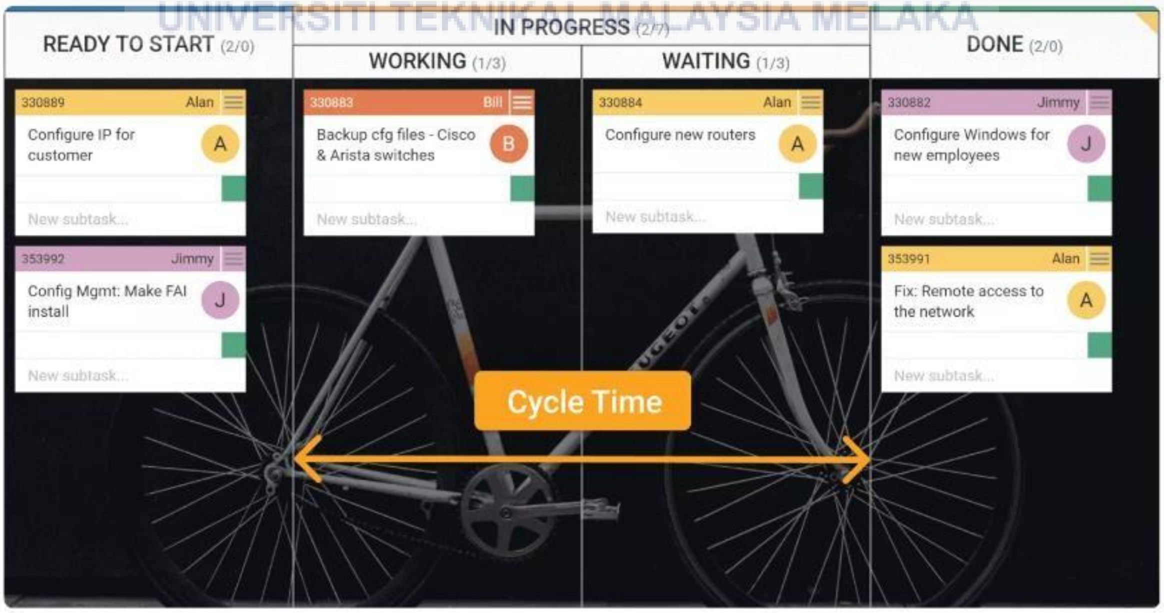

Figure 2.1: Visualization of cycle time on a Kanban board (*Lead Time Vs Cycle Time: The Complete Guide*, n.d.)

2.2.1 Cycle Time Calculation Techniques

Cycle time is defined as the period that separates the start of a procedure from its conclusion. The cycle time of a manufacturing business that produces expensive goods could also be defined as the period from the time raw materials are received until the point at which the product undergoes final inspection (How to Calculate Cycle Time : PresentationEZE, n.d.). The cycle time may differ as the process type changes. Below is an example of cycle time calculation in different processes. The formula of cycle time can also be used:

Cycle Time = 1/Throughput rate (unit/minutes) Equation 2.1

Where: Throughput rate = (Units Produced or Tasks completed)/ Time

2.3 Takt Time

"Taktzeit" is a German word that refers to rhythm or tempo (Brioso et al., 2017). This is the ideal interval between unit releases, which must be coordinated with consumer demand. When takt is used, different processes' production rates are aligned(Linck & Cochran, 1999). The Toyota Production System (TPS) is a widely recognized industrial manufacturing production process that utilizes takt time management to establish the rate of product flow. TPS schedules, plans, and manages its raw supplies and resources in accordance with the necessary takt time.

In the manufacturing sector, goods move along the production line while the operators stay in their locations of employment. This helps to prevent situations where slower tasks interrupt the execution of quicker tasks because all the tasks that are part of it have to start and finish within equal-duration takt cycles (Kozlovská & Klosova, 2022). As a result, employees shift jobs on a regular basis, a process known as takt time.

The job buffers will increase if the workers move more quickly than the takt time until they are deemed surplus inventory and waste. However, if employees move more slowly than the takt time, tasks will take longer to complete than ideal and will postpone the next job, which will result in low production that cannot satisfy the expectations of the client(Yassine et al., 2014).

Takt Time = Effective working hour / Customer demand Equation 2.3

2.4 Lean Tools in Workstation

Lean manufacturing methods have become worldwide these days, but what does actually lean manufacturing method mean? Originally, lean was used in the automotive industry in the 1950s when Toyota company created the Toyota Production System (TPS) by combining lean tools (Bescky, 2018). This system's value lies in its capability to cut the cost of the non-value-added process in the mass production process. Even though it was originally known as the TPS, the system is then was named Lean by a studyer involved in the International Motor Vehicle Program in 1988 and was made known to the whole world by James. P. Womack, Daniel Roos, and Daniel T in their book " The Machine That Change the World ".

All factories that implement lean manufacturing systems should apply a situation where all the right things are in the right places and at the right time (Lean Manufacturing, 2021). All factories should apply the principle of lean to optimize their resources and maximize their incomes. Every process should be made with the action that adds value for the customer. Analyze the entire value chain to identify waste. Create a new value chain with no downtime. Produce exactly as the customer wants and eliminate waste throughout the whole process and value chain. Every factory may use lean tools such as 5S, KANBAN, PDCA, KAIZEN, and Value stream mapping to implement the lean principle and eliminate waste.

2.5 Lean Tools Used In Reducing Cycle Time

2.5.1 KAIZEN

When Japan's management and government realized there was an issue with the country's confrontational management style and that a labor crisis was imminent, kaizen was born in that country in 1950. Japan attempted to address this issue in collaboration with the labor force. The majority of large corporations adopted the labor contracts that the government had pushed, laying the foundation for lifelong employment and rules for benefit distribution that would aid in the growth of the business. Kaizen is beneficial to the manufacturer in that it become a part of their manufacturing system. Kaizen has become a part of the Japanese manufacturing system and has contributed enormously to the manufacturing success (Ashmore, 2001).

Kaizen is just a shorthand for continual improvement. Japanese words kai and zen, respectively, mean "to take apart" and "to make good." When combined, these two words signify to disassemble something to improve it. Kaizen is founded on the principles of scientific analysis, which involve dissecting a process or system to learn how it functions and then figuring out how to impact or enhance it (make it better). Kaizen, or continuous improvement, is the foundation of lean production. Small, gradual, incremental adjustments implemented over an extended period can have a significant impact on business outcomes (Hargrave, 2023).

Kaizen is establishing benchmarks and then iteratively raising them. Kaizen also includes giving staff members the guidance, resources, and support they need to meet and exceed more outstanding standards while continuing to do so in order to support the higher standards on a continuous basis. Some people interpret the term "standard" to mean something inflexible, unchangeable, and unalterable. This kind of misunderstanding makes it difficult to implement Kaizen.

Researchers are very interested in the Kaizen philosophy because it helps companies generate high-quality products with less effort and enhances productivity. Kaizen is a continuous improvement process involving everyone, managers and workers alike (Imai, 1986). According to Imai (1986), Kaizen is an umbrella concept. In his study, he stated that when kaizen is carried out properly, it becomes a process that humanizes the workplace, gets rid of needless physical and mental labor, teaches workers how to do quick tests using scientific methods, and gets rid of waste in corporate procedures. Kaizen is also one of the most widely utilized terms used in Japan. The concept of Kaizen is evident in the Japanese trade exchange balance, social security system, and company productivity.

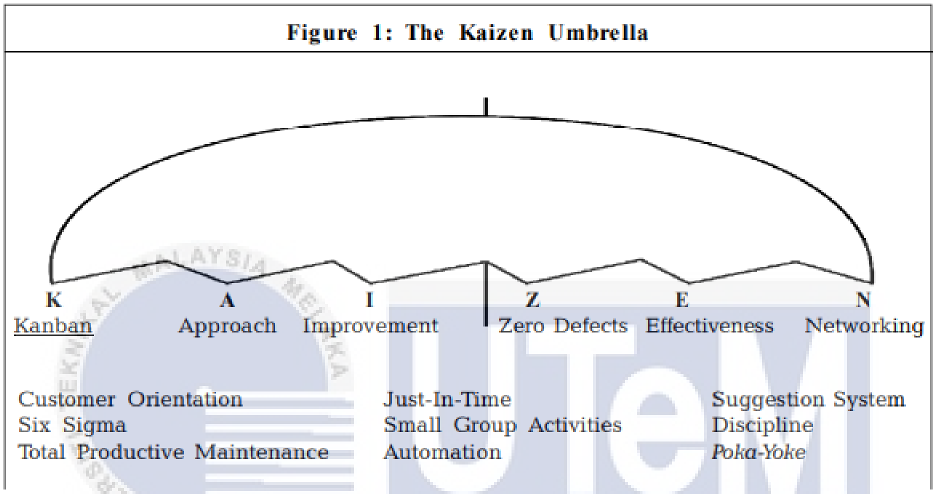

Figure 2.2: Umbrella of Kaizen (Naveed, 2010)

Figure 2.2 shows the kaizen umbrella which consists of techniques such as kanban, total productive maintenance, Six Sigma, automation, just-in-time, and suggestion systems are covered under the kaizen umbrella.

Kaizen is based on three guiding principles. The first is a strong emphasis on the necessity to develop the ability to notice events as they occur and the business outcomes that arise from the causal process sequence. Next is teamwork, where even in situations when a system seems to be working, everyone's viewpoint is respected and taken into account. This involves their active engagement in the form of ideas meant to achieve continuous improvement sufficiently. The kaizen philosophy acknowledges that progress can constantly be made.

Lastly, adopt a way of thinking that there is no one to blame and not to criticize an individual for a mistake, the responsibilities should be held accountable by every member of the team and find a better solution together. This principle makes use of quality circles, which are gatherings of employees who collaborate to find creative solutions to issues and make novel adjustments. This aspect of Kaizen philosophy is obviously derived from Japanese cultural tradition, which places more value on reaching a consensus within the group. The Kaizen strategy's emphasis on developing human resources foreshadowed postmodern advancements in competitive advantage and management (Andrea, 2021).

A kaizen blitz must be carried out within the context of a dedication to the kaizen principle itself to succeed. The foundation of lean production is the concept of kaizen, or continuous improvement the slight, gradual adjustments made over an extended period of time that have a significant impact on business outcomes. The cornerstone of all lean manufacturing techniques and the basis upon which they have all been constructed is kaizen.

Kaizen aims to eliminate waste or activities that increase cost without adding value. It also promotes just-in-time delivery, leveling the amount and types of production load, standardized work, timed moving lines, and appropriately sized equipment. Kaizen basically involves disassembling systems, goods, services, and processes and rebuilding them in a more efficient manner. Kaizen and quality control are closely related (Aksessribu, 2023).

Problems are not seen negatively by kaizen rather, they are seen as constructive chances for advancement. By identifying, documenting, and resolving issues, Kaizen facilitates change. Employees who point out inefficiencies and other problems are encouraged to be rewarded under this program. Kaizen involves acting to produce ideas and then putting those ideas into practice as quickly as feasible.

2.5.2 TIME STUDY

Masniar et al. (2023) stated in their study that Time Studies are carried out using a stop clock tool to observe task times. A worker's repetitive cycle of tasks is observed to determine the standard time for a given task. Standard time, once established, applies to all other employees doing comparable tasks. Workers who have been chosen are those who comprehend accurately. The standard of work is the amount of time required to complete specific tasks under typical working circumstances. A standard time or standard time is required as a reference for establishing the best work technique to be able to compare the best work time from the existing work methods (Masniar et al., 2023)).

According to Masniar et al., (2023), the quantitative descriptive method was one of the time study methods. The goal of the descriptive technique is to describe things that happen in a genuine, realistic, actual, and current setting by using a study to create descriptions, images, or drawings that are methodical, factual, and truthful manner with reference to the details, traits, and connections between the phenomena under investigation. The other method is the quantitative method. Quantitative study techniques focus on objective phenomena that are examined through quantitative analysis. Study design objectivity was maximized by the use of structured experiments, statistical processing, statistics, and statistical processing.

Masniar et al. (2023) further stated in their journal that there are two techniques that can be used for working time measurement, which is first the direct measurement of work time, where measurement is carried out directly at the place where the work being measured is in progress. Stopwatch Time Study and Work Sampling might be used in this technique. The second technique is indirect measurement of work time; measurements made without an observer must be in the place where the work being measured is in progress, but the observer must understand the work process being measured. Standard Time Data and Movement Time Data (Predetermined Time System) might be used in this technique. Table 2.1 shows the example of data collection for cycle time analysis in a table form.

Table 2.1: Example of cycle time analysis (Mnzool et al., 2024)

Material: waste	Digger: PE04				Digger: PE01			
No.	Loading time		T. taken	Passes	Loading time		T. taken	Passes
	Start	End			Start	End		
1	8:05:31	8:08:47	0:03:16	6	3:20:13	3:22:39	0:02:26	5
2	8:10:05	8:14:27	0:04:22	9	3:23:03	3:25:36	0:02:33	6
3	8:16:11	8:19:53	0:03:42	6	3:26:07	3:29:27	0:03:20	4
4	8:21:50	8:25:56	0:04:06	8	3:29:50	3:33:50	0:04:00	4
5	8:29:11	8:33:21	0:04:10	7	3:34:17	3:36:26	0:02:09	4
6	8:36:10	8:40:00	0:03:50	6	3:37:20	3:40:27	0:03:07	6
7	8:43:03	8:46:57	0:03:54	8	3:43:31	3:45:57	0:02:26	6
8	8:48:01	8:52:18	0:04:17	7	3:47:22	3:49:41	0:02:19	5
9	9:01:03	9:04:23	0:03:20	6	3:51:14	3:54:02	0:02:48	6
10	9:07:10	9:12:04	0:04:54	7	3:55:01	3:59:00	0:03:59	4
Average			0:03:59 = 3.98 min	7			0:02:55 = 2.92 min	5

2.6 Benefits of Implementing Kaizen & Time Study

Organizations outside of the manufacturing sector, including marketing companies or human resources departments, can also benefit from the procedures of kaizen & motion and time study. The benefits of this framework could vary depending on the objectives and commercial needs of the manufacturer. Nevertheless, kaizen could benefit a manufacturer. The benefits are :

- Save time:

Improving productivity and cutting down on time are two of lean manufacturing's main goals. Those who put it into practice might be able to save time at work. Kaizen could be applied to enhance the process of the assembly line (Stanke, 2023). Through process analysis and identification of opportunities for improvement, such as shortening task completion times, the manufacturer can implement gradual modifications to enhance productivity and efficiency.

- Save money:

Manufacturers can reduce costs by minimizing waste in resources and other production- related aspects. Even minor process changes can have an influence on overall costs because waste can frequently result in extremely large expenses for the manufacturer (How Does Kaizen Reduce Cost?, n.d.). For instance, manufacturers can save money on supply and material purchases if they reduce the quantity of faulty items they scrap.

- Encourage staff members:

Kaizen emphasizes the value of learning, adaptation, and continuous development. Workers are involved in making suggestions and possible changes for improvement. When workers can approach errors with critical thinking abilities, learn from each other, and address themselves going forward, they may feel more motivated (D., 2022).

- Preserve the environment:

Reducing waste during production can frequently help to preserve the environment over time. For instance, optimizing the transportation route can reduce the impact of energy and transportation on air quality and pollution levels due to carbon monoxide and dioxide emissions while simultaneously saving firm money on petrol and delivery fees (Pedroto, 2023).

- Shorter Lead Times:

By removing obstacles, cutting down on waiting times, and enhancing workflow, kaizen concepts seek to shorten lead times. Organizations can gain a competitive edge, shorten time to market, and better meet consumer demands by optimizing processes and reducing delays (Case Study, Manufacturer Uses Kaizen Events to Eliminate Production Delays and Late Shipments | Firefly Consulting, n.d.).

- Enhanced Adaptability and Flexibility:

Kaizen's approaches foster a culture of ongoing learning and development.

Encouraging staff to suggest suggestions for improvement and cultivating an adaptable mindset makes organizations more flexible and better able to react to shifting demands from customers, market dynamics, and technology breakthroughs (Musyoka, 2023).

- Employee Empowerment and Engagement:

Kaizen promotes teamwork, employee involvement, and problem-solving. By involving workers in enhancement initiatives, companies use their expertise, abilities, and inventiveness, resulting in heightened workplace contentment, drive, and self-determination (Stanke, 2023).

- Sustainable Outcomes:

Kaizen is a long-term attitude and method of continuous improvement; it is not a one-time project. Organizations can maintain the gains realized and consistently aim for greater performance and excellence by integrating lean methods into their culture.

- Increased Customer Satisfaction:

Kaizen is centered on providing value to consumers by identifying their needs and removing tasks that don't help fulfill them. Organizations may supply goods and services faster, more precisely, and more consistently by increasing efficiency, quality, and responsiveness. This increases customer happiness and loyalty (Bland, 2024).

2.7 Constraints of Implementing Kaizen & Time Study

While Kaizen & Time Study brings many benefits to the manufacturer, there are also some problems or constraints that manufacturers may face, especially for manufacturers that are new to lean manufacturing. These are some of the constraints that may be faced by the manufacturer in implementing Kaizen & Time Study:

The required training of kaizen and time study concentrate on the framework's tools but fall short of adequately fostering the values and culture of the organization. Business success depends on providing staff with the necessary support, including training, guidance during the transition to kaizen processes, encouragement, and feedback gathering (Janjić et al., 2019).

Kaizen and time study might become a challenge to manufacturers because it will take a while to completely execute inside an organization. This is because implementing new procedures also requires educating stakeholders and personnel (Change Management When Implementing Kaizen | Rever, 2022). Continuous learning is one of the main focuses in implementing kaizen and time study.

Before introducing kaizen, a leader must confer with coworkers and staff. This is because team members may be more adaptable if they are aware of the issue beforehand. Manufacturers can typically carry out procedures more easily, efficiently, and with greater support if they recognize the advantages of working together.

Putting kaizen into practice frequently necessitates adjusting roles, responsibilities, and work procedures. Because of this, workers are afraid of losing their jobs due to being unsure of the new methods of working or are worried about having more work to do; some employees might oppose these changes (P., 2023). Effectively managing the transition and overcoming resistance to change are essential for the successful adoption of kaizen.

Kaizen implementation takes time, energy, and resources (McGarry, 2023). Financial, human resource, and schedule limitations are possible for organizations. The pace and scope of kaizen implementation can be affected by a lack of resources, which could delay the time it takes to adopt kaizen and observe noticeable gains.

2.8 Tools that are suitable for kaizen and time study data collection

During Kaizen implementation, analysis tools such as the Ishikawa diagram and failure mode error analysis can be utilized to collect data for process and task analysis, discover inefficiencies, and enhance overall work process efficiency by implementing the right countermeasure.

2.8.1 Failure Mode Error Analysis

Failure Mode Error Analysis (FMEA) refers to the process of identifying possible or actual faults or errors in a product design or process, with a focus on those that could have an impact on the customer or end user. Failures are ranked by severity, frequency, and detectability in FMEA. The gravity of the repercussions of failure is described by severity. How frequently failures can happen is described by frequency. The term "detectability" describes how difficult it is to find errors.

Documenting current knowledge about failure risks is another aspect of FMEA. By prioritizing steps that either avoid failures or at least lessen their severity and/or likelihood of occurrence, FMEA aims to manage risk at all levels. Additionally, it outlines and facilitates the choice of corrective actions that lessen the effects and fallout from mistakes. Throughout the life of the system or product, FMEA can be used from the very beginning of design and conceptualization, through the development and testing phases, and into process control throughout continuing operations.

Failure Mode Error Analysis (FMEA) consists of :

- Identify Potential Failure Mode

To develop a failure mode error analysis (FMEA), we are required to identify all of the problems that might occur during completing the work process. To identify the problems, we need to list the function of the work process. After all functions had been listed, it required us to brainstorm about all the possible ways it could fail. Historical analysis data and past records are suitable for brainstorming ideas.

- Determine the Effect of Failures

After all of the potential failures had been listed and filled in the FMEA checklist, the consequences of all of the possible failures were made. It is important to also consider the impact of the failure in developing the effect of failure. The effect of the failure should consider the perspective of the system, process, and customer or end user. From there, the severity of the failure needs to be classified with a rating of 1 – 10, where 1 represents no significant impact and increases as the rating increases.

- Identifying the cause of failures

The cause of failure is also one of the important elements in developing the FMEA for the work process. 4M elements, which are manpower, method, material, and machine in the Ishikawa diagram, are useful in identifying the cause of failure. After that, the rating of occurrence can be given by following the likelihood of the problems to happen, rating from 1- 10, where 1 represents that the problems are unlikely to happen and increases as the rating increases. Historical data and statistical analysis should be made to indicate the rating.

- Asses Current Control

Existing control measures of the potential failure should be included in the FMEA table. Some of the current controls might be regular inspection, maintenance, and standard operating procedures. A detectability rating is given from 1- 10, where 1 represents that the problem is certainly to be detected and decreases as the rating increases.

After all of the ratings have been assigned to each process step, the risk priority number can be attained by multiplying the values of severity, occurrence, and detection. The higher the risk priority number means that the higher the priority should be given to the problems.

Process FMEA of Rear Axle Housing.

Sr.	Function	Failure Mode	Effect of Failure	S	Cause of Failure Mode	O	Current Process Control Method	D	RPN
1	Material Receiving	N.G. Material	No Production	6	N.G. Supply, Poor Inspection	1	Test Certificates	2	12
2	Sharing	Burred Edges	Safety Hazard	9	Worn out Blade	7	Visual inspection after 1000 cycles	6	378
		Twisting	Problematic for Next Process	6	Excessive Rake Angle	1	Adjustment of Rake Angle Periodically	6	36
3	Forging	Unfilled Forging	Forging section Remain Unfilled	8	Poor Heating Before Forging	2	Manual Temperature Control (10 %)	7	112
		Forging Cold Shut	Small Cracks at Corners	8	Sharp Corner in Die	1	Periodic Maintenance of Die (Every 3 Months)	6	48
4	Hole Punching	Hole Position Out	Assembly Problem	7	Worker's Negligence	6	Visual Inspection	9	378
5	Boring for Seal & Bearing Sizing	N.G. Bore Diameter	The pipe would not Fit in Hub	6	Program Error, Wrong Tool Offset	4	Gauge Inspection (25 %)	6	144
		Bore Position Out	Assembly Problem	7	Worker's Negligence	7	C.F. (5 %)	8	392
6	Hole Drilling	NG Hole Position	Fitting Problem	7	Operator Negligence, stopper not guiding job	6	WIS, Jig, Periodic Inspection	6	252
7	Turning	N.G. Turning	N.G. Part	8	Incorrect Parameters	1	Manual inspection (100 %)	4	32
8	Hole Chamfer	N.G. Chamfer Angel	Counter Sunk Bolt Would Not Fit	4	Tool Worn Out	1	Manual inspection (10 %)	7	28
9	Blank Cutting	NG Blank	Scraped	8	NG Clearance b/w Punch & Die	4	Inspection with Reference Sample (5 %)	8	256
10	Drawing	Cracks in Draw	Strength Compromised	8	High Pressure, Insufficient Lubrication	7	Visual inspection (100 %)	4	224
		Wrinkles in Draw	Crack or N.G. Part	8	N.G. Material or Parameters	3	C.F. & Visual Inspection (100 %)	4	96
		Scratches in Draw	N.G. Appearance	5	Rough Punch/Die Surface, Insufficient Cooling	2	Visual inspection (100 %)	4	40
11	Pipe Radius Punch	N.G. Pipe Radius	NG Fitting on Housing Pipe	7	Die Problem	1	Die Maintenance (Every 3 Months)	6	42
12	Forming	Forming Splits	Strength Compromised	8	Stretching beyond Material safe limits.	1	Visual inspection (100 %)	4	32
		Spring back	Dimensional Inaccuracies	6	Less Resistance to compressive strains due to Less Thickness	5	C.F. (10 %)	7	210
13	Sub Assy. Parts Inspection	N.G. Sub Assy. Parts	Fitment Problem	7	Supplier Process Failure, Poor Inspection	6	Manual Inspection, Supplier Inspection Sheets (100 %)	4	168
14	Assembly	N.G. Assembly	N.G. Part	8	Personal Error, N.G. Machining	2	C.F. (10 %)	7	112
15	CO_2 Welding	Weld Crack	Less Strength, Leakage	8	Poor Ductility of Base Metal	5	Leakage Test (100 %)	3	120
		Spatter	Uneven Surface	4	High Current, Longer Arc	3	Visual inspection (25 %)	6	72
16	Fatigue/ Durability Testing	Fewer Fatigue Cycles	N.G. Part, Failure at User End	9	N.G. Material	1	Part Inspection, Test Certificates	2	18
17	Painting and marking	N.G. Paint	Rust, N.G. Appearance, Less Durability	6	N.G. Paint Parameters	4	WIS, Visual Inspection, Thickness Tester, SST	3	72
18	Final Inspection	NG CF Fitment	N.G. Part	8	NG Machining, NG Fitting	2	Process Inspection (50 %)	5	80
		Appearance N.G	Unsatisfied Customer	5	Handling	5	Visual inspection (100 %)	4	100

Figure 2.3: Failure Error Mode Analysis Framework(Yousaf et al., 2023)

Figure 2.3 illustrates how the study assesses the potential failure mode, effect, cause, and current control. The rating of severity, occurrence, and detection was also assigned to every function of the process. As a result, this study determined the problems with the highest risk by identifying the highest value of the risk priority number (rpn).

2.8.2 Ishikawa Diagram

Tiann (2012) stated that Ishikawa's diagram is known as the "fishbone" because of its fish-like shape, with a head (an effect) and a body made up of bones that are shown as the root causes of well-known issues. A cause and effect diagram, often known as a fishbone diagram, is a graphic technique that can be used to discover and examine essential aspects that have a substantial impact on the quality of the job product (San, Tjitro, & Santoso, 2003). Figure 2.4 is mainly used to identify the possible root cause and issue that problems might have. Root cause is the most profound underlying reason, or causes, of any process's positive or negative symptoms that, if resolved, would lead to the symptom's complete eradication or significant reduction (Preuss, 2003).

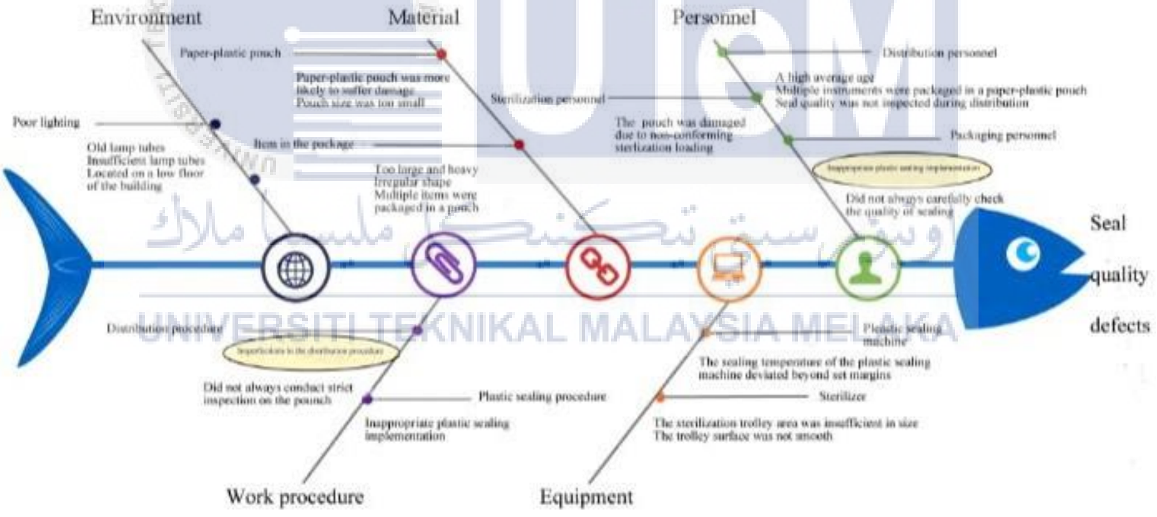

Figure 2.4: Ishikawa Diagram (Huang et al., 2023)

2.8.3 Why-why analysis

Why-Why analysis is a valuable technique for resolving issues at work. This approach aids in keeping the emphasis on the layer of symptoms that may reveal a problem's underlying cause. This depth analysis method should be used for that reason. In Figure 2.5, this analysis technique will be use to find the actual root cause due to its nature in questioning the cause of the problems until the final and reasonable cause has been identified.

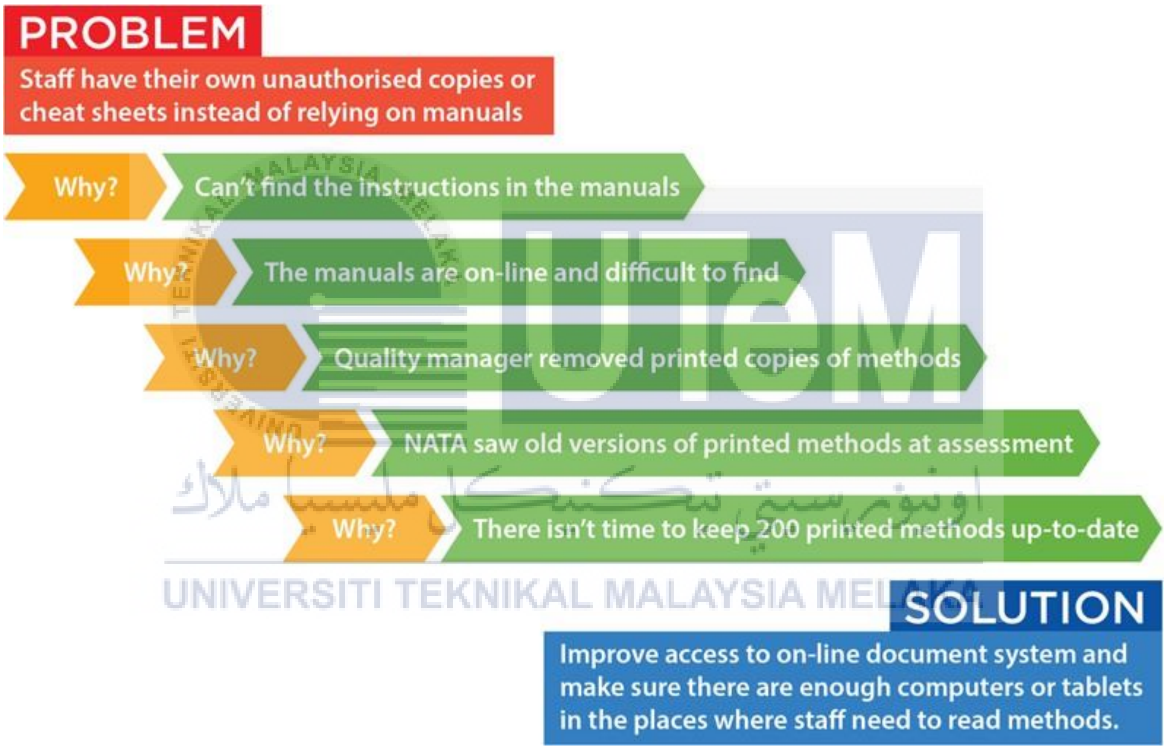

Figure 2.5: Example of Why-Why analysis (Sigma, 2023)

2.9 Other Lean Tools

Lean tools are intended to enhance quality control and lessen "Muda," or organizational uselessness. Put differently, the goal of lean tools is to get rid of unnecessary procedures. Many industries, including manufacturing, engineering, and finance, use lean tools to further increase their profit and productivity (Vandenberg, 2021).

2.9.1 5S

5S originally came from the Japanese words which are seiri, seiton, seiso, seketsu, and shitsuke. If translated to English it has the meaning of sort, straighten, sweep, standardize, and sustain. The 5S concept aims to increase workplace productivity and efficiency by establishing a safe, orderly, and clean work environment. It offers a methodical and transparent approach to the workstation and material organization with the goal of eradicating waste, decreasing errors, and raising employee satisfaction.

For the first S, which is sort, the action required in this step is to sort the workstation by separating the items that may or may not be used in the manufacturing process (What Is the 5S Methodology? | Lean Production, n.d.). Removing any unnecessary item that is not related to or used in the work done at the workspace will create more space that can be utilized for other functions and purposes. This step can reduce the waste and might eventually eliminate the waste and improve the efficiency of the manufacturing process. This is due to the elimination of waste in searching for items that need to be used for the manufacturing process since all of the items had been placed in their places. With sort we will also eliminate the time that is used to clear the workstation in case we have to work with a more extensive product that may need a bigger space. All of this elimination of waste will further enhance the productivity of the manufacturing process.

Next, S stands for straighten or set in order. This step comes after sorting, which requires us to take action to emphasize arranging all of the items needed during the manufacturing process in suitable and ergonomic places for the users to take the items when required. Set in order does not only apply to the tools that will be used, it also applies to the equipment, material, files, and anything else that might need to be put in place for a purpose.

To further improve the workflow of the manufacturing process, proper labeling and visual indicators can be used. Some of the factories use a borrowing record system to ensure that every tool or equipment that has been taken will be put back in the right place after it has been used (What Is the 5S Methodology? | Lean Production, n.d.). This system will allow the company to monitor the record of the tools used and make sure it is correctly found and included.

After that is sweep, which means cleaning. Frequent cleaning makes it possible to find and remove sources of chaos and keep work environments tidy. The cleanliness of the machine, the workspace, the floor, the equipment's tightness, the cleanliness of the lines, pipes, and light sources, the current data, and the legibility and comprehension of the information are all examined during cleaning. It is often carried out in the plant by the person in charge of the designated workspace. A more comfortable and safe workplace is ensured in the third 'S.' With a clean environment, the quality of work will surely increase and employees will also enjoy the benefit of working in a clean place (Gupta & Jain, 2014). Clean and organized work areas act as motivation factors for the employees. Every employee enjoys their work in a clean and healthy environment.

The next S stands for standardized. Establishing and executing guidelines in the form of protocols and directives enables the maintenance of order in the workplace (What Is 6S Lean? 5S + Safety: A Guide | SafetyCulture, 2024). Standards ought to be highly comprehensible, unambiguous, and straightforward. All process participants at the designated workplace, which includes direct workers, should be included in this during the planning and improvement phases. The group has the greatest awareness of the details of its own operations, and utilization allows them to comprehend the fundamentals as well as every facet of the process. Mandatory standards ought to be present in conspicuous locations at all times in order to guarantee everyone's simple access. Order can be maintained in the workplace by establishing and following rules in the form of directives and protocols. Standards should be obvious, concise, and easy to understand.

Last S stands for sustain. Putting the 5S concept into practice will require employees to have the strict self-control necessary to follow and adhere to the regularity guidelines for organizing and cleaning until it becomes a part of the work culture (What Is 6S Lean? 5S + Safety: A Guide | SafetyCulture, 2024). It results in improving employee awareness, lowering the quantity of non-conforming goods and procedures, enhancing internal communication, and ultimately improving human relations. It's also critical to comprehend the necessity of carrying out regular usage inspections according to the 5S guideline. The so-called checklist is used to assist with this examination, and the radar graph of the 5S, which estimates the workplace, is made based on it.

2.9.2 KANBAN

Triana & Beatrix (2019) stated in their journal that according to Papalexi et al. (2014), Kanban is defined as a Material Flow Control mechanism (MFC), and it controls the proper quantity and proper time of the production of necessary products(Graves et al.. The Toyota manufacture System (TPS), which was designed to manage inventory levels, component manufacture and delivery, and occasionally raw material, contains a subsystem called Kanban. Because it uses cards to control the supply or manufacturing of parts, commodities, or raw materials, the term "card" has gained widespread usage. Though the Kanban system's interpretation is so limited, it can be said that most businesses employ a system similar to this since shop floor materials are managed through the use of cards of various kinds, such as production orders, schedule sheets, material lists, or product structures. The phrase "kanban" is used indiscriminately in a number of works, denoting both "the system" and "card."

Kanban needs to have a level of production where it needs to balance the schedule to achieve a low variability number of parts from one time to the next. On a production floor, stay away from hierarchical control systems and sophisticated information. Withdraw parts only with a Kanban in place. Take out only what is necessary at each step. Sending faulty parts to the next stage is not advised. Provide the precise number of parts that were removed.

If a system doesn't use a marker of some kind, it does not fall under the category of kanban. Two cards are used in the Toyota Production System's kanban system: the production kanban and the withdrawal or move kan-ban. This move card permits one standard container to be moved from one work center to another, holding a specific quantity of parts. Other terms that are employed include move ticket, WLK (withdrawal kanban), C- kanban (conveyance kanban), and receiving kan-ban.

Delivering materials to manufacturing workstations just in time and communicating information to the stage before about what and how much to create are the main goals of a Kanban system. Work-in-progress (WIP) and material flow are integrated as Kanban moves with their components. The Kanban that is separated from the next step completes a production control function by indicating the kind, quantity, and timing of the parts that need to be produced. The quantity of inventory is actually measured by the number of Kanban. As a result, managing the quantity of inventory is equal to managing the number of Kanbans. There is a direct correlation between increasing the number of Kanbans and inventory levels. It is far easier to control the quantity of Kanbans than the actual amount of inventory.

Just like 5S system, kanban was produced in order to satisfy the things that the company (Toyota) wanted. This kanban system works extremely well under specific production and market conditions. Every company or organization might require a different kanban system that might be suitable for them. It is not adequate in situations with unstable demand, processing time instability, non-standardized operations, long setup time, a great variety of items, and raw material supply uncertainty (Papalexi et al., 2015).

Figure 2.6 has been widely used in industries as a result of transformation in a competitive environment. The crescent customer sophistication has been the most important of such transformations, among others (Sipper and Bulfin, 1997). Punctuality, variety, low cost, and high quality are some of the aspects that are widely sought by the customer. It is essential because it might be one of the key factors that determine the survivability and success of a company in such an environment. Van Veen-Dirks (2005) concludes in his study that speed, economies of scope, and core competencies are the basis of the new competitive environment.

However, the kanban system varies from its original concept in order to match the manufacturing process or the organizational function. Kanban systems have been studied intensely in recent years, and many models have been proposed to understand their behavior and analyze their performance (Uzsoy and Martin-Vega, 1990).

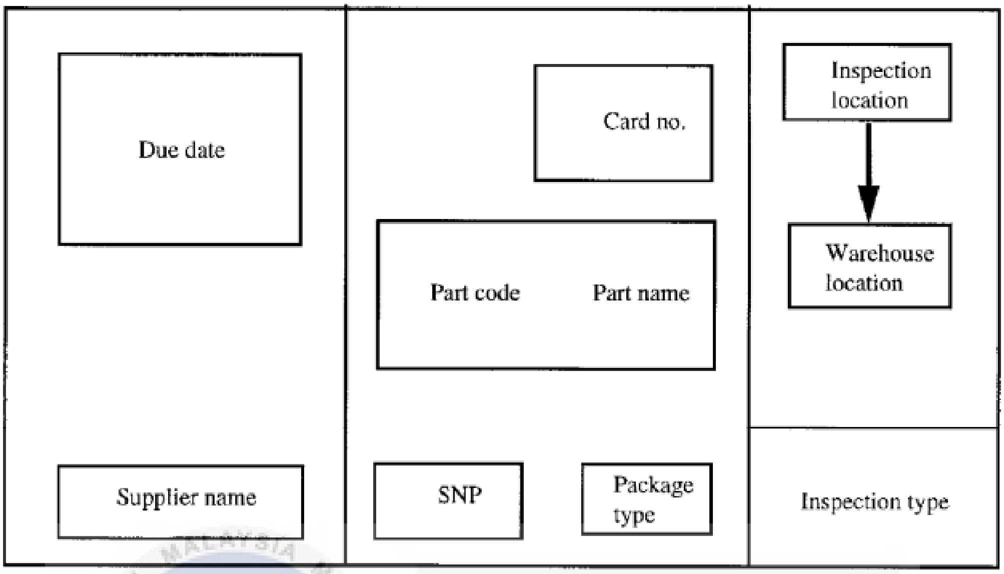

Figure 2.6: Overview of kanban systems (Biswas, 2020)

2.9.3 PDCA

The quality management method known as Plan, Do, Check and Action (PDCA) is extensively employed in the manufacturing and service industries as a tool for continual improvement. Plan, Do, Check, and Action are the four steps that act as pillars in every activities, and these processes are repeated to form a circle. A popular tool for continuous improvement in the industrial and service industries is PDCA. The PDCA cycle starts small to test potential effects on systems and gradually moves on to more significant and targeted improvements (Patel & Deshpande, 2017). The actual outcomes of an action are compared with a target or a defined point in a manufacturing process. After mentioning the differences between the two, corrective action is taken if the. The gap widens. This standard description of control is followed by the recurring and ongoing nature of continuous improvement, which the PDCA symbolizes.

This PDCA technique, which comprises four steps, focuses on potential deviations and makes necessary adjustments to improve manufacturing processes (Moreno, 2018). A plan entails establishing objectives and procedures to accomplish particular outcomes. In the do phase, all of the information is selected, and unexpected events also need to be considered. In the check phase, the stages of the inspection procedure have been observed and assessed in compliance with the guidelines. The act step involves taking steps to enhance outcomes and fulfill or surpass requirements.

Planning, which entails goal identification, data analysis, and action plan development, is the first stage of the PDCA process (Toynton, 2023). In order to facilitate decision-making, organizations establish specific goals during this phase, as well as key performance indicators (KPIs) and pertinent data. A manufacturing company can aim to employ quality control procedures in order to reduce defects (SYDLE, 2023). By guaranteeing alignment with organizational objectives and offering guidance for subsequent actions, this phase lays the groundwork for success.

Executing the plan or taking action is the next stage once it has been established. Putting the planned actions into action and altering the procedures as needed are the tasks of this phase. Making sure that everyone knows their jobs and duties is crucial. The manufacturing company, for example, would train staff, supervise production processes, and put quality control systems into place. The "Do" phase places a strong emphasis on action and gives organizations the chance to evaluate their plan's efficiency in a practical situation.

The third phase is called "Check" or evaluation, during which organizations evaluate the outcomes of the actions that have been put into action. To gauge success in relation to the preset objectives, data must be gathered and analyzed. In the manufacturing scenario, the business would gather information on defect rates, evaluate if the implemented procedures have resulted in the intended reduction, and compare it to the initial baseline. This stage identifies areas that still need work and offers insightful information on how well the activities were implemented.

The "Act" step entails implementing the required changes and making modifications based on the evaluation from the previous phase. This stage places a strong emphasis on applying the lessons gained from the review process to improve and streamline the strategy (PDCA Cycle, 2021). In the case of the manufacturing company, the organization would examine the data, determine probable reasons, and adjust the quality control procedures in accordance if the targeted decrease in defect rates was not achieved. Organizations may continuously develop and adapt to changing conditions thanks to this iterative strategy. It may be necessary to employ additional high-quality tools in order to carry out these stages effectively.

The primary functions of these high-quality tools are problem analysis and action definition. The most popular quality tools used by businesses and supporting the PDCA cycle are the following: the flowchart, histograms, SMED, Poka Yoke, Servqual, brainstorming, benchmarking, checklists, Ishikawa diagrams and the Pareto chart, Failure Mode Analysis and Effects (FMEA), 5W1H, checklists, and statistical process control (SPC) (Realyvásquez-Vargas et al., 2018).

In the manufacturing sector, Figure 2.7 is typically used to cut waste (idle time, waiting times, failures, and defects). Several corrective, temporary, and permanent actions are generated by the PDCA cycle idea. The goal of ongoing and corrective action is to eradicate the underlying cause.

Figure 2.7: Overview of the PDCA system (Corporation, 2024

CHAPTER 3

METHODOLOGY

This chapter is all about relaying the flow of the project and studies to attain the objective and goals that had been stated in the previous chapter 1. There is also an attached flow chart that explains the process that is taken to complete the final year project. Every detail of the workflow is included in this chapter.

3.1 Flow Chart

Figure 3.0 depicts the flow of the study from the beginning of conceptualization to the end of the improvement after implementation. From the flow chart, PSM I's main purpose is to cover only project planning, which includes project conceptualization, study on historical information related to the project title, and methodology design to develop the overall project. In contrast, PSM II's main purpose is to cover project implementation and study result measurement based on the studies and data collected on PSM I.

During the stage of project implementation, the whole process of filling the needle into the magazine (manually) is observed, and a time study analysis is performed to identify the difficulties faced by the operator that affect the whole process. From there, quality tools are offered to be implemented to eliminate waste, which also refers to the seven significant wastes that possibly are the root cause of the problem.

The main objective of stage two is to accomplish objectives (a) and (b), which are to investigate and identify the seven types of waste that are involved during the process of filling a needle into the magazine (manually) and coming out with a solution to enhance the effectiveness and efficiency of the work process for filling needle into the magazine (manually). In the final stage, the result is measured, and the process of filling the needle into the magazine is evaluated using the work motion and time study. Stage three's goals are to provide a solution that can be used in the filling needle into the magazine process. As a result, recommendations for improvement are made based on the examination of the results.

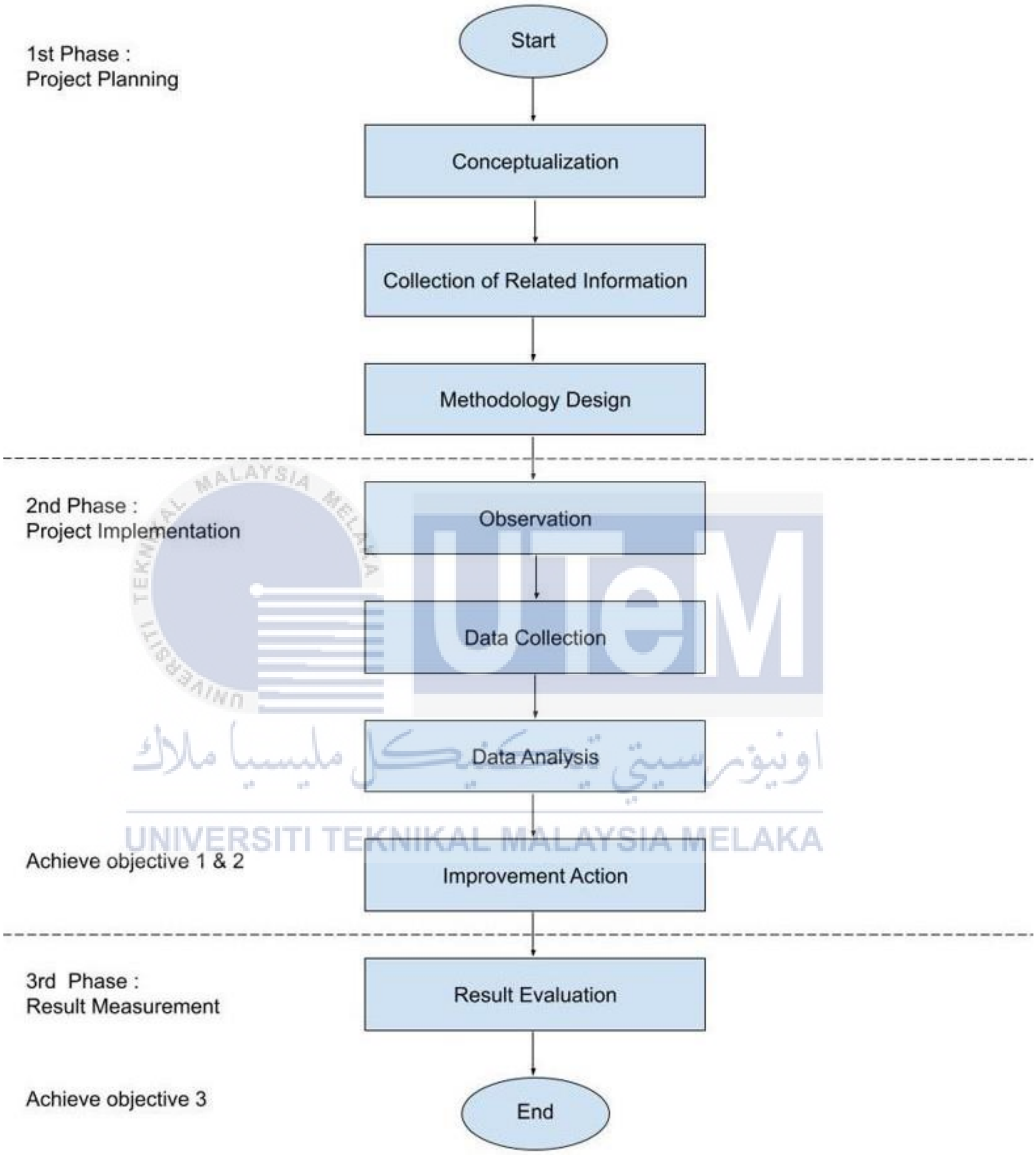

Figure 3.0: Flow Chart

3.2 PSM Project Flow

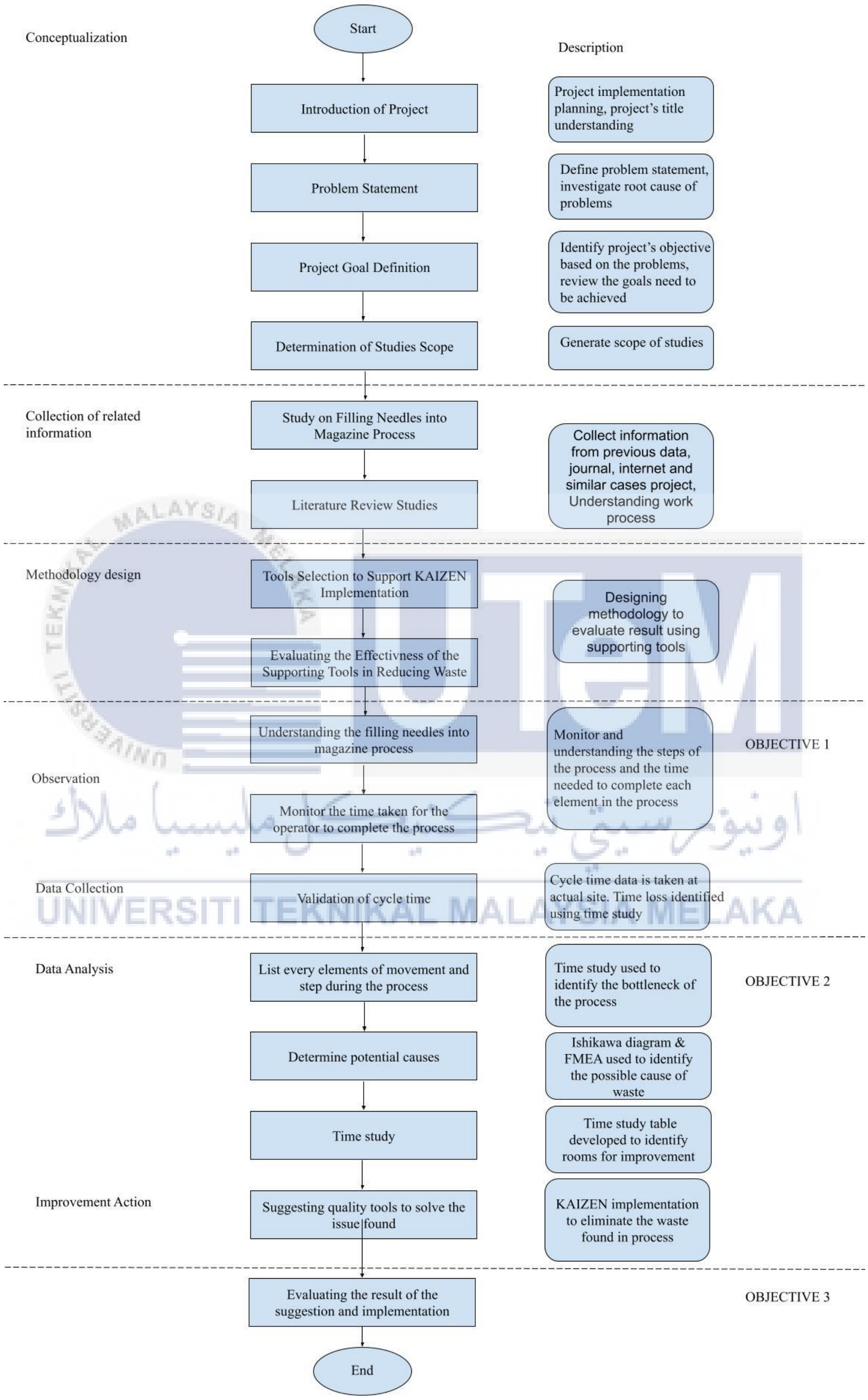

Figure 3.1: PSM Flow Chart

3.2.1 Conceptualization

Figure 3.1 shows in the conceptualization stage, the focus is on the PSM's problem definition. Understanding the PSM title needs a thorough investigation because it is essential for generating the problem statement and objectives. Conceptualization can serve as a goal for the project to be established as well as a guideline for the overall project for PSM to be proven successful. Due to that, conceptualization is a key beginning point because it dictates the overall project's direction, the information to be acquired, and the project plan in methodology design. The objectives and job scope for this project are well specified and precise so that the aim is explicit and achievable while also being very effective in solving the problem of the subject of study that had been identified, which is reducing the time taken for the filling needles into the magazine process.

3.2.2 Collection of Related Information

After the objectives of the study have been finalized, it is essential and important to understand the problem by studying and looking for published information relating to the study topic in journals, scientific reports, books, articles, theses, and other reputable information on the internet. Past data from the company or other sources can also be used to guide the project's methodology design. The information included in this section contains the processes taken to conduct time study, comprehend the nature of the subject of study, which is filling needles into the magazine, the method used to evaluate the data acquired, and how past similar studies attempted to solve a similar problem that the PRYM company had.

3.2.3 Methodology Design

Based on the objectives that had been specified, a methodology is then developed and produced to carry out the whole project, which is focused on the literature reviews conducted during the second stage. This methodology technique would be used as a set of guidelines and procedures that would be followed throughout the project flow. It is useful to ensure timely production over time. The designed actions and procedures are primarily focused on the observation and implementation stages to be followed in the second part for the project's complement, which is in semester 2 and will be explained in the next section.

3.2.4 Observation (Objective 1)

Understanding the filling needles into the magazine process is crucial in conducting the project study since it allows for the differentiation of before and after implementation of lean tools in the operation line. After the problem is identified, its related effects can be set as scheduling guidance for rooms of improvement, as well as a better and more efficient way of completing the work process. For this project, the filling needles into the magazine process flow are observed at the manufacturing site, and data for the process, such as cycle time and filling process schedule, are obtained from the operators on site.

3.2.5 Data Collection (Objective 1)

Data for calculating the time taken to complete the filling needles into the magazine are gathered from the manufacturing site at the company, which includes a set of worker's motion reports, a filling process report, unnecessary time taken, and other necessary papers. The computation of data recorded in the report is used to validate the cycle time data. The data collection, which illustrates the cycle time and performance of the operator from September 2023 to January 2024, has been collected.

3.2.6 Data Analysis (Objective 2)

Following data collection in which the collected data is interpreted using the motion and time study approach, the value before implementing lean tools such as kaizen will be compared to the value after lean tools implementation, and analysis will be performed to identify and eliminate the losses that contribute to the waste found in the process. The probable causes are identified utilizing many techniques mentioned in Chapter 2, such as the kaizen and time study tools. This kaizen tool is thought to represent chances for development through the integration of several quality tools to improve the filling needles into the magazine process. Once the time study are implemented, specific quality tools will be recommended to tackle the problem. For example, in this project, Kaizen is proposed to reduce repetitive process and hence improve the cycle time of the work process. The losses that have accrued in the existing filling needles into the magazine operation are clearly defined in this data analysis step, which might contribute to the next stage in determining the improvement action.

3.2.7 Summary of Implementation Stage (Objective 2)

This study incorporates other quality tools in addition to time study and kaizen so that the core quality tools may be deployed smoothly. The supportive tools may be used to detect the problem with the filling needles into the magazine process and the problem-solving tool can be utilized to limit the chance of waste occurring.

3.2.8 Result Evaluation (Objective 3)

Following the adoption of many quality tools, the outcome is evaluated using time study. The goal is to look for more suggestions for improvement and to see if the quality tools in place are compelling enough to reduce and eliminate waste. The results will show that there is still room for development to get a higher level of productivity and reduce cycle time.

CHAPTER 4

RESULT AND DISCUSSION

In this chapter, the results and discussion obtained from the conduct of the study are recorded. Every data collected from the observation and discussion that had been made to ensure the success of the study is associated with achieving a favorable result for the Prym Consumer Sdn Bhd company.

4.1 Process Identification and Verification (Objective 1)

During the methodology stage, all data collection through observation is done in order to determine the phases and flow of the process involved in packing needles into the magazine. The observation for the case study had mainly taken place at the operator's work area, where packaging needles into the magazines is done. The time study is gathered, and the observation is completed to proceed with the subsequent phases in the case study. The following implementation actions were done in order to confirm the operation and determine the processing steps:

Step 1: Observation of the entire work operation

The actual work process flow is determined using the process flow chart's standard as a guide. A total of 5 months is needed for the study, and data collection is conducted during the observation phase. The actions are made to pinpoint the issues that come up while the production is in operation. The amount of time an operator spends to complete the work process is recorded using a stopwatch to analyze cycle time. Every detail and element description is accurately documented.

Step 2: Data collection of the working operation time

A Stopwatch time study is conducted in order to record the actual time taken by the operator to complete the task on hand. A brainstorming session with the operators and engineers regarding the work process is also made before the improvement of the work area is done which then can also be used to compare the performance of the operator before and after the improvement had been implemented.

Step 3: Calculation of the actual cycle time

All of the time data that had been documented is then used to calculate the actual and current cycle time that an operator in the packaging needles into the magazine at the Prym Consumer Sdn Bhd needed to complete the work process. The cycle time of the process is calculated using the cycle time formula that had been stated before in section 1.2 equation 1.1.

Step 4: Determine the cycle time and proper work sequence

In this final step, the work process is investigated and the cycle time is then calculated again after eliminating the wastes that had been identified in the process. The work area also has a significant impact on the new cycle time since there might be a change in the work area that reduces the movement of the operator, which will automatically reduce the time taken to complete the work process.

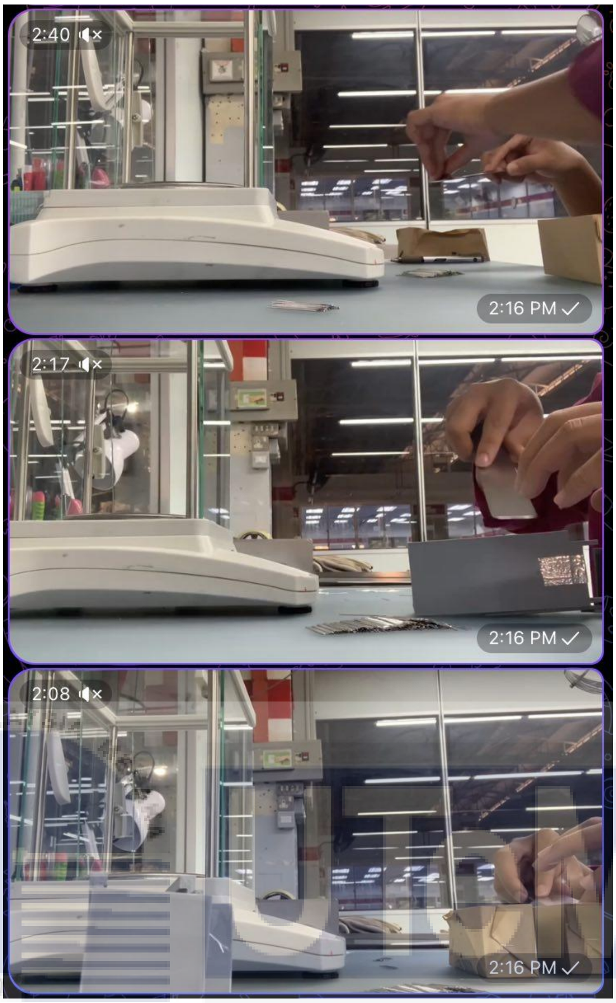

Figure 4.0: Example of data collection through the stopwatch method (video)

4.1.1 Process flow of packaging needles into the magazines

Based on the observation that had been conducted in Figure 4.0, the flow process of packaging needles into the magazine work process in the packaging section is developed as a guide to proceed with the study. There are a total of 3 work process lines in the packaging section that do the packaging needles into the magazine work process. Even though every work process line had a different dimension of needles to be packaged, the workflow process for packaging needles into the magazines is the same in every work process line. Since the dimension of the needles had an insignificance impact, the flow process will be the same for every work process line and will still give accurate data. Figure 4.1 shows the flow process of packaging needles into the magazines.

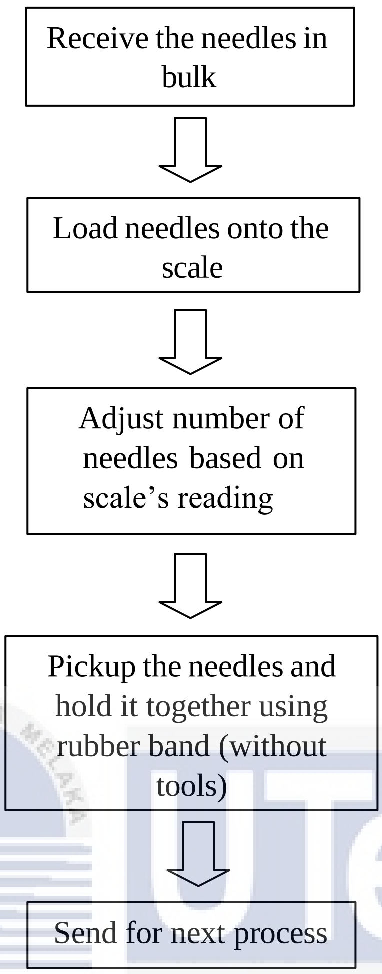

Figure 4.1: Flow diagram of packaging needles work process

4.1.2 Rate of Customer Demand

The first objective of this study is to investigate the current performance of the actual cycle time of the process through the time study study. In this section, we will discuss the rate of customer demand, which is the definition of takt time. Takt time is essential in comparing the cycle time obtained with the time rate of the customer demand. From the calculated takt time information, the current cycle time can be justified to be perfect for the current production pace, or do we need to improve it? Data for takt time calculation are as stated in table 4.1 below.

Table 4.1: Working hours data

Data Collection	Time, minutes
Operation Hour	600 minutes
Evening Break	15 minutes
Lunch Break	30 minutes
Breakfast	10 minute
Demand	40 magazines

Calculation of takt time :

Effective working Hours = (600 – 15 – 30 – 10)minutes

= 545 minutes

Takt time = Effective working hour / Demand

i. Takt time = 545 / 40 = 13.625 minutes per magazines

ii. 1 magazines = 3000 needles

iii. 1 packaging work cycle = 500 needles

iv. Each magazine = 6 packaging work cycle

v. Takt time for each packaging work cycle = 13.625/6 = 2.27 minutes per packaging work cycle

Takt time of 2.27 minutes per packaging work cycle will be compared to the cycle time to identify the performance of the current cycle time.

4.2 Actual Data Collection (Objective 1)

During the 5 months (September 2023 until January 2024), the time study for the entire packaging needles into the magazine process is conducted to obtain the actual current data of the cycle time in the company and to clarify by using the calculation of cycle time. Table 4.2 until Table 4.6 below shows the average cycle time of the packaging needles in the magazine work process.

Table 4.2: Cycle time data collection in September

	Weeks	Cycle Time, minutes
September	Week 1	2.40
	Week 2	2.45
	Week 3	2.50
	Week 4	2.57
	Average	2.48

Table 4.3: Cycle time data collection in October

	Weeks	Cycle Time, minutes
October	Week 1	2.50
	Week 2	2.80
	Week 3	3.30
	Week 4	2.40
	Average	3.00

Table 4.4: Cycle time data collection in November

	Weeks	Cycle Time, minutes
November	Week 1	2.56
	Week 2	2.30
	Week 3	2.00
	Week 4	1.90
	Average	2.19

Table 4.5: Cycle time data collection in December

	Weeks	Cycle Time, minutes
December	Week 1	3.44
	Week 2	3.40
	Week 3	3.20
	Week 4	2.80
	Average	3.21

Table 4.6: Cycle time data collection in January

	Weeks	Cycle Time, minutes
January	Week 1	2.40
	Week 2	2.30
	Week 3	2.10
	Week 4	1.92
	Average	2.18

Table 4.7: Average cycle time data collection for 5 month period

	Weeks	Cycle Time, minutes
Total	September	2.48
	October	3.00
	November	2.19
	December	3.21
	January	2.18
	Average	2.61

The data that had been collected is based on the observation and time study that had been conducted every week in the past 5 months (September 2023 until January 2024) at the packaging workstation. Table 4.7 above shows the current cycle time is 2.61 minutes, which is higher than the takt time; this means that the current production will not be able to meet the customer demand since the time required to complete every process is at 2.27 minutes per process. There will be delays in production or increase in labor costs due to extended working time to meet the demand.

To further analyze the possible issue that might cause the cycle time problem, every process was investigated to collect the data and identify the likely cause of the problems. As stated in the previous chapter, several tools are used in the data collection process. These tools are :

a) Ishikawa diagram

   Real-time data regarding the possible root cause of problems with the packaging needles in the magazine were analyzed and listed in the fishbone diagram for further investigation.

b) Stopwatch method

   A digital stopwatch is used in the study to record the time required for an operator to complete every work element in the packaging needles into the magazine work process. The time taken is then used for cycle time calculation.

c) Method-Time Measurement

The method-time measurement technique is used in the study where every motion done by the operator is given a predetermined time standard based on its nature and the circumstances surrounding it.

4.3 Root Cause Analysis Data (Objective 2)

4.3.1 Brainstorming

Brainstorming is one of the techniques that had been used in this study to collect the data for analysis. Brainstorming works by generating a large number of ideas that might be the problems to the problems. This brainstorming idea is attended by the operator and industry engineer in the packaging needles department to give their idea and identify the leading cause of the cycle time problem at the packaging needles department.

- **Needles fall off**

There are three process steps where it might be possible for this problem to happen, which are picking up needles from the box using a flat ruler, filling needles into the magazine, and unloading the needles from the weighing box. Since this failure is declared as the non- value added to the customer it also seemed as a waste in the process.

- **Targeted weight not achieved**

For this process, the needles are first counted manually to get 50 pieces of needles to be used to calibrate the sensitive laboratory scale for 500 pieces of needles. The ideal step for the weighing process is for the process to be done only once to ensure that the number of needles is 500 pieces with a tolerance of ±3%. However, after the investigation had been made, we observed that this process was not achieved and might be the major cause of the cycle time problem.

Figure 4.2: Example of acceptable weighing process

4.3.2 Ishikawa Diagram

Figure 4.3 is a crucial tool for troubleshooting production line issues. Based on brainstorming and observation that had been made at the operator working area, there are several possible causes that had been recorded, which are contributing to the main categories of the 4M, which are man, method, machine, and material. The issues with the packaging of needles in the magazine process are depicted in Figure 4.3

The 4M are explained below:

A. Man

The worker/employee lacks of practice and skill to complete the task on hand since the packaging needles into the magazine process with a portion of 500 needles each is a new work process to the production line.

B. Method

The method used in the production line is entirely hands-on. It lacks the usage of proper tools to help complete the working task which leads to repetitive motion becoming necessary in the production line. The current method that the company uses now can also be declared as unergonomic for the operator.

C. Machine

Machine factors do not have an impact on the process since all of the process is made entirely by the operator without the usage of any machines.

D. Material

Since the material used in the packaging needles into the magazine is metal with a pointy part, the operator needs to be extra careful with their hand so that it will not prick their finger.

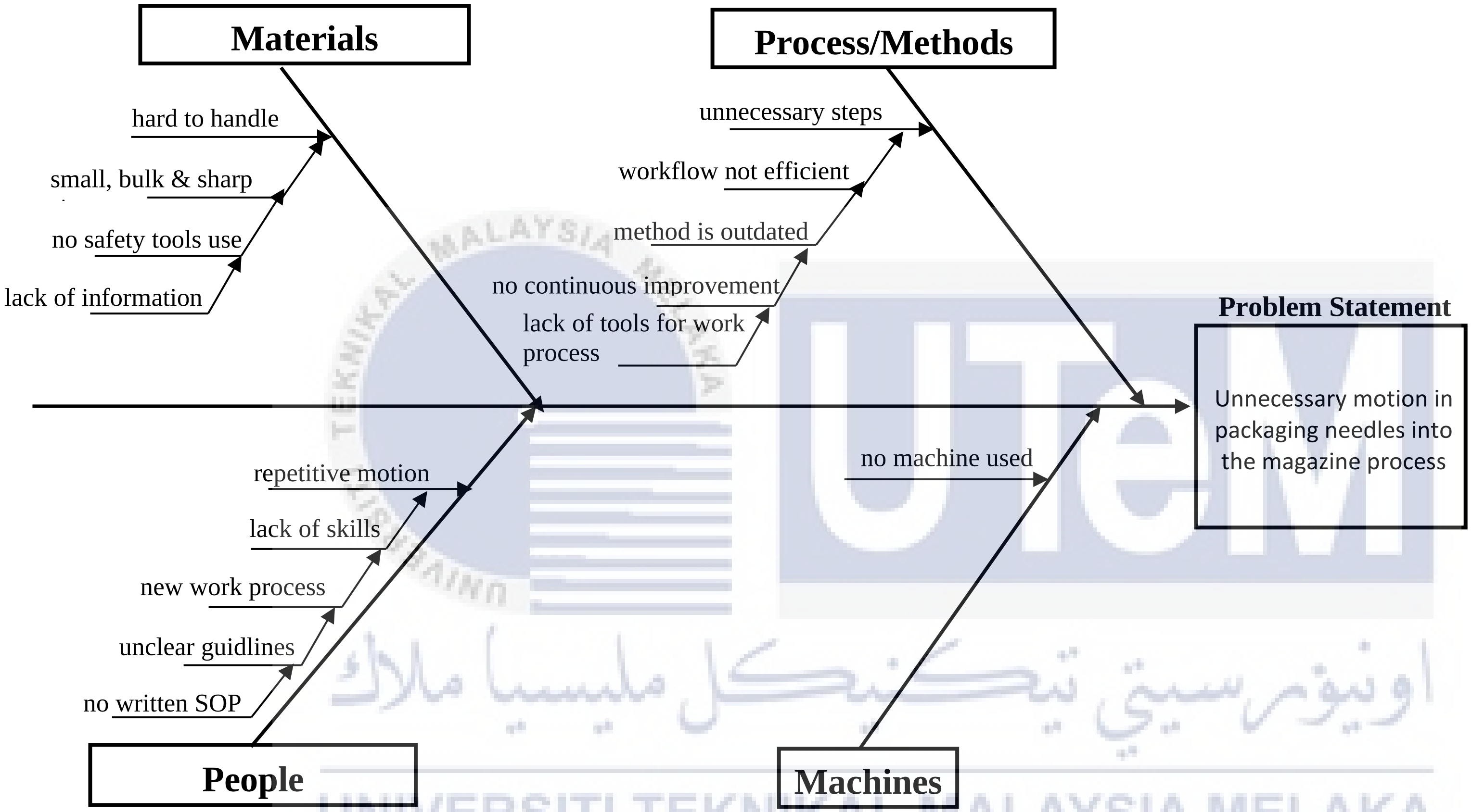

Figure 4.3: Ishikawa diagram for unnecessary motion in packaging needles into the magazine process

4.3.3 Why-why Analysis

A why-why analysis is used in this study in order to see every element that had been filled in the Ishikawa diagram into a table form. This method provides us with a clearer vision regarding the cause of the problem, which is unnecessary motion in packaging needles into the magazine process in a table form. Table 4.8 show the analysis to identify the root cause that affected the process and declared it to be a waste for the company. Below is the completed form of the why-why analysis table:

Table 4.8: Why-why analysis table

Weigh the needles on the scale (500 pieces)	Causes	Why?	Why?	Why?	Why?
Man	Repetitive motion	The targeted scale not achieved	Operator new to the work process	No clear guidelines	No written SOP provided
Process	Unnecessary steps	Workflow not efficient	Method is outdated	No continuous improvement	Lack of tools for the work process
Material	Hard to handle	Small and sharp			
machine	No machine used	Not cost-effective			

Table 4.8 above, we can conclude that the major problems that would play a major factor in unnecessary motion in packaging needles in the magazine process are due to no written standard operating procedure (SOP) to complete the task provided and the lack of tools provided for the work process that can help the operator.

4.3.4 Failure Mode Error Analysis (FMEA)

Based on the input that had been discussed during the brainstorming session, a failure mode error analysis (FMEA) was developed to have a deeper insight into the problems that occur and to identify the main problems by observing which problems generate the highest value of risk priority number (rpn). In this table, we have listed all of the potential failure modes, failure effects, causes, and current control for the cycle time problem. To identify the main cause, we have assigned a rating for the severity, occurrence, and detection to see which one of the listed processes gives the highest risk to the company. Table 4.9 below shows the FMEA table that had been generated.

From the result of the highest risk priority number (rpn) value in FMEA, we can relate it to the main causes in the why-why analysis, which are no proper written standard operating procedures provided and the lack of tools provided to help the operator complete the task. The highest risk priority number (rpn) value also indicates that we need to put our focus there due to the risk it has on the whole process compared to others' risk.

Table 4.9: failure mode error analysis table

Process step	Potential failure mode	Potential failure effect	severity	Potential cause	occurrence	Current control	detection	rpn
Pick up needles from the needles box using a flat ruler.	Needles fall off from the ruler	Need to pick up back the needles	4	Too many needles on the ruler	4	Regular checks by the operator	4	64
Fill the needles into the magazine	Needles fall off from the box	Need to pick up back the needles	5	Ruler not aligned with boxes	3	Regular checks by the operator	4	60
Weight the needles on the scale (500 pieces)	Target weight not achieved	Need to repeat filling needles process	6	No limit indicator	3	Regular checks by the operator	5	90
Unload the needles	Needles fall off from the box	Need to pick up back the needles	4	No needles holder	3	Regular checks by the operator	5	60

Table 4.9 above shows that the process of weighing the needles on the scale (500 pieces) is the main cause of our cycle time problem. This result is related to the main issue that had been identified in the why-why analysis. The hypothesis is that the cycle time of the company does not meet the rate of customer demand due to repetitive motion in the process of the weighing needle. From the analysis, we also conclude that the repetitive motion waste in the process of the weighing needle happens due to improper working steps that occur because of the lack of SOP and the lack of tools to help the operator complete the weighing process.

4.3.5 Classification of cause and effect

The problems that had been identified in each stage that are related to some of the 7 types of waste, which are unnecessary motion, inventory, transportation, defect, overprocessing, overproduction, and waiting, are then arranged and summarized in Table 4.10. The Ishikawa diagram, more known as the cause and effect diagram, can identify the problems, including the why-why analysis to determine the root cause of the problems that occur during the packaging needles into the magazine process. The cause of the problems possibly occurs due to the nature of the work process, which is new to the operator. The process took a longer time than it needed to be completed because the operator needed to be careful while completing the work process.

Table 4.10: Table classification

Process	Problems identified	Type of waste & description	Root cause
Load needles onto the scale.	• This process might need to be performed multiple times. • Excessive loading time	Unnecessary motion: the operator needs to load the needles on the scale multiple times to achieve the targeted number	No tools with marking as standard for the procedure.
Adjust the number of needles based on the scale's reading.	• Hard to get the target number on the scale. • Need to add or reduce the needle number multiple times.	Waiting: the operator needs to add or reduce the number of needles repetitively.	Trial and error method until target achieved.
Pickup the needles and hold them together	• Hard to pick the tiny needles. • Long time is taken because the operator needs to be extra careful.	Longer processing time: the operator needs to be extra careful with their finger in handling the needles.	No suitable tools were used for the process.

4.4 Kaizen Implementation (Objective 2)

Based on the highest rpn value in FMEA and its relationship with the conclusion of the other analysis, it is proven that the critical problem regarding the repetitive and improper process of packaging needles in the magazine department is the lack of proper tools to complete the work process. After a detailed investigation and observation, we identified that the operator has to weigh the needles on the scale multiple times because there is no indicator to show that the batch of needles is 500 pieces.

Operators have to use the trial and error method until the batch of needles achieves its target, which is 500 pieces. Because of the trial and error method, the operator has to perform the same steps repetitively, which is a waste to the company and needs to be reduced or eliminated. Besides the lack of standard operating procedure regarding the task also causes the cycle time not to meet the customer demand.

The solution to this problem problems is by providing a tool that can act as an indicator for the 500 pieces of needles which is a significant improvement to reduce or eliminate the repetitive motion in completing the task. The tool's main function is to eliminate the trial and error method by giving the operator the ability to see the required level for 500 pieces of needles and fill the needles according to the level.

By doing this, the cycle time of the process can be reduced because the repetitive motion has been eliminated from the work process. Since there is also no standard operating procedure, a detailed SOP was also developed with figures included to make it more understandable by all operators because there are a variety of races in the packaging needles in the magazine department.

4.5 Data Collection (Objective 2)

As stated in all of the analyses above, the repetitive motion in the weighing process is the main issue. Due to that a correlation analysis between the cycle time and the weighing frequency had been made to observe its relationship. From the study based on the table of data and figure below, it is clear from the forecast linear graph that if the weighing frequency increases, the cycle time also increases. From this statement, we can also make a hypothesis that if we are able to reduce the weighing frequency, the cycle time will also decrease.

Table 4.11: Cycle time and weighing frequency table

Cycle Time	Weighing Frequency (times)
2.48	6
3.00	7
2.19	5
3.21	10
2.18	5

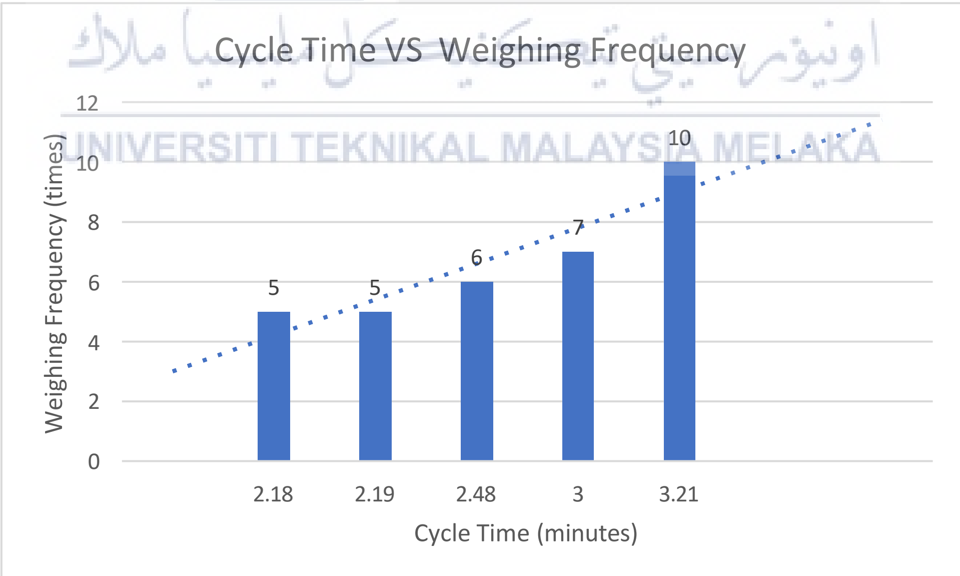

Figure 4.4: Linear forecast graph between cycle time and weighing frequency

4.6 Improvement suggestion (Objective 2)

Based on the data analysis that had been made by observing the time taken the operator needed to complete the process, the bottleneck of the process had been identified and clarified using the Ishikawa diagram and time study analysis. There are also steps that the operator can terminate to shorten the time taken to complete the task on hand and eventually improve the working posture of the operator by having a more ergonomic workstation. Due to the defined problems above a prototype had been designed and fabricated to act as a proper tool to help the operator to have a more efficient way of working and more safely in handling the sharp and pointy material. Some of the steps in the working list element, like bending, were also terminated to help reduce the cycle time of the operator's working process.

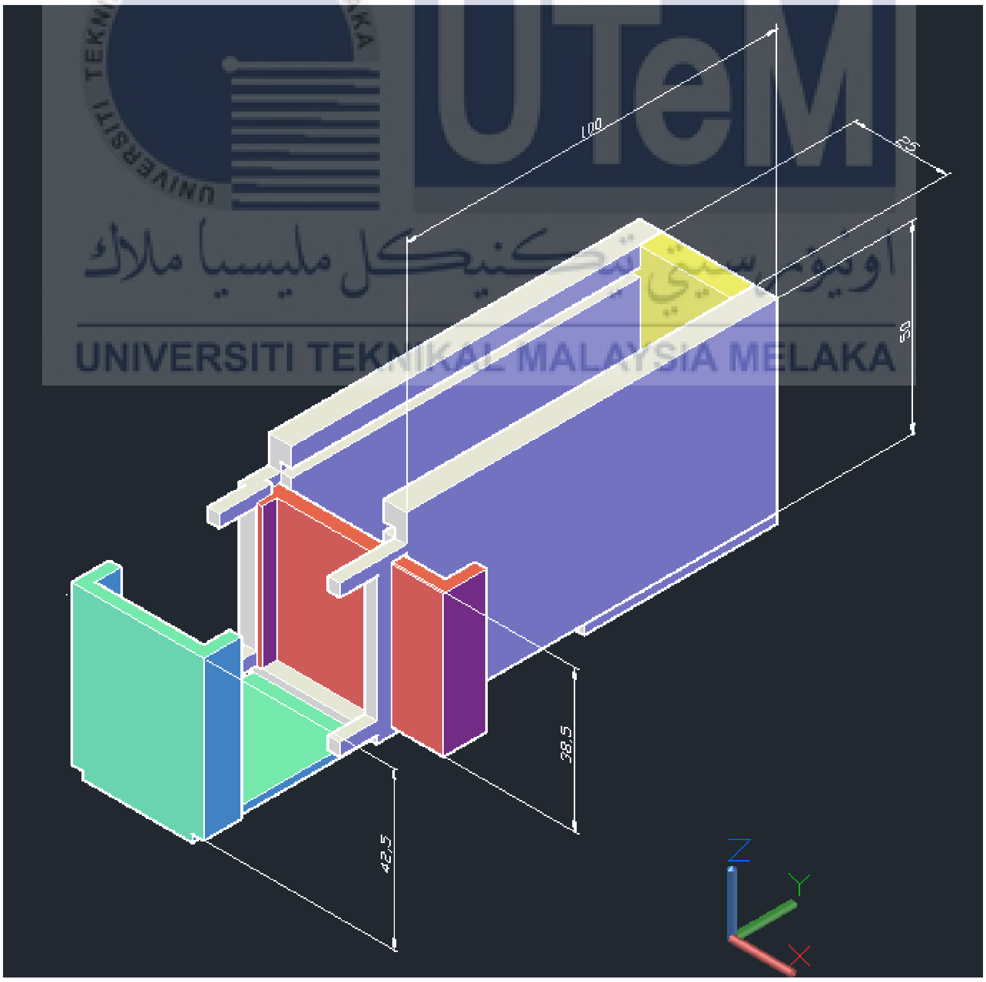

Figure 4.5: Prototype design

4.6.I Guidelines & SOP

Since unclear guidelines are one of the factors that lead to repetitive motion waste in the work process, clear guidelines regarding how to use the fabricated prototype are produced to help the operator understand the flow of work and how to use the prototype correctly. Below are the guidelines for the usage of the prototype :

Notes: Make sure the scale and prototype are free from any foreign object before usage.

- Firstly the needles will be put into the hollow compartment of the prototype (between the yellow and red parts).
- Then the yellow parts which act as a gate will be moved forward and backward as the blue arrow indicates to match the length of the needles.
- If the length of the needles is short then the yellow parts will be moved forward (left direction) and otherwise if the length is longer.

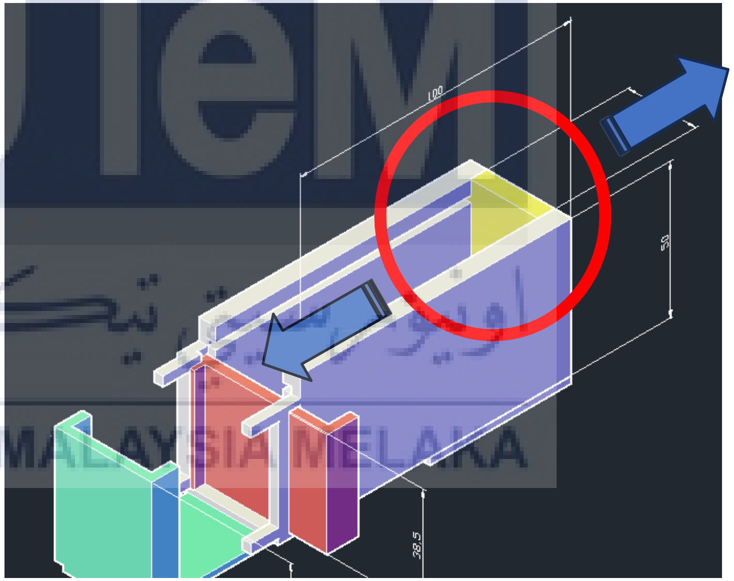

Figure 4.6: Guidelines for using prototype (1)

- After the previous process, the needles will be weighed on the weighing scale (with the prototype).
- Then a height marking will be made on the prototype to show that there are 500 needles in the prototype.
- The height marking is made to ease the next process where the height of the marking is already made and the operator does not need to weigh the needles every single time anymore.
- The red parts is used to prevent the needles inside the hollow compartment from falling out.
- After the needles inside the hollow compartment reach the marking height then the red parts will be pulled out to let the needles fall in a standing position onto the green part.

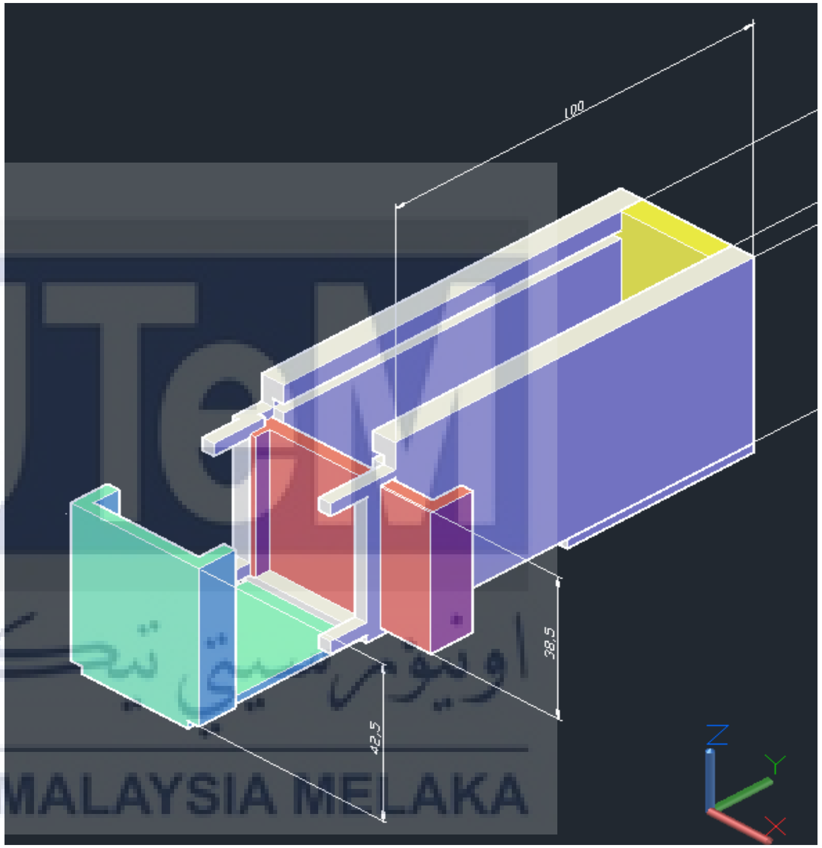

Figure 4.7: Guidelines for using prototype (2)

- After all of the needles are in standing position on the green part then a rubber band will be pushed down using the operator’s finger.
- The rubberband is held by the 4 parts in the figure that is in the red circle.
- That will be the last step in the whole process and repeated another 5 times to complete for a magazine.

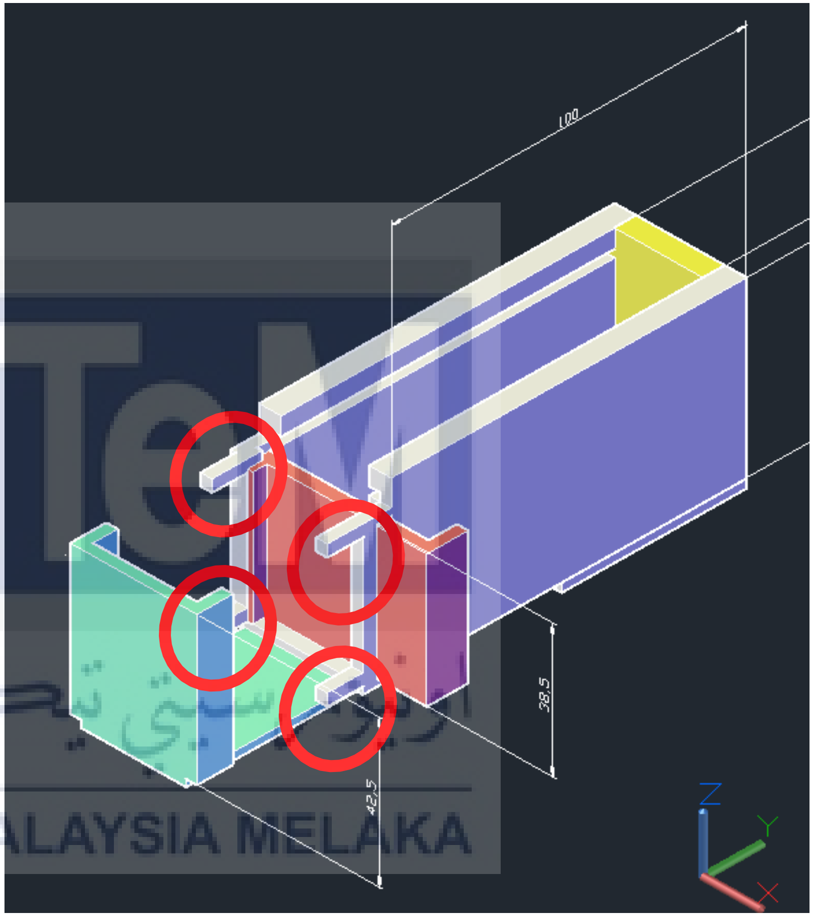

Figure 4.8: Guidelines for using prototype

4.7 Prototype Fabrication (Objective 2)

After the design and SOP had been made, the prototype was then fabricated using the 3D printer provided by the university. The fabricated prototype is then brought to the industry and tested. All of the results are recorded then analyzed and compared with the current cycle time performance.

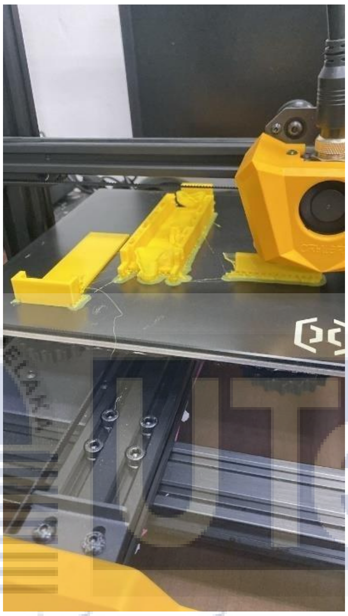

Figure 4.9: Fabrication of prototype using 3D printer

Figure 4.10: Finished product

4.8 Result Evaluation (Objective 3)

After the tools had been fabricated and the SOP had been developed, it was given to the operator to help them complete the task of packaging needles into the magazine. The new cycle time is then recorded to be compared with the previous cycle time. From the comparison that was made, we can determine if the cycle time is successfully improved or not.

Table 4.12: Evaluation table after implementing Kaizen

Process	Cycle Time (before) minutes	Cycle Time (after) minutes	Improvement Percentage
1	2.48	1.59	35.89%
2	3.00	1.41	53.00%
3	2.19	2.02	7.76%
4	3.21	1.31	59.19%
5	2.18	1.59	27.06%
Average	2.61	1.58	39.36%

From the result shown in Table 4.12, the cycle time had been reduced from 2.61 to 1.58 minutes due to the reduction in the weighing frequency. Theoretically, the ideal cycle time needs to be the same as the takt time to prevent delays or overproduction. Still, in this case, 1.58 minutes is acceptable because the excess production will be stored in the factory as the safety stock in preparation for unforeseen events and seasonal changes.

4.8.1 Percentage Improvement Calculated

Improvement Percentage = [(CT before – CT after) / CT before]*100

$$= [(2.61 - 1.58) / 2.61]*100$$

= 39.36% of improvement

Finally, objective 3 is achieved through the implementation of the prototype into the weighing process.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In this final chapter, the whole study regarding the methodology, findings, and results was summarized as a reference for future study. Recommendations are also included in this chapter to help future study and to show the potential for suggested improvement as well.

5.1 Conclusion

In conclusion, the three objectives that had been stated in Chapter 1 were successfully achieved. The first objective, which is to investigate the performance of the current cycle time, was achieved through the observation and data collection over 5 month period at the textile manufacturing company. All of the data collected is then compared with the pace of customer demand, also known as takt time, to determine the current performance of the company's cycle time.

The second objective of this study, which is to propose proper tools for the problems by implementing kaizen to eliminate waste and improve the cycle time of the filling needles in the magazine process, was achieved by implementing tools in kaizen such as FMEA and Ishikawa diagram to analyze all of the possible cause of failure and identify the leading cause of the problem. Based on all of the analysis, the weighing process is the most critical area that has the highest priority to be improved.

A proper design for the prototype that will be used as a tool in the weighing process is developed using the Autocad software. The prototype is then fabricated and tested at the company to observe the packaging needles in the magazine cycle time after prototype implementation.

The last objective, which is to check the level of the suggestion's effectiveness to be implemented, was achieved through the investigation and observation of the process cycle time before and after the kaizen implementation. A reduction in cycle time was collected as a result of the tool usage in the packaging needles in the magazine process. After the comparison of the cycle time had been made, the percentage of improvement was calculated to be 36.39%, and successfully improve the cycle time of the packaging needles in the magazine process.

5.2 Recommendation

The improvements have a massive impact on the cycle time of the packaging needles in the magazine work process. Current improvements might be suitable for the company but the need to sustain it and make continuous improvement are more crucial for the company to survive in the industry. Because of that, the company needs to provide training for the operator and use the 5S approach to enhance the result further and sustain the kaizen implementation that had been done. In addition to that, kaizen implementation should also be implemented in other departments to improve the overall cycle time of the company and smoothen the supply chain of the company to keep up with the fast-paced production nowadays.

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APPENDIX A

The figures below shows the data collection process.

Figure 1(A): Weighing process without tools usage

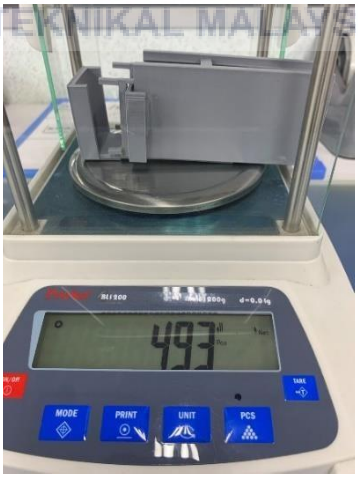

Figure 2(A): Weighing process using the tool (prototype)

APPENDIX B: GANTT CHART FOR PSM I AND II

No	Project Description	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
1	Selection of title and briefing regarding PSM																
2	Proposal submission																
3	Site visit to the company and data collection																
4	Literature review study																
5	Work process study																
6	Proposal submission to the company																
7	Problem statement study																
8	Determined objectives																

9	Methodology study																
10	Report progress to supervisor																
11	Designing project methodology																
12	Presentation of poster																
13	Format and final report element discussion																
14	Report preparation																
15	Report and logbook submission																

No	Project Description	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
1	Study the current performance of cycle time															
2	Classify and analyze the work process															
3	Critical problem identification															
4	Lean tools implementation															
5	Designing prototype															
6	Testing prototype															
7	Evaluate previous and current cycle time data															
8	Report progress to supervisor															
9	Drafting thesis															
10	Final thesis															
11	logbook submission															

APPENDIX C: FMEA RATING SCALE

The table below shows the rating scale for FMEA at the packaging needles in the magazine process.

Table 1(C): FMEA Evaluation

Abbreviation	Description	Ranking
Severity (S)	Severity of the problems	1 – 10, where 1 represents no effect on the process and 10 represents very severe
Occurrence (O)	Probability to happen	1 – 10, where 1 indicates not likely to happen and 10 indicates surely to happen
Detection (D)	Level of detection	1 – 10, where 1 means not likely to be detected and 10 means highly detectable
RPN	Risk Priority Number	(Severity)*(Occurrence)*(Detection)

Table 2(C): FMEA Evaluation (Severity)

Rating	Description	Severity of the effect
10	Dangerously high	Hazardous and cycle time might not achieve two day target
9	Extremely high	Hazardous and cycle time might not achieve a day target
8	Very high	Major effect on cycle time, the target cannot be achieved
7	High	Significance impact on cycle time
6	Moderate	Major effect on cycle time but target can be achieved
5	Low	Moderate effect on cycle time
4	Very low	Minor effect on cycle time
3	Minor	Slight effect on cycle time
2	Very minor	Very slight effect on the cycle time
1	None	No effect on the cycle time

Table 3(C): FMEA Evaluation (Occurrence)

Rating	Description	Occurrence of the problem to happen
10	Very high	Frequently happen
9	High	Almost frequently happen
8	Almost certain	Inevitable to happen
7	Very high	Almost inevitable to happen
6	High	Very frequently happen
5	Moderately high	Frequently happen
4	Moderate	Repeatedly happen
3	Moderate	Occasional to happen
2	low	Relatively few happen
1	Remote	Unlikely to happen

Table 4(C): FMEA Evaluation (Detection)

Rating	Description	Detection level of the problem
10	Cannot detected	The long cycle time of packaging needles cannot be detected
9	Very difficult to detect	The long cycle time of packaging needles is very difficult to detect
8	Difficult to detect	Long cycle time of packaging needles difficult to detect
7	Trouble to detect	Long cycle time of packaging needles causes trouble to detect
6	Moderate low to detect	The long cycle time of packaging needles is moderately low to detect
5	Moderate to detect	Long cycle time of packaging needles moderately detected
4	Moderately high to detect	The long cycle time of packaging needles is moderately high to detect
3	Frequently detected	Long cycle time of packaging needles frequently detected
2	Easy to detect	Long cycle time of packaging needles easy to detect
1	Very easy to detect	The long cycle time of packaging needles is very easy to detect