OPTIMIZE PRODUCTIVITY THROUGH OVERALL EQUIPMENT EFFECTIVENESS AT FOOD AND BEVERAGE INDUSTRY

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2021

Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfilment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled “Optimize Productivity Through Overall Equipment Effectiveness at Food and Beverage Industry” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 17/01/2022

APPROVAL

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

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DEDICATION

This dissertation is dedicated to my beloved parents, my supervisor and those who are unwavering affection, guidance and encouragement have enriched my soul and driven me to undertake and complete this work.

ABSTRACT

In the era of Industrial Revolution 4.0, manufacturing sector should be able to meet up global market demand with assurance of consistence in producing quality product. Therefore, to maintain a smooth production the equipment effectiveness should be considered for better productivity in every manufacturing including Food and Beverages. Problem statement is used to define the problems of the study and can be used to determine the goal of completing the study. For an optimized productivity, the objective of the study should be start by identifying the factors that effects the production productivity in the manufacturing sector The Overall Equipment Effectiveness, OEE is one of the most effective tools that can be used to measure the performance of the equipment. This implements the second objective which is measuring the equipment's effectiveness using OEE. OEE can identify the performance, availability and quality of product produced by equipment. Hence, this determine the hidden losses that are found during manufacturing. Identification of losses leads to propose for improvement in equipment. Using OEE's evaluation, can suggest improvement for better equipment effectiveness. Besides objective there are other tools required to complete the study. Next, the data collection plays an important role of completing the study. The data collection is done using interviews, capturing image, literature review, and arranging given company data in spreadsheet for formulation and calculation. Next, the analysis is conducted using collected data. Evaluating availability, performance and quality determines the OEE's rate. These determines most effected element based on OEE evaluation and will be used for proposing improvement. These proposals are discussed with the industrial representative at the same time presenting the research to them for evaluation.

ABSTRAK

Dalam era Revolusi Perindustrian 4.0, sektor pembuatan seharusnya mampu memenuhi permintaan pasaran global dengan jaminan konsisten dalam menghasilkan produk berkualiti. Oleh itu, untuk mengekalkan pengeluaran yang lancar keberkesanan peralatan harus dipertimbangkan untuk produktiviti yang lebih baik dalam setiap pembuatan termasuk Makanan dan Minuman. Pernyataan masalah digunakan untuk mentakrifkan masalah kajian dan boleh digunakan untuk menentukan matlamat menyiapkan kajian. Untuk produktiviti yang dioptimumkan, objektif kajian hendaklah dimulakan dengan mengenal pasti faktor-faktor yang mempengaruhi produktiviti pengeluaran dalam sektor pembuatan Keberkesanan Peralatan Keseluruhan, OEE adalah salah satu alat paling berkesan yang boleh digunakan untuk mengukur prestasi peralatan. . Ini melaksanakan objektif kedua iaitu mengukur keberkesanan peralatan menggunakan OEE. OEE boleh mengenal pasti prestasi, ketersediaan dan kualiti produk yang dihasilkan oleh peralatan. Oleh itu, ini menentukan kerugian tersembunyi yang ditemui semasa pembuatan. Pengenalpastian kerugian membawa kepada cadangan untuk penambahbaikan dalam peralatan. Menggunakan penilaian OEE, boleh mencadangkan penambahbaikan untuk keberkesanan peralatan yang lebih baik. Selain objektif terdapat alat lain yang diperlukan untuk menyelesaikan kajian. Seterusnya, pengumpulan data memainkan peranan penting dalam menyiapkan kajian. Pengumpulan data dilakukan dengan menggunakan temu bual, menangkap imej, tinjauan literatur, dan menyusun data syarikat yang diberikan dalam hamparan untuk perumusan dan pengiraan. Seterusnya, analisis dijalankan menggunakan data yang di kumpul. Menilai ketersediaan, prestasi dan kualiti menentukan kadar OEE. Ini menentukan elemen yang paling berkesan berdasarkan penilaian OEE dan akan digunakan untuk mencadangkan penambahbaikan. Cadangan ini dibincangkan dengan wakil industri pada masa yang sama membentangkan penyelidikan kepada mereka untuk dinilai.

ACKNOWLEDGEMENTS

Praises to the Almighty Lord, the Most Gracious, the Most Merciful

Most importantly, I'd like to take this time to offer my heartfelt gratitude to my supervisor Ts. Dr. Amir Hamzah bin Abdul Rasib of the Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for his invaluable help, encouragement, and supervision in the completion of my thesis.

Secondly, I'd want to extend my feelings to all of my friends, as well as my dear mother, father, and siblings, for their moral support during the programme. Finally, I'd want to express my gratitude to everyone who has contributed to the successful completion of this project.

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LIST OF SYMBOLS AND ABBREVIATIONS

TPM	-	Total Productive Maintenance
OEE	-	Overall Equipment Effectiveness
OOE	-	Overall Operation Effectiveness
SMED	-	Single Minute Die Exchange
TEEP	-	Total Effective Equipment Performance
F&B	-	Food and Beverage

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the era of globalization, the customers are demanding for a high-quality product at the same time requesting it at an affordable price. In today's manufacturing, there are greater complexity and uncertainty due to the upraising globalization of markets and operations with varied consumer expectations and drastic reductions in product lifecycles and manufacturing, P. Dicken (2007). Hence, the global competitive market, manufactures are keen to know various method on manufacturing their product with low production cost with good quality standards. Based on this problem, manufactures are focused on optimizing their production productivity through various performance measuring tools. Based on Ericsson (1997) research, with proper accuracy in performance measure data can lead to a long-term equipment effectiveness. This can be achieved through Total Performance Measure, TPM.

TPM serves as a tool that address hidden cost and unwanted procedures in the manufacturing process. Besides that, TPM also helps in optimization of equipment ensuring the performance, availability and quality is at its best. In supporting to this statement, Fleischer et al, (2006) highlights that availability and productivity of production facilities are important to stay competitive in manufacturing industry. TPM concept was launched by Nakajima (1988) in the 1980s to provides a metric evaluation the equipment performance at the same time highlighting the losses found in it. These identification and measure of losses will support in improving in equipment effectiveness and thereby increasing production

productivity. These measurements can be done using the performance measure tool called Overall Equipment Effectiveness, OEE.

Similarly, to TPM, OEE is used to measure performance of productivity using TPM's identification of losses that is found on the equipment. OEE is becoming a widely popular concept that is used as a quantitative tool which is essential in measuring productivity, Huang et al (2003). Today in industries, the OEE concepts are modified according to requirement but at the same time the basic principles are still being used. For instance, the use of Six Big Losses is still used to categorize the loses that is found on the equipment.

Ericsson and Dahlean (1993) proves that 80% of disturbance occur during production was due to machine down time. In addition to that statement, Suehiro (1992), states that idling and minor stoppages causes 20% to 30% of disruption. Hence to resolve these losses into categories Nakajima (1988) introduces the Six big Losses to categories these losses which later can be used to calculate availability, performance rate and quality. These values are the basic elements to determine the OEE rate. OEE rate determines the standard of equipment performance. Nakajima (1988) suggest that the standards of equipment should possess an availability of 90%, performance rate of 95% and the quality rate at 99% which can result an OEE rate of 85% which is the world standard performance efficiency result. Ljungberg (1998) supports these suggestions by highlighting world class performance assures that idling and minor stoppages can be eliminated which causes a smooth production.

Consequently, the purpose of these study is to ensure an optimized production productivity by enhancing Overall Equipment Effectiveness, OEE in manufacturing industry. It is a achievable process whereby first the losses data are identified, collected and categorized according to the concept of Six Big Losses. Then with the data, availability,

performance rate and quality are calculated. Then these values are used to determine the OEE rate which can determine the standards of equipment effectiveness based on World Class OEE indicator.

1.2 Problem Statement

Every manufacturing company aspect a smooth production without any disturbance. To achieve such performance, it is not impossible but requires long time and effort. This is because it requires to collect data from various departments and production lines. Hence with a precision data collection for performance measure of an equipment, production line or the whole plant can be calculated. Nachiappan and Anantharam (2006) claims that it is necessary to incorporate right metric measurement for effective decision making. As mentioned earlier, to compete with global market, manufactures must first know the factors that can affect the production productivity. Once knowing these factors, then the performance measure can be done by using the OEE performance measuring tool. OEE is introduced to manufacturing companies to provide performance measurement of equipment and overall process for better productivity. Similarly, P Gibbons and S Burgess (2010) stated that the enhancement of OEE as a measurement framework in the manufacturing industries provides a good benchmark.

Besides that, both small and large cooperate companies face the problem of identifying root cause of failures found in equipment. This is mainly due to unnecessary procedures causing reduction in performance of equipment. Underperforming equipment leads to increasing the cycle time of production with results in higher production cost. Therefore, TPM can be used as it is one of strong methods to enhance productivity quality at the same time reduce production cost, Mcadam and Duffner (1996). Besides that, the Eight Pillars of TPM allows manufactures to identify root and hidden cause and suggest improvement action for manufacturers for improvement. In addition to this assertion, TPM guarantees the participation of employees from the highest levels of management in

maintenance tasks that maximize available resources and enhance OEE, Campbell and James (2006). We can safely assume that OEE is the best performance measure to determine the equipment effectiveness with the implementation of TPM where it helps in identifying the hidden losses which leads to a reduced production cost and a more optimized and effective productivity.

1.3 Research Question

In regarding to the problem statement, there are research question which are identified.

RQ1: What are the factors that effects the production productivity in the manufacturing industry?

RQ2: How to measure the performance of equipment effectiveness during the manufacturing process?

RQ3: How does the Overall Equipment Effectiveness, OEE can improve the equipment effectiveness?

1.4 Objective

The main objective of the study is to ensure manufacturing industry to have an optimized production productivity with enhancement of Overall Equipment Effectiveness, OEE. In regarding to primary objective there are several specific objectives that need to be accomplished in this study.

i) To identify the factors that can affect the production productivity in manufacturing industry.

ii) To measure the Overall Equipment Effectiveness, OEE of equipment in manufacturing industry.

iii) To propose action for improvement in the efficiency of equipment in the manufacturing industry.

1.5 Scope

The study first focuses on knowing the factors that can affects the production productivity. Next, the production performance is measured with OEE to know if the equipment is working in optimized and fully utilized condition. The performance measure is done before and after implementing the TPM concept to compare results. This is because TPM able to identify the hidden losses found in equipment and eliminate them to reduce production cost and increase in the production rate. This technique will reduce downtime and unnecessary stoppages proportionally increasing equipment performance and quality rate of product.

1.6 Expected Result

The expected outcome of this study is the factors that affect the performance measure of an equipment can be identified. First, implementation of TPM allows manufacturers to identify the hidden losses, failures and other procedures that contributes to the performance of machine. This is because that, the factors can cause the cycle time for the manufacturing process to increase causing an increase of production cost and not fully utilized machine performance. Hence modified, improvement or elimination of waste should be done on these factors for better performance.

After using TPM, the state of equipment can be determined with the usage of OEE. This is because OEE able to calculate the availability, performance and the quality of a

machine, production line also the overall process itself. Hence, this tool would bring out the best results in determining the performance of equipment. Based on the results, we can compare the performance measure before and after the implementation of TPM. With the results knows, the type of losses can be categorized based on the Six Big Loss found in the OEE then improvement can be done to increase its value.

1.7 Thesis Frame

Chapter one focuses on the introduction of the overall thesis's introduction. The introduction part elaborates details of the study. This is followed by the problem statement that is faced in the study. Based on the problem statement, a research question is developed which later allow to develop the objective for this study. Finally, after going through the objective, an expected result is created for the study that is being conducted. As an overall conclusion, a summary is written to tell the whole study in a summarized version.

Next, in chapter two is about the literature review that have been gathered for this study. This chapter allows for gather, read, and understand the previous case studies and journals made which is similar to the tittle of the study. This chapter tells the information about the factors that affects the performance measure, implementation of TPM into manufacturing, the 8 Pillars of TPM, tools that able to measure performance, introduction of OEE, the 6 Bis Losses of OEE, calculation of OEE and the status of OEE based on worldwide performance guideline. The technique of writing this chapter will be based on the findings in case study, journals and articles that has been done in the past. Hence, many subtopics are made to provide a detail explanation of this study.

Furthermore, chapter three explain the methodology of the study is being conducted. Based on the previous studies being conducted, chapter 3 tells on the tools and technique that is used to conduct the study. The details of the techniques and tools that is used on this

study are mentioned clearly. These tools and technique are used for problem solving and achieve objective.

Subsequently, in chapter four will present the result and the discussion of the study made. In this chapter, the tools and technique mention earlier will then be used to obtain results. The technique and the type of tools used to collect results will be discussed. Once results are gathers, a discussion is made based on the result to tell on the effect of implementing the tools and technique for this study.

To sum up evidently, chapter five express the conclusion of the overall study. This chapter will recap the overall studies and findings of the study. This chapter also stress out the future enhancement for a better result. Future plans for introducing an updated framework to smooth the production line are discussed. Overall, the factors that contribute to performance measure are identified, investigated and then implement TPM for improvement and then the performance is measured with OEE which then compared the results for future improvement.

1.8 Summary

As a conclusion, manufacturers have to continuously monitor the performance of their productivity for them to meet customers demand on time. Thus, they are required to have continuous improvement, identify failure types and measure equipment performance for and efficient and smooth production. In additional to the statement, manufacturers needed to identify the factors that affect that contribute to performance measure of equipment. To identify them, they must first collect the data during manufacturing process as accurate as possible. This requires the collaboration to top management all the way to workers in shop floor. The collection of data will be able to tell the initial performance of production using OEE. Then, TPM is implemented to identify hidden losses and suggest improvement for the equipment efficiency.

Using the TPM's 8 Pillars, the type of improvement made can be suggested for each scenario faced. Besides that, the loses that are found in the equipment can be categorized by OEE's Six Big Losses. When the losses are categorized, they can be used to calculate the availability, performance rate and quality which determines the OEE rate of equipment. Based on these values, manufacturers can focus on the particular part for improvement that can increase the OEE value. By increasing the OEE value, the cycle time of the manufacturing process can be decreased hence making a faster production rate.

OEE is a tool that determines the performance measure of an equipment based on its rate of availability, performance and quality. By knowing these values and OEE rate, we can determine which loses contribute the least to increase the OEE rate and improvement can be made starting from there. These improvements can be based on TPM implementation which helps in identifying the types of losses found in the equipment and suggest the methods of overcoming these failures. Like the thesis's objective, OEE aims to measure the performance of equipment, identify the potential losses found in equipment and overcomes them with the expected result of better performance and efficiency in the equipment for a better productivity.

CHAPTER 2

LITERATURE REVIEW

2.1 Preliminaries

In today's revolution of industry to IR 4.0 and the approaching IR 5.0, many companies are striving to compete to gain control over the worldwide market to gain profit similarly as pointed out by Miyake and Enkawa (1999). At the same time, manufacturing company try to produce product from raw material until the end product with best quality, efficient, cost effective, safe and environment friendly. Hence to produce such high standard product, the company must be able to focus on product and also the overall process of the manufacturing with cooperation of employees. Therefore, the company should emphasise on productivity which determines performance measure and continuous improvement. The measurement of productivity level is considered as a very important aspect because it effects the organizational practices and process until bottom line. Based on the ideas of Becker and Huselid, (1998) a study conducted by Human Resource Management proven that a company should have practice of implementing standard procedures, training, empowerment and communication which subsidize to companies' improvement. In addition, the process of continuous improvement should be done with joint effort from top management until floor worker. Firstly, to measure a company's performance, we must use tool and techniques that able to measure in matric form for evaluation. Thus, a firm or a company should know the productivity of the overall manufacturing and determine the level of utilization. The development of a company is based on production and the rate of productivity. Hence, before setting up a tool to measure the productivity, the production productivity process state should be known.

2.2 Production Productivity

Firstly, production is the process where a product is being created, processed, manufactured, and having improvement of goods and services while productivity is defined as measure of efficiency in rate of production. Diewert (1992), formulates the productivity as the ratio of input and output coefficient that changes over time. In other words, rate of the product is being produced over time is called productivity. For every firm or company, the product production and productivity are very important. When there is production and sales at local or global market, as a consequence there will be increasing in demand. In support to this statement, Basu (2001) and George (2002) agrees that global marketplace has observed that there are growing pressure among the customers and competitors in manufacturing due to the high demand. Therefore, required a faster productivity to meet the demand at the same time maintaining performance and quality of the product. Hence maintaining these key features are very important to very company all around the world.

Since the early 18th century, product demand was always increasing from time to time especially when people more often use the product. As the demand and the market scope increase, more labour, tools and machine are brought into the manufacturing line to increase the production performance. By the middle of 18th century, manufacturing companies begin to focus on the production performance of their product as there was more demand and sales market available. Manufacturers begin to focus on the production performance to determine the rate of success of a company.

2.3 Performance Measuring

Performance measure is an important part in any industry as it is one of the main keys that helps in achieving the company's goals. Thus, performance measure is used to evaluate, control, improve and eliminate waste of a production in a company. Similarly said

by King (2005), the performance measure should be done with a system that able to forecast, monitor and prevent disturbance to occur with performance assurance tools. However, Heim and Camptom (1992) mentioned that performance measure is used for comparing the different types of organization's performance in the same field, departments, project teams and individuals to be accessed. The importance of the performance measure is also focused by the Foundation of Manufacturing Committee of National Academy of Engineering where they are one of the top ten world class foundations. The performance measure can be described in two types of states where the first state is the Traditional State which begins in the late 1880s and was implemented until the early 1980s. In this state, majority companies focus more on the financial state of the company with sales and profit rather than the product manufacturing performance and quality. The second state is the modern state where it started at late 1980s and the practice is still applied and being improved till these days. This is where companies decided to focus on the performance development of the product.

2.3.1 Traditional Performance Measure

Back in the old days, performance of a firm or company is mainly based on the financial statement. A company with the most sales and profit is considered the best performing company in that time of period. This statement is supported by Teague and Eilon, (1973) where the primary indicator of performance measure is sales of productivity, profit per-unit production and the return of sales and investment. The importance of productivity comes with "strategic" which is to compare performance with other firms, "tactical" which is management control over the performance at the firm or company, "planning" which is comparing the relative benefits of different improvement and finally "internal management" which is the bargains with trade unions. In traditional performance measure, there are limitations that cause the performance measure to be not as accurate and effective as the modern method. These limitations are classified into two categories which are General

Limitations and limitations that are specific to certain traditional performance measure such as the cost or productivity.

2.3.2 Modern Performance Measure

In contrast to traditional method, modern performance measure focuses on the measure of optimisation of machine and workflow rather than only focusing on the value of profit and finance. This gives information to the overall management and workers to identify the errors and unnecessary steps in their work procedures and eliminate them to obtain maximum output with minimal resourced which results in obtaining maximum profit. This statement supports the action of time management. When the cycle time of a process is controlled and reduced it will lead to a faster operation. Lower cycle time in producing a product will eventually increase the productivity time which results to produce more finished product on time to meet customer's demand. Similarly, Bockerstette and Shell, (1993) confirms that having a control on the lead time of a manufacturing process will certainly have more outcome which contributes to successful business establishment. In addition to the earlier point, Kurpka, (1992) highlights that time is more important than money because it helps in improving production and sales. Hence for a proper time management, various tool can be used in order to have a good performance. These tools able to measure in metric form where they can point out the problem and evaluate its value. This enables to identify the type of procedure that cause more waste and inefficiency in the manufacturing process.

2.3.3 Tools for Performance Measurement

Performance of a manufacturing process can't be based just on the statement of a machine, or a production line is running smoothly rather it should have a proper matric evaluation in them to show evidence that a process is done with optimized input and maximum output. In addition to it, there has to be time management, elimination of waste

and continuous improvement on process. Besides that, Ericsson, (1997), claims that the overall cost of production can be attributed to production losses which is known as hidden cost. These hidden costs are the excessive or unwanted process and procedure that contributes to extension of cycle time and product cost. Hence, various tools that has been introduced to measure and evaluate a process and identifying the cause of hidden cost which results in longer production time and failure in the process. The following tools are listed below with their functions and explanations.

2.3.3.1 Production Volume Variance

The cost of production against the expectation reflected in the budget is called production volume variance. In other words, it is used to compare the actual overhead cost per unit that will be achieved through expected or budgeted cost per item. By knowing the production volume variance, we are able to determine the quantity of the product that can be produce in order to achieve profit at the same time focusing on the overhead cost per unit rather than the total cost of production. Besides that, production volume variance also helps in fixing production cost, therefore higher production will return in higher profit. Knowing the overhead cost of a product is crucial because it is a fixed cost. This type of cost is needed to be paid even there is no production process. When the actual production volume is more than the budgeted production thus it indicates a good production volume variance. The total fixed overhead that has been allocated to a greater number of units resulting lower production cost. This type of tool mainly used in measuring financial performance of a company.

$$Production\ Volume\ Variance = \left(Actual\ Unit\ Produced \times Budgeted\ Production\ Unit\right) \times Budgeted\ Overhead\ Rate\ PerUnit \quad (2.1)$$

2.3.3.2 Overall Operation Effectiveness, OOE

The overall operation effectiveness also known as OOE is a similar tool as Overall Equipment Effectiveness, OEE where OOE mostly targets on the on the availability of the machine in the production line. A common example of difference between OOE and OEE is that in OOE calculation the values such as planned maintenance is added where in OEE these values are neglected. This is because that machine maintenance time is not being productive. Besides that, factors such as changeover time plays a role in the rate of OOE. Overall, OOE is a tool that measure the rate of performance of a machine the moment the machine begins to be used until the machine is fully stopped in the production line. Majority factories the production line will not be stopped unless due to unavoidable scenarios, and this is the part where OOE plays the role on calculating the total utilization of the production of product. Similar to OEE, OOE measures the performance, quality and the availability of any asset, production line or production machine. In OOE, the availability is calculated based on unplanned downtime. This is because it is believed, the unplanned events are the most used to determine the availability of a machine, production line or the process itself rather than having a planned process such as planned maintenance or planned product changeover. OOE helps in determining the theoretical capacity of equipment with production demand. If a process does not meet the demand that is being set, hence the process is required to be inspected as an underperforming process because it is operating at low OOE. The following is the formula used to calculate the OOE rate of performance of a manufacturing process.

$$OOE = Performance \times Quality \times Availability \quad (2.2)$$

$$Availability = Actual\ Production\ Time/Uptime \quad (2.3)$$

2.3.3.3 Overall Equipment Effectiveness, OEE

According to Nakajima (1998), Overall Equipment Effectiveness, OEE is a tool that measures the productivity of an individual equipment in the factory which is done in quantitative matric form to assess the concept of Total Productive Maintenance. It helps in analysing and measure losses that can be found in the availability, performance, and quality in producing the product from raw material until the end product. The main goal of OEE is to achieve an ideal performance where it means that there are no defects occur during production process, no scrap production, no breakdown, no accident, and no waste in process running or changeover. For a full effective OEE usage into the process requires cross-functional team from various department and layers or management level involvement as requires a proper data gathering for analysis purpose and requires skills to identify the root cause of the problems. The waste time in the productions is gathered and quantified then the data is used to compare to the total available time for the production and maintenance to obtain the actual available time for production. These data will be able to describe the rate of availability of the machine, production line or the plant itself for the production process to occur. The advantage of using OEE in the manufacturing sector is that it helps in improving output with the existing resource available to meet customer demand. Furthermore, it allows more flexibility within existing production process and promote sustainable culture and moral which allows to be focus on continuous improvement until world standard is achieved. Besides that, the use of OEE helps in increase in sales margin by reducing the production cost in other words eliminating waste or not relevant process that is being added into the manufacturing process.

$$OEE\ \% = Performance\ \% \ x\ Availability\ \% \ x\ Quality\ \% \qquad (2.4)$$

2.3.3.4 Single Minute Exchange of Dies, SMED

Single Minute Exchange of Dies origin back in 1950 where Shingeo Shingo founded and developed to eliminate bottle neck process. Later, he perfected it by implementing eight techniques for SMED, Shingo (1985). SMED is a process of ensuring the time of equipment changeover is least of at the fastest time to ensure a smooth and simplifies streamline of production. The word single in SMED is used to shows that the changeover process that occurs should be conducted in less than 10 minutes also known as single digit minute. The statement of conducting a changeover in less than 10 minutes is encouraged by Womack (1990) and McIntosh (2001) as they agree that although there are use in technologies and machinery in the manufacturing process, if there is proper standardization in process is applied especially with involvement of human effort and organization, then it will lead to faster time to reach the market and improve work flexibility. Implementation of SMED into the streamline ensures a lower manufacturing cost, smaller lot size, improve responsiveness to customer demand and smoother start-ups due to the standardized changeover process to maintain consistency. SMED was developed by Shigeo Shingo, 1985 where his development in reducing in changeover time has an effective time about 30% to 50%. SMED can be implemented by starting with identifying pilot area, which is to create targeted area of implementation followed by identifying the elements of changeovers. Next is to separate the external elements and then convert the internal elements into external elements. Finally, the remaining elements are reviewed and simplified to be applied into the streamline.

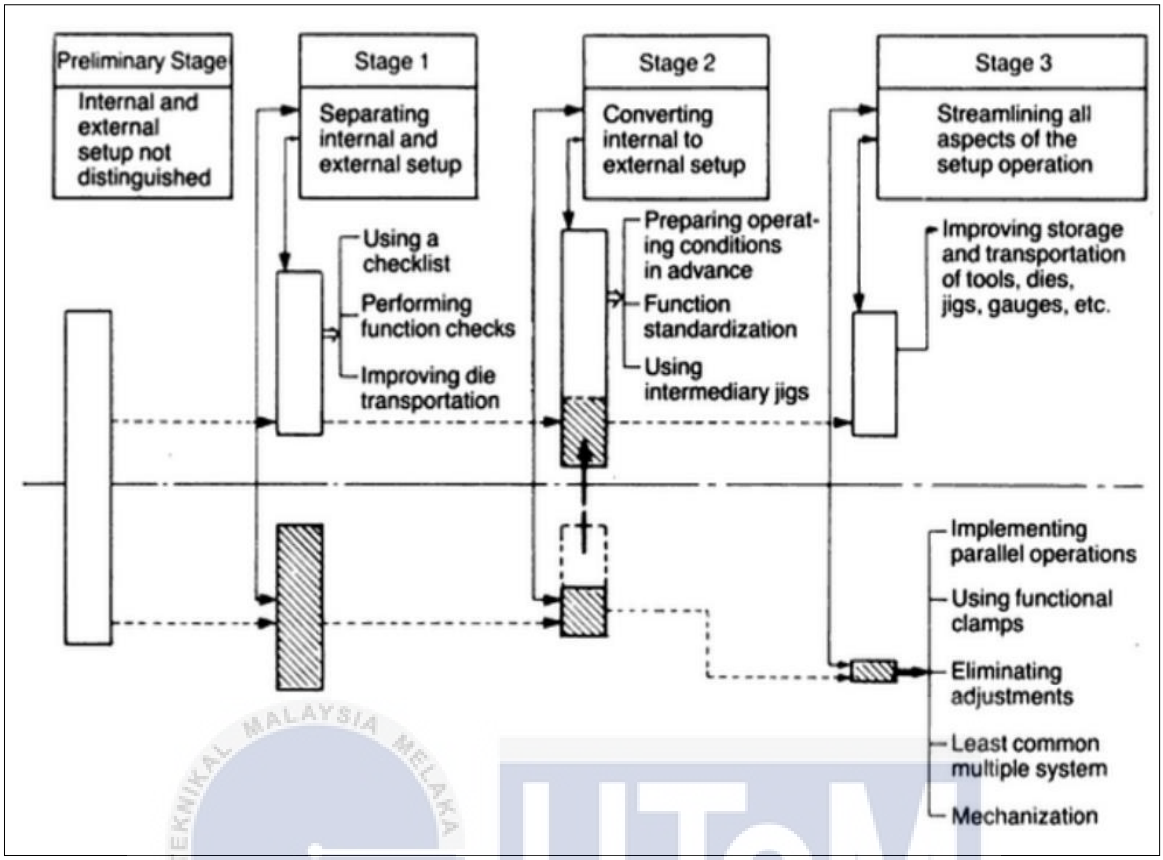


Figure 2. 1 SMED conceptual stages, Shingo (1985).

2.3.3.5 Total Effective Equipment Performance, TEEP

Ivancic (1998) relates that Total Effective Equipment Performance, TEEP is a similar tool as the OEE and schedule losses. TEEP measure the capacity of manufacturing operation using the maximum availability of operation time which is 24 hours in 365 days. Hence the TEEP measure the full availability of the manufacturing process using the OEE formulas that is known. This is because that, TEEP calculate the whole available time in a day thus encouraging to maximum utilization of the machine or process to obtain maximum profit or outcome. Besides that, Pintelon et al (2000), also mention that the unplanned down time occurs during production can be a function that determines the TEEP by measuring Mean Time Between Failure, MTBF and Mean Time to Repair, MTTR. The goal of TEEP is to increase the percentage of utilization as much as possible in a day and identify the

unexplored potential that is found in the process without inventing for new equipment. In other words, TEEP helps in identifying the unwanted hidden factors in mechanism and removes them fort maximum outcome and find alternative methods of optimizing the process in more convenient way. When a TEEP score is 100% it indicates that the process of producing goods is fast and efficient with no stops in between around the clock for 24hours. This means that there is no scheduled loss or OEE losses found in the process.

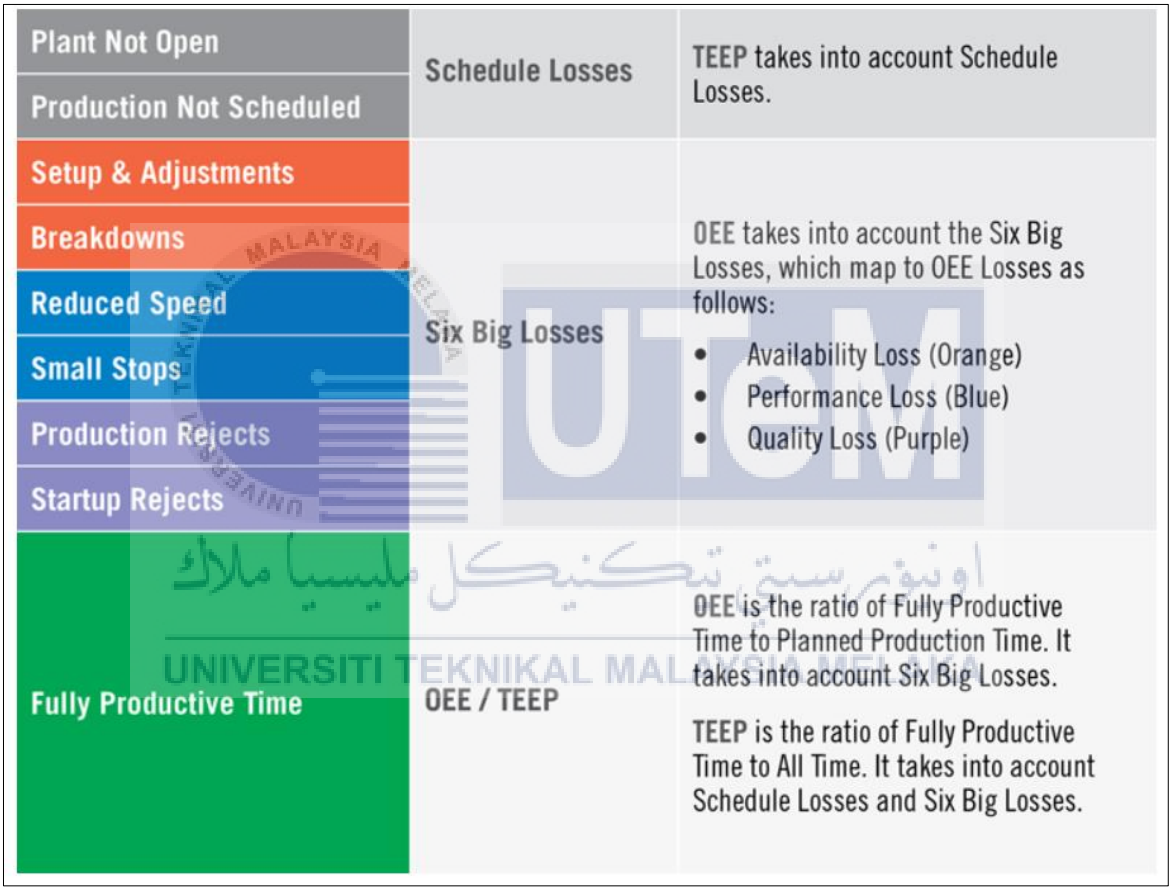


Figure 2. 2 TEEP compared to other performance measuring tools, Pintelon et al (2000),

To summarize the overall statements, these tools are very effective in measuring the performance of the machine, production line or the overall plant. But still, to use these full of fullest effectiveness, manufacturing company are required to have maintenance and improvement process. Thus, majority companies tend to use Total Productivity Maintenance, TPM.

2.4 Total Productive Maintenance, TPM

The Japanese have developed an innovative concept called TPM which is a maintenance program to increase production while at the same time increasing employee morale and job satisfaction. TPM intends to show that maintenance as an important aspect in the manufacturing industry. TPM will try to address all the non-profit activities and then removes it. Nakajima (1988) and Wheelwright (1992) describes the goal or TPM is to achieve a smooth production line without any interruption that stop and defects the production process.

2.4.1 Origins of Total Productive Maintenance, TPM

In the year 1952, twenty Japanese companies decide to form a preventive maintenance research group and study the equipment maintenance in the Japan Institute Plant Engineering, JIPE. Later in 1969, an automotive component manufacturer called Nippon Denso decides to change the roles of operator encouraging them to perform maintenance to machinery as a routine before start-up. This was the early stages of TPM being implemented in manufacturing companies. Tajiri and Gotah (1992) expressed their opinion that only small companies in Japan were applying the concept of TPM. Only after the serious economic situation in the early 1970s caused major companies to participate on the TPM program into their manufacturing process.

Then in 1970s, Nippon Denso followed preventive maintenance and the concept of maintainability improvement into their production process. This process then soon takes off on the automotive industry thus introducing the term Productive Maintenance. Productive Maintenance was to maximize plant and equipment effectiveness to achieve optimum cycle cost of production equipment. This intervention was further improved by Nippon Denso

where they implement with cooperation of all employees. Afterwards, Nippon Denso was plant prize by JIPE, and Toyota group become the first company to obtain TPM certificates.

Afterwards in the early 1990s, the western organizations show more interest on TPM as Suzuki and Wilmoot (1994) hypothesised that TPM have so much in common on Total Quality Maintenance, TQM which is mainly used by them. This statement is also supported by Sekine and Arai (1998) where that both these methods use empirical study and analyse to improve performance state of a manufacturing process. Soon after more studies and research are done on TPM and being experimented in real productivity line to show the benefits and discover new solutions for new problems.

Table 2. 1 The difference between TQM and TPM

Category	**TQM**	**TPM**
Object	Quality (Output and Effect)	Equipment (Input and Cause)
Mains of attaining goal	Ensure a systematic management. More software oriented.	Employee participation and more hardware oriented.
Target	Quality of Part-Per Million, PPM	Elimination of losses and waste.

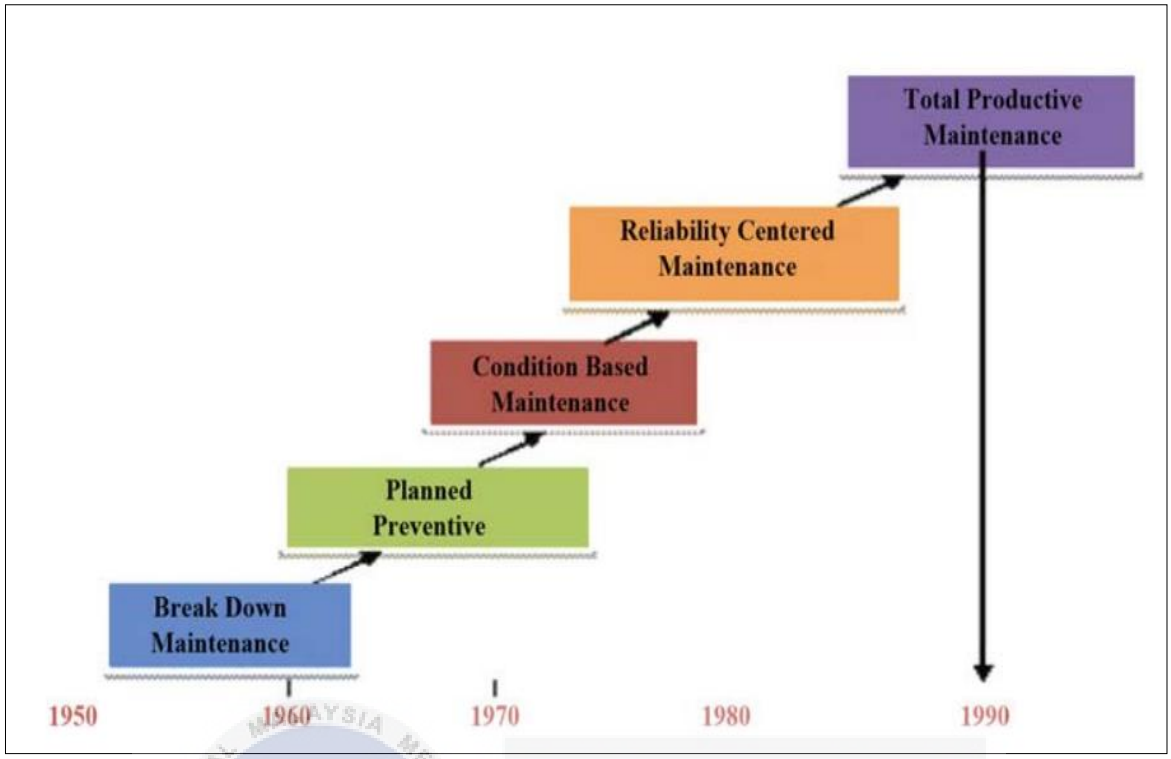


Figure 2. 3 The evolution of TPM from 1950 to 1990, Shirose (1995)

2.4.2 Current Total Productive Maintenance, TPM

In today's globalization, countries such a China and Korea has join the league to complete in global manufacturing industries. This is because, the market segment is inconsistent hence slow and steady improvement will not be able to survive as a profitable organization. Therefore, as suggested by Kaur et al (2013), a cost-effective manufacturing become a need for all manufacturing industry and also calls for performance improvement, quality management and maintenance for sustainable organization.

2.4.3 Pillars of Total Productivity Maintenance, TPM

Major companies are now keener in handling maintenance and operation departments as they play a major role in costing, production and quality issues. Besides that, having zero breakdowns, waste and downtime is the major goal of TPM. To achieve these goals, the eight pillars are used as a standard practice of TPM implementation.

Sangameshwran and Jagannathan (2002) stated that the maintenance has becoming an important feature in manufacturing as it is a profit generating feature. As recommended by Japan Institute Plan Maintenance, JIPM states TPM implementation will help in maintenance cost reduction, increase in labour productivity, and reduce stoppage time and downtime. The following are the TPM's eight pillars with explanation.

2.4.3.1 Autonomous Maintenance, (Jishu Hozen)

This pillar is for operators to be able take in charge of minor maintenances task. This will allow them able to increase their maintenance skills and the more practice the take the faster the time taken to solve a task at the same time gaining more experience and knowledge about their routine. Naghshbandi et al (2020) stated that autonomous is achievable with multiple design level which can be implemented either through software or by hardware where workers learn technique on establishing work to perfection.

2.4.3.2 Focused Improvement

Focused improvement is a process where there is continuous improvement takes place in the process until there is maximum utilization with optimized performance and no defects and waste found at the result. This type of improvement mainly to focus on finding the cause and effect of the process than takes place in the machine and being able to modify or upgrade to a better performance state.

2.4.3.3 Quality Maintenance

This pillar aims to produce product with high quality standards which satisfy the customers expectation at the same time focusing on defect free maintenance. With this implementation, the worker will understand more equipment effects on quality and able to eliminate current quality concerns and move to potential quality concern. Ahuja, I. Khamba

(2008) mentions that this pillar's main advantage is to reduce the rate of defective product which consequently increase profit of product.

2.4.3.4 Training and Education

Training is to encourage the employee to have multi skill and talent in working field. This skill encourage works to execute a task without hesitation which may result delay in process. Education give exposure to the employee of learning more about their work task. Gaining new knowledge helps develop new skills and implementing onto task able to produce greater result. With the gain of knowledge, the skills can be improved with proper training. Hence these two elements are depending one another.

2.4.3.5 Office TPM

Office TPM state that the improvement of productivity should include in administrative level. This is because administrative can have an overview on the production process. Thus, this can lead to an effective administrative function while identifying and eliminating losses. Offices TPM may include losses such as processing loss, communication loss, idle loss, and other losses.

2.4.3.6 Safety, Health and Environment

This pillar focusses on creating a safe working environment for everyone. The goal is to create a surrounding are that is not damaged by the working process or procedure at the same time ensuring the safety of the worker and environment. A committee which includes operators, technician, managers and mainly safety officers should work together to bring a safe working awareness among other staffs. This will promote a safer and smoother working environment.

2.4.3.7 Planned Maintenance.

Planned maintenance is to ensure a problem free machine with no defect in producing product. A proper planned maintenance will reduce maintenance and repair cost at the same time prevent unplanned breakdowns. This is ensuring a smoother production and produce good quality product.

2.4.3.8 Development Management

Finally, this pillar states that workers must ensure minimum problems and running in time on new equipment. Besides that, the workers should also be able learn from existing process and procedure before being able to adapt to a new system. Furthermore, maintenance improvement initiatives should be encouraged and developed for future usage.

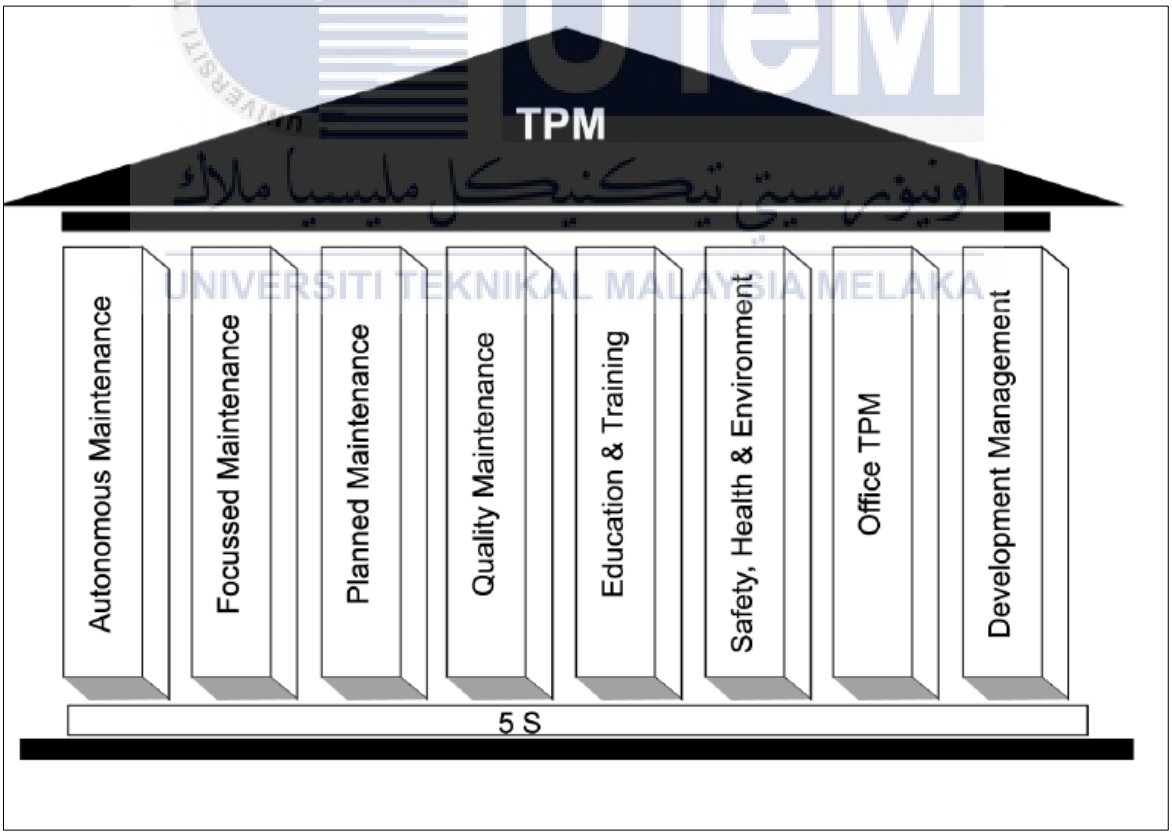


Figure 2. 4 Eight Pillars of TPM, Nakajima (1988)

The TPM's eight pillars leads to innovation performance which motivates on innovativeness implementation on problem solving activities, Hung et al (2009). Based on the eight pillars explanations and function, there are various benefit that can be obtained for developing the process for more efficiency and utilization. These benefits can be described in direct and indirect benefits from TPM.

2.4.4 Direct Benefits of TPM

i) Chances of productivity to increase from 1.5 to 2 times.

ii) Able to reduce manufacturing cost up to 30%.

iii) Number of accidents can be reduced.

iv) Able to satisfy customers' needs and demand.

v) Create and follow pollutant control process.

vi) Increase consistency in the manufacturing process.

2.4.5 Indirect Benefits of TPM

i) The employees feel more confident in job handling

ii) Workers feel ownership towards machine.

iii) Creating a clean, near and attractive workplace.

iv) The operators' behaviour is more favourable to the company.

v) Knowledge and experience can be share among employees and newcomers.

vi) All workers tend to work efficiently to achieve company goal.

vii) Horizontal deployment of new concept in all areas of organization.

TPM is helps manufacture to focus on improving efficiency rate of their manufacturing process as stated by Marcus (2004). To achieve TPM standards, hence requires a long-term vision and commitment of overall workers. To measure the equipment effectiveness with the implementation of TPM, Nakajima (1989) suggest the use of Overall Equipment Effectiveness, OEE. This is because that OEE could present result in matric for thus providing solid evidence on the state of effectiveness. In my point of view, the use of OEE would be much easier due to the fact OEE able to show equipment availability, performance and quality which can help to conclude the overall utilization.

2.5 Introduction of Overall Equipment Effectiveness in TPM

Overall Equipment Effectiveness, OEE is considered one of the best tools that measure performance for equipment effectiveness. According to Nakajima (1989), TPM concept are mainly to maximize equipment effectiveness and autonomous maintenance by operators with small group activities. Based on these goals, OEE can be stated as the combination of operation maintenance and management of manufacturing of resource as stated by Dal (1999). Rouse (2017) defines OEE as the values that is expressed in percentage regarding the measure of production operation in performance, quality, and availability.

To achieve long term effectiveness of equipment it is required to have an accurate performance measured data is required. Ericsson (1997) also pointed out that manufacturer preferred long term usage of equipment as they ensure that the data collected can be as

accurate for long term success rate of equipment. Hence an accurate performance measuring tool should be used to avoid new purchase. To fully utilize TPM, equipment failure and production have to be identified. Hence Ericsson (1997) and Nakajima (1989) agreed that OEE is used to address major problems which degrades performance and production losses which directs to hidden costs. In addition to the statement, the basic quality tools such as Fish Bone diagram, Pareto chart and other similar tools would be useful in identifying the root cause for failure.

2.5.1 Function of Overall Equipment Effectiveness, OEE.

OEE can be applied in three different stages of manufacturing industries. Firstly, OEE can be applied to measure the entire plant or line which can be used as a benchmark to tell effective the performance state. Next, the OEE value can be used a tool for comparison. This is because the value of different sets of lines or machine can be measure then from the result obtain. From the results then we can know which site is having bad performance and actions can be taken. Finally, OEE can be act as an individual measurement tool. For example, in a production line with various machine, have different performance level can be compared. Based on the result then we can focus on a specific machine and implement TPM tools to improve performance. Similarly, Nakajima (1989), emphasised that the ability of OEE making individual assessment can be used to indicate the focus of TPM resource.

To measure these losses. identifying the performance, availability and quality of a equipment, these losses have to be categorized. These losses come in six different types of categories which is known as the Six Big Losses of a manufacturing equipment.

2.5.2 The Six Big Losses

According to Johnson and Lesshammar (1999), each type of loss that is found during the manufacturing process can be categorized according to frequency of occurrence. These losses occur mainly due to the disturbance or failures that happens in the state of expected and unexpected. The disturbance can be categorized into two different types. The first type is called Chronic disturbance where it is usually small, hidden and complicated and the cause of it to occur is not direct. The second type is Sporadic which is more obvious and can be spotted quickly. The effect of Sporadic disturbance is huge as it could lead to severe damage. However, Nord et al (1997) argued that Chronical disturbance will cause low utilization of equipment and more costly due to repeated actions. To sum up these losses, Nakajima (1988), have categorized the losses and defines the Six Big Losses.

i) The first loss is the equipment failure and breakdown losses. These losses fall in the category of time losses. This is because the reduce the production time and increase defect in product.

ii) Next loss is setup or adjustment time loss during production. During the production, these losses occur as a result from downtime or defective product thus requiring adjustment in equipment.

The above first 2 losses can be used to calculate the Availability of the machine. This is because that availability is ratio of the run time of the machine to planned production time. Thus, measuring all time of different losses as well as the overall time for whole process falls in calculating availability.

iii) The third losses found in the process are the idling and minor stoppages. This mainly occurs due to temporary malfunction or when the machine itself is idling.

iv) Besides that, there are also losses due to reduction in speed of machine. The speed of machine slower than it was intended can also be categorised as loss. In other words, the actual operating speed of machine is slower than the design speed.

These types of losses can be used to measure performance efficiency of the machine. Speed and idling indicate that the machine is not as efficient as it supposes to be. This shows that there is a disruption that cause the machine not to perform as intended. Similarly, the machine is not up to optimum performance.

v) Yield reduction is also categorised as a loss in machining process. This usually occurs at the beginning of the process when machine start up is done.

vi) Finally, when there are defects in quality or required to perform rework, it is also considered as losses. This type of losses occurs mainly due to machine or equipment to malfunction during production.

The final two types of losses determine to know the quality of the machine. When there is defect in the product, it is considered as quality loss. When there is large number of defects in product hence the quality level is lower.

Using categories, the equations for availability, quality and performance rate can be calculated. These then can be used to know the rate of OEE which can determine the efficiency and effectiveness of a machine.

2.5.3 Calculation of OEE

OEE calculation can be done based on the elements such as the quality, performance rate and availability. These elements depend on the losses that is found during the manufacturing process. With the use of Six Big Losses, the losses are categorised and then all the element that determines the OEE rate can be calculated. Firstly, the availability element is calculating by using the total stoppage time which results from unscheduled down time, process set up time, changeovers and other unplanned downtime. This is actually the ratio of actual operating time to planned operating time. Unlike Overall Operation Effectiveness, the planned maintenance is not categorised as loss when calculating the availability. In OEE there are other factors that is used to calculate the availability. The following are the list of factors that is used to calculate availability and its equations.

- Waiting due to other parts are delayed.
- No worker available due to breaks
- Planned maintenance activities
- Equipment trials and improvement activities
- Machine general maintenance
- Operator training

Nakajima (1998), address that the following formula stated is the method of calculating the rate of OEE. Using this formula, the affected region or equipment or production line can be identified.

$$Availability, \% = \frac{Actual\ Operating\ Time\ (mins)}{Planned\ Operating\ Time\ (mins)} \times 100\% \qquad (2.5)$$

$$Planned\ Operating\ Time = Total\ Shift\ Time(min) - Planned\ Maintenance(min) \quad (2.6)$$

$$Actual\ Operation\ Time\ (min) = Planned\ Operation\ Time\ (min) - Unplanned\ Maintenance\ (min) - Minor\ Stoppages(min) - Setup\ and\ Changeovers\ (min) \quad (2.7)$$

Next, to calculate the performance rate the ratio of actual speed to ideal speed should be known. According to Nakajima (1988), defines that it is the actual derivation in production from idle cycle time. Meanwhile De Groote (1995) argues that performance rate is calculation based on deviation of production from its planned. In the end of the day both formulas are agreeing that can be used in calculating the performance rate of machine. A product performance efficiency is based on the is based on the operating speed rate and the net operating rate. The operating speed rate is based on the differences in idle speed and actual operating speed. The net operating rate comes from a unchanged processing speed on a period of time.

$$Performance\ Rate\ \% = (Net\ Operation\ Rate \times Operating\ Speed\ Rate) \times 100\% \quad (2.8)$$

$$Net\ Operating\ Rate = \frac{Number\ Produced\ \times Actual\ Cycle\ Time}{Operation\ TIme} \quad (2.9)$$

$$Operating\ Speed\ Rate = \frac{Theoretical\ Cycle\ TIme}{Actual\ Cycle\ Time} \quad (2.10)$$

Finally, the quality can be measured by indicating the proportion of defective production with total production volume. The following formula is used to calculate the quality rate but, the defective occurs due to machine failure or starts at early stage of production. Hence, the machine defect should be resolved to obtain a higher quality rate.

$$Quality\ Rate = \frac{Total\ Number\ Produced - Number\ of\ Scrapped}{Total\ Number\ Produced}\ x100 \qquad (2.11)$$

The final step after knowing the values of all elements that measures the losses categorised from Six Big Loss, then the value of OEE can be calculated. OEE requires a detail and accurate measurement of the Six Big Loss parameters. Hence the effort and contribution of overall workers in gathering data for OEE calculation is required with good team effort. The OEE rate determines the different standard and state of overall production productivity.

$$OEE\ \% = Availability\ \% \times Quality\ \% \times Performance\ Rate\ \% \qquad (2.12)$$

2.5.4 Standards of Overall Equipment Effectiveness, OEE

OEE measurement determines the equipment effectiveness. There results have range that indicates if the effectiveness is in poor, average, good or world class standards. According to Dal (2000), suggest that the value of OEE elements such as availability, performance rate and quality should be more than 90%, 95% and 99% respectively. Only then the OEE world standard of 85% is then achievable. Another statement made by Kotze (1993) says that OEE rate which is more than 50% is reasonable for manufacturing industries. Similarly said by Ericsson (1997) that the OEE performance in the range of 30% to 80% is fair. However, Ljungberg (1998) demonstrated that in manufacturing industry the average performance efficiency is 68% due to the reason such as idling and minor stoppages

which contributes most in results as root cause. Hence when these losses are overcome, then the OEE rate can be increased up to 70% to 90% same time achieving world class standards.

Once again Ljungberg (1998) support the statement made by Nakajima (1988), where when quality of the product is 99% it means that majority losses and failures are overcomes. Although it is difficult to achieve by average manufacturing industries but still it is an achievable target that helps to ensure a higher rate of OEE.

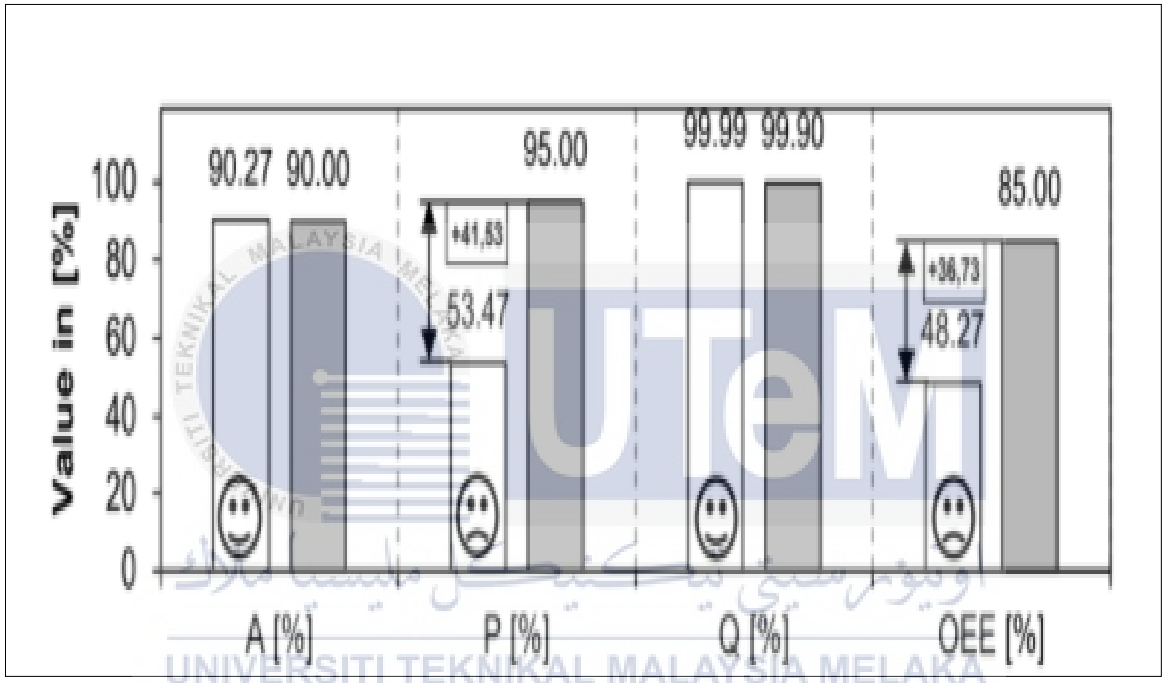


Figure 2. 5 Comparison of OEE value with World-Class OEE indicator, Nakajima (1988)

2.6 Summary

In a nutshell, to achieve an efficient production productivity, the equipment effectiveness is one of the major factors that helps in increasing its rate. When measuring the performance of production productivity, various tool such as Production Volume Variance, OOE, OEE, SMED and TEEP can be used. Based on Ericsson (1997), these tools can be used to find the production loss which contributes to hidden cost. To increase the production productivity, TPM was introduced as a tool that identifies the losses found during production process and eliminates them. Sangameshwran and Jagannathan (2002), proposed that maintenance is an important part of manufacturing. Thus, TPM helps in initiating maintenance program using the Eight Pillars of TPM as reported by JIPM. Nakajima (1988) agrees that TPM will identify and removed unwanted process that is being done during manufacturing process. In addition, Nippon Denso who introduce preventive maintenance into his automotive component manufacturing later perfected it into TPM later made Toyota groups awarded with TPM certificates of world class.

Based on TPM concept, Nakajima (1988) and Dal (1999) highlights that OEE is a combination of operation maintenance and management. In other words, OEE main function of highlighting the losses found in equipment effectiveness is highlighted and eliminated is as similar to TPM's goal. Thus, using OEE in identifying hidden losses and calculating the performance rate of equipment ensure a proper overall equipment utilization. Besides that, Huang et al (2003), address the Six Big Loss found in equipment can be formulated using elements such as Availability, Performance Rate and Quality. With this value being known, the OEE rate can be calculate and hence the equipment effectiveness can be identified with the standards that assured by Nakajima (1988).

CHAPTER 3

METHODOLOGY

3.1 Preliminaries

This chapter highlights the different types of methods that are arranged accordingly to achieve the objective of study. Moreover, there are flow chart constructed to show the starting point until the end of the study conducted. In addition, for each process that are mentioned in the flow chart, there are given explanation with proper statement that supports on the process that is being conducted to complete the research conducted. The methods and tools that are used for the study are based on previous case studies with achievable results.

Besides that, this chapter also mentions the proper method for data collection that is being done during the industrial visits. It is an important part for the study as it helps in determining the analysis and result of this research. The collected data are then analysed with accuracy using various formulas and equations based on the previous study. Based on analysis's results, future improvement is suggested to the company for a better performance.

3.2 Design of Study

The design of study is an approach of defining the details of research design that are carried out during the study. The approach can be categorized into two categories which are qualitative research and qualitative research. Qualitative research is based on statements that are approved or justified with proper evidence such as journals, experience, opinions, and theory. These types of data can be collected by using techniques such as questionaries, surveys, interview with workers, and literature reviews that are made based on other

findings. Meanwhile, quantitative research is an approach more towards statistical and figurative. These types of data can be quantified with measurable figures and proven with various formulas, calculation and other computational techniques. Figure 3.1 shows the flow of design of study that is conducted to fulfil the requirement of objective using the method such as literature study, interview, and case study.

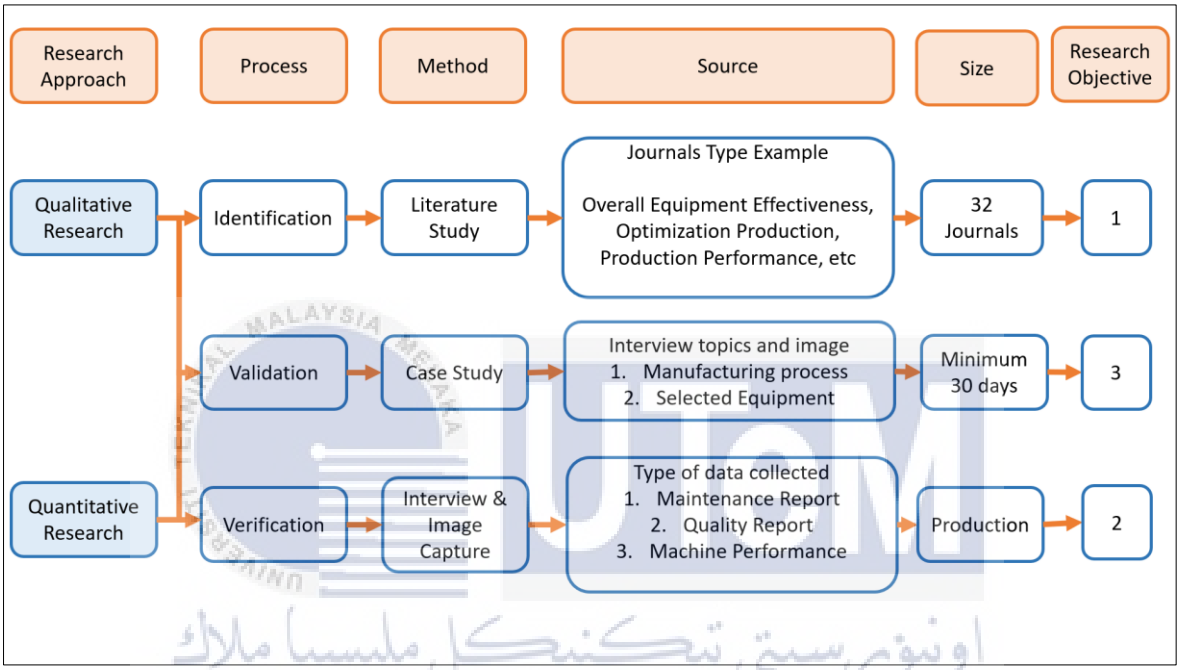


Figure 3. 1 Design of study

3.3 Flow Chart

The figure 3.2 show the overall flow of methodology that details the steps taken for the objective of the study to be achieved. A flowchart is constructed to design a guideline that shows each phase or task that should be carried out in an arranged manner to conduct the study. This type of approach will be able to simplify the required the techniques and methods that are needed to be applied in each phase of the study. The problem statement and objective of this study is used as a reference point in constructing the flow chart.

The flow chart is started by highlighting the problems and the questions for the research. These problem statements are based on the current manufacturing scenario which

encourage to make an objective for the study. The second step is the objective and research scope are done by referring the existing literatures, articles and journals which can be a source of information. Next, the gathered data are then simplified as reference. When collecting data ensure that they are sufficient to be used as supporting statement for each explanation mentioned regarding the factors of production productivity in manufacturing.

Besides that, there is a process of collecting data which can be done on Microsoft Excel's spreadsheet, capturing pictures of selected factory's production line and machine and interview from the worker of the factory. In addition to collecting data, there are also checklist and computerized information that can be used for accurate results. Based on the gathered data, an analysis can be performed using the Overall Equipment Effective, OEE method. Subsequently, the analysis results will provide information to suggest the type of improvement that can be taken for an optimized equipment effectiveness. These improvements will lead to a better equipment performance and availability to produce high quality product outcome. The discussion and conclusion of the study will be based on the gathered and analysed data with the suggested improvement for the equipment effectiveness. Once then, the complete research is proposed and presented to the panel and industrial representative.

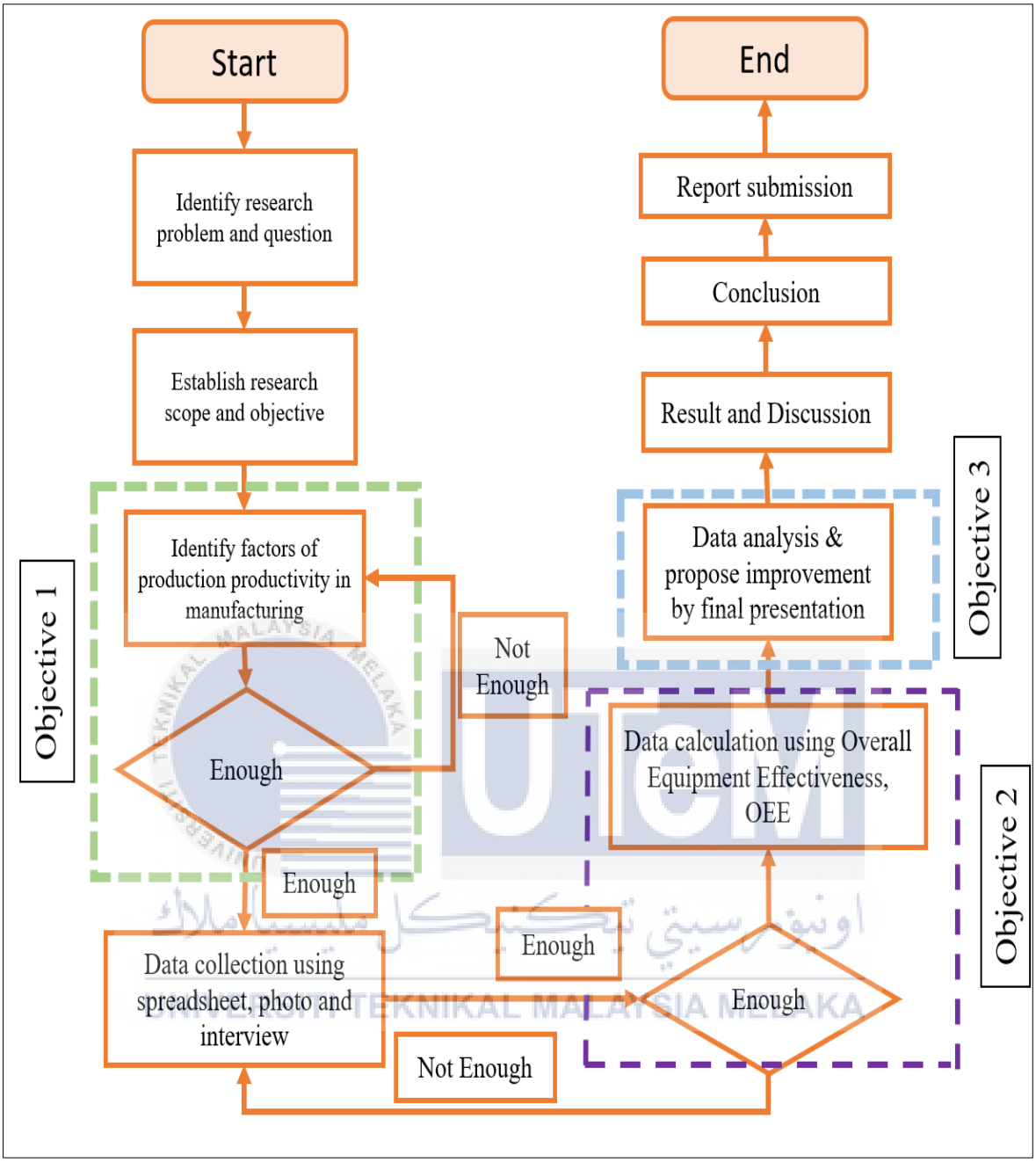


Figure 3. 2 Detailed Process Flow of Research Methodology.

3.3.1 Identify Research Problem and Question

The first step of a research is the needs of identifying research problems and question. This can be identified based on the current situations that are faced in the industry during the manufacturing process. The problems can be from the equipment of different part of production line at the industry. As an example, the machine down time due to unexpected requirement of maintenance could cause the availability and performance of equipment to

be disrupted. Therefore, the research problem and question should be based on factors of production productivity through equipment effectiveness and efficiency in the manufacturing industry. With the aid of modern technologies and programs, these types of problems can be resolved with computerizing the date into spreadsheet and programmed with formulas to obtain status of machine. The formulas can be based on Overall Equipment Effectiveness, OEE where it is known for identifying the rate of availability, performance, and quality of equipment.

Furthermore, the research problems can be categorized into three segments. Firstly, the initial problem of identifying the factors that affects the production productivity in the manufacturing industry, followed by the method of measurement in determining the equipment effectiveness and finally the proper action that are required to be taken in improving the equipment effectiveness. Therefore, the research problem is first step in any research for a continuous flow process.

3.3.2 Establish Research Scope and Objective

The next segment of research is the establishment of research scope and objectives. The research scope is done to clarify and show the details the overall study phases that are needed to be known. Next, the objective is made based on the research question that are developed earlier. This is because every research aims to resolve the problems that are faced in the given case study. Therefore, the achievement of objectives in a study proves that the research problems are solved and fulling the case study which is identifying the factors of performance productivity and optimizing it with the help of OEE. Moreover, the assistance of literature review brings up more points for the conduction study as they provide more ideas and information from the previous conducted related studies.

3.3.3 Literature review

A literature review can be used as a guideline when conducting a study as it is verified and approved by previous scholars on the topics or case studies that they have made. Besides that, it also helps in gathering data from various resources such as books, journals, articles and other approved materials. These resources can be found online or as documents which can be dated from 5 years or even more than that. These resources are gathered, read, analysed, and summarized into points which can be used for the research being conducted. The literature review gives information on focused study as particular topics and fields can be chosen from it.

In this research, the type of literature that are being focused are the ones with key words such as manufacturing industry, production productivity, and Overall Equipment Effectiveness, OEE. This is because that the main concept of the study is about on optimizing the production productivity by knowing the factors that ensure the equipment's effectiveness is well performed. Besides that, the measure of equipment's effectiveness rate should be knowing. Hence, the technique of applying OEE formula should be utilized clearly. Therefore, reviewing the literature helps in providing information regarding the formula used to calculate the rate of OEE from formula of multiplying rate of performance, availability and quality of equipment. Finally, ideas and suggestion on improvement of equipment can be gathered based on literature reviews.

3.4 Data Collection

The next step of a conducting research is the data collection. The collection of data can be divided into 2 categories qualitative data and quantitative data. To conduct the research the data are gathered from a roof tiles production company. Referring to the objective of the study, the data that are needed to be collected are bottleneck machine found

in the production line of the company and other relevant data such as downtime of machine, cycle time, production time, number of defects found in the machine production, and other variables will determine the rate of OEE. Hence the data collection method should be started with the two categories that is mentioned earlier.

i) Qualitative data

A qualitative data focuses on the collective of data which are not countable. Therefore, these types of data a written or recorded based on the methods such as interview with the factory workers and capturing image of the type of machine that is proposed for improvement with the production line. Besides that, interviews also helps in knowing the current maintenance that is being carried out on the machine. Hence, this helps in proposing other alternative ways on fixing the current machine problems that is being faced.

ii) Quantitative data

Meanwhile, a qualitative data is collection of data which are able to measure, count and statistically show the data. This data is very important as it able to full filling the second objective of the research which is measuring the equipment rate with OEE formula. To record a large data of the production process and every equipment's effectiveness therefore computerized application are used to summarize the values gathered.

3.4.1 Interviews

An interview is a constructed conversation where one participant ask question to the other for gathering information regarding certain topic. In this study, we are going to

interview the factory workers on the machine performance, cycle time of the manufacturing process and other relevant information. Besides that, there are information such as personal experience on equipment handling during the downtime and steps which are taken on machine repairing can also be identified.

3.4.2 Capturing Image

Capturing image of the production line and the equipment which are being focused on is also an important data collection method. The main purpose of capturing image is to show the studies main focus which is on evaluating the effectiveness of equipment which can promise on optimizing the production productivity. Therefore, the image of equipment focused, the production line and the overall manufacturing process is important.

3.4.3 Spreadsheet

Spreadsheet is one of the most useful and simplest program to store information, summarize, formulate and calculate it. The collection of data from factory majority will be based on computerized method and provide information using this format. Therefore, the obtained can be sorted and summarized then later used it by adding the required formulas for calculation process. The spreadsheet is usually available in Microsoft Excel, which can support big data and the formulas can be added manually into the spreadsheet.

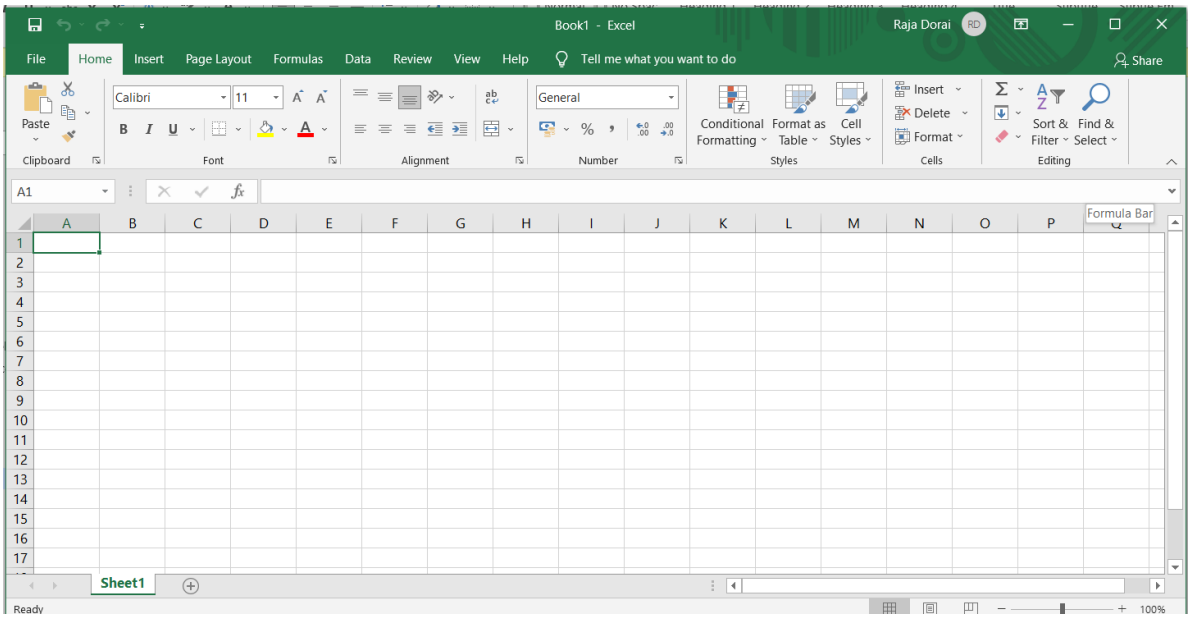
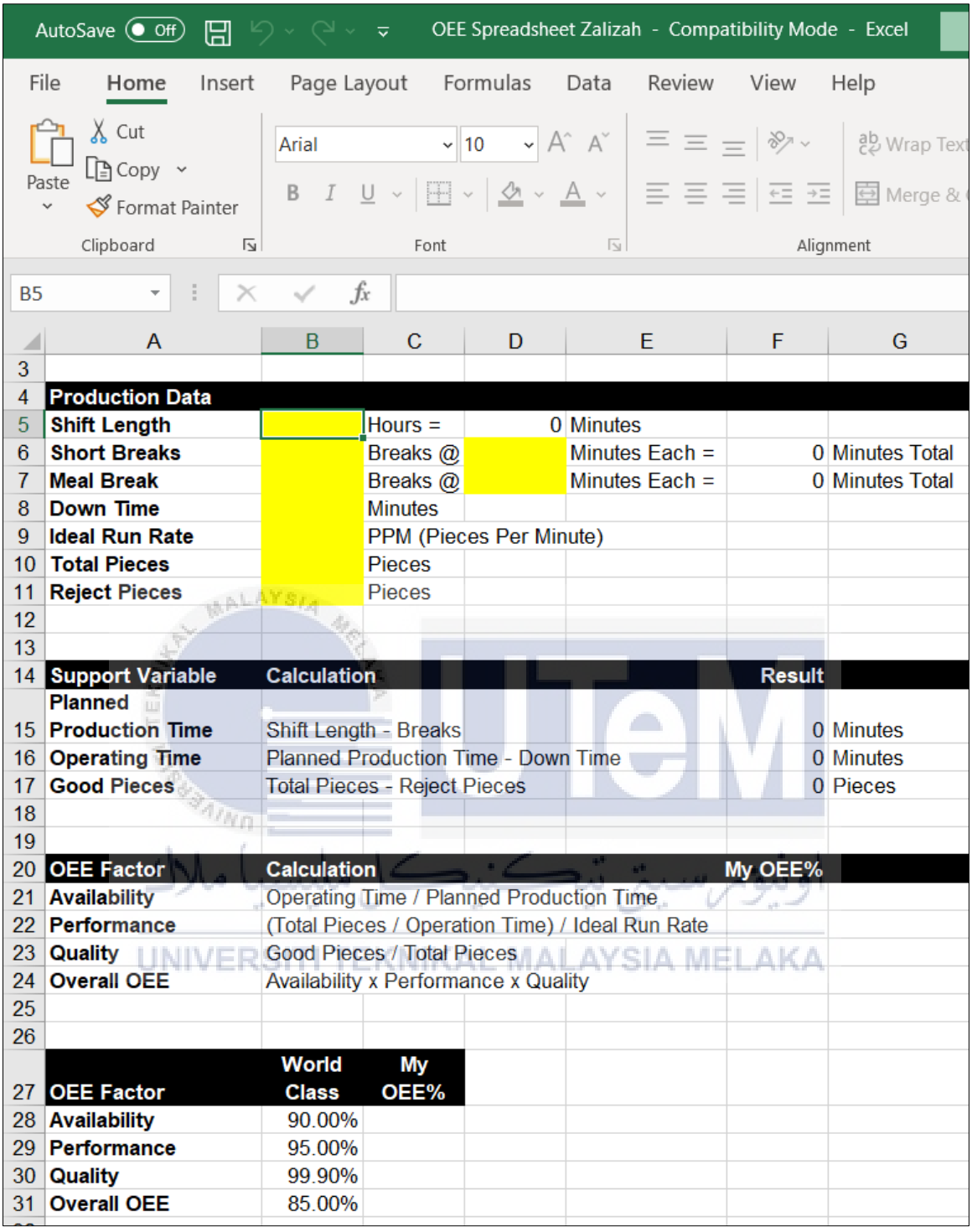


Figure 3. 3 Homepage of Microsoft Office (Excel)

3.4.4 OEE Spreadsheet Template

The following template is created using the formulas of OEE at spreadsheet. This template consists of data such as shift length, the break time, rejected piece, total production and others. This is to ensure that there are no error occur during the calculation of availability, performance, quality and rate of OEE. The following image illustrate the formulas and the value that are being used to calculate the respective values.



	A	B	C	D	E	F	G
3							
4	**Production Data**						
5	**Shift Length**		Hours =	0	Minutes		
6	**Short Breaks**		Breaks @		Minutes Each =	0	Minutes Total
7	**Meal Break**		Breaks @		Minutes Each =	0	Minutes Total
8	**Down Time**		Minutes				
9	**Ideal Run Rate**		PPM (Pieces Per Minute)				
10	**Total Pieces**		Pieces				
11	**Reject Pieces**		Pieces				
12							
13							
14	**Support Variable**	**Calculation**				**Result**	
15	**Planned Production Time**	Shift Length - Breaks				0	Minutes
16	**Operating Time**	Planned Production Time - Down Time				0	Minutes
17	**Good Pieces**	Total Pieces - Reject Pieces				0	Pieces
18							
19							
20	**OEE Factor**	**Calculation**				**My OEE%**	
21	**Availability**	Operating Time / Planned Production Time					
22	**Performance**	(Total Pieces / Operation Time) / Ideal Run Rate					
23	**Quality**	Good Pieces / Total Pieces					
24	**Overall OEE**	Availability x Performance x Quality					
25							
26							
27	**OEE Factor**	**World Class**	**My OEE%**				
28	**Availability**	90.00%					
29	**Performance**	95.00%					
30	**Quality**	99.90%					
31	**Overall OEE**	85.00%					

Figure 3. 4 Template used to add data and calculate availability, performance, quality and OEE rate

3.5 Data Analysis

Data analysis is the second part of data collection where the gathered and arranged data will be now interpreted and calculated to achieve the second objective. Data analysis

is an important aspect in research as it allows to produce results which can be obtain by pointing out the problem statement, summarize the gathered data, formulate and calculate the data and then finally suggest on future improvement. There are several data analysis methods that can be carried out on this study. Measuring the rate of OEE allows to determine the equipment effectiveness of a production line. Eventually, this will create a focus point on a specific equipment to make improvement which can lead to a better production line.

3.5.1 Overall Equipment Effectiveness, OEE

In 1989, OEE was introduced by Nakajima as a tool that measures the rate of effectiveness of an equipment. Since then, this measuring technique is still being used till today as a tool that states the equipment's capability at the same time suggesting way on improving them. The rate of OEE is based on three categories which are the machine's availability rate, performance rate and finally the quality rate. Using these values, then the OEE rate is then compared to the OEE's World Standards to determine the if the equipment is capable enough to be considered as an optimized state. It is stated that the availability rate, performance rate and the quality rate should be at 90%, 95% and 99% respectively to produce a World Standard OEE rate which is 85% and above. The following is the formula that is used to calculate the OEE rate.

$$OEE\ \% = Availability\ \% \times Quality\ \% \times Performance\ Rate\ \% \qquad (2.13)$$

3.5.1.1 Availability Rate

Firstly, the availability rate of an equipment is the total time that is used for stoppage in an unscheduled downtime. In other words, availability is the total time that the equipment runs without any interruption in the production process. These values are calculated based on the actual operating time and the planned operating time. The following are the formula used to calculate availability rate.

$$Availability, \% = \frac{Operating\ Time\ (mins)}{Planned\ Production\ Time\ (mins)} \times 100\% \quad (2.14)$$

$$Planned\ Production\ Time = Shift\ Length(min)\ -\ Breaks\ (min) \quad (2.15)$$

$$Operational\ Time\ \ (min) = Planned\ Production\ Time\ (min) - Downtime\ \ (min) \quad (2.16)$$

3.5.1.2 Performance Rate

The performance rate is the ratio of actual speed to the idle speed of the equipment during the manufacturing process. Another way of measuring performance is that by knowing the number of products produced divided with operational time and then the answer further divided with idle run rate. Based on the product produced and the operational time the idle run rate is known. Using this the performance rate can be obtained easily.

$$Performance\ Rate\ \%= \frac{Number\ Produced\ /Operational\ TIme}{Idle\ Run\ Rate}\ x\ 100\% \quad (2.17)$$

$$Idle\ Run\ Rate = \frac{Number\ Produced}{Operation\ TIme} \quad (2.7)$$

3.5.1.3 Quality Rate.

Finally, quality rate is ratio of non-defected product produce with total product produced. The quality rate is usually affected by the machine availability and performance. When there is interruption or minor stoppages causing the machine to stop production there will be slight changes in the alignment of machine and other changes which can lead to product defect. These minor stoppages contribute mostly to product defect. Therefore, having a proper performance and availability could lead a better-quality product production.

$$Quality\ Rate = \frac{Total\ Number\ Produced - Number\ of\ Defect}{Total\ Number\ Produced} \quad (2.18)$$

3.5.2 Fishbone Diagram

The fishbone diagram is used in the analysis as a basic concept of identifying the problem that is faced by the selected equipment. Based on the availability, performance, and quality rate the effected region that contributes the rate of OEE can be identified. Hence, based on these values gathered from the calculation, the main factors that contribute the defectiveness is drawn into the fishbone diagram. The diagram will identify the initial stage of the problem that causes the equipment to not to be effective can be identified.

3.5.3 Why-Why Analysis

The Why-Why Analysis is an analytic method that is design in a table for or any form that is being arranged in sequence which allow to find the core cause of the stated problem. Based on the fishbone analysis, the initial problem identified becomes the main problem for the why-why analysis. Then based it, the problem is further derived into more smaller components by questioning "Why is occurred" until the root cause of the problem identified. This is one of the quality tools that used in manufacturing industries to identify root cause in their production line and for continuous improvement process.

3.5.4 Total Productivity Maintenance, TPM

An innovative concept called TPM was developed which is used to highlight the hidden cause of equipment failure and plan for improvement based on the Pillars of TPM. This is one of the best methods on conducting analysis to determine the types of losses found in the equipment. Similarly, Why-Why Analysis, Fishbone diagram and the OEE

measurement, TPM gathers these data and then make suggestion for improvement based on the Pillars of TPM. These pillar of TMP not just to be used in identifying the root cause of problem but also to be used as ways on improving the issue.

3.6 Propose Improvement

Proposing an improvement is a process where every possible method, techniques, steps, and ideas are accounted into testing if there are any changes of making the process better than the original state with clarification. In other words, proposing an improvement is a condition of making a process better and required to have support of all parties before executing it. In this study, all ideas for improvement are presented to panels and then will be for the best idea that can be implemented. The main reason for making a proposal for improvement is that the industry can adapt the new findings and methods that are used in conducting the research and able to apply in future and discuss further for continuous improvement. Based on the study, there are several improvements that can be proposed to the industry panel during the final presentation.

3.6.1 Pillars of TPM

TPM mainly used for identifying the hidden losses that are found in the equipment can also be used in improving the equipment. This is because each hidden loss found falls in the categories of eight pillars of TPM. These categories are autonomous maintenance, continuous improvement, quality maintenance, training and education, quality maintenance, office TPM, safety-health and environment, planned maintenance and developed management. Based on these categories, the following losses found in the equipment can be categorized in one of these elements mentioned. Therefore, when changes are made the new OEE result can be obtain with new data of equipment to prove that there are improvements made to it.

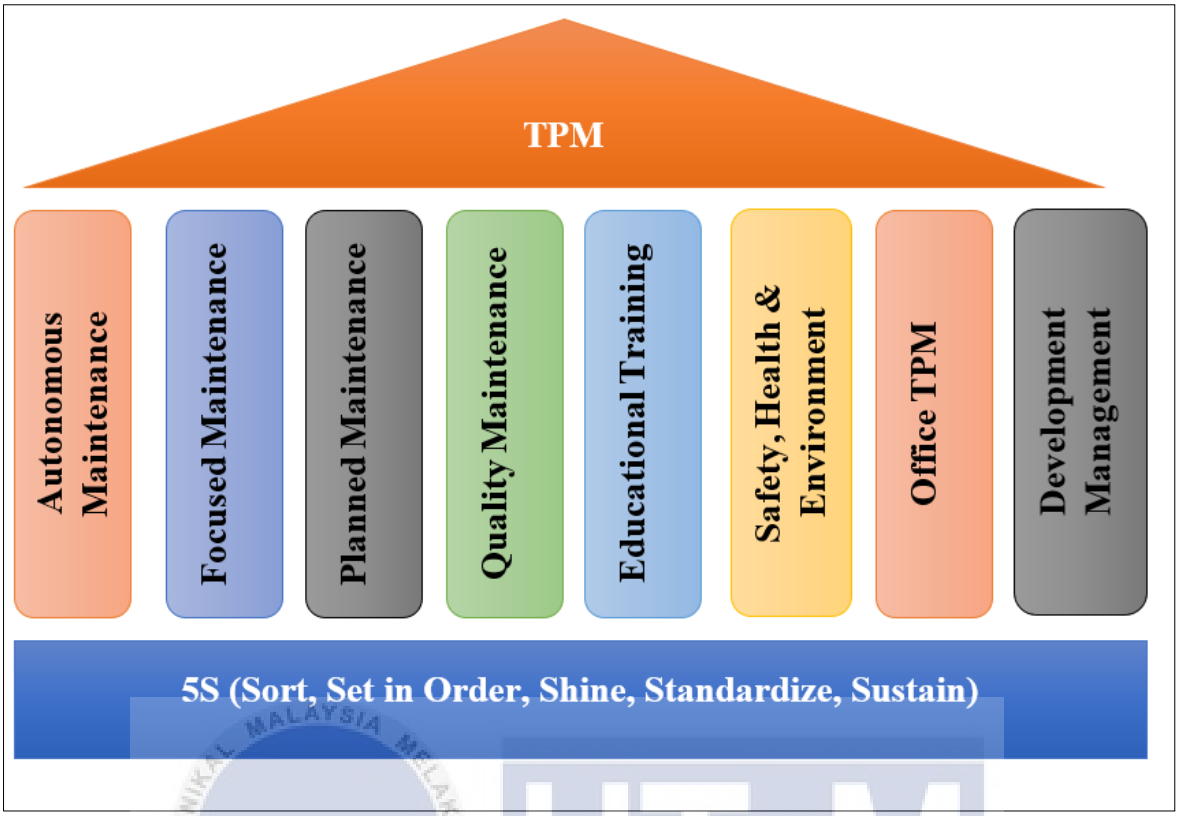


Figure 3. 5 Eight Pillars of TPM

3.7 Summary

In conclusion, this chapter explain the flow process and steps on conducting this research. It is started by creating a flowchart that can summarize the flow process for the study conducted. In the flowchart notes down the main topics that are needed to be focused on whole research.

The content of the flowchart is started with the identification of research problem. Based on this, the scope and objective are created. The objective is purposed to solve the problems that are stated. Next, using the key point of the study, the literature review is studies and summarized. The resource for literature review is obtained based on the objective of the study which is the factors of production productivity and overall equipment effectiveness.

Besides that, the data for conducting the study are gathered. There are two types of data, quantitative and qualitative data. the qualitative data are made based on capturing image and interviews with the factory workers while quantitative data are numerical data. they can be statistically shown and hence these data are collected, sorted, and summarized in spreadsheets.

The gathered information is then analysed using the OEE to measure the effectiveness of equipment. The data analysis result will be then discussed and will be used to determine the required improvement that needed to be taken. The data analysis will provide hidden cause of the equipment which can be used to propose improvement with the aid of TPM's Pillars. These proposed improvements and reports are submitted to the industrial panel followed by a presentation to sum up the research.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Preliminaries

This chapter is established based on the data given directly from the company that this study is being conducted. This chapter explains on the usage of Overall Equipment Effectiveness on solving the problems face in the manufacturing company of producing food and beverage by accomplishing each objective as mentioned. This is done by first defining the problems that is being face in the company which leads onto determining the factors that effects the production productivity. Next, a series of data collection is involved onto calculating the rate of OEE. The required data to conduct the study are such as the flowchart, plan layout and secondary data. The collected data then are clarified meeting the expectations and then will be used for analysis for improvement.

The data collection is carried out from the observation, interview with workers and the relevant information about the production line. Once the collected data is sufficient and up to date then these data is used in calculation for analysis to know the initial state of OEE. To do this the collected data are first transferred into spreadsheet and Minitab will be used for later purpose. The spreadsheet will allow to arrange the relevant data and then make calculations while Minitab is used to present the data in a graphical manner using graphs and pie charts. It also eases the calculation once the related formulas are added into the software for a faster calculation. Based on this calculation, an analysis can be conducted to determine the initial OEE rate and the most effected region (availability, performance, or quality). Once the factors are determined, calculations are made to find the initial OEE, then Why-Why analysis is made to determine the root cause of the failure in the machine.

Finally, once analysis is conducted then improvement is proposed to the company authorities. This is done once the root cause identified based on the effected region using cause and effect diagram and why-why analysis. This interview is done to know what are the previous steps that they have taken when similar problem is faced. In this session, the improvement suggestion will be based on the Six Big losses of OEE and the Eight Pillars of TPM which allow the authorities to know the type of improvement can be made to increase the OEE rate of machine.

4.2 Problem Definition

The first step that needed to be taken on conducting this study is to define the problems faced by the industries. At food and beverage company, the customers are not satisfied with the delivery time of the ordered parts which has been made. This is because that the time take on part making is longer and this causes a delay in the schedule. The customers often complain about the time taken by the company workers on producing drinks and often not able to produce results on time.

Secondly, the company workers are reporting that the machine that they use in making the drinks often takes a longer time than usually. The works stated that the machine is running slower than its original state. They also mentioned that the same machine often breaks down and requires time to repair and making them work again. This causes the time and expenditure cost to increase also effecting the time on producing end product to be delayed for the customers.

4.3 Data Collection

Data collection is an important process on conducting this study as it able to solve the problem statement and achieving the objective stated. To overcome the problems in the company, the most recent and relevant data are needed to be collected for the identification

of factors, calculation, and analysis in the performance of factory. Therefore, cooperation of factory representatives is required to achieve the goal.

The food and beverage company selected is founded in 2006, a company that manufacture drinks such as soya, tamarind, rose milk, sour plum, and carbonated drinks. This company located at Kompleks Kilang SME Bank, Melaka, Malaysia. This company produces drinks and supplies to various local stores and import them to countries such as Indonesia and Thailand.

4.3.1 Primary Data

In data collection there are two types of data collection which are primary and secondary data. Primary data reflects the initial study before going further in detail. There are two methods that is used to complete the primary data which is interview and observation which is done by capturing image. These data are directly obtained from the company itself to conduct the study. The primary data that is obtained from the company is used to show the layout of the company and manufacturing process of soya drink.

4.3.1.1 Layout of Food and Beverage Company

The figure that is being shown is the layout of the soyabean production of the selected food and beverage company. This shows the position of the selected equipment for the case study which is the boiler. The boiler is located at the very back of the company. This is because that the boiler is connected to the cooking and detoxification process in making the soyabean. Hence the connection needed to be shot and able to supply enough pressure for both equipment to be able to run sustainably.

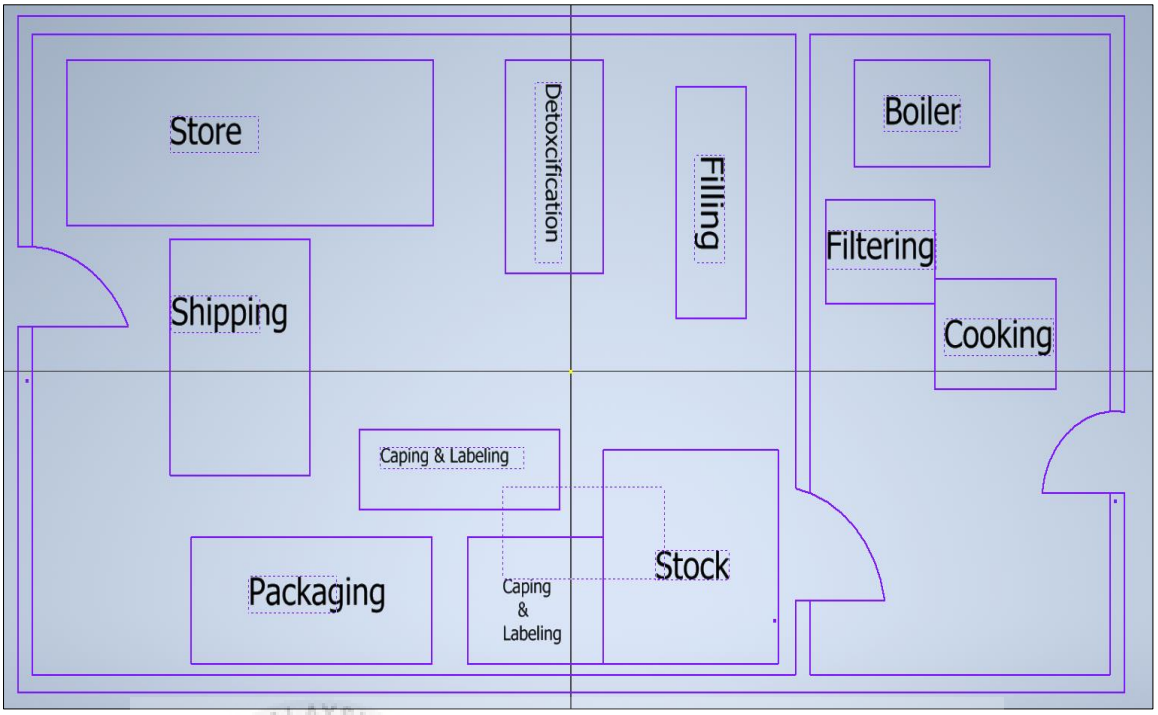


Figure 4. 1 Layout of soyabean production manufacturing company

Figure 4. 2 The following is the actual factory image during the factory visit

4.3.1.2 Flow Process of the Soyabean Production in F&B Company

The following figure 4.2 is the process flow chart of soyabean manufacturing in the F&B company. This shows the company on who the soyabean is manufactured from the raw material all the way till it is packed and sealed for shipping.

The following process start with the arrival of grinded soya as a raw material at the company. The beans are then added into the cooked followed by the mixture of hot water from the boiled and then the cooking process starts for one hour. The process may take longer if the grinded beans are not cooked as up to expectation. The beans are cooked with added secret ingredients to add flavour to their drinks.

Once the beans are fully cooked then it is moved into the filter chamber where the juice of soya is separated from the bean. While the filtering process occurs at the same time, the juice is sent into filling machine. The labour will sort out the bottles for the soya bean to be filled in. The bottles are sent by the supplier to the company.

Then the filling process is done at the same time the bottle is sealed with topping cover. The bottle is then closed with caps manually by the labours. One all bottles are filled; it is sent to the detoxification machine to remove any impurities and avoid inspection to the drinks. Once done, the drinks undergo quality inspection where the check for any colour disorientation or any changes in the taste of the drink. If the drink does not pass the quality inspection, then the drinks are disposed else it moves onto the next process.

The final process is where the labels are added onto the bottles manually by the workers. Then the bottles are packed in the sealing machine and sent to shipping to customers.

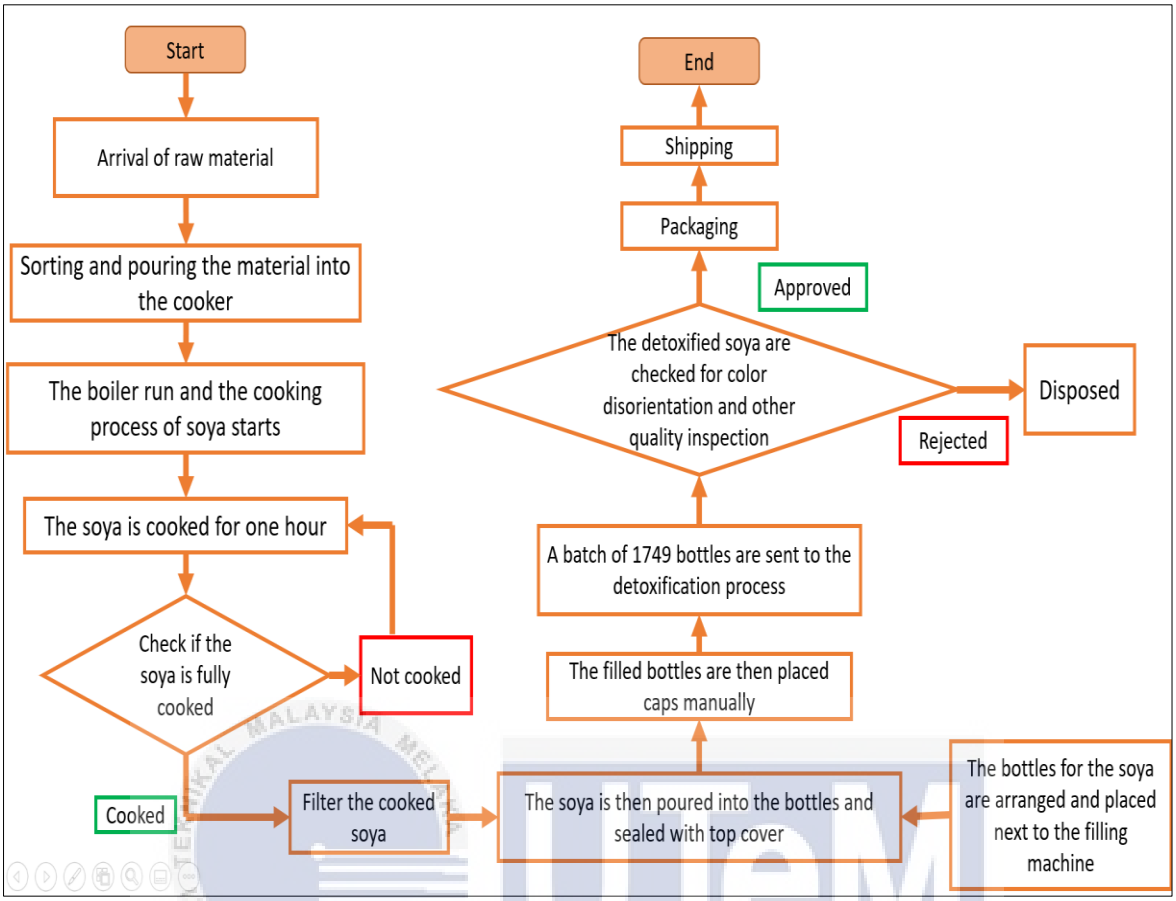


Figure 4. 3 Process flow chart of the soya manufacturing in the F&B company.

4.3.1.3 Machine Detail

Based on the data collection and the worker's statement, the following is the machine is selected for the case study where the machine causes a delay in the production line of the company. The Boiler machine (Vertical One-through type Steam Boiler) is the heard of the soyabean manufacturing process. This is because that this machine involves in the starting and ending process of the production and it is also one of the crucial machines that determines the quality of the product. Any imbalanced or uneven supply of pressure could cause the beans to over or undercooked and the detoxification process which happens at the end after the filling process could damage the entire batch made. This boiler is purchased the same year the company was opened which is in 2006 and was inspected in 2009. This boiler is a vertical boiler unlike the common horizontal boiler where it is mainly used for

steam powered purposed machines. The maximum working pressure that it could distribute is 142psi and maximum allowable temperature is about 183 degrees Celsius which is enough to cook through the beans to make the drinks. The time that this boiler is used during production is early morning 8a.m till 10.30a.m and in the afternoon 11.30a.m till 12.30p.m

Figure 4. 4 Boiler machine (Vertical One-through type Steam Boiler)

Figure 4. 5 The interview session that have conducted with the worker at the F&B company

4.3.2 Secondary Data

Secondary data is the data where that focusses on the goal rather than giving the overall common information. The secondary data fill focuses on a specific set of information that is needed to conduct the study. In this case study, the type of secondary data that will be using to accomplish the objectives of the studies are articles that proves the factors that

effects the production of a company, selected machine that causes the delay in production process and production data information (data that can be used to calculate the rate of OEE).

4.3.2.1 Factors Effecting Production Productivity based on Literature Review

First, this segment explains the method for fulfilling the first objective of the case study which is to identify the factors that effecting the production of the selected F&B company. As mentioned earlier the method that is used to understand the factors that can affect the production is carried out by doing literature review. There are several numbers of literatures that has been read, used, and selected that relates to the case study that is being conducted. The following table which is constructed shows the most effected factors in the manufacturing company which the OEE study conducted. The total number of journals selected are 31 for this case study.

Table 4 1 Identifying the factors effecting production

Factors Effecting Production	**Literature References**	**Total Related Journals %**
Man	Mhetre and Dhake,(2012), Dal, Bulent(2000), Fekri Sari, Mahsa Avakh Darestani and Soroush (2019), Prinz, Christopher (2017), Ireland, F. and Dale, B. G. (2001)	16.13
Machine	Muchiri, P. Pintelon, L. (2008), Saleem, Faizan (2017), Ahuja and Kumar (2009), Sharma and Trikha (2011), Tsarouhas, Panagiotis (2019), Liberopoulos (2002), Tsarouhas, Panagiotis H. (2019), Sujová, Erika (2018), Bamber, C. J. (2003), Ranjan, Raju (2018), Gupta, Pardeep (2016), Nallusamy, S. Majumdar and Gautam (2017), Guariente, P. Antoniolli, I. (2017), Zakuan, Norhayati (2019),	51.61

	He, Fei and Shen, Kang (2018), Venkatesh, J (2007),	
Material	Ljungberg, Õrjan(1998), Corrales, Lisbeth del Carmen Ng (2020), Febianny Susilo and Claudia (2016),	9.68
Method	Arabian-Hoseynabadi et al. (2010), Chikwendu, Okpala Charles (2020), Sutoni, Akhmad (2019), Cheah, Chew Keat (2020), Ghalayini, Alaa M. (1996), McKone, Kathleen E. (1999), Pellegrini, S (2012)	22.58

Based on the tables results, this proves that majority in a manufacturing company the factors that effects the production is due to machine then follow by the method of handling the production line. Besides that, men which is the workers also effects the production and then finally raw material effect as its mainly the material used are defective due to environmental factors and defective before even being processes.

4.3.2.2 Machine Production Data

The machine production data collection helps in the measuring the rate of OEE of the machine. This data collection is done based on the most recent data that can be obtain from the company itself to conduct the study. Statistically the minimum data required to conduct the calculation is from 5 to 30 days of data but due to this pandemic situation the data which obtain from the company is 30 working days. This following table 4.1 consist of data explain the company working days and the machine production data. The following tables are the table that tells the state and condition of machine that has been selected for the study. These data will be used in calculating the OEE rate of machine.

Table 4. 2 Details of working hours in F&B manufacturing company

Details of Food & Beverage Company	
Working days	6 working days
Shifts	1
Working hours	8 hours (480 minutes)
Breaks	1.25 hours (75 minutes)
Overtime	: if it is necessary…
Machine Operating Hours	3 hours 40 minutes (220 minutes)
Production Per Batch	1749 bottles
1 Day Production	5247 bottles (3 batches)
Product	Soya Bean Juice

The following table 4.3 and 4.4 are the raw data of the machine and the simplified form data of knowing the machine's specific details such as the run time, idle time, production time and other relatable data. The raw data is the basic data of the machine where it is obtan ined directly from machine production while the simplified table requires a slight calculation on determining the few factors that are needed to calculate the availability, performance, and quality. This will then be used to calculate the OEE rate of the machine. Besides that, knowing the rate of each segment will determine which are of the machine is mostly affected. This will allow to find the root cause of the machine as it is not as efficient as it is.

Table 4 3 Shows the raw data of the selected boiler machine in the F&B company

Date	Data	Input Quantity	Output Quantity	Reject
5/2/2019	Tuesday	5240	5231	9
6/2/2019	Wednesday	5247	5189	58
7/2/2019	Thursday	5200	5088	112
8/2/2019	Friday	3498	2816	682
9/2/2019	Saturday	3489	3337	152
10/2/2019	Sunday	4000	3915	85
11/2/2019	Monday	0	0	0
12/2/2019	Tuesday	3498	3465	33
13/2/2019	Wednesday	2500	2485	15
14/2/2019	Thursday	4000	3995	5
15/2/2019	Friday	4800	4793	7
16/2/2019	Saturday	5247	5241	6
17/2/2019	Sunday	5247	5233	14
18/2/2019	Monday	0	0	0
19/2/2019	Tuesday	5200	5187	13
20/2/2019	Wednesday	5000	4994	6
21/2/2019	Thursday	4500	4478	22
22/2/2019	Friday	4800	4780	20
23/2/2019	Saturday	5000	4989	11
24/2/2019	Sunday	5240	5236	4
25/2/2019	Monday	0	0	0
26/2/2019	Tuesday	5240	5232	8
27/2/2019	Wednesday	5247	5245	2
28/2/2019	Thursday	5240	5237	3
1/3/2019	Friday	3498	3475	23
2/3/2019	Saturday	3490	3433	57
3/3/2019	Sunday	2000	1458	542
4/3/2019	Monday	0	0	0
5/3/2019	Tuesday	4800	4587	213
6/3/2019	Wednesday	5240	5153	87

Table 4 4 Availability, Performance and Quality Report of Boiler Machine

		Dates									
		5/2/2019	6/2/2019	7/2/2019	8/2/2019	9/2/2019	10/2/2019	11/2/2019	12/2/2019	13/2/2019	14/2/2019
		Days									
	x	1	2	3	4	5	6	7	8	9	10
Production Time / Availability	Planned Production time, minutes	480	480	480	480	480	480	0	480	480	480
	Run time/Actual Operating Time, minutes	220	220	220	210	200	220	0	210	220	220
	Down time, minutes	260	260	260	270	280	260	0	270	260	260
Production / Quality	Input Quantity	5240	5247	5200	3498	3489	4000	0	3498	2500	4000
	Output Quantity	5231	5189	5088	2816	3337	3915	0	3465	2485	3995
	Reject	9	58	112	682	152	85	0	33	15	5
Setup and Adjustments / Performance	Machine Warm up, minutes	43	40	44	66	54	40	0	48	69	53

	Other adjustments, minutes	142	145	141	129	151	145	0	147	116	132
	Total	185	185	185	195	205	185	0	195	185	185
	Rest time, minutes	75	75	75	75	75	75	0	75	75	75
	Ideal Run Rate, piece per minute	10.92	10.93	10.83	7.29	7.27	8.33	0	7.29	5.21	8.33

		Dates									
		15/2/2019	16/2/2019	17/2/2019	18/2/2019	19/2/2019	20/2/2019	21/2/2019	22/2/2019	23/2/2019	24/2/2019
		Days									
	x	11	12	13	14	15	16	17	18	19	20
Production Time / Availability	Planned Production time, minutes	480	480	480	0	480	480	480	480	480	480
	Run time/Actual Operating Time, minutes	220	220	220	0	220	220	220	220	220	220
	Down time, minutes	260	260	260	0	260	260	260	260	260	260

Production / Quality	Input Quantity	4800	5247	5247	0	5200	5000	4500	4800	5000	5240
	Output Quantity	4793	5241	5233	0	5187	4994	4478	4780	4989	5236
	Reject	7	6	14	0	13	6	22	20	11	4
Setup and Adjustments / Performance	Machine Warm up, minutes	50	48	44	0	33	35	30	36	35	33
	Other adjustments, minutes	135	137	141	0	152	150	155	149	150	152
	Total	185	185	185	0	185	185	185	185	185	185
	Rest time, minutes	75	75	75	0	75	75	75	75	75	75
	Ideal Run Rate, piece per minute	10.00	10.93	10.93	0	10.83	10.42	9.38	10.00	10.42	10.92

		Dates									
		25/2/2019	26/2/2019	27/2/2019	28/2/2019	1/3/2019	2/3/2019	3/3/2019	4/3/2019	5/3/2019	6/3/2019
		Days									
	x	21	22	23	24	25	26	27	28	29	30
Production Time / Availability	Planned Production time, minutes	0	480	480	480	480	480	480	0	480	480
	Run time/Actual Operating Time, minutes	0	220	210	210	200	200	200	0	210	220
	Down time, minutes	0	260	270	270	280	280	280	0	270	260
Production / Quality	Input Quantity	0	5240	5247	5240	3498	3490	2000	0	4800	5240
	Output Quantity	0	5232	5245	5237	3475	3433	1458	0	4587	5153
	Reject	0	8	2	3	23	57	542	0	213	87
Setup and Adjustments / Performance	Machine Warm up, minutes	0	30	33	39	40	44	55	0	48	46
	Other adjustments, minutes	0	155	162	156	165	161	150	0	147	139

	Total	0	185	195	195	205	205	205	0	195	185
	Rest time, minutes	0	75	75	75	75	75	75	0	75	75
	Ideal Run Rate, piece per minute	0	10.92	10.93	10.92	7.29	7.27	4.17	0	10.00	10.92

4.4 Data Analysis

This segment plays an important role on conducting the study as this derives and explains the results obtained based on the data collection done. Firstly, based on the literature reviews conducted, it has been seen that machine plays an important role in productivity. This is proven based on the selected journals to conduct the study, majority stated that machines are the main cause of inefficiency in production line. This proves the first objective of the study which is to identify the factor effecting productivity is mainly due to machines. Hence, the conducted study is done are required to find the root cause that defects the machine. To find the root cause, there methods used which are calculation based on OEE's formula, Fishbone analysis and Why-Why analysis. This calculation allows to determine the most effected region of the machine while Fishbone and Why-Why analysis will determine the root cause for the selected region to be affected.

4.4.1 OEE Rate of Boiler Machine in F&B Factory

The following calculation is based on the OEE rate formula. The availability, performance and quality of the machine is determined using the collected data from 30 working days. Based on these root formulas, an OEE templet is used to calculate this value and finally determine the OEE rate for the day.

Availability Rate

$$Availability, \% = \frac{Actual\ Operating\ Time\ (mins)}{Planned\ Operating\ Time\ (mins)} \times 100\% \quad (4.1)$$

Performance Rate

$$Performance\ Rate, \% = \frac{\frac{\text{Total Pieces}}{\text{Operation TIme}}}{Run\ Time}\ x\ 100\% \quad (4.2)$$

Quality Rate

$$Quality\ Rate = \frac{Total\ Produced - Number\ of\ Scrapped}{Total\ \ Produced}\ x\ 100\% \qquad (4.3)$$

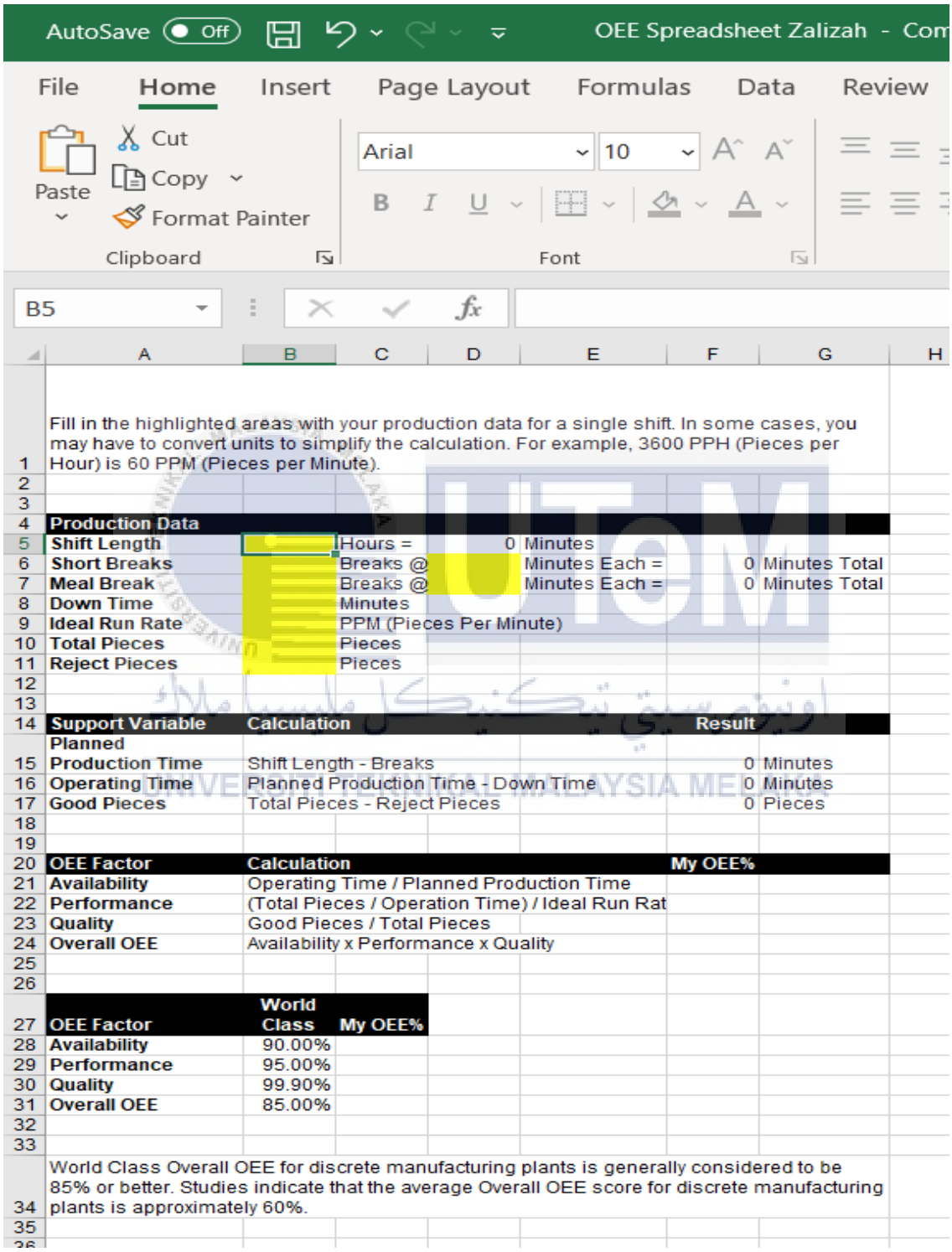


Figure 4. 6 The template that is used in Microsoft Excel to calculate daily and 1 month rate of availability, performance and quality of the machine followed by OEE rate

Table 4 5 The summary rate of availability, performance, quality and OEE in the 30 days

DAY	AVAILABILITY %	PREFORMANCE %	QUALITY %	OEE %
DAY 1	45.83%	100.00%	99.83%	45.75%
DAY 2	45.83%	100.00%	98.89%	45.33%
DAY 3	45.83%	100.00%	97.85%	44.85%
DAY 4	43.75%	100.00%	80.50%	35.22%
DAY 5	41.67%	100.00%	95.64%	39.85%
DAY 6	45.83%	100.00%	97.88%	44.86%
DAY 7	0.00%	0.00%	0.00%	0.00%
DAY 8	43.75%	100.00%	99.06%	43.34%
DAY 9	43.83%	100.00%	99.40%	45.56%
DAY 10	45.83%	100.00%	99.88%	45.78%
DAY 11	45.83%	100.00%	99.85%	45.77%
DAY 12	45.83%	100.00%	99.89%	45.78%
DAY 13	45.83%	100.00%	99.73%	45.71%
DAY 14	0.00%	0.00%	0.00%	0.00%
DAY 15	45.83%	100.00%	99.75%	45.72%
DAY 16	45.83%	100.00%	99.88%	45.78%
DAY 17	45.83%	100.00%	99.51%	45.61%
DAY 18	45.83%	100.00%	99.58%	45.64%
DAY 19	45.83%	100.00%	99.78%	45.73%
DAY 20	45.83%	100.00%	99.92%	45.80%
DAY 21	0.00%	0.00%	0.00%	0.00%
DAY 22	45.83%	100.00%	99.85%	45.76%
DAY 23	43.75%	100.00%	99.96%	43.73%
DAY 24	43.75%	100.00%	99.94%	43.72%
DAY 25	41.67%	100.00%	99.34%	41.39%
DAY 26	41.67%	100.00%	98.37%	40.99%
DAY 27	41.67%	100.00%	72.90%	30.38%
DAY 28	0.00%	0.00%	0.00%	0.00%
DAY 29	43.75%	100.00%	99.56%	41.81%
DAY 30	45.83%	100.00%	98.34%	45.07%

4.4.1.1 Average OEE Rate of Boiler Machine

Using the same templet that calculates each day of OEE rate, the 1-month OEE rate of the boiler machine is calculated by summarizing the values such as production time, operation time, down time, total good pieces, and total pieces produced. The idle run rate will be based on division of total pieces produced and total production time for 30 days. The following table 4.5 shows the OEE rate of the boiler machine for one month.

Table 4 6 OEE rate of the selected Boiler Machine for 1-month

AVAILABILITY	52.15%
PERFORMANCE	100.00%
QUALITY	98.12%
OEE	51.17%

Based on the results of table 4.4 and 4.5 it is proven that the most effected factor of the boiler machine is the availability of the boiler. The performance and quality of boiler shows a good result of 100% and 98.12% respectively for the 1-month average result. Even in the daily basis result, the value of performance manages to stay at 100% and the quality rate is ranged within the 90% value. However, the availability rate both in daily and 1-month average result shows a not convincing result of 52.15% as there are improvement needed to be done to overcome this problem. Therefore, investigation needed to be taken to find the root cause of the boiler having a lower availability rate.

4.4.1.2 Rate Boiler Machine's OEE Compared with World Class OEE Rates

The World Class Rates that is indicated here is based on Nakajima's standardization that tells if the equipment is functions on its best states. Based on the graphs that is being presented, the machine's performance rate is at 100% for all 30 days and average 1-month result proving that the machine performance producing product satisfies the world class quality standards set. Next is the quality of the machine shows that it did not achieve world class standard, but it still reaches rewarding level of 98.12% as the average for 1-month result although there are time such as in day 4 and day 27 the rates are as low as 80% and 72% respectively. The downside of the machine can be seen on the machine's availability as the average rate of availability for 1-month of the machine is 52.15% which is very low compared to the world class measure which is 90%. Due to rate of availability of machine causing the average OEE rate of machine for the 1-month is to be at 51.17%. This value shows that the machine did not achieve world class level.

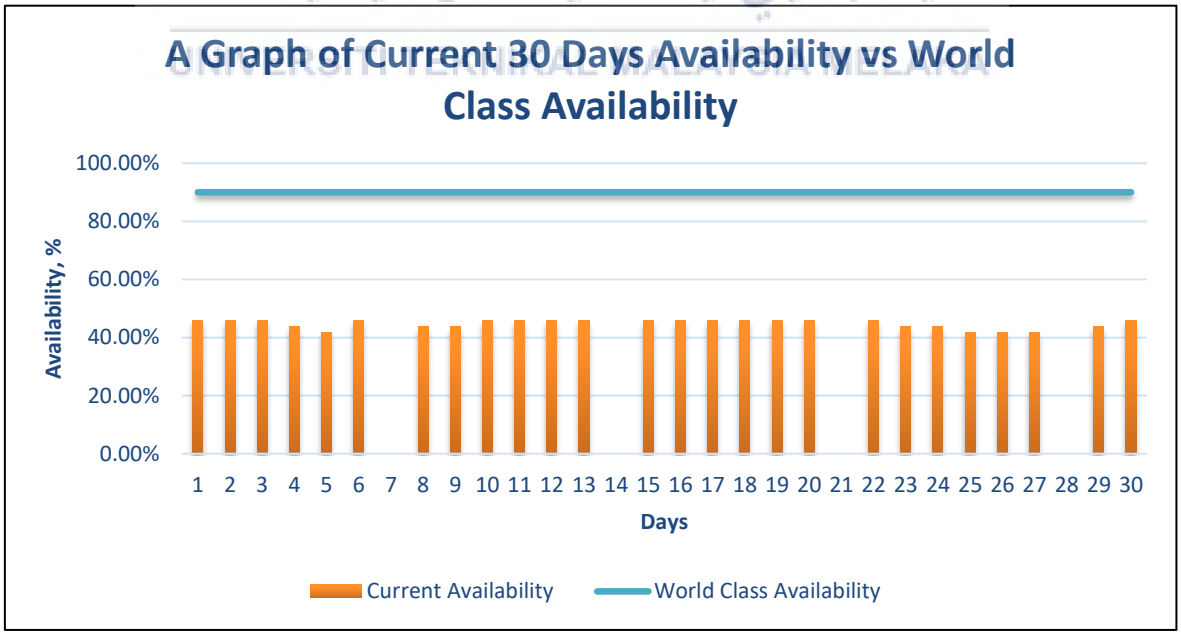


Figure 4. 7 The graph indicates the machine availability level for 30 days with the world class availability rate level

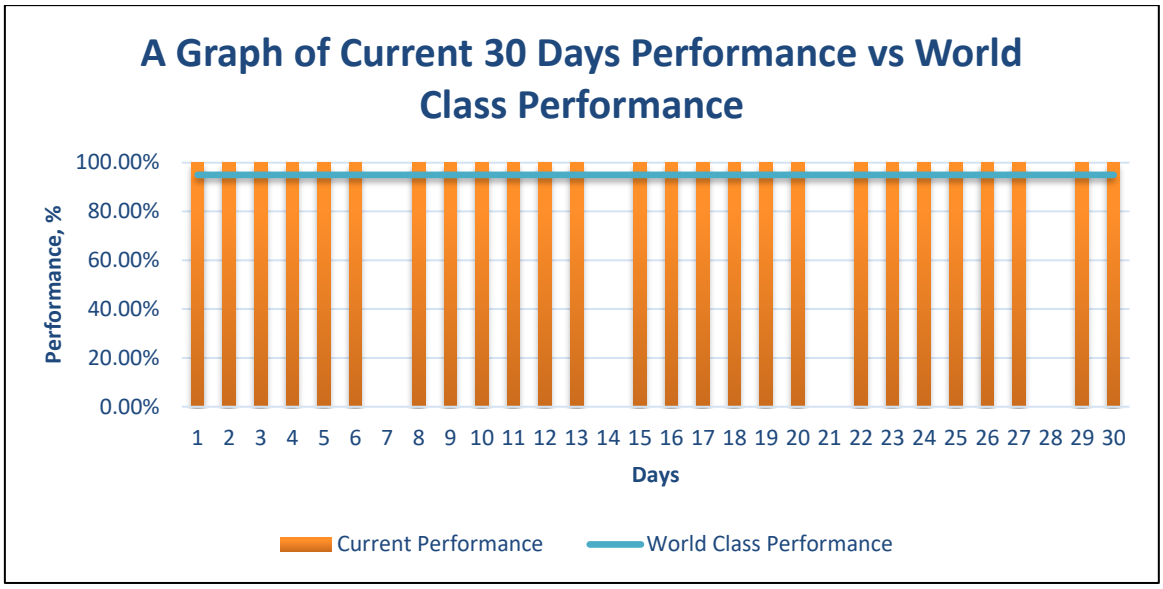


Figure 4. 8 The graph indicates the machine performance level for 30 days with the world class performance rate level

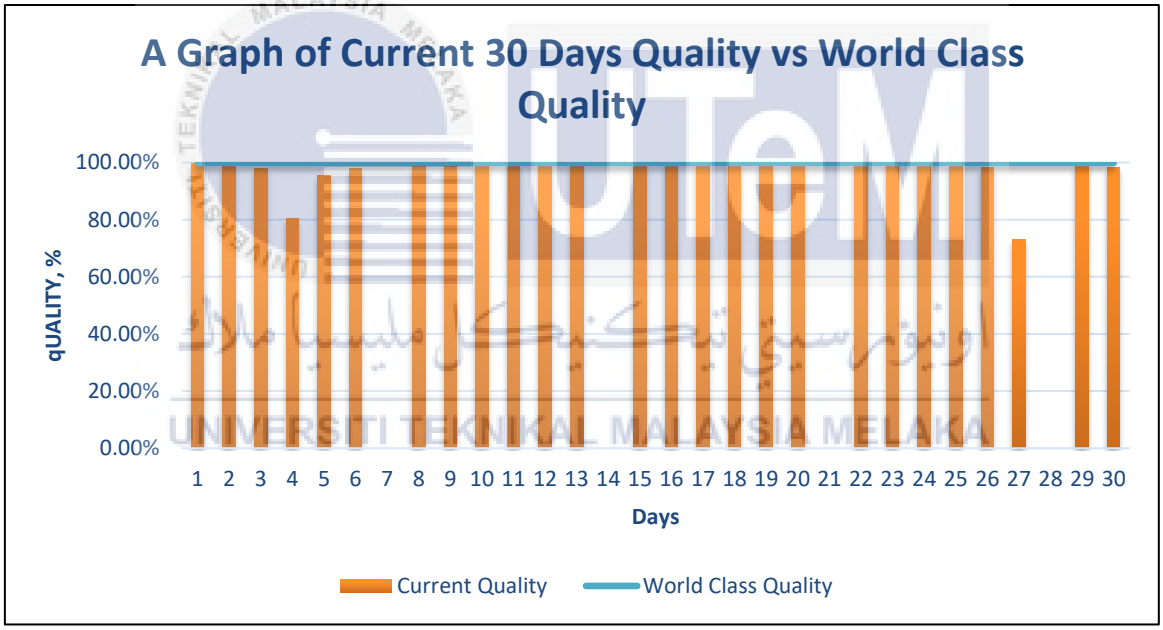


Figure 4. 9 The graph indicates the machine quality level for 30 days with the world class quality rate level

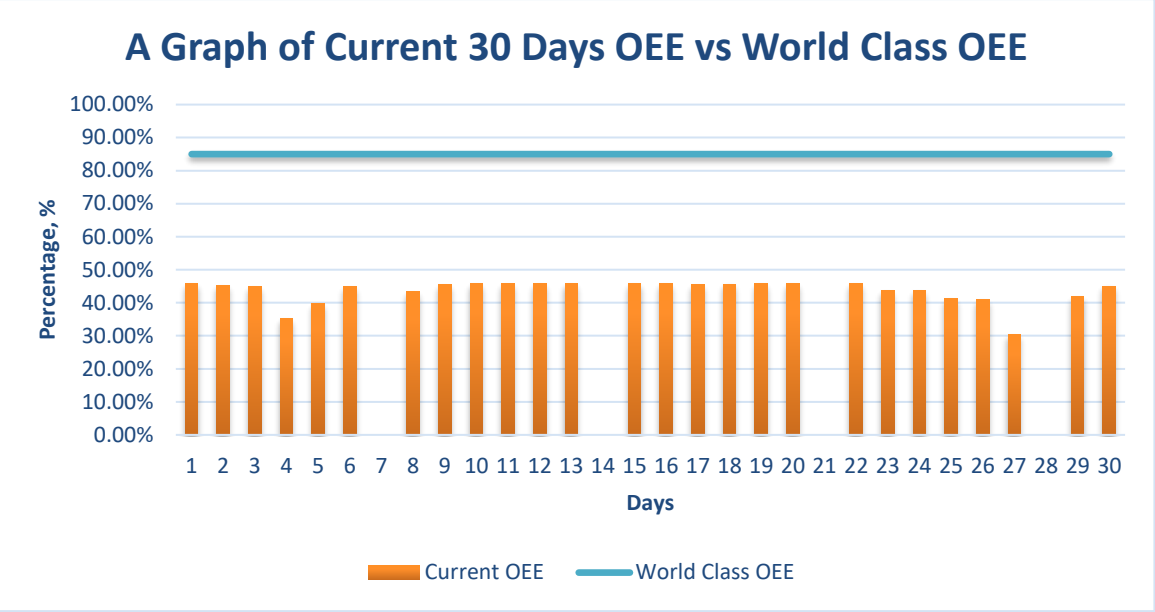


Figure 4. 10 The graph indicates the machine availability level for 30 days with the world class availability rate level

1	Fill in the highlighted areas with your production data for a single shift. In some cases, you may have to convert units to simplify the calculation. For example, 3600 PPH (Pieces per Hour) is 60 PPM (Pieces per Minute).						
2							
3							
4	**Production Data**						
5	**Shift Length**	277.5	Hours =	16650	Minutes		
6	**Short Breaks**	1	Breaks @	450	Minutes Each =	450	Minutes Total
7	**Meal Break**	1	Breaks @	1800	Minutes Each =	1,800	Minutes Total
8	**Down Time**	6890	Minutes				
9	**Ideal Run Rate**	9.33	PPM (Pieces Per Minute)				
10	**Total Pieces**	116,461	Pieces				
11	**Reject Pieces**	2,189	Pieces				
12							
13							
14	**Support Variable**	**Calculation**				**Result**	
15	**Planned Production Time**	Shift Length - Breaks				14,400	Minutes
16	**Operating Time**	Planned Production Time - Down Time				7,510	Minutes
17	**Good Pieces**	Total Pieces - Reject Pieces				114,272	Pieces
18							
19							
20	**OEE Factor**	**Calculation**				**My OEE%**	
21	**Availability**	Operating Time / Planned Production Time				**52.15%**	
22	**Performance**	(Total Pieces / Operation Time) / Ideal Run Rate				**100.00%**	
23	**Quality**	Good Pieces / Total Pieces				**98.12%**	
24	**Overall OEE**	Availability x Performance x Quality				**51.17%**	
25							
26							
27	**OEE Factor**	**World Class**	**My OEE%**				
28	**Availability**	90.00%	**52.15%**				
29	**Performance**	95.00%	**100.00%**				
30	**Quality**	99.90%	**98.12%**				
31	**Overall OEE**	85.00%	**51.17%**				
32							

Figure 4. 11 shows the template used to calculate OEE rate of the F&B Company for 1 month

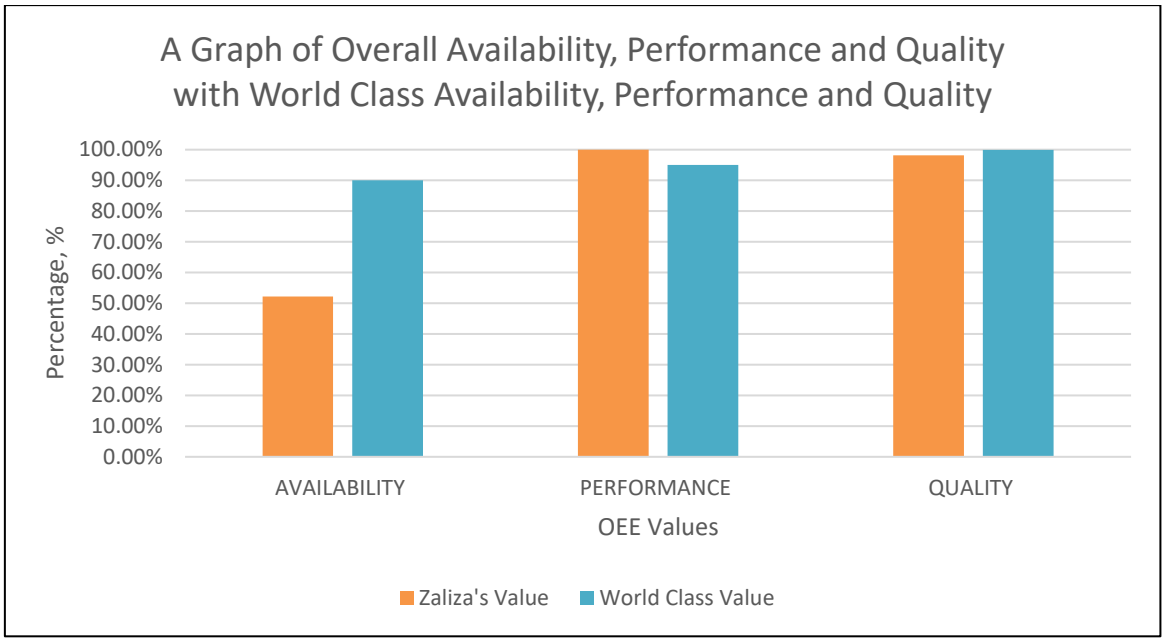


Figure 4. 12 The graph indicates the machine availability, performance, and quality for 1-month with the world class rate

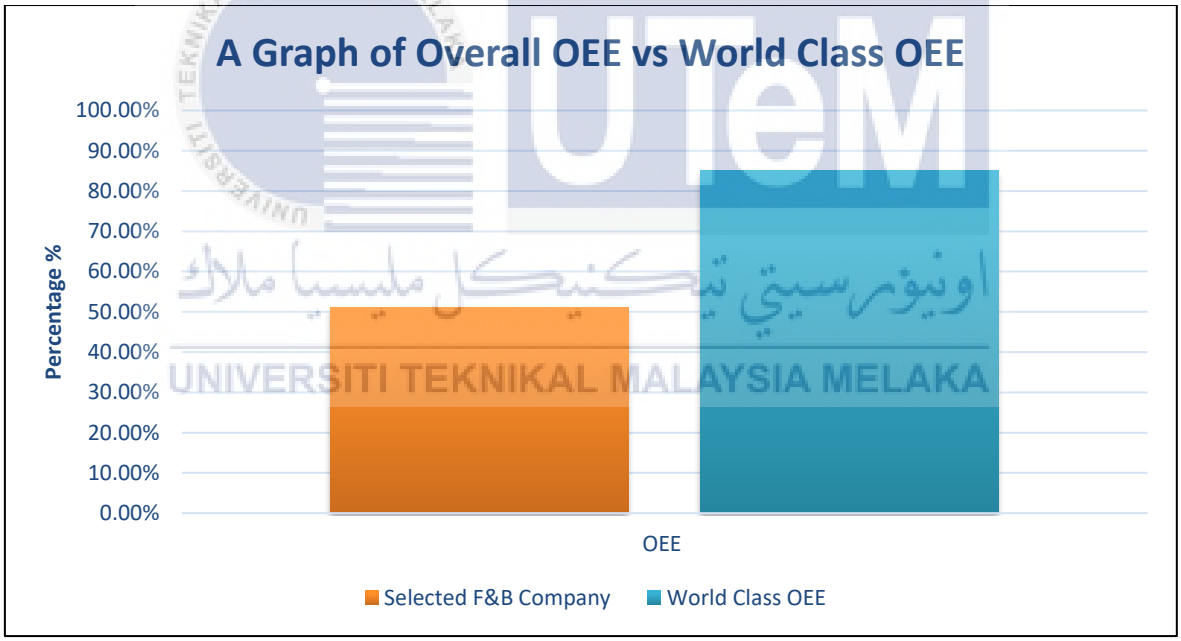


Figure 4. 13 The graph indicates the machine OEE rate for 1-month with the World Class OEE rate

4.4.2 Fishbone Analysis

Fishbone analysis was introduced in the early of 1920s where this analysis is used for determining the root cause of a problem or issue that is being encountered. In this case study, the fishbone diagram addresses the main cause from the aspects of 4M which is Man,

Machine, Method and Material. Based on the diagram, it is found that the majority aspect effecting the delay in part production is mainly by Machine, then followed by Method and Man. The Material does not affect as much as other factors of 4M and therefore it is neglected in the Why-Why Analysis. This is because that Machine contribute the most as it shows a 51.61% followed by Method 22.58 and finally Men about 16.13%.

As mentioned in earlier paragraph, Machine contributes the most on effecting the delay in part production. This is because that, firstly the machine takes a longer time to process the product that is being places. When the investigation is done deeper than it is found that there is no planned downtime causing the machine to be shut down during the production. This is causing machine not to be available as it required maintenance to continue the production. This is because it is found that there is leakage in the inner walls of the boiler. This is caused by the tubes that channels the water into the cooker and the detoxifier.

The second factor effecting the delay in production is because of the method that is being carried out during the production of part. This is because the machine is not fully utilized from morning until the end of the shift. The machine is used only if needed for cooking the soyabean or detoxification process. Therefore, the times during filling process, labelling or caping the machine remains not used, hence increasing the downtime.

The third factor is the Men where in this case the workers become the factor the causes delay on part production.t this is because that the company workers are not skilful to fix the machine when there is a unplanned downtime. The machine having an issue in the tubes channel of the boiler causing to have leakage whenever high pressure is used. Hence as a solution they hired a third-party contractor to fix the problem by welding onto the leakage walls to continue the production. Until then the production of soyabean will remain

stopped. The figure 4.12 illustrates the factors that effecting the production of parts based on the 4M element which is Men, Machine, Method and Material.

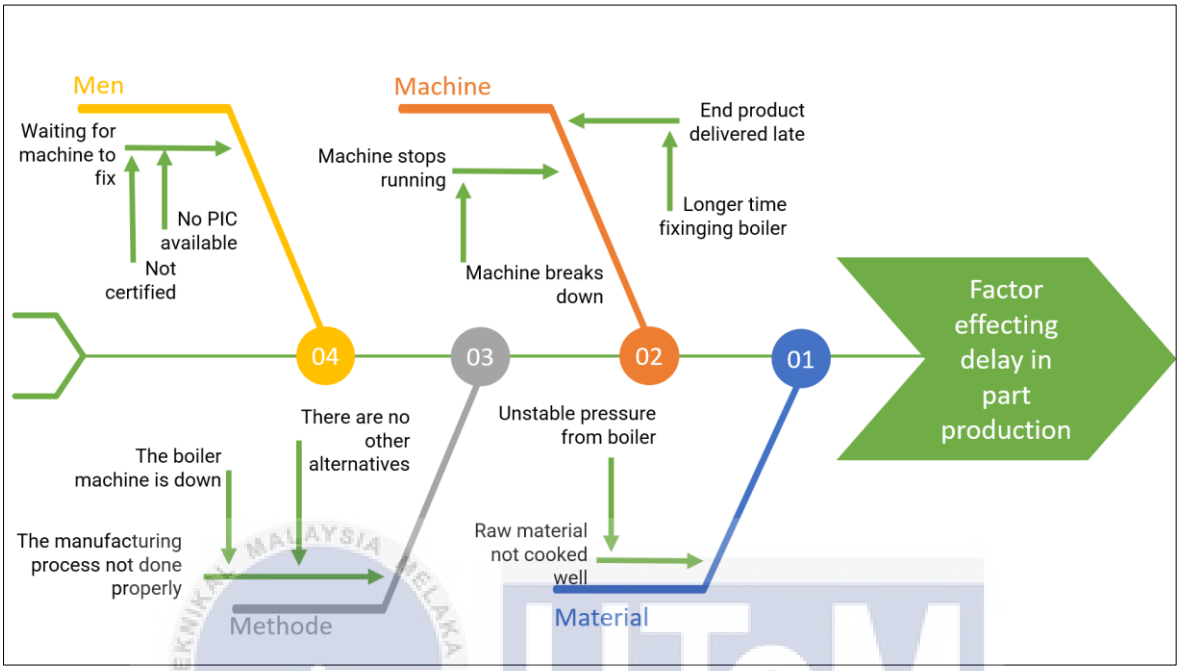


Figure 4. 14 The Fishbone diagram for the identifying factors effecting delay in part production

4.4.3 Why-Why Analysis

In this section explains further based on the findings from the fishbone diagram and then determine the root cause for the study. The root cause is determined using the Why-Why Analysis. This helps in the investigation for future suggestion for improvement for the part precision making company. From the 4M aspect that is being mentioned (Men, Machine, Method, Material) the main 3 aspects which as more than 10% is selected and discussed. The material is neglected due to low percentage effecting delay in part production. The Why-Why analysis no just use to identify the root cause rather producing solutions for the root cause found during the investigation. Each root cause determines possible behaviours that decrease the probability of the cause's occurrence or outcome. Based on

Table 4.7, shows the problems and causes that occur in precision part production according to critical issues detected in Fishbone Diagram which are machine, method, and man.

Table 4 7 Why-Why Analysis for finding root cause of delay in part production

Factor	Problem	Why 1	Why2	Why 3	Why 4	Why 5	Root Cause
Machine	The boiler runs slower and stops	The boiler breaks down	There is leakage inside the boiler walls	The tube that flows the water in high pressure leaks the water	The wall tubes are unable to support high pressure caused by the boiler	The boiler is outdated	The boiler is too old to perform the task
Method	The process of cooking and detoxification on the soya is not done properly	The pressure supply from the boiler to cooker and detoxifier is not reached	The boiler breaks down	The inner tubes of the boiler leaking	The boiler is not able to support high pressure	There is no other method to continue cooking and detoxification process	There is no alternative method to continue cooking and detoxification process
		The cooking and detoxifying process of soya is not stable	The soya cooked and detoxified for a longer time	The pressure is not stable when boiler is down	-	-	The boiler is not functioning
Man	The boiler breaks down	The workers stop working	There is no PIC (person-in-charge) to handle boiler	The workers are not certified for this job	The workers wait until contractors fix the problem	-	The workers are not provided with training or certified for boiler handling

Based on the table, in machine it is seen that the boiler is too old to be used as there are parts that are required to be replaced. The inner tubes of the boiler causing there is a leakage inside the boiler. This makes the boiler not to be able to supply pressure to the cooker and also detoxification tank to continue the process. This causes to happen a delay in their production. This is because that both cooking, and detoxification process occur in the early

and end of production. Therefore, the boiler is needed to be active in that period to continue to be available and perform.

Next, in the method the root cause for the delay is the boiler is not functioning and there is no other alternative way. This is because that the manufacturing process of producing soya is made in a connective way where every machine is interconnected depending on one another. The early cooking process of soya depending on the boiler, only then it can be filtered and supplied to the bottling process until then the bottling process is on hold. After the bottling process is done it is detoxified into the detoxification machine which is once again depending on the boiler. Therefore, if the boiler is down due to maintenance or having an unexpected downtime, there are no other alternatives that can be done to continue the manufacturing process.

Final factor, men which is the workers of the company are unable to fix the problem (leakage tube of boiler) because they are not certified to conduct boiler jobs. They may only do minor fix but when comes to major problems such as handling the interior parts of the boiler, they are required to hire a contractor to solve the problem. Besides that, the method that they used to fix the problem are just temporary and there is no permanent or long-term solution used by the company management or workers to fix the boiler.

Figure 4. 15 The boiler walls are leaking

4.5 Propose Improvement

Based on the why-why analysis made, the main root cause is identified based on the most contributed factors which is machine, method, and men. There are few steps suggested to the F&B manufacturing company which could overcome the problems faced in the company based on the root cause that has been identified. These suggestions are based on the Total Productive Maintenance, TPM's Eight Pillars of productive maintenance. The following table are the root cause and the suggestion to overcome the problem.

Table 4 8 Suggestion for each root cause that have been identified.

Factor	Root Cause	Suggestion
Machine	1. The boiler is too old to perform the task.	1. Replace the whole boiler with a new boiler and use the replaced boiler as a secondary boiler for emergency or maintenance for new boiler 2. Replace the tubes inside the boiler that cause the leakage within the boiler and wrap the boiler walls with new foils. 3. Categorize the tubes from most effected to still usable and replace the ones with critical condition. Then wrap the inner walls with foil.
Method	1. There is no alternative method for producing soya	1. Have a separate manufacturing process that does not depend on just one boiler.
	2. The boiler tends to breakdown	1. Have regular maintenance weakly, and preventive maintenance before and after the usage of boiler daily.
Men	1. The worker is not experienced or certified to fix boilers	1. Hire a person who is boiler expert to fix the boiler faster. 2. Provide training or send the workers to training centers for them to be certified.

4.5.1 Suggestion for Machine's Root Cause

Based on the Why-Why Analysis and the literature review, the machine contributes the most effect part of this manufacturing process. This is because the inner tubes of the boiler are leaking into the boiler causing an imbalanced pressure distribution to the cooking machine and detoxification machine. The current method used to overcome this is that the leaked tubes are sealed, and the walls are welded with foils to close the holes to continue the process. This is the temporary measure that is taken to overcome this problem. The first suggestion to overcome this problem is that the boiler itself is needed to be replaced. This is because that the boiler is purchased in 2006 and was used for over 17 years. The condition of the boiler can be seen in on the maintenance report as the boiler breaks down at least once every month and causes the production to be disrupted not to achieve its target. Hence the

first suggestion for this is to replace the boiler. Therefore, the company needed to perform a Minimal Acceptable Rate of Return, MARR to identify return of their investment.

The second suggestion will be the replacement of the boiler tubes and the attachment of new foils around the inner walls of the boiler. This is because that, the main cause of disruption of the production line is that the tubes inside the boiler which channels the water leaks causing the walls of the boiler to be rot and causing a leakage. Hence replacing the tubes and the walls could increase the life span of the boiler and have a stable production.

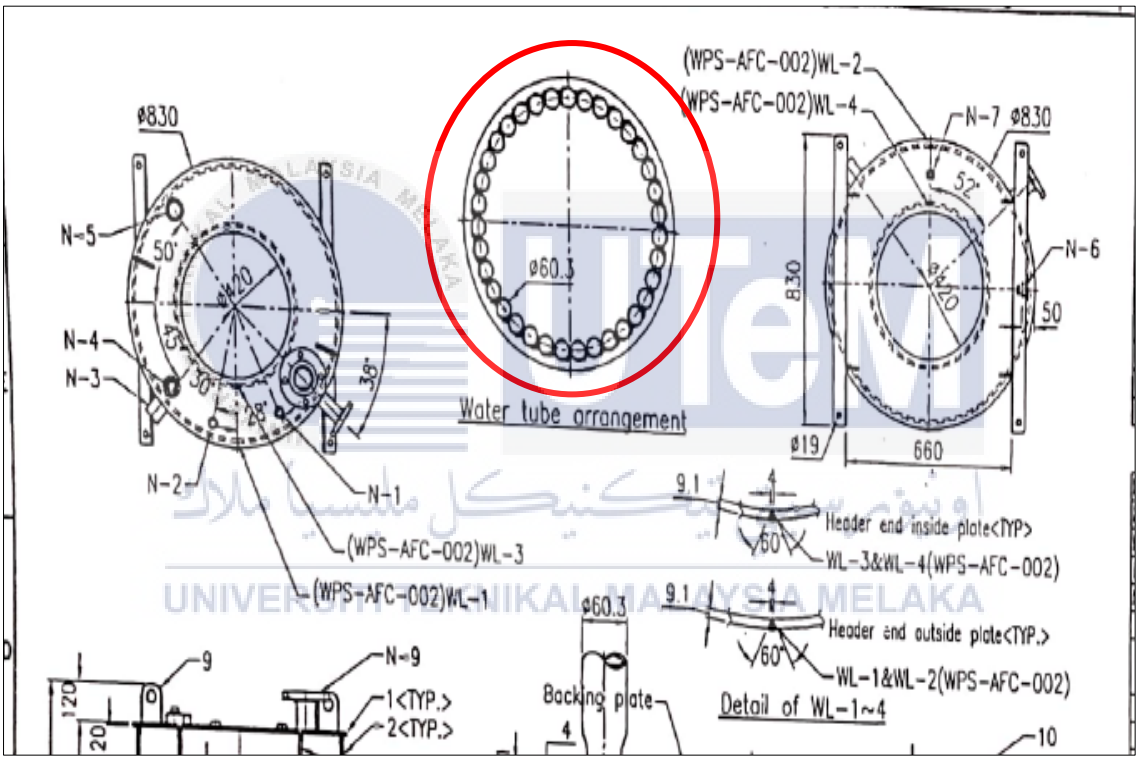


Figure 4. 16 Circle marks shows effected tubes of the boiler that is needed to be replaced.

Other than that, the least that can be done to ensure the process is not disturbed, the tube of the boiler is removed categorized from critical condition to least effected tubes and the most critical tubes are replaced. The walls are still needed to be replace as majority part are rotting due to the leakage.

4.5.2 Suggestion for Method's Root Cause

The method of soya manufacturing is that it is a continuous process where the machines process depending on one another to continue the process from start till the end. The following image shows the process that interconnects one another. Based on the image, if the boiler is down, the earliest process of cooking the beans is disrupted and if the boilers stop at the end the detoxification process is disrupted. If the boiler malfunctions early the beans are unable to be cooked to its perfection hence it will be wasted or if the boiler stops during the detoxification process there will be more waste produced as the milk from the beans are filtered, bottled, and sealed. This will cause more waste than the earlier ones and also effect more in financial state. Hence having a separate process of investing on boiler which match the capability of the cooking and detoxification could solve the problem. This is because that if the 1st boiler stops the second would still run and able to support their respective process or if there is a purchase of 2 boilers that is able to support both processes hence it can be useful as well.

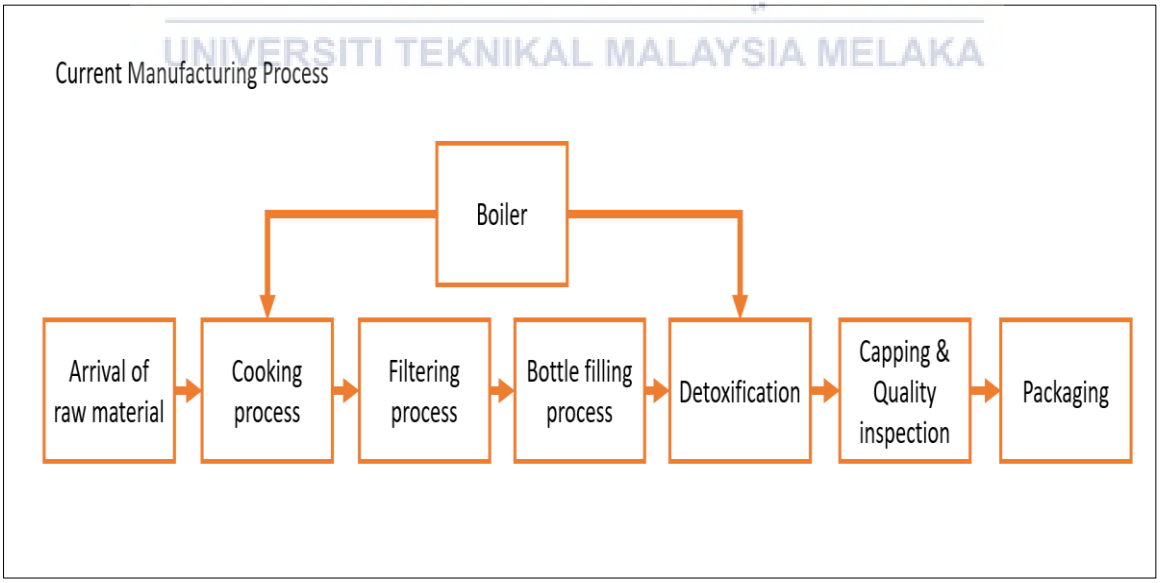


Figure 4. 17 Current manufacturing process of soya is used in the F&B company

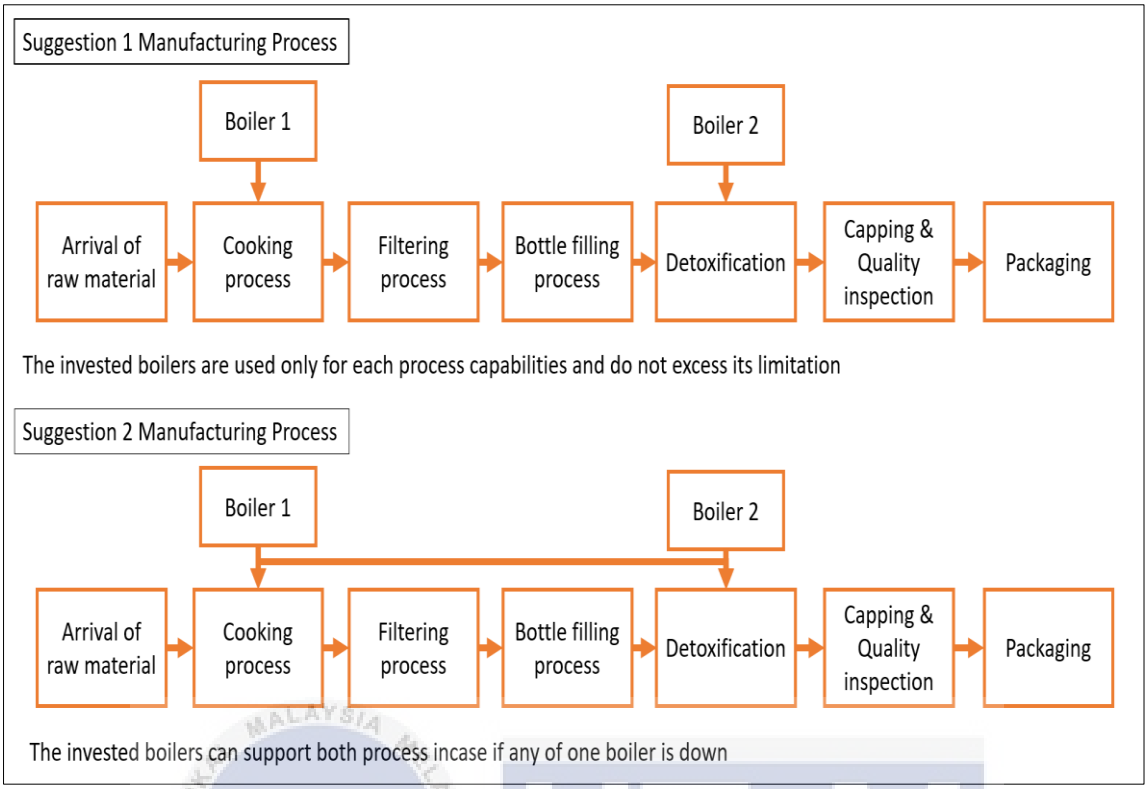


Figure 4. 18 The 2 suggestions of separate process of the soya manufacturing for the F&B company

4.5.3 Suggestion for Man's Root Cause

The root cause for man in the delay of the process is that when the machine (boiler), breaks down, the workers there could not fix it and continue with the process as they are not certified or inexperienced on fixing the machine. They have to hire a third-party contractor to fix the problem hence causing a delay for the day. The best suggestion for this type of problem is that the company management is required to hire a new worker who is experienced in fixing the problem. Besides that, the worker should consist basic knowledge on applying temporary fix onto the machine and continue the production. Therefore, they are needed to be sent for training for them to gain knowledge on handling these machines.

4.6 Control and Continuous Improvement

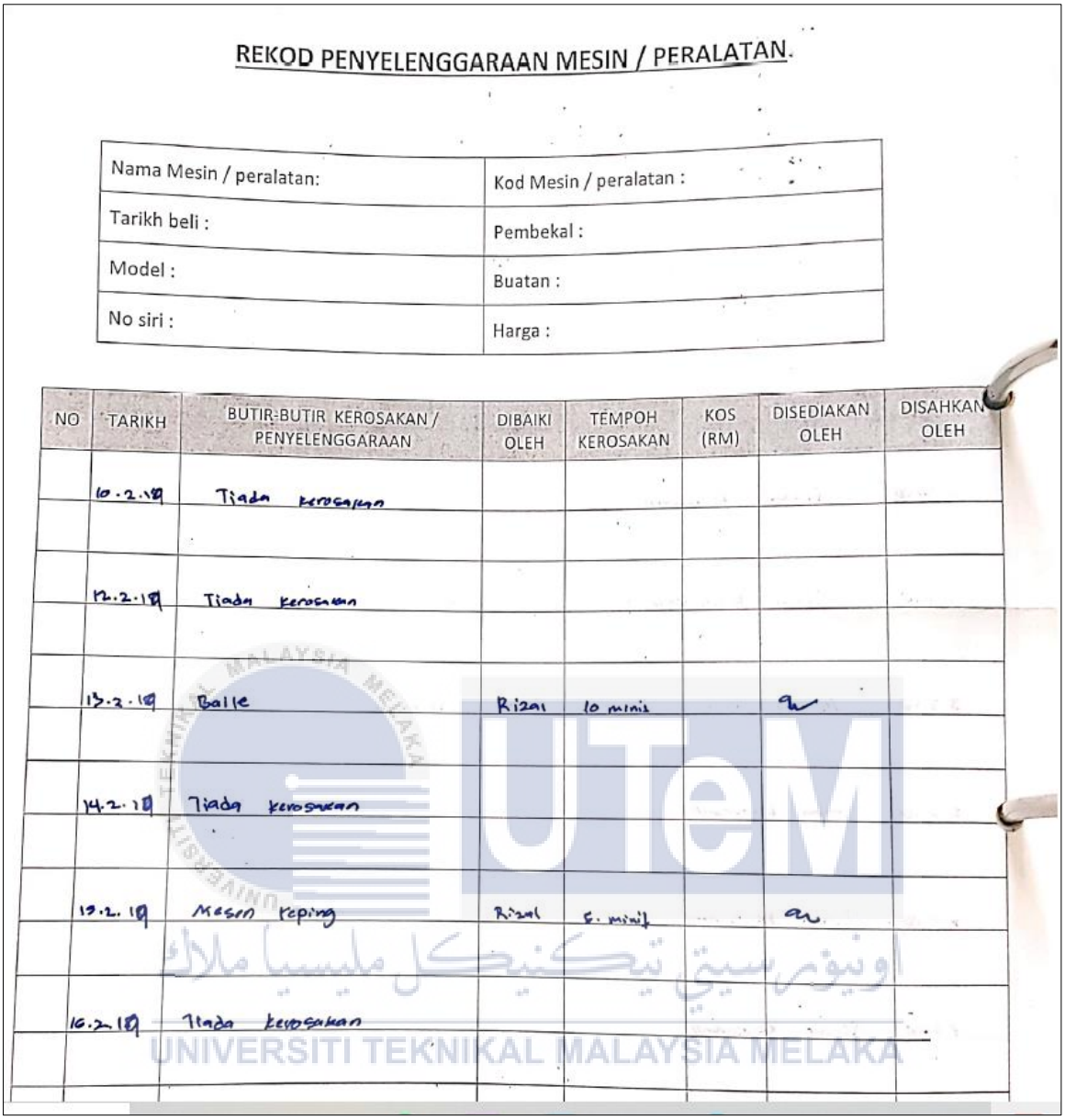
Using the principle of DMAIC, the final part that are required for the study is to ensure that the suggested process for improvement in done in a controlled and sustainable way for a continuous improvement in the manufacturing process. The continuous improvement can be mentioned as a part of TPM's Eight Pillars as they also encourage for improvement at a regular state. Hence, this assures not just to increase the production process but to eliminate other waste and to achieve a World Class OEE standard. The following are the suggestion for the continuous improvement for the F&B company.

4.6.1 Maintenance Report

The current maintenance report does not reflect many details for the continuous improvement. This is because that there is only time taken for the fixing process, person responsible fixing and the machine that caused problems. They did not mention on type of measures taken for it to reflect on how long the taken measure last long. Hence the maintenance report required to be modified as the suggested table below. Besides that, the maintenance report should be created for each machine and must be placed in a reach of the workers for them to note down each failure and maintenance process taken immediately for an accurate record.

No	Name of Component	Date	Down Time	Restart Time	Reason For Downtime	Maintenance Action Taken	Person in charge
1.							
2.							
3.							
4.							

Figure 4. 19 Suggested maintenance report needed for the F&B Company



REKOD PENYELENGGARAAN MESIN / PERALATAN.

Nama Mesin / peralatan:	Kod Mesin / peralatan :
Tarikh beli :	Pembekal :
Model :	Buatan :
No siri :	Harga :

NO	TARIKH	BUTIR-BUTIR KEROSAKAN / PENYELENGGARAAN	DIBAIKI OLEH	TEMPOH KEROSAKAN	KOS (RM)	DISEDIAKAN OLEH	DISAHKAN OLEH
	10.2.19	Tiada kerosakan					
	12.2.19	Tiada kerosakan					
	13.2.19	Belle	Rizal	10 minit			
	14.2.19	Tiada kerosakan					
	15.2.19	Mesin reping	Rizal	5 minit			
	16.2.19	Tiada kerosakan					

Figure 4. 20 Example current maintenance report of the F&B company

4.6.2 Employment of New Employees

Based on the current staffs working for the F&B company, they are still in lacking in skills in handling the boiler. The company should consider hiring a boiler expert on managing the boiler for the production. Besides that, a planer should be hired as well to plan the production process ahead for the company. This will allow to know the production time, idle time, and cycle time of the company's production process and able to avoid unplanned

breakdowns from various machines. This helps not just to keep track of the progression made by the company but also saves financially on major loss due from shutdown.

4.6.3 Training for Current and Upcoming Employees

Similar to the second point, the workers are stated to be unskilful when handling the boiler and hence there are required to be given basic training on handling the boiler. This is for them to make minor adjustment and to be able to ensure no disturbance during production and also preventing major breakdowns with just minor ones. Besides that, they should be thought with basic skills such as the “DO’s and Don’ts “before, during and after production process. This will increase the knowledge and have the initiative for preventive maintenance for the used machine.

4.7 Summary

To sum up this chapter, the following are done based on the DMAIC concept where first the problem is defined for the study. The problem that is being stated is the delay in the delivery time which cause dissatisfaction among the F&B customers. The for the measurement, the data is collection where it consists of primary and secondary data. these data are then used in the analysis of the study which is the third concept of DMAIC. The analysis is done to know the selected equipment's rate of availability, performance, and quality for 30 days and the average of a month (based on the calculated 30 days) of the recent times. Based on the results it is found that the availability of the boiler is in a bad condition which is about 52%, while the quality of the boiler did not achieve World Class standards, but it has a acceptable rate over 98%.

The investigation is further discussed using the Fishbone diagram and Why-Why analysis to determine the root cause that made the value of availability and quality to be lower than the World Standards of OEE rate. It is seen that majority factor that contributes is by the machine similarly stated in the literature review. In this case it, there is a leakage in the tubes of the boiler causing the boiler to send imbalanced pressure to the cooking and detoxification machine which delays the cycle time of production.

Finally, the remaining two elements of DMAIC which is Improvement and Control are stated for the F&B company. This suggestion is mentioned to ensure that the company can improve the production at the same time to have continuous improvement at constant rate.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Based on the overall thesis, the Overall Equipment Effectiveness, OEE is a technique whereby can be implemented onto any industry for improvement, sustainability and optimizing the process. In this thesis proves the usage of OEE into the F&B manufacturing that it helps in improvising the production productivity of part manufacturing. The implementation of OEE in F&B manufacturing company not just helps in optimized production rather identifies root cause of the even and prepares for a continuous improvement reaching the world class standards.

In finalizing the thesis, the first objective which is to identify the factors effecting the production productivity is done with the aid of data collection from the journals identifying the main cause in industry. Other than journals, Fishbone diagram and Why-Why Analysis is then used to deepen the identification of root cause. Then the second objective is accomplished with the aid of OEE formula and the secondary data collection from the F&B manufacturing company the equipment effectiveness can be identify. A series of equipment's data such as quality reports, machine idle run rate, run time and many others are used to identify availability, performance and quality of equipment with then used to identify OEE. This value is then compared to the World Class Standards of OEE and then determine if the machine is in optimized state.

The final objective which to propose improvement for the equipment is done based on the root cause that is identified and the Eight Pillars of Total Productive Maintenance, TPM. This is because that TPM serves the purpose of eliminating unnecessary task and

losses from the production process which ensures a optimized production. The OEE is utilized to increase and differentiate production efficiency from the current process flow. This adjustment in the project will be communicated to the organization in order to assist in the resolution of this problem.

5.2 Contribution

To sum up this thesis has been in a good help for the manufacturing company as it helps to identify, and elimination losses at the same time suggest room for continuous improvement. OEE technique has been able to identify the equipment's effectiveness in the manufacturing company. The part precision manufacturing company gain to know the equipment's availability, performance, and quality during production. This also helps is narrow down the most effected region of the equipment and then focusses on removing losses and unnecessary procedure for improvement. Furthermore, this thesis ensures that the equipment functions at its best with no unplanned stoppages between production time which helps in saving time and cost by increasing the equipment's end of life for longer. Finally, this very same technique can be applied not just to one equipment but the overall production line for a complete identification of effectiveness of line.

5.3 Improvement for Future Research

The suggestion for future research is to focus on other effected area of equipment effectiveness and implement the suggested method to solve the current problem found in the thesis. Due to pandemic of Covid-19, the suggested method for improvement could not be applied onto the selected company. Therefore, the suggestion for future research is to implement those steps onto the equipment and then view the changes in the results. Besides that, the other minor effected region such as the performance can be improved by identifying the minor cause for imperfection is results. This is because that OEE method can be used as

a continuous improvement not just for equipment but rather the overall production line in any industry, hence it is suggested to use this method for continuous improvement, sustainable and optimized performance.

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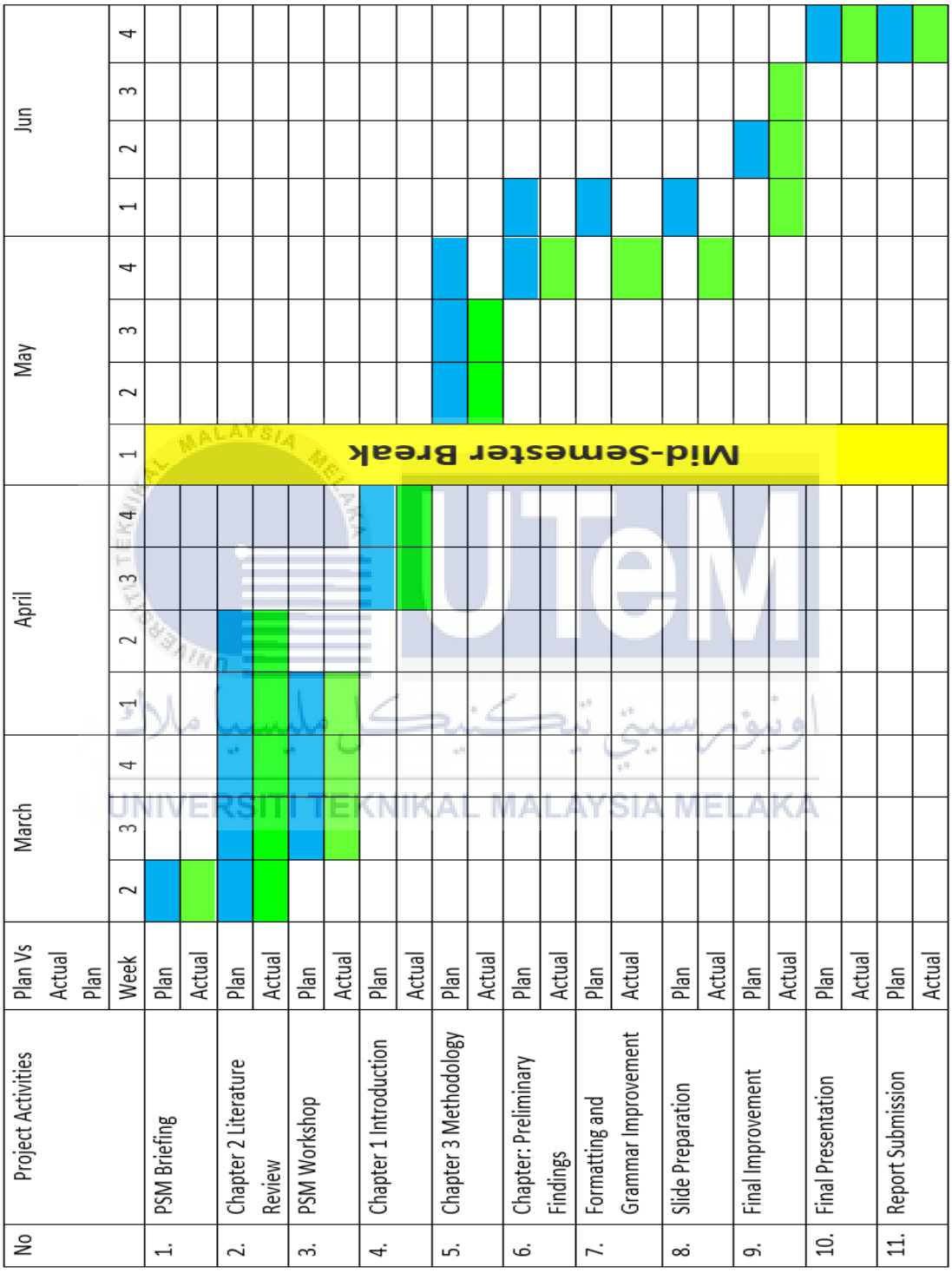
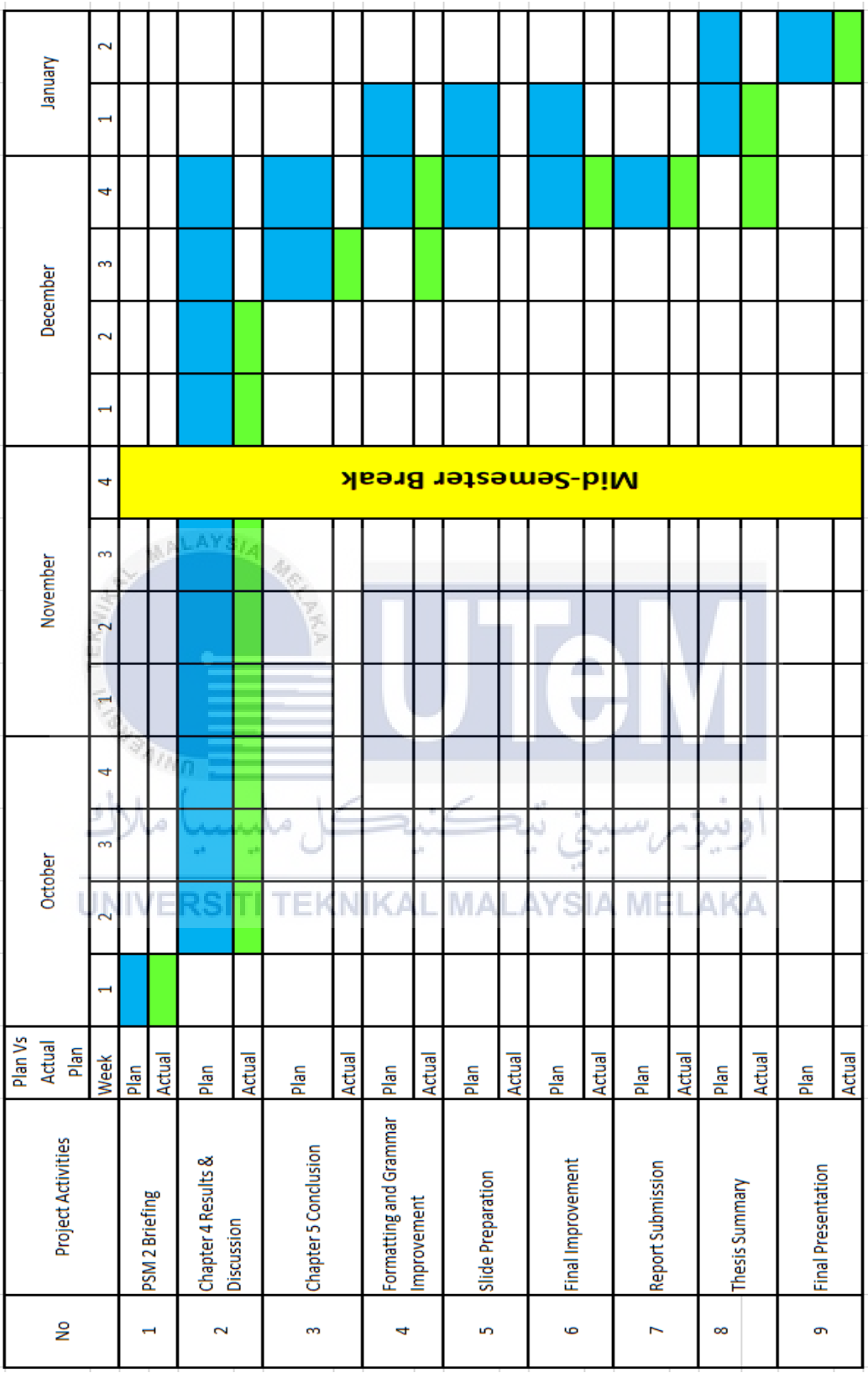
APPENDICES

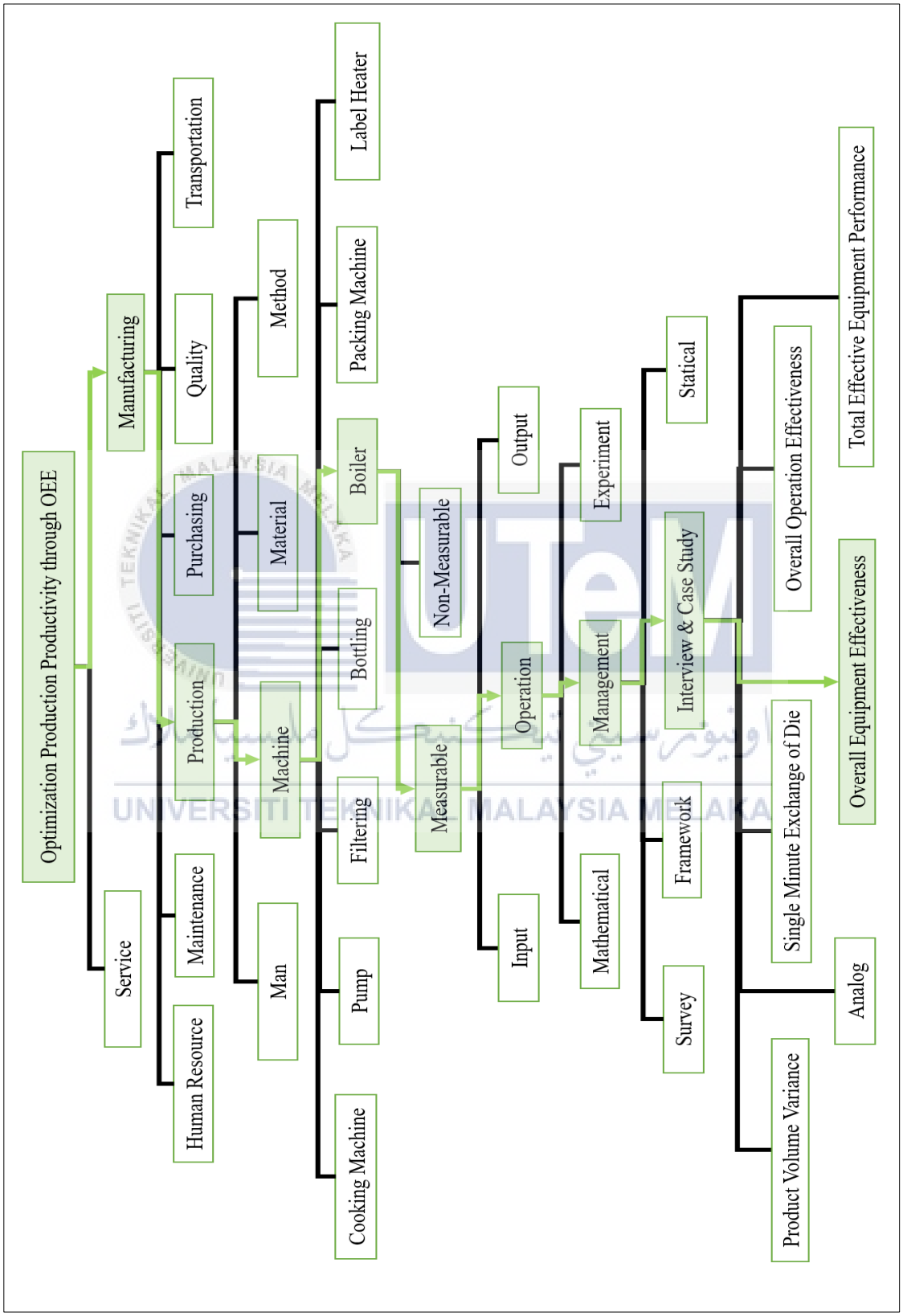
APPENDIX A Gantt Chart PSM 1



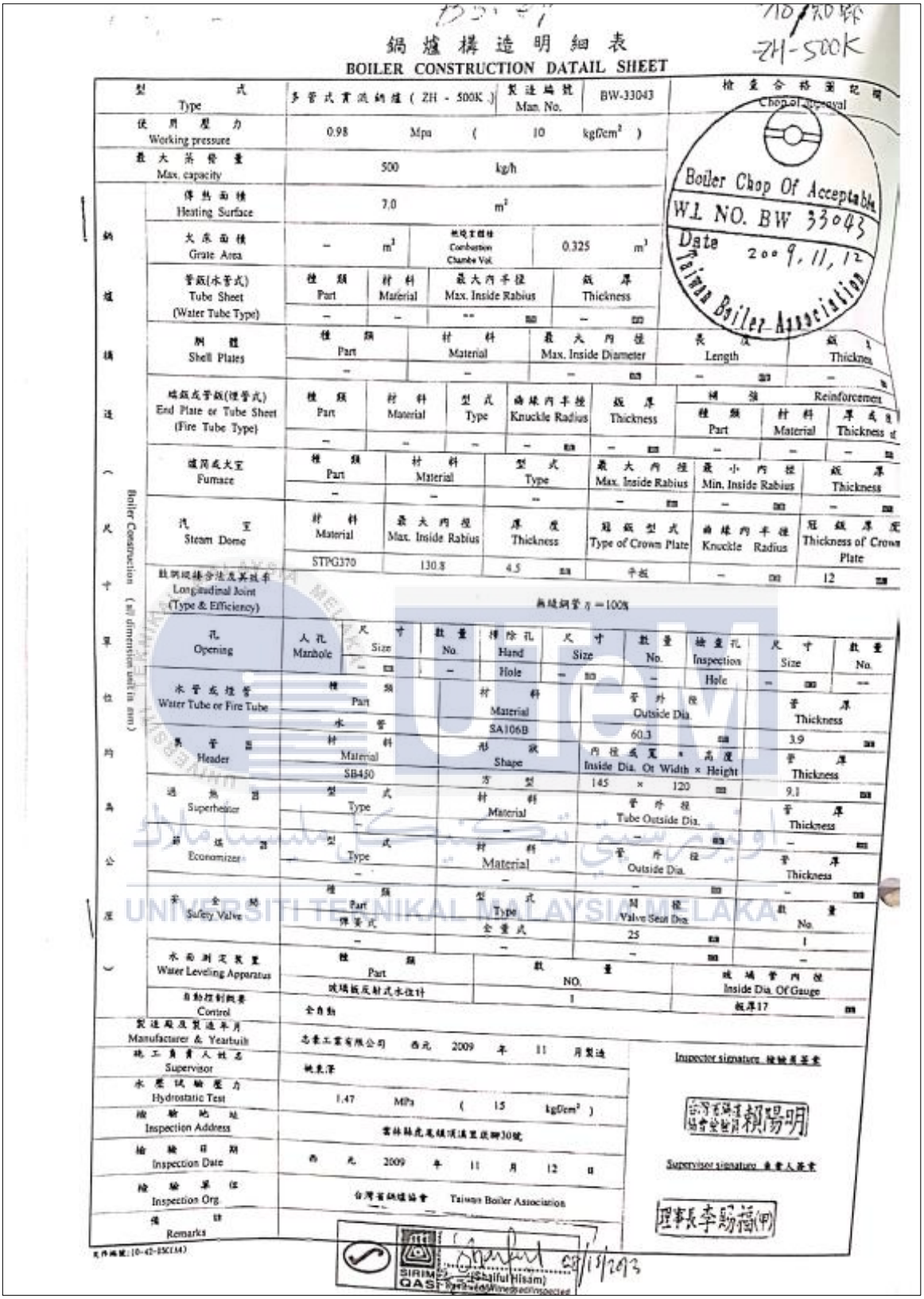
APPENDIX B Gantt Chart PSM 2



APPENDIX C K-Chart



APPENDIX E Boiler Details



鍋爐構造明細表
BOILER CONSTRUCTION DATAIL SHEET

ZH-500K

型式 Type	多管式貫流鍋爐 (ZH - 500K)	製造編號 Man. No.	BW-33043	檢查合格蓋記號 Chop of Approval
使用壓力 Working pressure	0.98 Mpa	(10 kg/cm²)		
最大蒸發量 Max. capacity	500 kg/h			
鍋爐構造(尺寸單位mm) Boiler Construction (all dimension unit is mm)	傳熱面積 Heating Surface	7.0 m²		
	火床面積 Grate Area	– m²	燃燒室體積 Combustion Chamber Vol.	0.325 m³

Boiler Chop Of Acceptable
W.I. NO. BW 33043
Date 2009, 11, 12
Taiwan Boiler Association

管板(水管式) Tube Sheet (Water Tube Type)	種類 Part	材料 Material	最大內半徑 Max. Inside Rabius	板厚 Thickness		
	–	–	– mm	– mm		
胴體 Shell Plates	種類 Part	材料 Material	最大內徑 Max. Inside Diameter	長度 Length	板厚 Thickness	
	–	–	– mm	– mm	– mm	
端板或管板(煙管式) End Plate or Tube Sheet (Fire Tube Type)	種類 Part	材料 Material	型式 Type	曲線內半徑 Knuckle Radius	板厚 Thickness	補強 Reinforcement 種類 Part / 材料 Material / 厚或徑 Thickness of
	–	–	–	– mm	– mm	– / – / – mm
爐筒或火室 Furnace	種類 Part	材料 Material	型式 Type	最大內徑 Max. Inside Rabius	最小內徑 Min. Inside Rabius	板厚 Thickness
	–	–	–	– mm	– mm	– mm
汽室 Steam Dome	材料 Material	最大內徑 Max. Inside Rabius	厚度 Thickness	端板型式 Type of Crown Plate	曲線內半徑 Knuckle Radius	端板厚度 Thickness of Crown Plate
	STPG370	130.8	4.5 mm	平板	– mm	12 mm
縱向縫接法及其效率 Longitudinal Joint (Type & Efficiency)	無縫鋼管 η = 100%					

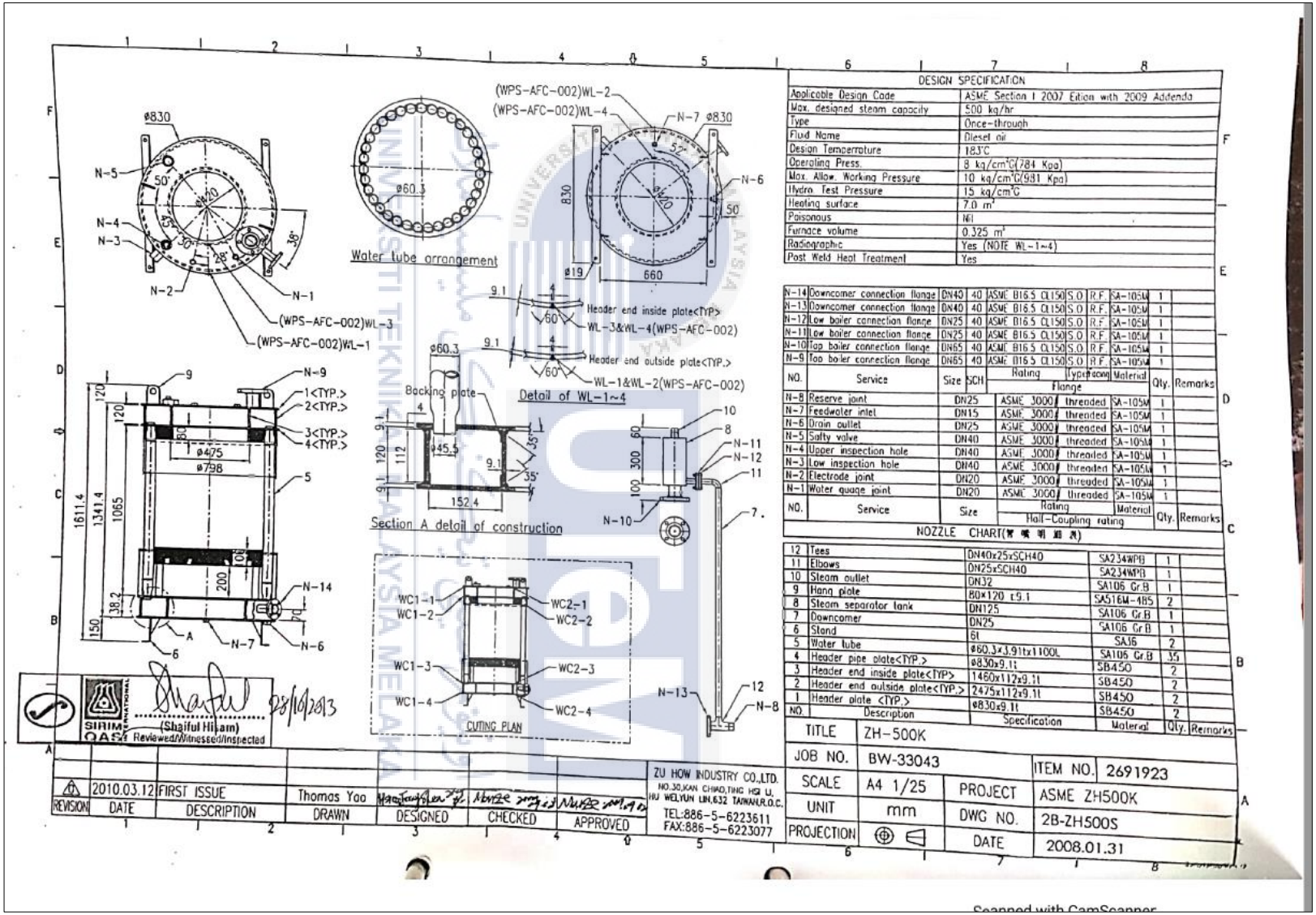
孔 Opening	人孔 Manhole	尺寸 Size	數量 No.	掃除孔 Hand Hole	尺寸 Size	數量 No.	檢查孔 Inspection Hole	尺寸 Size / 數量 No.
	–	– mm	–	–	– mm	–	–	– mm / –
水管或煙管 Water Tube or Fire Tube	種類 Part		材料 Material		管外徑 Outside Dia.		管厚 Thickness	
	水管		SA106B		60.3 mm		3.9 mm	
集管 Header	材料 Material		形狀 Shape		內徑或寬×高度 Inside Dia. Or Width × Height		管厚 Thickness	
	SB450		方型		145 × 120 mm		9.1 mm	
過熱器 Superheater	型式 Type		材料 Material		管外徑 Tube Outside Dia.		管厚 Thickness	
	–		–		– mm		– mm	
節炭器 Economizer	型式 Type		材料 Material		管外徑 Outside Dia.		管厚 Thickness	
	–		–		– mm		– mm	
安全閥 Safety Valve	種類 Part		型式 Type		閥座 Valve Seat Dia.		數量 No.	
	彈簧式		全量式		25 mm		1	
水面測定裝置 Water Leveling Apparatus	種類 Part		數量 NO.		玻璃管內徑 Inside Dia. Of Gauge			
	玻璃板反射式水位計		1		板厚17 mm			
自動控制概要 Control	全自動							
製造廠及製造年月 Manufacturer & Yearbuilt	忠泰工業有限公司 西元 2009 年 11 月製造							
施工負責人姓名 Supervisor	魏東澤							
水壓試驗壓力 Hydrostatic Test	1.47 MPa (15 kg/cm²)							
檢驗地址 Inspection Address	雲林縣虎尾鎮頂溪里民族30號							
檢驗日期 Inspection Date	西元 2009 年 11 月 12 日							
檢驗單位 Inspection Org	台灣省鍋爐協會 Taiwan Boiler Association							
備註 Remarks								

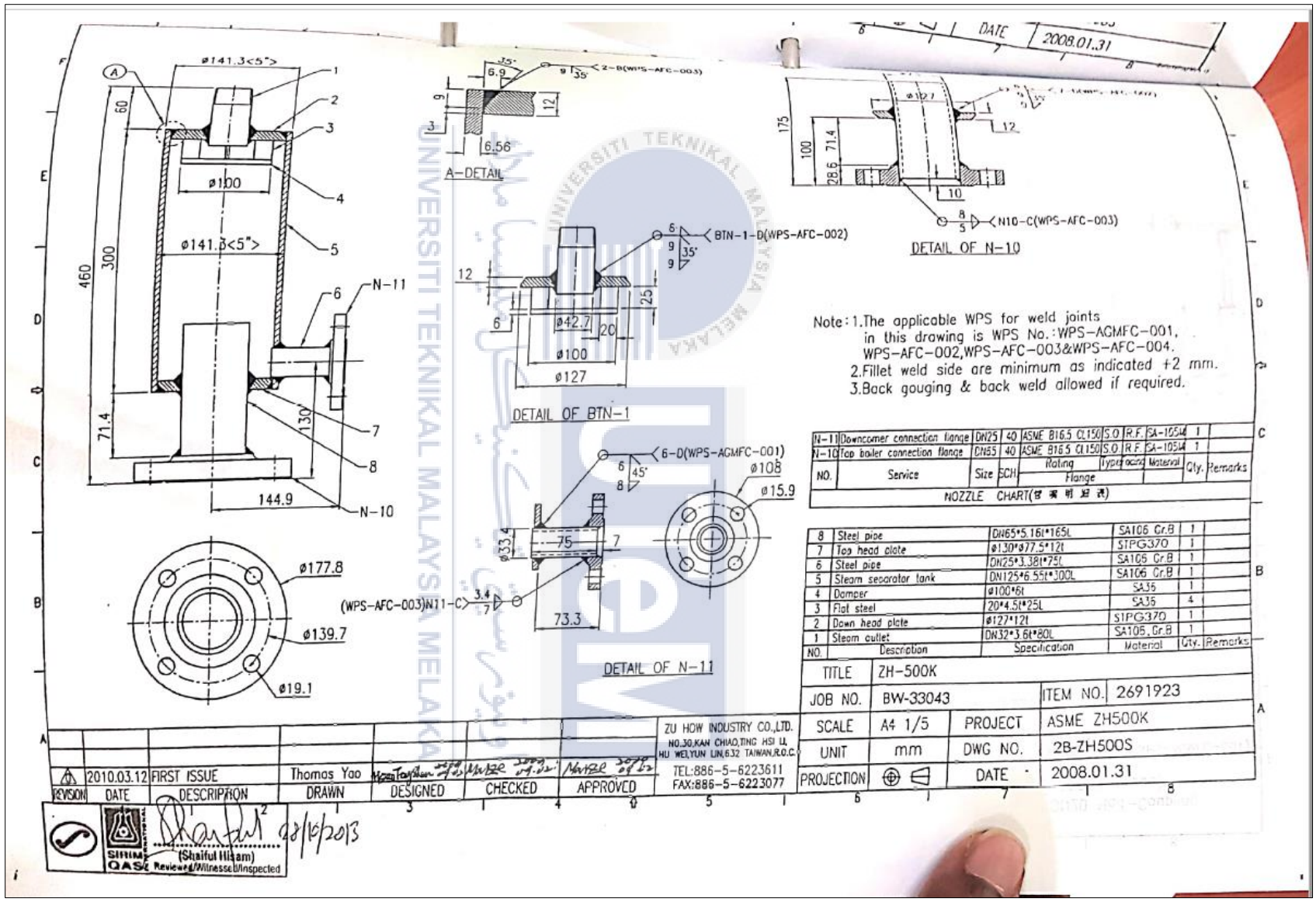
Inspector signature 檢驗員簽章

Supervisor signature 負責人簽章

理事長李賜福(印)

SIRIM QAS (Shaiful Hisam) Inspected




DATE 2008.01.31
ø141.3<5">
ø100
ø141.3<5">
460
300
71.4
60
130
144.9
N-11
N-10
A-DETAIL
6.56
2-B(WPS-AFC-003)
BTN-1-D(WPS-AFC-002)
DETAIL OF BTN-1
ø42.7
ø100
ø127
N10-C(WPS-AFC-003)
DETAIL OF N-10
6-D(WPS-AGMFC-001)
ø108
ø15.9
ø33.4
75
73.3
(WPS-AFC-003)N11-C
DETAIL OF N-11
ø177.8
ø139.7
ø19.1
Note: 1.The applicable WPS for weld joints in this drawing is WPS No.: WPS-AGMFC-001, WPS-AFC-002, WPS-AFC-003&WPS-AFC-004.
2.Fillet weld side are minimum as indicated +2 mm.
3.Back gouging & back weld allowed if required.
N-11 Downcomer connection flange DN25 40 ASME B16.5 CL150 S.O R.F SA-105M 1
N-10 Top boiler connection flange DN65 40 ASME B16.5 CL150 S.O R.F SA-105M 1
NO. Service Size SCH Rating Flange Type Facing Material Qty. Remarks
NOZZLE CHART(管嘴明細表)
8 Steel pipe DN65*5.16t*165L SA106 Gr.B 1
7 Top head plate ø130*ø77.5*12t STPG370 1
6 Steel pipe DN25*3.38t*75L SA106 Gr.B 1
5 Steam separator tank DN125*6.55t*300L SA106 Gr.B 1
4 Damper ø100*6t SA36 1
3 Flat steel 20*4.5t*25L SA36 4
2 Down head plate ø127*12t STPG370 1
1 Steam outlet DN32*3.6t*80L SA105, Gr.B 1
NO. Description Specification Material Qty. Remarks
TITLE ZH-500K
JOB NO. BW-33043 ITEM NO. 2691923
SCALE A4 1/5 PROJECT ASME ZH500K
UNIT mm DWG NO. 2B-ZH500S
PROJECTION DATE 2008.01.31
ZU HOW INDUSTRY CO.,LTD.
NO.30,KAN CHIAO,TING HSI LI, HU WEI,YUN LIN,632 TAIWAN,R.O.C.
TEL:886-5-6223611
FAX:886-5-6223077
REVISION DATE DESCRIPTION DRAWN DESIGNED CHECKED APPROVED
2010.03.12 FIRST ISSUE Thomas Yao
SIRIM QAS (Shaiful Hisam) Reviewed/Witnessed/Inspected 28/10/2013

APPENDIX F Maintenance Report

REKOD PENYELENGGARAAN MESIN / PERALATAN

Nama Mesin / peralatan:	Kod Mesin / peralatan :
Tarikh beli :	Pembekal :
Model :	Buatan :
No siri :	Harga :

NO	TARIKH	BUTIR-BUTIR KEROSAKAN / PENYELENGGARAAN	DIBAIKI OLEH	TEMPOH KEROSAKAN	KOS (RM)	DISEDIAKAN OLEH	DISAHKAN OLEH
	1.2.19	Tiada kerosakan					
	2.2.19	Tiada kerosakan					
	3.2.19	Mesen lebal	Rizal	15 minit		au	
	5.2.19	Tiada kerosakan					
	6.2.19	Tiada kerosakan					
	7.2.19	Tiada kerosakan					
	8.2.19	Baiki	Rizal	10 minit		au	
	9.2.19	Tiada kerosakan					

REKOD PENYELENGGARAAN MESIN / PERALATAN.

Nama Mesin / peralatan:	Kod Mesin / peralatan :
Tarikh beli :	Pembekal :
Model :	Buatan :
No siri :	Harga :

NO	TARIKH	BUTIR-BUTIR KEROSAKAN / PENYELENGGARAAN	DIBAIKI OLEH	TEMPOH KEROSAKAN	KOS (RM)	DISEDIAKAN OLEH	DISAHKAN OLEH
	10.2.18	Tiada kerosakan					
	12.2.18	Tiada kerosakan					
	13.2.18	Baile	Rizal	10 minit			
	14.2.18	Tiada kerosakan					
	15.2.18	Mesin reping	Rizal	5 minit			
	16.2.18	Tiada kerosakan					
	17.2.18	Tiada kerosakan					
	19.2.18	Pam air	Rizal	9 minit			

REKOD PENYELENGGARAAN MESIN / PERALATAN

Nama Mesin / peralatan:	Kod Mesin / peralatan :
Tarikh beli :	Pembekal :
Model :	Buatan :
No siri :	Harga :

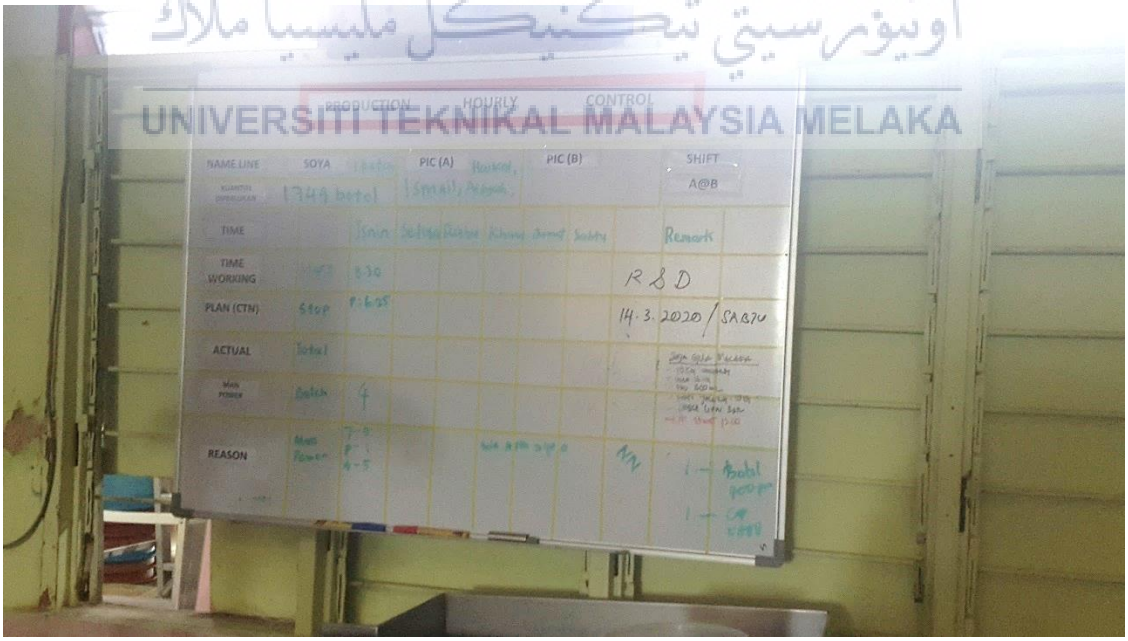
NO	TARIKH	BUTIR-BUTIR KEROSAKAN / PENYELENGGARAAN	DIBAIKI OLEH	TEMPOH KEROSAKAN	KOS (RM)	DISEDIAKAN OLEH	DISAHKAN OLEH
	20.2.18	Tiada kerosakan					
	21.2.18	Mesin fising	Rizal	15 minit		a/c	
	22.2.18	Tiada kerosakan					
	23.2.18	Tiada kerosakan					
	24.2.18	Tiada kerosakan					
	26.2.18	Mesin reping	Rizal	10 minit		a/c	
	27.2.18	Tiada kerosakan					
	28.2.18	Rihat	Rizal	15 minit		a/c	

REKOD PENYELENGGARAAN MESIN / PERALATAN

Nama Mesin / peralatan:	Kod Mesin / peralatan :
Tarikh beli :	Pembekal :
Model :	Buatan :
No siri :	Harga :

NO	TARIKH	BUTIR-BUTIR KEROSAKAN / PENYELENGGARAAN	DIBAIKI OLEH	TEMPOH KEROSAKAN	KOS (RM)	DISEDIAKAN OLEH	DISAHKAN OLEH
	1.3.18	Tiada kerosakan					
	2.3.18	Boile	Rizal	10 minit			
	3.3.18	Tiada kerosakan					
	5.3.18	Tiada kerosakan					
	6.3.18	Tiada kerosakan					
	7.3.18	Filing cage	Rizal	5 minit			
	8.3.18	Tiada kerosakan					
	9.3.18	Tiada kerosakan					

APPENDIX G Food and Beverage Factory Visit



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **OPTIMIZE PRODUCTIVITY THROUGH OVERALL EQUIPMENT EFFECTIVENESS AT FOOD AND BEVERAGE INDUSTRY**

SESI PENGAJIAN: **2021/22 Semester 1**

Saya **RAJADORAI A/L RAJU@DORAIRAJU**

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

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3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
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☑	TIDAK TERHAD	

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Alamat Tetap:

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Cop Rasmi:

TS. DR. AMIR HAMZAH BIN ABDUL RASIB
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Pembuatan
atau Teknologi Kejuruteraan Mekanikal dan Pembuatan
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Tarikh: 17/01/2022

Tarikh: 17 Jan 2022

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

Nama pelajar: RAJADORAI A/L RAJU@DORAIRAJU (B091810022)
Tajuk Tesis: OPTIMIZE PRODUCTIVITY THROUGH OVERALL EQUIPMENT EFFECTIVENESS AT FOOD AND BEVERAGE INDUSTRY.

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

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
"KOMPETENSI TERAS KEGEMILANGAN"

Saya yang menjalankan amanah,

TS. DR. AMIR HAMZAH BIN ABDUL RASIB
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Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
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