DMAIC APPLICATION FOR THE REDUCTION OF DEFECT IN MANUFACTURING INDUSTRY

NIK MUHAMMAD IBRAHIM BIN NIK REZALI

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

by

NIK MUHAMMAD IBRAHIM BIN NIK REZALI

FACULTY OF MANUFACTURING ENGINEERING

2021

DECLARATION

I hereby, declared this report entitled "DMAIC application for the reduction of defect in manufacturing industry" is the result of my own research except as cited in references.

Signature : ……………………………………….

Author's Name : NIK MUHAMMAD IBRAHIM BIN NIK REZALI

Date : 2 September 2021

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

……………………………………………………

Supervisor's Name : MR. NOR AKRAMIN BIN MOHAMAD

Date : 2.9.2021

NOR AKRAMIN BIN MOHAMAD
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

ABSTRAK

DMAIC adalah strategi kualiti yang didorong oleh data yang digunakan untuk meningkatkan keberkesanan dan kecekapan proses organisasi merentasi industri. Pada masa kini, DMAIC digunakan untuk meningkatkan kualiti pengeluaran dengan meminimumkan variasi, menghapuskan kecacatan, dan meningkatkan keupayaan proses. Tujuan projek ini adalah untuk melaksanakan metodologi DMAIC (Define-Measure-Analyse-Improve-Control) dalam industri pembuatan biskut untuk mengkaji pengurangan kecacatan. Projek ini mengikuti metodologi DMAIC untuk menyiasat secara sistematik punca kecacatan dan menyediakan penyelesaian untuk mengurangkan atau menghapuskannya. Alat Six Sigma yang sesuai digunakan seperti piagam projek, gambar rajah SIPOC, carta pareto, Why-why analisis, dan gambar rajah tulang ikan. Khususnya, teknik Design of Experiment (DOE) digabungkan untuk menentukan secara statistik sama ada pembolehubah proses utama iaitu suhu proofer, suhu ketuhar (pembakar), suhu ketuhar (pengeringan), dan berat doh, mempunyai kesan ke atas bilangan kecacatan kualiti yang dihasilkan. Dari analisis, didapati bahawa penyumbang utama kepada kecacatan bentuk dan saiz adalah suhu proofer, suhu ketuhar (pembakar) dan suhu ketuhar (pengeringan). Punca suhu mesin telah dikenalpasti, dan pelan tindakan telah dilaksanakan. Berikutan Perintah Kawalan Pergerakan (PKP), satu cadangan telah dibuat kepada Syarikat Biskut untuk melaksanakan Penyelenggaraan Pencegahan Menyeluruh (TPM) dan teknik pemotongan adunan baru. Projek ini menunjukkan bahawa kitaran DMAIC adalah pendekatan yang berkesan yang boleh menyelesaikan isu kecacatan menggunakan penyelesaian mudah. Ia mempunyai potensi untuk memberikan pulangan yang baik kepada syarikat jika dilaksanakan dengan betul dan cekap.

ABSTRACT

DMAIC is a data-driven quality strategy used to improve effectiveness and efficiency of organizational processes across industry. Nowadays, DMAIC is used to improve the quality of production output by minimize the variation, eliminate the defects, and improve the process capability. The aim of this project is to implement DMAIC (Define-Measure-Analyse-Improve-Control) methodology in a biscuit manufacturing industry to study the reduction of defects. The project follows the DMAIC methodology to systematically investigate the root cause of defects and provide a solution to reduce or eliminate them. Suitable Six Sigma tools is applied such as project charter, SIPOC diagram, pareto chart, Why-why analysis, and fishbone diagram. In particular, the Design of Experiments (DOE) techniques was combined to statistically determine whether the key process variables which is proofer temperature, oven temperature(baking), oven temperature(drying), and weight of dough, had an impact on the number of quality defects produced. From the analysis, it is found that the major contributor to the shape and size defect are the proofer temperature, oven temperature(baking) and oven temperature(drying). The causes of the machine's temperature were identified, and action plans were implemented. Due to a Movement Control Order (MCO), a proposal was made to the Biscuit Company to implement Total Preventive Maintenance (TPM) and a new dough cutting technique. The project demonstrated that DMAIC cycle is an effective approach that can solve a defect issue using simple solutions. It has the potential to provide good returns to the company if conducted properly and efficiently.

DEDICATION

Dedicate to my beloved parents, brothers, sisters, all my friends and relatives,

Thank you for your inspiration and encouragement,

You all are everything to me.

May Allah bless all of us. Insya-Allah

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Firstly, to my supervisor En. Nor Akramin bin Mohamad, I would like to express my deep gratitude for advice, provide feedback, guidance, and supervision throughout the project.

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LIST OF ABBREVIATIONS

DMAIC	-	Define, Measure, Analyse, Improve, Control
DMADV	-	Define, Measure, Analyse, Design, Verify
SIPOC	-	Supplier, Input, Process, Outcome, Customer
RCA	-	Root Cause Analysis
DOE	-	Design of Experiment
OPL	-	One Point Lesson
COPQ	-	Cost of Poor Quality
ANOVA	-	Analysis of Variance
DPMO	-	Defects per Million Opportunities
VSM	-	Value Stream Mapping
SPC	-	Statistical Process Control
SMED	-	Single-Minute Exchange of Die
SOP	-	Standard Operating Process
VOB	-	Voice of Business
VOC	-	Voice of Customer
MSA	-	Measurement System Analysis
QFD	-	Quality Function Deployment
R&R	-	Repeatability & Reproducibility
FMEA	-	Failure Mode and Effects Analysis
TPM	-	Total Productive Maintenance
HOQ	-	House of Quality
MCO	-	Movement Control Order

CHAPTER 1

INTRODUCTION

The introduction chapter shows an overview of the study. The overview starts with research background. Then, identify the project's problem statement. The chapter then provides the research objectives and scope of the project. Lastly, it concludes with an outline of the study and a chapter summary.

1.1 Research background

Manufacturing company may involve the volatile condition of economic. Nowadays, company and organization need to proactively stay in competition to survive within the competitors toward success. Therefore, the improvement needed to fulfill customers satisfaction such high quality product, eliminates waste, achieve low cost involved and maximizing the profit.

Many statistical and business tools have been developed and systemize by Six Sigma. The tools developed for reducing costs, decrease number of defects and improve cycle time of production. In all stages of the manufacturing and administrative process, the lean tools may be applied (Zu, Fredendall & Douglas, 2008). There are two main Six Sigma methodologies which are DMAIC (Define-Measure-Analyse-Improve-Control) and DMADV (Define-Measure- Analyse- Design- Validate). DMAIC is applied in the manufacturing of existing process or service. DMADV use to develop new products or process design.

The attention of Six Sigma is on the critical requirement to satisfy the customers. Therefore, The root cause is determined by Six Sigma and the faults or failures that may affect processes or services are reduced (Jirasukprasert, Arturo Garza-Reyes, Kumar & K. Lim, 2014). DMAIC is an integral part of Six Sigma and refers to five interconnected phases that have been systematically designed to resolve issues and optimize their processes. The objective of achieving high quality or minimal defects can be defined as Six Sigma. Moreover, the objective of Six Sigma is achieved not more than 3.4 defects per million opportunities (DPMO) (Gaikwad, Teli, Majali & Bhushi, 2015).

With the original task of minimizing variance, the DMAIC stage model is a systematic problem-solving approach, the method is now common for more general tasks, such as quality improvement, performance improvement, cost reduction, and other activities in operations management, and beyond development in services, healthcare, and other forms of operations (Kumar & Sosnoski, 2009). Six Sigma is a process improvement tool which implement in organization to improve consumes time, determination, capital and ground-breaking developments (Garg, Raina & Sharma, 2020). Lastly, this project focuses on reduction of defect by implementing DMAIC stages of Six Sigma in Small and Medium-Sized Enterprise (SMEs) in Jasin, Malacca.

1.2 Problem statement

The company explores new ways of continuously maintaining consumer expectations by enhancing quality, production prices, leads to competitive improvement and growing market share (Srinivasan, Muthu, Prasad & Satheesh, 2014). Good performance companies will have low cost with high quality. Making quality and customer satisfaction a top priority for all employees in your company is one way to help ensure business success. In downturn days, every company focuses on reduction of defect ratio to improve economical production reduction which loss due to quality issues (Krishna Priya, Jayakumar & Suresh Kumar, 2020). DMAIC model is introduced to provide a better tool and method used in the driven line to minimize the rate of defects and improve the quality of product.

This project was carried out at the Small and Medium-sized Enterprises (SMEs) in Jasin, Malacca. The nature of the business of this enterprise is the bakery foodstuffs, and biscuit 'tongkat'. The company receives the customer complaint regarding the quality of biscuit 'tongkat'. The complaint was regarding the texture, appearance, packaging, and smell of biscuit. Table 1.1 shows the average number of customer complaints for one week. The biscuit's texture is the major problems where the complaint is about the shape and size of the biscuit. Also, the appearance of biscuit such the surface texture and overcook are a problem complained by customer. Figure 1.1 shows the example of biscuit 'tongkat' produce by company.

Table 1.1: Customer complaints on quality of biscuit 'tongkat'

Complaint defect	Count
Seal	3
Plastic torn	2
Surface texture	5
Overcook	4
Shape	14
Size	11
Smell	2

Figure 1.1: Example of biscuit ‘tongkat’

1.3 Objective

The objectives of this project are as follow:

1. To define the problem occurred and current situation of production based on customer complaints.
2. To analyse the root cause of problems which affect the quality of product.
3. To propose method to reduce the defect and improve the quality of product.

1.4 Scope

This project involves applying the Six Sigma DMAIC strategy in the manufacturing sector. The Implementation of DMAIC model in selected manufacturing industry for reduction of defects. The research focuses on reducing the defect issue and improve the quality of the product. Also, DMAIC approach as a methodology for cost reduction and quality improvement within the research period. Due to the pandemic Covid-19, the idea of improvement will not be implemented in industry. A proposal for the proposed idea will be submitted to the company for feedback.

1.5 Significant of Study

The study will enhance the effectiveness of the Six Sigma approach to reduce the percentage of defects, especially in the manufacturing sector, by focusing on reducing costs and improving the quality of product. The outcome of this project is confirmation that the Six Sigma approach is a systematic methodology and is relevant for the enhancement of quality and productivity in the manufacturing industry.

1.6 Outline of Study

This project is divided into five chapters:

Chapter 1: Introduction

The study begins with a research background, problem statements, research objectives, scopes, significance of the study, outline of study and conclusion.

Chapter 2: Literature Review

Literature review of the critical points of current understanding in the application of DMAIC phases in the manufacturing industry. Literature review is to past case study on type of lean tools and how the experiment is carrying out to find a solution in manufacturing industry. After that, the literature review briefly addresses the application and implementation in different industries of the Six Sigma DMAIC strategy.

Chapter 3: Methodology

Description of the steps used in the development of this study. The designated tool and problem-solving technique used during the project period. This chapter explain the data collection method, conceptual framework, process flowcharts, and diagrams used to explain the problem and method to solve the issue.

Chapter 4: Result and Discussion

Presentation of the data collection, data analysis, and identified problem during the project period. Then, this chapter shows and discusses in detail about the data and result from implementation of DMAIC stages using lean Six Sigma tools.

Chapter 5: Conclusion and Recommendation

Conclusions and recommendations for further lines of research on the subject.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the related DMAIC application literature and case study to minimize the gap in the manufacturing industry. The chapter discusses the definition of manufacturing, followed by introduction on Six Sigma. The second part is discussed on six sigma methodology, DMAIC model and five phase of DMAIC. The last part is focus on lean tool used in industry and implementation of DMAIC stages of Six Sigma methodology.

2.1 Definition of manufacturing

Manufacturing is a business and organization where manufacture process of raw materials or component part into a finished product. According to Encyclopedia Britannica, Manufacturing is characterized as an industry that, through the use of manual labor or machinery, produces products from raw materials and is commonly divided by labor. Desai and Shrivastava (2008) stated that the important issue to increase the sales for the company's profit is quality and cost of the products. The manufacturing or service, firms continuously to plan to improve the quality of the products. Barot et al., (2020) stated that in any manufacturing industry, most important factor in manufacturing is reduction of defects and fulfill customer's requirement by achieve good quality of product.

2.2 Introduction of Six Sigma

Six Sigma tools is designed and implement in many manufacturing sectors, which aiming to make continuous improvement. Six Sigma is a validated technique for enhancing process variation, lowering costs, and obtain high quality of end products which lead to profitability of the organization.

Omachonu and Ross (2004) indicate that the variation of process or output is measure by based on value of sigma (σ). Six Sigma may be a systematic approach focused on data and statistical analysis to analyze and enhance the company's operating efficiency and to recognize and eliminate "defects" in processes relevant to production or service. Six Sigma's aim is to reach a sigma value of less than 3.4 defects per million opportunities. Moosa, & Sajid (2010); Lei (2015) stated that a defect is defined as any error or irregularity issue regarding the manufacturing product which does not fulfill requirements and specification of customer.

The introduction of Six Sigma was studied to lead the production and advancement of several statistical and business techniques (Zu, Fredendall & Douglas, 2008). The result of the application is to reduce the cost of manufacturing, reduce the number of failures and production cycle time and, at the same time, improve market share, retain consumers and product growth. Six Sigma is implemented at all stage of the processes in production and apply in administrative process.

At the beginning, Six Sigma was suggested and apply in manufacturing processes. Gijo, Scaria & Antony (2011a) stated that in marketing, marketing, accounting, invoicing, taxation, human resources, and consumer call answering tasks, the Six Sigma approach has now been applied. The goal is to reduce the overall number of errors in the operations of the company. Moreover, Six Sigma may be a strategy of defining and reducing the amount of flaws that contribute to customer satisfaction in the tire industry (Gupta et al. 2012).

As studied by Kaushik & Kumar (2017) Six Sigma's key concept is to increase the efficiency of the process and make the procedure more efficient for the development of the process of waste reduction within industries. Six Sigma is a strategy for quality management by implements a systematic approach and analytic methods to identify and analyze the problem, evaluate the results, optimize process efficiency, monitor and sustain enhancement. Overall, Six Sigma is a strategy to focus on customer and potentially to realize exponential the improvement of quality over the reduction of variation in system processes.

2.3 Six Sigma Methodology

Six Sigma methods can be implemented by two different approach which is DMAIC (Define, Measure, Analyse, Implement, Control) and DMADV (Define, Measure, Analyse, Define, Validate). DMADV use to analyse new product development while DMAIC is deal to enhance the improvements in existing product or processes (Barot et al., 2020).

2.4 DMAIC model

The DMAIC phases are used by the Six Sigma approach as a data-driven quality technique to enhance industry processes. The DMAIC model is used to fulfill the customer specifications or use when the process not performing adequately. DMAIC methodology helps to reduce the wastes and suggest good solution for improvement within the process in industries (Gupta, Jain, Meena & Dangayach, 2017).

Mohamad, Ahmad, Samat, Seng & Lazi (2019) stated that DMAIC model is a strategic and comprehensive method for optimizing market efficiency by enhancing the operation of development or activity by applying both statistical and non-statistical methods or techniques effectively. C.R. & Thakkar (2019) stated that the enhancement of process efficiency in the industry by the application of the Six Sigma DMAIC approach is a powerful technique.

2.4.1 Five Phase of DMAIC

DMAIC is a structured, disciplined, and appropriate approach to achieving enhancement in 5 stage define-measure-analyse-improve and control. DMAIC methodology has been well established as a benchmarking tool for process improvement and customer satisfaction (Chen et al., 2005; Snee, 2010). Figure 2.1 shows the DMAIC cycle key point for all phase. To implement Six Sigma, the DMAIC approach must be followed step by step. Suitable statistical tools in each phases improve the process efficient and product quality by eliminate or reduce the variability (Morales et al.,2016; De Mast & Lokkerbol, 2012).

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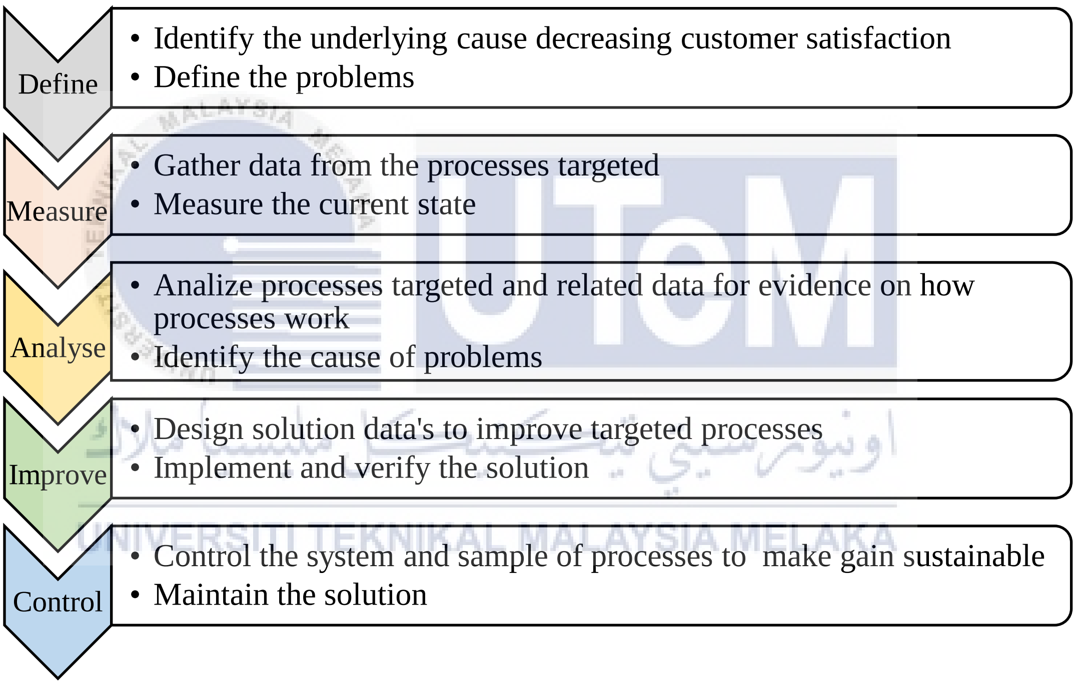


Figure 2.1: DMAIC cycle key points

2.4.1.1 Define

The goal of the define phase is to describe all preliminary data, such as the objective of project, problem statement, project scope, responsibility of team members and the indicators of success (Gijo and Scaria, 2010; Sharma and Chetiya, 2010). The project charter is helpful to initialize, planning and execute the project (Gupta, Jain, Meena & Dangayach, 2017; Srinivasan, Muthu, Prasad & Satheesh, 2014).

2.4.1.2 Measure

The purpose of the measure phase is to examine the current level of production by collecting baseline data, measure the process performance and identify the non-value-added activity (Nandakumar, Saleeshya & Harikumar, 2020; Gupta, Jain, Meena & Dangayach, 2017). All the related data about the production process is mapped to its respective stages, deciding all the variables for inputs and outputs.

2.4.1.3 Analyse

In order to evaluate the existence and complexity of the problem, the aim of the analyse phase is to analyse data previously obtained. Some real samples should be performed, and potential problems must be proven to be real problems. Use the data recorded to analyse the potential factor by using suitable lean tool (Oliya et al., 2012; Ferreira et al., 2019).

2.4.1.4 Improve

Improve phase focuses on the use of experimentation and statistical techniques to generate possible improvements to reduce the amount of quality problems or defects. The Six Sigma team will seek and develop potential solutions to remove the root causes and increase the efficiency of the process until the root cause of the issue is discovered. The improvement action to reduce the defect starts by identify the root cause to propose new design at low cost (Gupta, Jain, Meena & Dangayach, 2017; Mohamad, Ahmad, Samat, Seng & Lazi, 2019).

2.4.1.5 Control

The objective of control phase is to standardize that the operating procedure to ensure the result within the constraint of design and minimal variance. The new checklist control action monitors the production process to sustain the improvement result (Smętkowska & Mrugalska, 2018; Yadav & Sukhwani, 2016).

2.5 Lean Tool

The improvement quality of product, process and prevent the frequency of defect in the manufacturing industry can be achieved by application of lean tools & suitable methods (Krishna Priya, Jayakumar & Suresh Kumar, 2020). Table 2.1 is the summary of statistical tool and method for Six Sigma methodology based on previous case study.

Table 2.1: Summary of Statistical Tools/Method for Six Sigma methodology

Phases	Description	Lean Tool/ Methods	Author
Define	• Identify the problems • Set project goals and objectives (Junankar & Shende, 2011) • Defining the scope and goals (Gaikwad et al., 2015)	• Brainstorming • Project charter • Gemba walk (Mohamad et al., 2019) • Process flow • Supplier-Input-Process-Output-Customer (SIPOC) • Voice of customer (VOC) • Voice of Business (VOB) • Value stream mapping (VSM)	(Smętkowska & Mrugalska, 2018; Jirasukprasert et al., 2014; Gaikwad et al., 2015; Krishna Priya et al., 2020; Mohamad et al., 2019; Gijo et al., 2011; Syahputri, et al., 2018; Nandakumar et al., 2020; Srinivasan et al., 2014; Surange, 2015; Prashar, 2014; Gupta et al., 2012; Gaikwad et al., 2017; Yadav et al., 2019; Junankar & Shende, 2011)
Measure	• Evaluate the current performance level by collecting the data (Gaikwad et al., 2015) • Measure the defects that cause problems (Junankar & Shende, 2011)	• DPMO • Sigma level • Process capability analysis • Pareto Analysis • Process Map • Histogram	

		• Measurement System Analysis (MSA) (Prashar, 2014) • Repeatability & Reproducibility (R&R) (Surange, 2015)	
Analyse	• Identify root causes of failure (Gupta et al., 2012) • Trends, pattern and root causes shown by evaluate the data and information (Junankar & Shende, 2011)	• Cause and effect diagram • Why-why analysis (Krishna Priya et al., 2020) • Chi-square test (Gijo et al., 2011) • T-test • P-test • Failure Mode and Effects Analysis (FMEA) (Prashar, 2014) • ANOVA • Problem Tree Analysis	
Improve	• Identify, test and implement a solution (Gaikwad et al., 2015) • Redesign the improved process and test (Gupta et al., 2012)	• Single Minute Exchange of Die (SMED) • Total Productive Maintenance (TPM) • Design of Experiment (DOE) • KAIZEN (Gaikwad et al., 2017) • Cost of Poor Quality (COPQ) • Impact/Effort Matrix (Prashar, 2014) • Action Plan Analysis (Mohamad et al., 2019) • Cost/Benefit Analysis (Prashar, 2014)	
Control	• Maintain and control improved result of process and reduce deviations (Gupta et al., 2012) • Control the improvement achieved (Gaikwad et al., 2015)	• Work standardization • Control chart • One Point Lesson (OPL) (Mohamad et al., 2019) • Statistical Process Control (SPC) • Control Plan (Prashar, 2014) • 5S (Gupta et al., 2012)	

2.5.1 Pareto Chart

A Pareto diagram is a bar graph that helps classify the failures, complaints, or some other aspect that are most common. The length of the bars depends on the frequency, starting with the longest bars on the left and the shortest bars on the right. Pareto chart is typically used to classify the most relevant causes (Tague, 2005). When evaluating data on frequency, pareto chart show the critical and major contributor to the defect that should be focus (Slack et al., 2010; Barot et al., 2020).

2.5.2 SIPOC Diagram

SIPOC diagram is a lean tool apply before the work begin to identify all related elements in process improvement. SIPOC is an acronym that stands for Supplies-Inputs-Process-Outputs-Customers. SIPOC is used to provide a better understanding of the process flow used to produce the output of the process from the supplier to the customer (Gijo, Scaria & Antony, 2011a).

1. The suppliers are who supply the materials or inputs to be use in the process.
2. The inputs are what resources provide by suppliers which can be either materials or information.
3. The process is the steps or activities carried out to create value for the customer.
4. The outputs are the product or service that created by the process for customers.
5. The customer is the main users of the product output.

SIPOC provides the clarity regarding the process boundaries, the customers for the process outputs and the suppliers for the process inputs (Gijo and Scaria, 2010). The SIPOC method use to visualize the process involve in production to assist in identifying the bottlenecks in the process (Nandakumar, Saleeshya & Harikumar, 2020).

2.5.2 Root Cause Analysis (RCA)

RCA is used to determine the root cause of an issue of non-conformity or performance in the manufacturing process. RCA is a process used to determine the primary cause of the issue by using a standardized set of steps to identify the root of a concern with similar methods. Identify the root cause through strategies of problem solving that caused the number of defects and take steps to minimize those causes (Westcott, Russell T. 2014).

2.5.3 Process Flowchart

Flowchart is a diagram that shows the sequential steps flow of the process and the decisions needed to make the process work. Flowcharts help to visualize what is going on and contribute to understand about the process are used in designing and documenting simple processes or programs. Flowchart also use to standardize a process for optimal efficiency and repeatability. A flowchart reveals missing, redundant, or erroneous steps. Flow chart is a valuable starting point because it allows the organization to get a better view of the process flow (Westcott, Russell T. 2014).

2.5.4 Control Chart

By plotting the graph based on the data in time order, the control chart is a technique to analyse how a process evolves over time. A control chart includes of an upper control limit, a lower control limit and a median control line for the average control limit. The control limit is determined based on historical data. If analysis result is within the control limit, then the process control parameter is maintained. As mentioned by Tague (2005) by comparing the response by evaluating the existing data of the control limit definition, the operation variance is either stable (in control) or unpredictable (out of control). The systematic use of control chart help to identify the variation of process occurred and detect special causes of variation (Gaikwad, Sunnapwar, Teli & Parab, 2017).

2.5.5 Fishbone Diagram

The fishbone diagram known as the Ishikawa diagram, is a good method for visualizing the root causes in the fishbone structure diagram. Fishbone diagram use to identify the potential factors causing an overall effect to product design. The imperfection in process identified by fishbone diagram is a source of variation. In the diagram of the fishbone, the main issue is stated in a box on the right side of the diagram. The diagram sorts out the root causes and organize relationship between variables (Junankar & Shende, 2011). The popular problem references for the classification are based on 4M's (manpower, machinery, methods, and materials) (Westcott, Russell T. 2014).

2.5.6 Design of Experiment (DOE)

DOE is used to evaluate the relationship between variables that control a process and output by data collection and analysis in a number of experimental conditions of a process. DOE is a statistical technique for analyzing and organizing the experiments (Zahraee et al., 2013). Moreover, DOE is used to identify significant variables to optimize the process (Ghosh & Maiti, 2012). There are several types design of experiment: full factorial, fractional factorial, and screening factorial.

Full factorial design evaluates the combination of all levels of all factors in an experiment. These experiments completely characterize a process which give detailed results. This type of design able to identify the relationships among factor and estimate all main effects and interaction. Fractional factorial designs look at more factors with fewer runs. It can be effectively optimized for any number of factors. It is difficult to identify some of the interactions interpolation but able to reduce the resources requirements. Screening factorial are the ultimate fractional factorial experiments. These experiments consider that all interactions of variables, even two-way interactions, are not significant. The critical variables that effect of the process output is determine by screen the factors, or variables related in the process. Screening designs can be used for as few as four factors or as many as can be practically handled or afforded in an experiment.

2.5.7 One Point Lesson (OPL)

OPL is a standard document which describe the procedure of the operation using simple, visual, and often pointwise description of a task. It normally consists of 80% diagram and 20% words. An OPL is created by using diagram, picture, symbols, simple text and is a concise and short document. OPL should be easy and simple document to understand, and easy to follow during production. Mohamad, Ahmad, Samat, Seng & Lazi (2019) stated that OPL use to achieve the normal operating practice for operators and to improve output consistency. Moreover, the operator will be given the detailed working procedures as a guideline through the process.

2.5.8 5S

5S is as a methodology to reduce waste and optimize productivity by manage the workplace to clean, uncluttered, safe, and well organized. 5S practice reduce the non-value-added activity in production to improve workspace be more organized (Nandakumar, Saleeshya & Harikumar, 2020). 5S is designed to improve a quality work environment of workplace, both physically and mentally. Table 2.2 show the Japanese term and the definition of 5S.

Table 2.2: Definition of 5S's term

Japanese term	Meaning	Definition
Seiri	Sort	Eliminate and separating unnecessary tools, parts, and instructions from unneeded materials.
Seiton	Set in order	Organize the parts and tool by neatly arrange in suitable location for ease of use.
Seiso	Sweep/shine	Clean and clear the workspace area without garbage, dirt and dust, so problems will be more easily to identify.
Seiketsu	Standardize	Set up a standard for neat, clean and workplace condition by creating regular schedule for cleaning and maintenance.
Shitsuke	Sustain	Keep the situation to maintain the established standards over the long term.

5S is an important lean development tool that eliminates waste to maximize quality products and minimize phase lead time. In addition, implementation of 5S enhanced the safety aspect which improve the efficiency and productivity in the industrial sector (Barot et al., 2020).

2.5.9 Cost of Poor Quality (COPQ)

COPQ involves the cost of reducing to difference between the expected and real quality of the service or product. COPQ includes the cost of the potential wasted because of the loss of resources needed to fix the error. The labor costs, rework costs, recycling costs, and material costs that have been applied to the product before the point of rejection are included in this cost. The company can double the profit without make additional capital investment (Junankar & Shende, 2011). The cost of analysis and prevention does not include COPQ. Better control over the process will reduce the number of defects which resulting in reduction for cost of poor quality (Gaikwad, Teli, Majali & Bhushi, 2015).

2.6 The application of DMAIC stages of Six Sigma methodology

The previous case analysis demonstrates the use of the strategy of the Six Sigma has been successfully applied and has improved the quality of the process in various service areas in manufacturing industry. DMAIC methodology was designed for all types of manufacturing, healthcare, and service industries (Yadav, Mathiyazhagan & Kumar, 2019).

A study developed by Jirasukprasert, Arturo Garza-Reyes, Kumar & K. Lim (2014) involve in rubber gloves manufacturing industry which implement DMAIC methodology to focuses on reduce number the defects in manufacturing process. Six Sigma tools identify the main issue was about the temperature of oven and speed of conveyor which cause increase the number of defective gloved. The study found a new setting for the issue which resulting on the total percentage of defect was improve from 30.25% to 14.70%.

Krishna Priya, Jayakumar & Suresh Kumar (2020) investigate the result of a study which involve in automotive industry to eliminate unnecessary processes in the assembly line. The implementation of proposed solutions reduces the non-value-added processes and defect ratio in the assembly line. The quality of product is improved, reduction of waste, resolves defect issue and prevent the repetition of defect achieved by application of effective lean tools.

Syahputri, Sari, Anizar, Tarigan & Siregar (2018) applied DMAIC methodology to specific case of cigarette paper industry. The goal is to reduce non-value-added operations to optimize the process and the total production time. By evaluating the processing lead time, process cycle efficiency, process lead time and DPMO, the enhancement process is analyzed. Overall, the DMAIC six sigma approach has increased process cycle performance by 12.64% with 10 non-value-added activities eliminate cause in reducing 165.92 minutes from the total production time.

Nandakumar, Saleeshya & Harikumar (2020) shows the ability of DMAIC Six Sigma in achieving the quality improvement by using the case study of a food processing industry. VSM tool use to identify the non-value-added activities along with SIPOC, ANOVA and 5S methods cause in improve of defective level and loss of productivity in production process. The study reveals that the DMAIC methodology process is an effective approach to analyse and eliminate the bottleneck in process and improve productivity which focus on production and packaging process.

C.R. & Thakkar (2019) presented a case on implementation of the DMAIC Six Sigma strategy for reducing door panel defects in the production sector of telecommunications cabinets. The DMAIC approach is an effective strategy for enhancing the operation in every industry. The finding reveals that the DMAIC Six Sigma approach was used to improve the sigma value from 3.49 to 3.67. The rework cost investment percentage has decreased from 1.6% to 1.12%. Kumar & Sosnoski (2009) stated that the Six Sigma DMAIC technique is ideal for minimizing COPQ in production processes.

Barot et al., (2020) presented a study of the DMAIC methodology application in cast iron foundry industry. The study focuses on how to determine possible causes of defect and solution to overcome the issue. The result show reduction of average rejection rate from 15.4% to 6.7%. Overall, the percentage of defect reduce up to 9.7%, which reduce the overall cost about 4,74,414/- rupees per year. The result shows the reduction of manufacturing cost and consistent quality by improve the Sigma level from 2.6 to 3.0.

Literature analysis reveals that in industrial sectors, the DMAIC approach is a good and comprehensive for process enhancement capability. It continues to adopt Six Sigma in the continuous management culture system and incorporates its ideas and values to consistently overcome quality issues resulting in cost savings, product quality improvement and customer satisfaction (Jirasukprasert, Arturo Garza-Reyes, Kumar & K. Lim, 2014).

Prashar (2014) indicates that the main success element in a project is leadership. This initiative unfastened the trajectory for the business to a different culture and common priorities. Surange (2015) mentioned that Six Sigma project benefits can be apply in business with less employees cause cost reduction and cost avoidance by not hiring more people. Six Sigma's advantages, such as shortened time to market, expense avoidance, missing benefit avoidance, increased employee productivity, improved organizational profile, and other intangibles, can result in additional savings for the company, but are more difficult to measure.

The application of the DMAIC methodology in the project helped to decrease the root causes of rejection throughout the process and thereby improved quality level (Yadav & Sukhwani, 2016). Statistical process control (SPC) is not limited to production period only, but able to satisfy customers need and requirement by ensuring the product produced is monitored by machine tool (Gaikwad, Sunnapwar, Teli & Parab, 2017).

As conclusion, implementation of lean six sigma increases output cost reduction, retains good consistency, decreases rejection rate ratio, thus, profits can be increased. The introduction of Six Sigma and DMAIC allows companies to achieve improvement in production process and thus contribute to the objective in achieving the process and business excellence performance (Girmanová, Šolc, Kliment, Divoková & Mikloš, 2017). Table 2.2 shows the summary based on the previous case study on lean tool use and contribution of DMAIC methodology in manufacturing industry.

CHAPTER 3

METHODOLOGY

This chapter discuss the methodology implement throughout this project of DMAIC application in manufacturing industry. In general, this chapter illustrates the DMAIC methodology to understand the whole method to identify the problems in the company; the development of a method to collect data; the evaluation and analysis of data obtained from the measurements; implementation tools or method to improve the problems and control the improvement’s result.

3.1 Methodology of project

Research methodology is the specific method or techniques used to identify the cause, select the tools, method process, and analyze information of the project. The aim of methodology to define and solve the problems in production for waste reduction and enhancement to improve the efficiency and competitive of organization by using the right tools to solve the problems. DMAIC's five phases can be used to achieve the project's objective. Figure 3.1 show the DMAIC model use in this project.

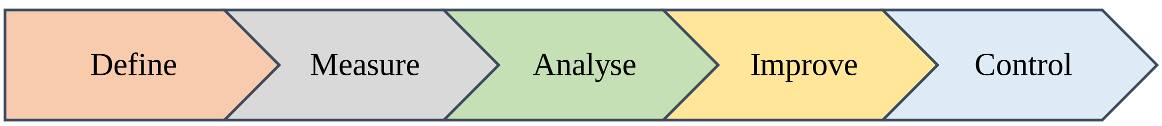


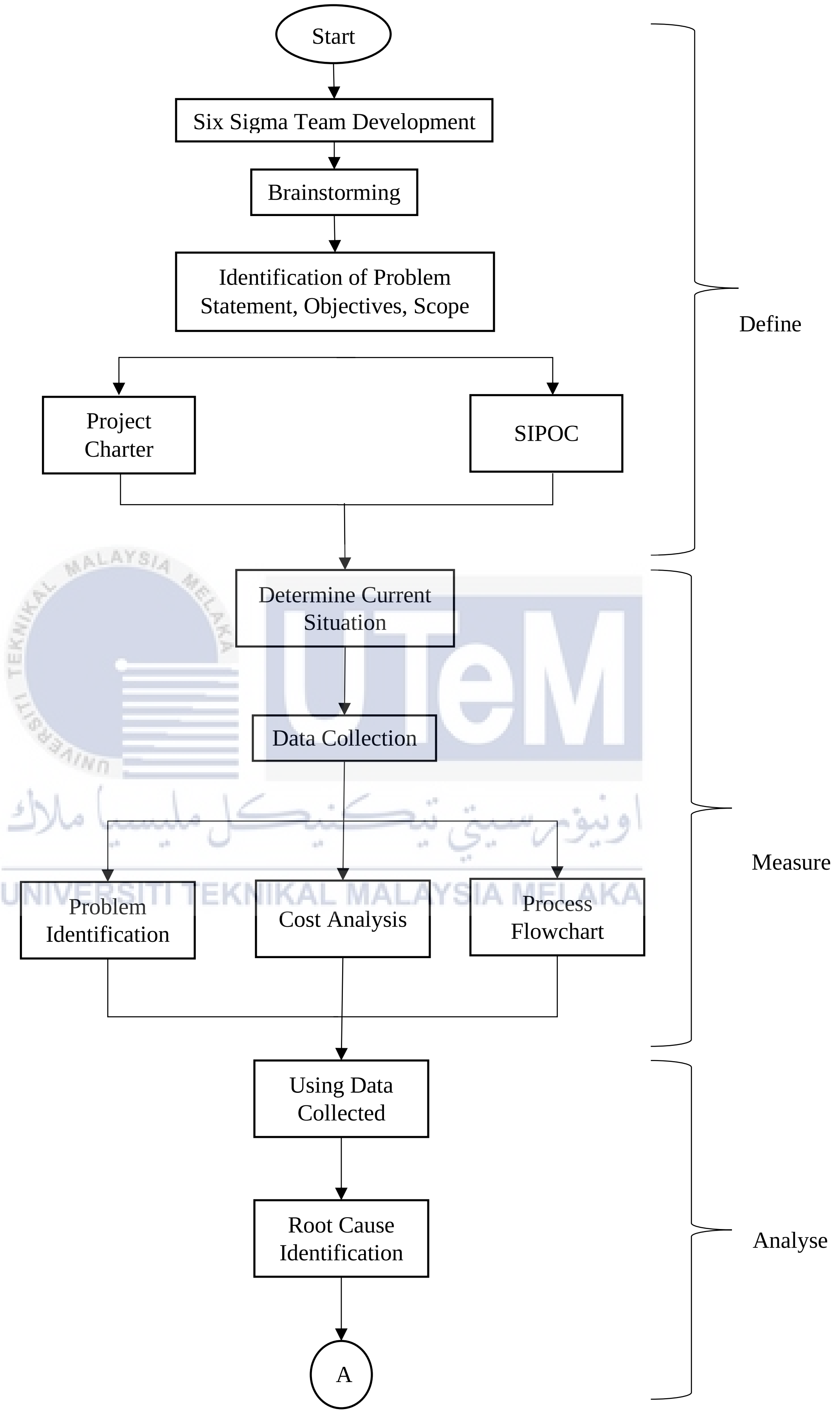
Figure 3.1: DMAIC model

The first objective is to define the problem that occurred, and the current state of production based on the customer complaint. A project charter formally outlines the project during the Define phase. It discusses the project's background, scope, objective, customer voice, project boundary, team members involved, and expected benefits to the company and customer. Before beginning a process improvement project, SIPOC is used to identify all relevant elements.

In Measure phase, the information was gathered in order to assess the company's current situation. The process of identifying problems is used to identify issues with product quality. The data was collected and plotted using a pareto chart to identify common causes in a process that must focus on the most significant. The cost analysis is then necessary to compare the costs for rejected product before and after improvement. Before identifying the root causes, a process flowchart is used to visualize the steps involved in the production process.

The second objective is to analyse the root cause of problems that affect product quality. The why-why method is used during the Analysis phase to identify the main root causes that contribute to the product's quality. Furthermore, the fishbone diagram is used to visualize in detail the root causes affecting product quality.

The third objective is to propose method to reduce the defect and improve the quality of product. During the Improve phase, the design of experiment (DOE) is used to determine the main factor influencing product quality. Following that, Total Preventive Maintenance (TPM) and Quality of Deployment (QFD) are performed to improve the product quality issue. In Control phase, the work standardization and Total Preventive Maintenance (TPM) schedule were implemented to monitor the results after the project was completed. Figure 3.2 depicts the methodology flowchart for this project's DMAIC phase.


Start
Six Sigma Team Development
Brainstorming
Identification of Problem Statement, Objectives, Scope
Project Charter
SIPOC
Define
Determine Current Situation
Data Collection
Problem Identification
Cost Analysis
Process Flowchart
Measure
Using Data Collected
Root Cause Identification
A
Analyse

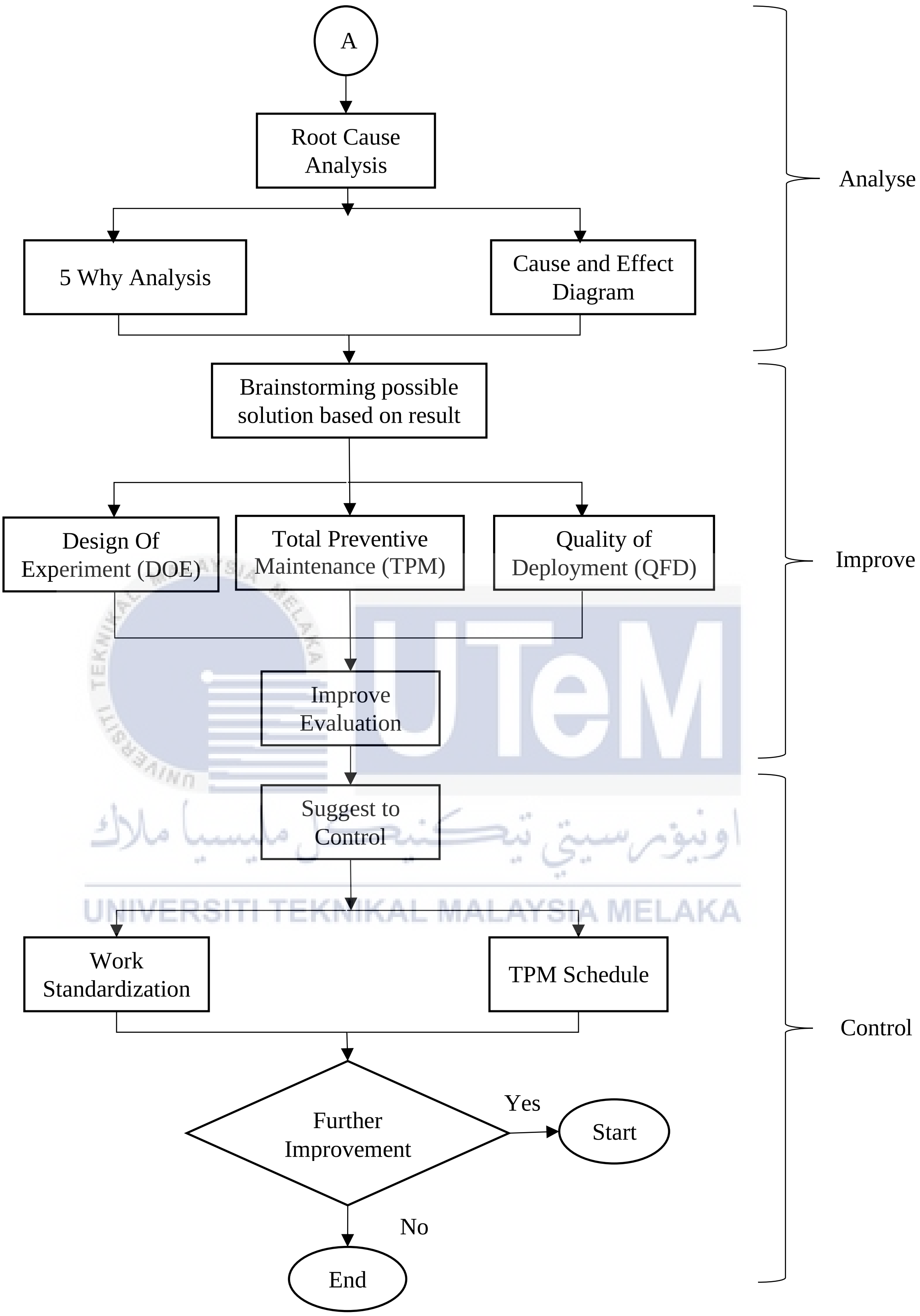


Figure 3.2: Flowchart of DMAIC

3.2 Define Phase

In define phase, the problem cause is identified, research scope and objective are determined. Define phase starts with brainstorming within the team to have clear identification of problems and process flow to define the objective and scope of project. The project charter and a typical high-level map, SIPOC, which stands for Suppliers, Inputs, Process, Outputs, and Customers, are used in the Define phase.

3.2.1 Project Charter

A project charter is a brief, straightforward document that serves as the project's foundation. The project charter serves as both an internal marketing tool and a project reference guide. Project charters in a project should briefly outline the project's background, objectives, voice of customer, boundary, and team members without delving into a sea of details. In addition, the project charter can include the anticipated benefits to either the customer or the company. By presenting a project charter at the start of the project, you can help to create a project roadmap and set expectations for the project.

3.2.2 SIPOC Diagram

SIPOC diagram used to identify related factor of process improvement project before starts the task. It analyses the necessary input for the process to operate, the supplier of input, the outputs of the process, and the consumer of the product. SIPOC is a tool used to identify problem areas, conduct process analysis, and demonstrate how business operations work to customers.

i. Supplier: The provider who supply the process input.
ii. Input: Materials, information, and other resources required to finish a process
iii. Process: Procedure in production process to converts input into output.
iv. Output: Final product produced from the process for customer.
v. Customer: Consumers who receive and use the product.

3.3 Measure Phase

In measure phase, significant measures are determined to establish a procedure to collect data efficiently to measure the success of the performance. It can identify the current situation and efficiency of execution process based on allocated resources. In the industry, the issue is determined by gathering data and identifying the problem. The pareto chart is used to visualize the most important issue to be addressed. The cost analysis and process flowchart are created to determine the current state of production.

3.3.1 Problem Identification

Data was gathered in order to determine the company's current situation. The average number of customer complaints is recorded in order to identify the main issue with product quality. Pareto charts are used to identify the most common defects and easily determine the prioritized causes by arranging them in descending order, beginning with the most defects and ending with the fewest. The tallest bar in a pareto chart represents the first and most frequent source of defect. Then, the type of defects to prioritize are determined based on the cumulative percentage line to achieve the greatest overall improvement. Figure 3.3 shows the example of pareto chart.

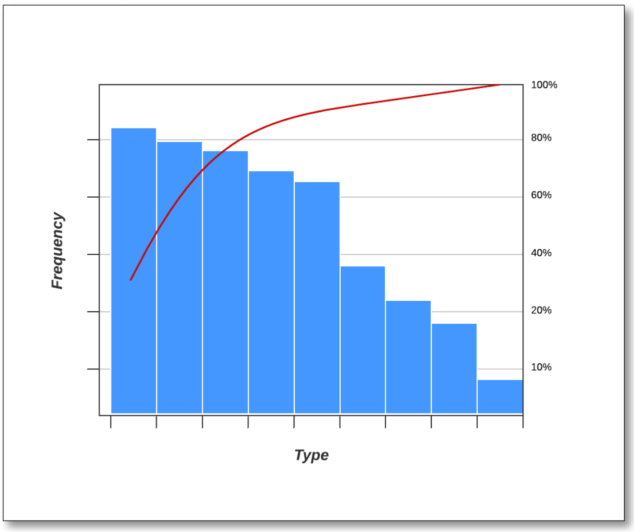


Figure 3.3: Example of pareto chart

3.3.2 Cost Analysis

The purpose of the cost analysis is to determine the total cost loss due to product rejection based on the average number of customer complaints. Calculate the cost of one product and the cost of a rejected product to determine the total cost involved in a business. Based on the average number of customer complaints, the average loss can be calculated. The costs will be compared before and after the implementation of the DMAIC stages to demonstrate the cost and profitability improvements.

3.3.3 Process Flowchart

A flowchart is a visual representation of the method and the process of the manufacturing production from the beginning to the end of a process. The flowchart is useful in the early stages of a project because it helps to establish priorities for improvement work. The process flowchart aids in the identification of bottlenecks or waste in a process and the development of a solution to improve process efficiency.

3.4 Analyse Phase

In the analyse phase, project teams determine the root causes of defect in the manufacturing process. Six Sigma tools assist in identifying problems in the manufacturing process and determining whether these problems are the root causes of defects. The 5 Why analysis is performed, and fishbone diagram is created to visualize the main root causes affecting the quality of product.

3.4.1 Five Why Analysis

RCA is used to identify the root cause of a problem that leads to defects and high overall production costs. RCA is the discovery of a solution based on a basic idea for production problems. The 5 Why technique is used to identify the root cause of problems.

The 5 Why technique is simply asking the question “Why” enough times until you get past all the causes of a problem and down to the root cause.

3.4.2 Cause and Effect Diagram

Cause and effect diagram also known as fishbone diagram or Ishikawa diagram, is a visual root cause analysis method that categorizes cause-and-effect relationships. The diagram is a method for identifying the root causes of all possible causes of a problem. Typically, potential causes are determined by work methods, materials, environment, and measurement. Brainstorming in a group can help capture and stimulate different ideas on the root causes of a specific problem. Figure 3.4 depicts an example of a fishbone diagram.

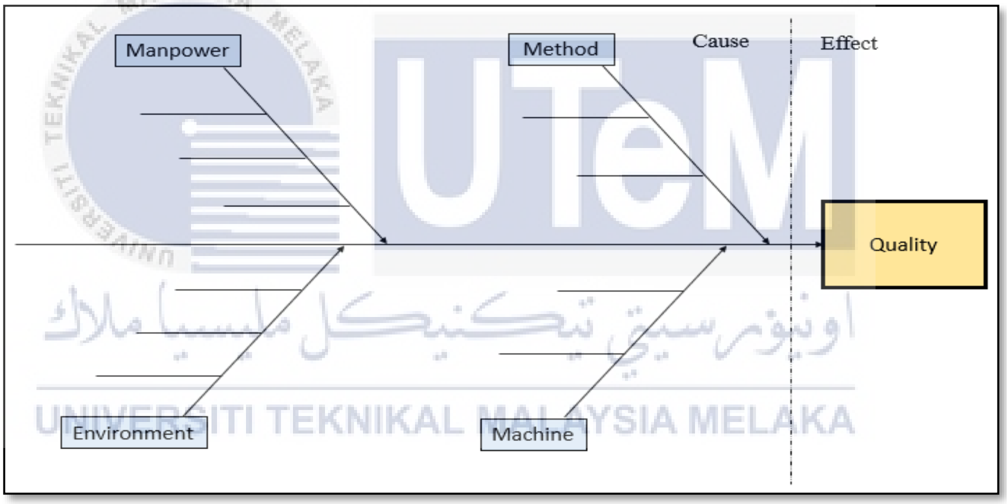


Figure 3.4: Example of cause-and-effect diagram.

3.5 Improve Phase

The goal of the improve phase is to find a solution to the problem that the project is attempting to solve. This includes the brainstorming of possible ideas, the selection of solutions for the analysis and review of previous process outcomes.

3.5.1 Design of Experiment (DOE)

DOE is a systematic method for improving process inputs in order to maximize the number of outputs. Concurrently investigating the effects of input variables (factors) on an output variable (response) is advantageous. By identifying the process conditions that affect product quality, the full factorial method is used to reduce the number of input variables. Figure 3.5 show the guidelines to use the Minitab to perform the DOE.

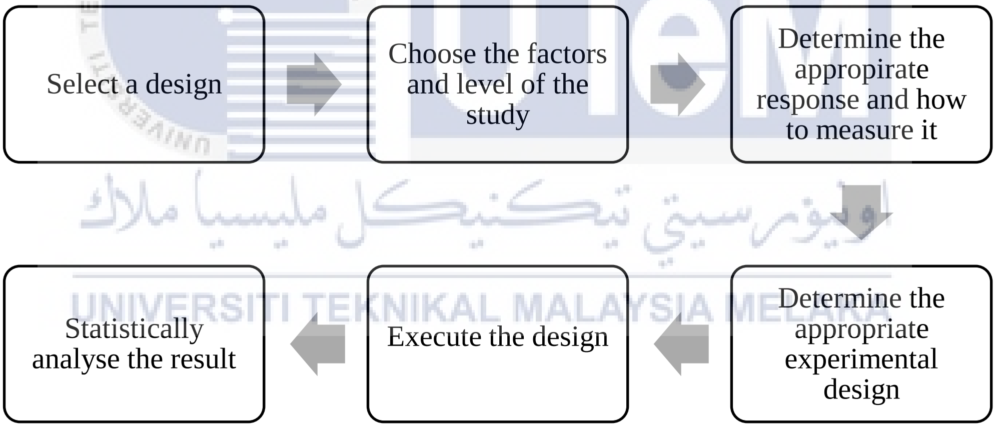


Figure 3.5: Guidelines for using DOE

3.5.2 Total Preventive Maintenance (TPM)

Workers' knowledge is used to increase machine reliability and productivity, lowering maintenance and operating costs. For example, equipment that is cleaned, lubricated, and inspected on a regular basis should experience fewer unexpected breakdowns, necessitating fewer maintenance resources. Operators can detect emerging issues with their equipment before they become major failures, resulting in potentially low-cost, minor repairs.

3.5.3 Quality Function Deployment (QFD)

QFD translating customer needs and expectations into technical requirements by listening to the voice of customer. QFD ensures that every technical requirement takes the customer into account, using matrix diagrams such as the House of Quality (HOQ) to drive customer value into every stage.

The goal of concept selection is to choose the best conceptual design for additional testing, development, or investigation while remaining objective throughout the concept phase of the development process. There are two methods for selecting concepts: concept screening and concept scoring. Screening is a quick, rough evaluation with the goal of producing a few variable alternatives, whereas scoring concept is a more thorough examination of a few relative concepts with the goal of selecting the single concept design. There are six step in concept screening which is:

1. Create the screening/selection matrix. All the customer requirements should be included in the selection criteria. Select the concept design references.
2. Rate the concepts. The relative score is placed in each cell of the matrix to demonstrate how each concept rate compares to the concept of reference in relation to the criteria. Table 3.1 show the rate for relative performance.
3. Rank the concepts. Sums all the number of scores and enter the answer of the sums in the lower row of the matrix. Calculate the net score according to Equation 1.
4. Combine and improve on the ideas. Check to see if the result makes sense and if the product can be improved by combining their concepts.
5. Choose one or more concepts. Consider the outcomes and the process.

Table 3.1: Rating for relative performance

Relative Performance	Rating
Much worse than reference	--
Worse than reference	-
Same with reference	0
Better than reference	+
Much better than reference	++

After the rating process the design are rank by number from 1 being the best and so on. The formula use is as followed:

NET SCORE = (Sum of +) – (Sum of -) Equation 1

There are six steps in concept scoring which is:

1. Prepare the selection matrix. The selection criteria should include all the customer requirement. Choose the references concept design.
2. Rate the concepts.
3. Rank the concepts. The weighted score is calculated by multiplying the raw scores by the weight of the criteria. Calculate the total score by adding all of the weighted scores together.
4. Combine and improve the concepts.
5. Choose one or more concepts for additional refinement and analysis.
6. Reflect the results and process.

3.6 Control Phase

After improve phase, final phase of DMAIC stages is control phase which is very important to maintain the improved methodology result after implementing the DMAIC methodology. The process standardization and TPM schedule is used to ensure the improvement strategies maintain the result.

3.6.1 Process Standardization

Process standardization is a strategy to create a set of systematic, validated, and accepted procedures that suitable practices to be carried out in manufacturing process. The systematic determination and documentation of work element sequence and process for each operation is referred to as standardized work. The Standard Operating Procedure (SOP) is an example of process documents that are required for the process to maintain operational continuity, along with other documents that include process flow charts, material requirements, and related tasks. To ensure that the process is sustainable, a standardized system was developed. (Roth & Franchetti, 2010).

3.6.2 Total Preventive Maintenance (TPM) Schedule

An effective preventive maintenance schedule necessitates inventory, careful planning, research, and the establishment of an easy-to-understand and facilitate maintenance routine. A TPM schedule is required to maintain the maintenance activity on a daily, weekly, monthly, quarterly, or annual basis. The schedule checklist must be updated on a regular basis and placed in an appropriate location to ensure that the maintenance practice runs smoothly. The schedule must be updated on a regular basis. Table 3.2 show the summary of tool use in each DMAIC phase.

Table 3.2: Tool use in each phase of DMAIC

DMAIC Phase	Tools
Define	1. Project Charter 2. SIPOC
Measure	1. Problem identification 2. Cost Analysis 3. Process Flowchart
Analyse	1. 5 Why Analysis 2. Cause-and-Effect Diagram
Improve	1. Design of Experiment (DOE) 2. Total Preventive Maintenance (TPM) 3. Quality Function Deployment (QFD)
Control	1. Process Standardization 2. Total Preventive Maintenance (TPM) Schedule

CHAPTER 4

RESULT AND DISCUSSION

In this chapter the results of the study are presented and discussed with reference to the objective of the study, which is to improve the quality of biscuit 'tongkat'. This chapter describes the practical application of Six Sigma, DMAIC methodology in the manufacturing process of biscuit 'tongkat'. Thus, this chapter is divided into sections based on the DMAIC model's sequential stages, which must be carried out in a systematic approach for process improvement and problem-solving. The result for each DMAIC phase is discussed throughout this chapter.

4.1 Define Phase

Define phase is the first stage in the DMAIC improvement methodology. The purpose of this phase of the DMAIC methodology is to define the scope and objectives of the improvement project in terms of customer requirements. The project charter is used to provide context for the project by summarizing the most important aspects of the project in order to achieve the goal. Then, SIPOC diagram is created to give a clear understanding of process flow start from the supplier till the customer receive the product.

4.1.1 Project Charter

The project charter provides clear direction and a sense of purpose to management from start till end of project. The voice of the customer (VOC) concept, which means identifying what customers want and prioritizing their needs, was used in this project to define the selected project's objective based on customer requirements. Project charter used to summarize the project’s background, boundary, objective, voice of customer (VOC), team’s role and expected benefits in this improvement project. The project charter is presented in Table 4.1.

The objective of project is to identify the root causes and improve the quality of biscuit. To ensure that the study is in control and explicitly focuses on the project problem, the project boundary is focusing on the quality of biscuit 'tongkat' production. The company production and the Six Sigma team are involved in this project. Brainstorming among team members is important to achieve the project's goal. Furthermore, the expected benefit to the company is cost savings as a result of less defective product. Also, expected benefits to customer is receive good quality of biscuit.

Table 4.1: Project charter

Project Charter	
Project title: Defect reduction for biscuit tongkat	
Background of project: A numbers of complain from the customer due to the defect on biscuit. This problem results in a variety of losses for the company, including material, time, and capital losses, as well as customer dissatisfaction, which has a negative impact on the company's image.	
Project objective: To identify the root causes of defect and improve the biscuit's quality	
Voice of customer (VOC):	Biscuit's quality
Project Boundary:	Focusing on quality of biscuit tongkat production
Team Members	Company production team, Six Sigma team
Expected Company Benefits:	A considerable cost saving due to defects reduction
Expected Customer Benefits:	Receiving the product with the expected quality

4.1.2 SIPOC Diagram

At the beginning of project, the SIPOC diagram (Suppliers, Inputs, Process, Output, Customers) was used to focus on brainstorming and assisting team members in agreeing on a common language and assessing the process to find all relevant parameters of the process improvement. SIPOC diagram has provided a clear understanding of the process steps needed to generate the process output. Refer to Table 4.2, the SIPOC diagram assists the team in gaining project clarity about the supplier, inputs, process, outputs, and customers of the manufacturing process.

Table 4.2: SIPOC diagram

Supplier	Input	Process	Output	Customer
• Distributor (Mydin Hypermarket)	• Material • Manpower • Machine • Resources	Step of process flowchart (Figure 4.2)	• Product with higher quality • Product with lower cost	• Agent (Biscuit 'tongkat') • Cafehouse

4.2 Measure Phase

In the measure phase, the data of the current situation were collected. During production, defects were identified through observation and brainstorming between team members. The average number of customer complaint were collected. In addition, the cost analysis is being performed in order to determine the current total lost cost due to the number of defects based on the number of customer complaints. Then, the process flowchart is used to show the process involve in production of biscuit 'tongkat'.

4.2.1 Problem Identification

The company receive the complaint about the quality of the biscuit 'tongkat'. The defect in the biscuit raises the number of complaints from customers. According to the company records, there were two major types of complaints that contributed to customers rejecting the biscuit. These two major complaint were about the texture of the biscuit which is shape and size of the biscuit. The shape and size of the biscuits are inconsistent, being either too small or too large. Table 4.3 shows the number of internal and external complaints. The average number of complaint were taken for one week.

Table 4.3: Customer complaints on quality of biscuit ‘tongkat’

Complaint defect	Count
Seal	3
Plastic torn	2
Surface texture	5
Overcook	4
Shape	14
Size	11
Smell	2

Refer to Table 4.3, the textures of biscuit, which clearly reveal that the shape and size of biscuit contribute to high number of customer complaint. The customer then complains about the appearance of the biscuit, such as the surface texture and overcooking of the biscuit. Also, the complaint is about packaging of biscuit such as seal and plastic torn happens effecting the quality of biscuit when received by customer. Finally, the customer expresses dissatisfaction with the smell of the biscuit.

Pareto analysis was used to identify the most commonly occurring defects and to prioritize the most critical problem that needed to be solved. As shown in Figure 4.1, the collected data was plotted in the form of a pareto chart. The highest customer complaint about the shape of biscuit which is 90%, while 70% complaint about the size which is not consistent. The lowest number of complaint is about 10% regarding the plastic torn and smell issue.

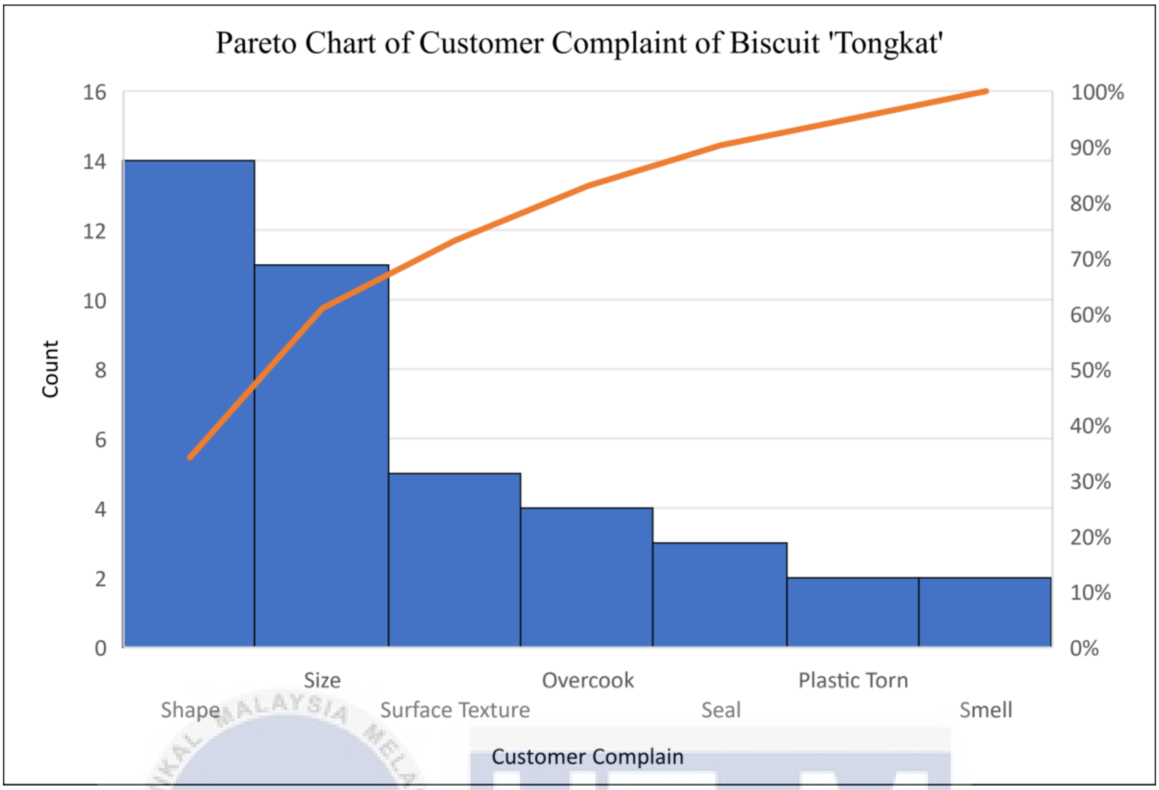


Figure 4.1: Pareto chart of customer's complaint

4.2.2 Cost Analysis

The rejected biscuit pieces result in waste and reduce the company's profit. The output is expresses as the number of biscuit produce in one tray, or in one packet. The calculation for one biscuit 'tongkat' is as follows.

1 piece of biscuit = approximately 12.5g

Net weight 1 packet of biscuit = 250g

1 packet of biscuit = 250g/12.5g

= 20 pieces/packet

1 tray = 612 piece of biscuit

1 tray = 30 packet

1 packet of biscuits = RM5.00

1 piece of biscuit = RM5.00/20 pieces

= RM0.25/pieces

Based on Table 4.3, the average number of biscuit being reject based on customer complaint is 36 pieces and 5 packet for one week. So, the average of total loss cost for a week can be calculated as below.

Average loss cost/per week = (36 pieces × RM0.25) + (5 packet × RM5)

=RM34.00

The current average total lost cost for a week was around RM34.00. The cost analysis was compared before and after improvement.

4.2.3 Process Flow of Biscuit 'Tongkat'

Process flowchart are used to show the procedure of the processes occur in the production. Figure 4.2 shows the complete steps of biscuit 'tongkat' production process. There are 18 step to complete the production of biscuit.

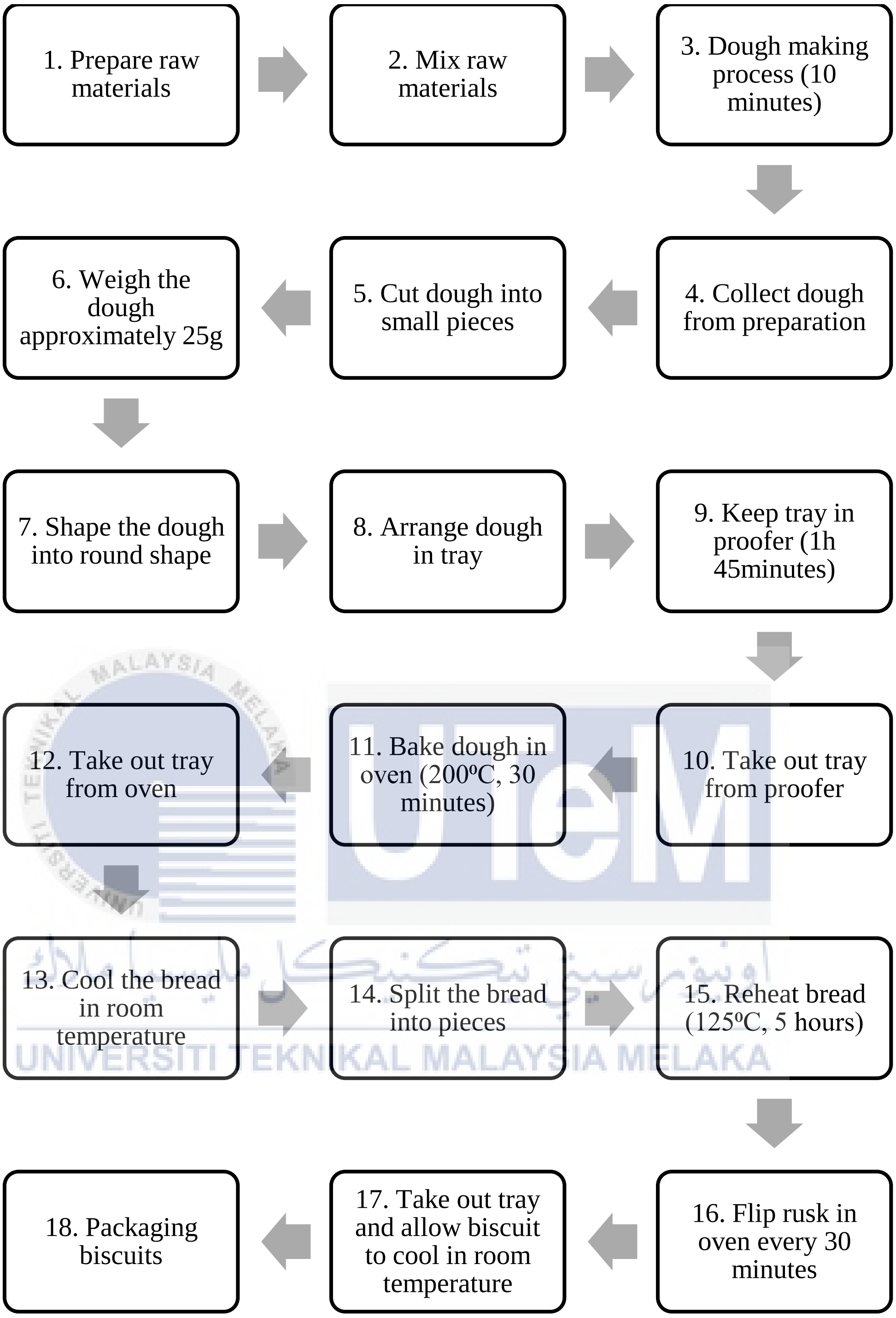


Figure 4.2: Process flowchart of biscuit 'tongkat'

4.3 Analyse phase

The Analyse phase includes a number of tools to aid in identifying manufacturing process issues and determining whether these issues are the root causes of defects. The five why method and cause-and-effect diagram is used to analyse the root cause of the defect. The root cause analysis focuses on the biscuit shape and size. There are four factors influencing the shape and size quality, which are: dough arrangement in tray not in order, different size of bread, texture of biscuit, and dry biscuit in the oven. To overcome the problems, a countermeasure is designed for each factor.

4.3.1 Dough Arrangement in Tray not in Order

The arrangement of the dough in the tray has an impact on the shape and size quality of the biscuit. The main root cause of the factor is about the dough cutting technique. The current technique manually by using plastic scraper is inconsistent according to the worker. This issue is more relevant to the new worker who has no prior experience with the process. The worker cut and weighed the dough in a hurry to reduce time taken for the process, the weight of the dough was not precisely 25g. This problem causes the rounded dough to be of varying sizes, either too small or too large, causing the rounded dough to be arranged not in line order in the tray. The dough arrangement has an impact on the rise process in the proofer machine. When the dough is not arranged properly, it rises to an inconsistent height. As a result, the solution to the problem is a new dough cutting technique that ensures the consistent size of the rounded dough and improves the dough arrangement in the tray. Figure 4.3 shows the cause-and-effect diagram analysis about the dough arrangement in tray not in order. There are four factor effecting the shape quality, which are: manpower, method, raw material and machine.

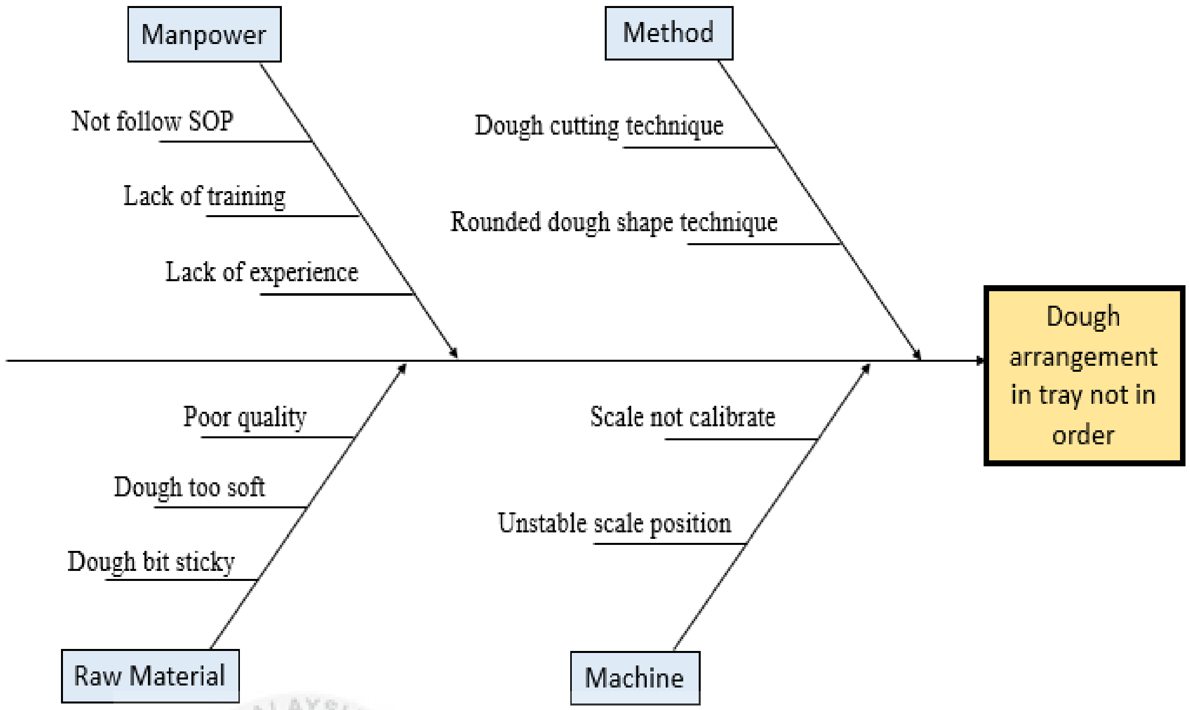


Figure 4.3: Cause and effect diagram related to dough arragement in tray not in order

4.3.2 Texture of Biscuit

The texture of the biscuit influences its shape and size quality. The root cause of this problem is inconsistency in proofer parameter setting during the dough rising process. The worker does not follow the SOP for keeping the machine within standard parameters. Furthermore, inconsistencies in internal conditions during production are caused by the condition machine itself. The dough does not rise properly in the proofer. As a result of this issue, the biscuit does not have a fine texture, and the large number of pores on the surface causes it to break easily. The issue can be resolved by rechecking the proofer parameters and monitoring the condition of the proofer throughout the process. Figure 4.4 show the cause-and-effect diagram for different size of bread. There are two factor effecting the shape quality, which are: manpower and machine.

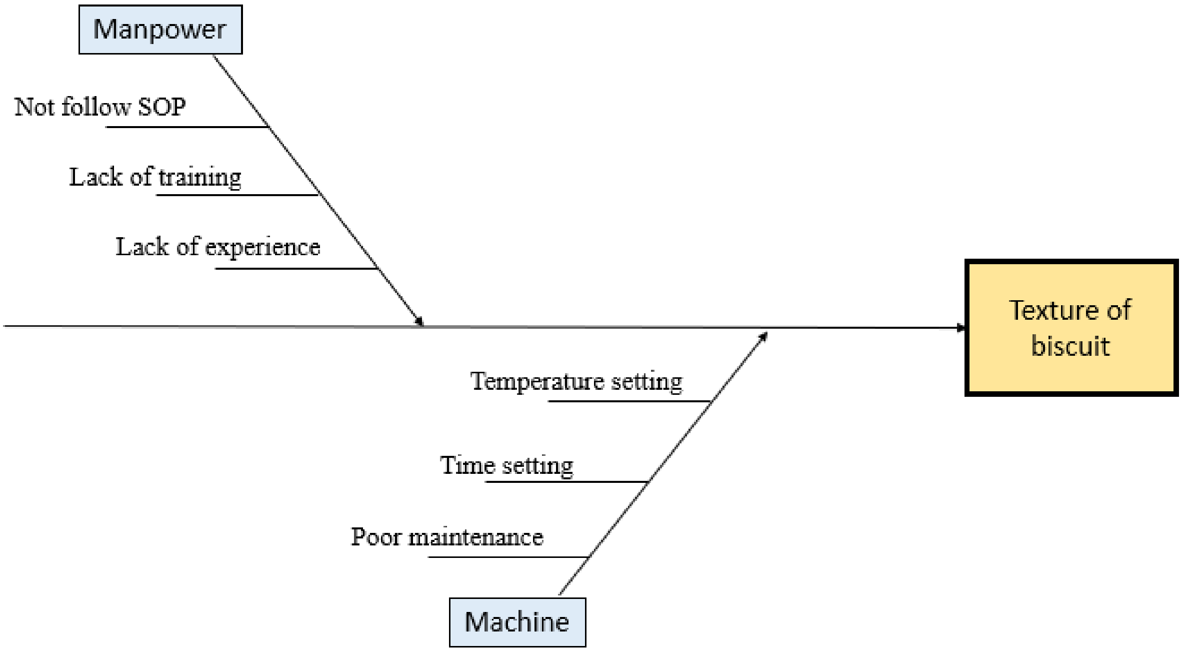


Figure 4.4: Cause and effect diagram related to texture of biscuit

4.3.3 Different size of bread

The different size of bread effect the shape and size quality of the biscuit. The root cause of this issue is inconsistent oven parameter setting during baking process. The worker does not adhere to the SOP for maintaining the machine to standard parameters. Furthermore, the condition machine itself causes inconsistencies in internal conditions during production. As a result of this problem, the bread does not bake properly in the oven. The problem is that the worker does not follow the suitable technique to split the bread into pieces before the drying process in the oven. So, the bread will split into various sizes, affecting the shape and size of the biscuit. As a result, the solution to the problem is to recheck the oven's parameters for the baking process and to monitor the oven's condition throughout the process. Figure 4.5 show the cause-and-effect diagram for different size of bread. There are three factor effecting the shape quality, which are: manpower, method, and machine.

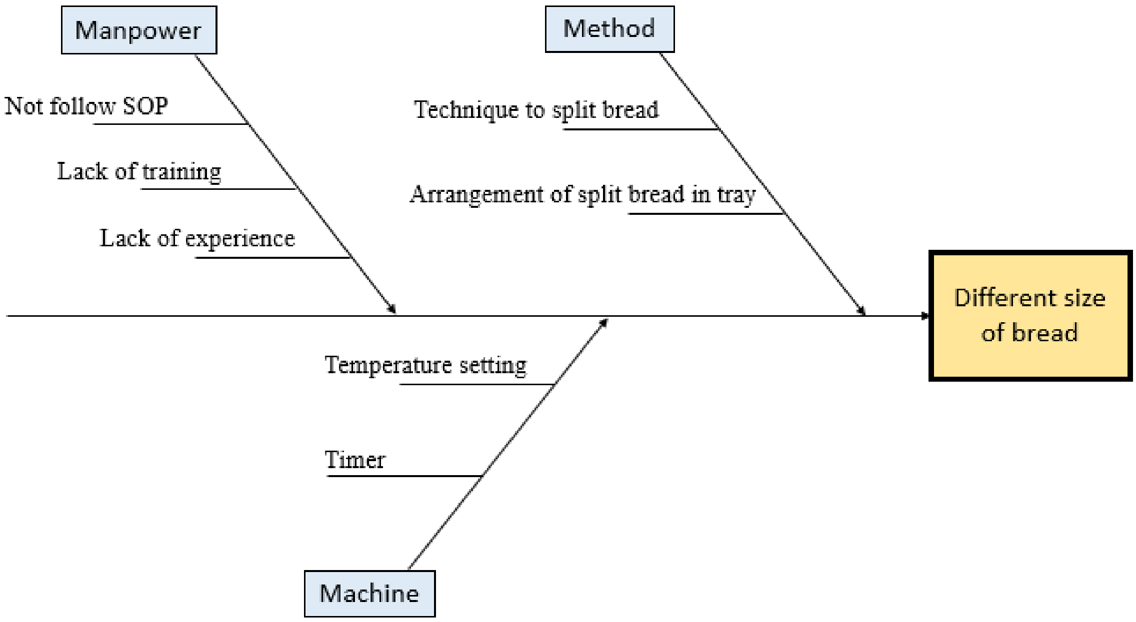


Figure 4.5: Cause and effect diagram related to different size of bread

4.3.4 Dry Biscuit in Oven

The dry biscuit in the oven has an impact on the shape and size quality of the biscuit. The underlying cause of this problem is inconsistency in oven parameter settings during the drying process. The worker does not follow the SOP for keeping the machine within standard parameters. Furthermore, inconsistencies in internal conditions during production are caused by the condition of the oven itself. As a result, the biscuit does not dry properly as it should. Depending on the size of the bread and the internal condition of the oven, the biscuit will be too crisp and dry. The biscuit will then become too fragile and may break during the packaging process effecting the shape and size quality. If a biscuit breaks during packaging, it will still be used to prevent waste as long as the net weight per packet is 250g. The problem can be solved by rechecking the oven's drying parameters and monitoring the oven's condition throughout the process. Figure 4.6 show the cause-and-effect diagram for different size of bread. There are three factor effecting the shape quality, which are: manpower and machine.

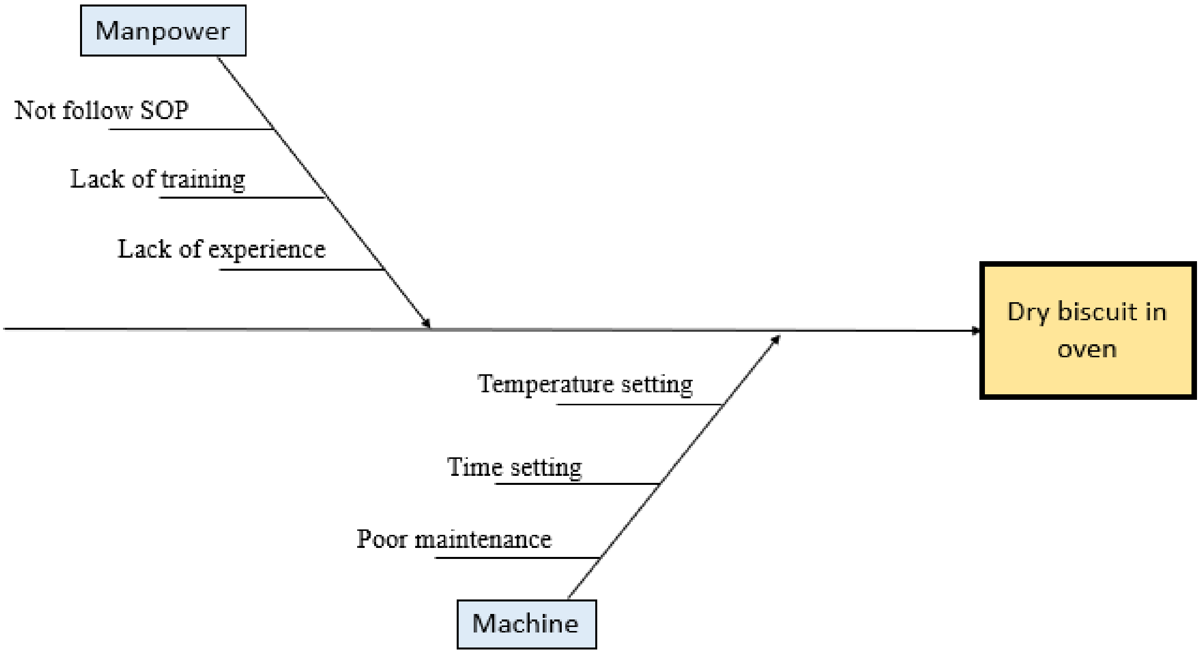


Figure 4.6: Cause and effect diagram related to dry biscuit in oven

4.3.5 Summary of Root Cause Analysis

Root cause analysis is carried out using the 5 Why method and a cause-and-effect diagram. Table 4.4 summarizes the 5 Why analysis performed to examine the factors that influence the quality of the biscuit. The following four factors have an impact on the shape and size of the biscuit: arrangement if dough in the tray, different bread sizes, biscuit texture, and dry biscuit in the oven. Furthermore, solutions to reduce the impact on biscuit quality include: improving dough cutting technique, rechecking the parameters and condition of the proofer, oven during baking process, and oven during drying process.

Table 4.4: 5 Why analysis

No	Factors	Why 1	Why 2	Why 3	Why 4	Why 5	Countermeasure
1.	Dough arrangement in tray not in order	Variation size of rounded dough	Size of rounded dough different	Weight of dough not accurately 25g	Worker cut and weight dough too fast	The dough cutting technique	Improve dough cutting technique
2.	Texture of biscuit	The biscuit easily breaks	The biscuit does not have fine texture	The dough not properly rise in proofer	Worker does not follow SOP	Inconsistent parameter setting of proofer	Recheck the parameter of proofer for dough
3.	Different size of bread	The bread split in different size	Technique to split the bread into pieces	The bread not properly baked	Worker does not follow SOP	Inconsistent parameter setting of oven	Recheck the parameter of oven for baking
4.	Dry biscuit in oven	The biscuit too fragile and break during packaging	Biscuit is too crisp and dry	The biscuits not properly dry the way it should be	Worker does not follow SOP	Inconsistent parameter setting of oven	Recheck the parameter of oven for drying biscuit

4.4 Improve Phase

The Improve phase of the project aims to identify solutions for all of the root causes identified during the Analyse phase, implement them after assessing the risk of implementation, and monitor the results. Design of Experiment is used to determine the major factor contribute to the shape quality of biscuit. Then, implementation of solution to solve the issue related to the quality of biscuit.

4.4.1 Analysis of Major Factor Contribute to Shape of Biscuit

Design of Experiment (DOE) is a systematic series of test where the relationship between factors and responses are being evaluated. DOE use in this study to determine the main factor contributing to the shape of the biscuit. The method of DOE used in this project are full factorial which used as screening design. It is used to reduce the number of input variables by identifying process conditions that have an impact on product quality. Table 4.5 shows the input variable implement in DOE with 4 factors with several set of experiments. Figure 4.7 shows the planning matrix of full factorial during the experiment.

Table 4.5: The DOE factors and its level

Input variable	Unit	Low level	High level
Weight of dough	g	24	26
Proofer temperature	ºC	34	36
Oven temperature (Baking)	ºC	190	210
Oven temperature (Drying)	ºC	124	126

↓	C1	C2	C3	C4	C5	C6	C7	C8
	StdOrder	RunOrder	CenterPt	Blocks	Weigth of dough	Proofer temperature	Oven temperature (Baking)	Oven temperature (Drying)
1	20	1	1	1	26	36	190	124
2	8	2	1	1	26	36	210	124
3	40	3	1	1	26	36	210	124
4	31	4	1	1	24	36	210	126
5	1	5	1	1	24	34	190	124
6	32	6	1	1	26	36	210	126
7	19	7	1	1	24	36	190	124
8	38	8	1	1	26	34	210	124
9	16	9	1	1	26	36	210	126
10	2	10	1	1	26	34	190	124
11	13	11	1	1	24	34	210	126
12	36	12	1	1	26	36	190	124
13	23	13	1	1	24	36	210	124
14	14	14	1	1	26	34	210	126
15	5	15	1	1	24	34	210	124
16	30	16	1	1	26	34	210	126
17	46	17	1	1	26	34	210	126
18	49	18	0	1	25	35	200	125
19	43	19	1	1	24	36	190	126
20	37	20	1	1	24	34	210	124

Figure 4.7: Planning matrix of full factorial

The pareto chart shows in Figure 4.8 had been constructed where every factors are being analyzed in several set of experiments. The pareto chart show that relationship factor of proofer temperature, oven temperature (baking) and oven temperature (drying) becoming the main factor contributing to the response for the experiment which is shape of biscuit 'tongkat'. The weight of the dough is second factor effect to the shape of biscuit since the experiments conducted.

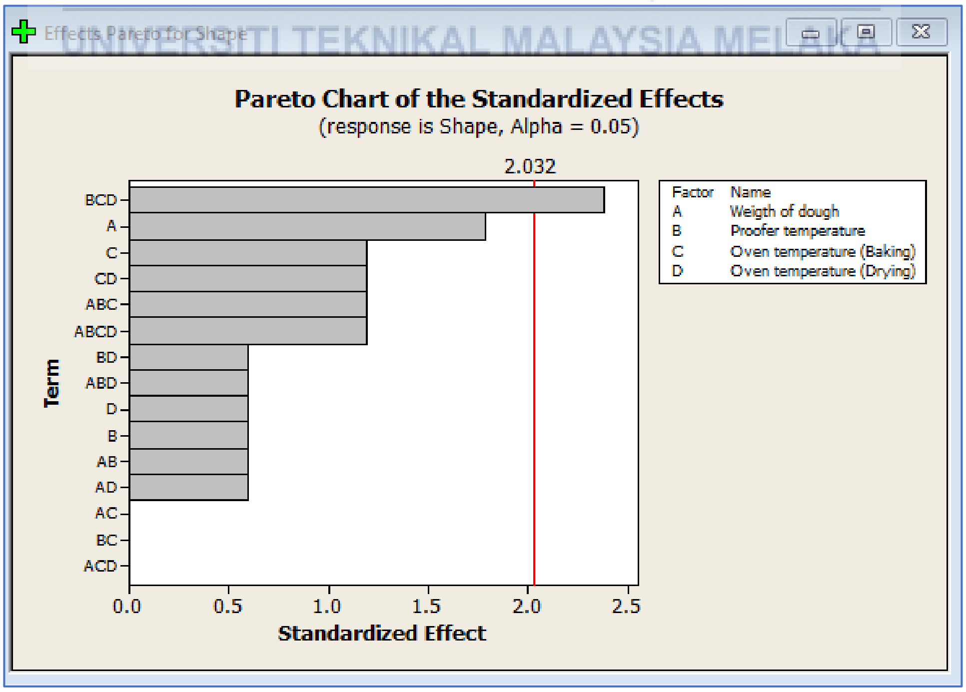


Figure 4.8: Pareto chart of standardized effects

The result executed are with the attributes response which the experiments run with shape as a response and evaluate with either good or not good shape. The result of DOE in Figure 4.9 shows the normal plot of the standardized effects. Effects that are further from 0 on the normal probability plot of the effects are statistically significant. It shows that the relationship between proofer temperature, oven temperature during baking and oven temperature during drying is significant effect in normal plot.

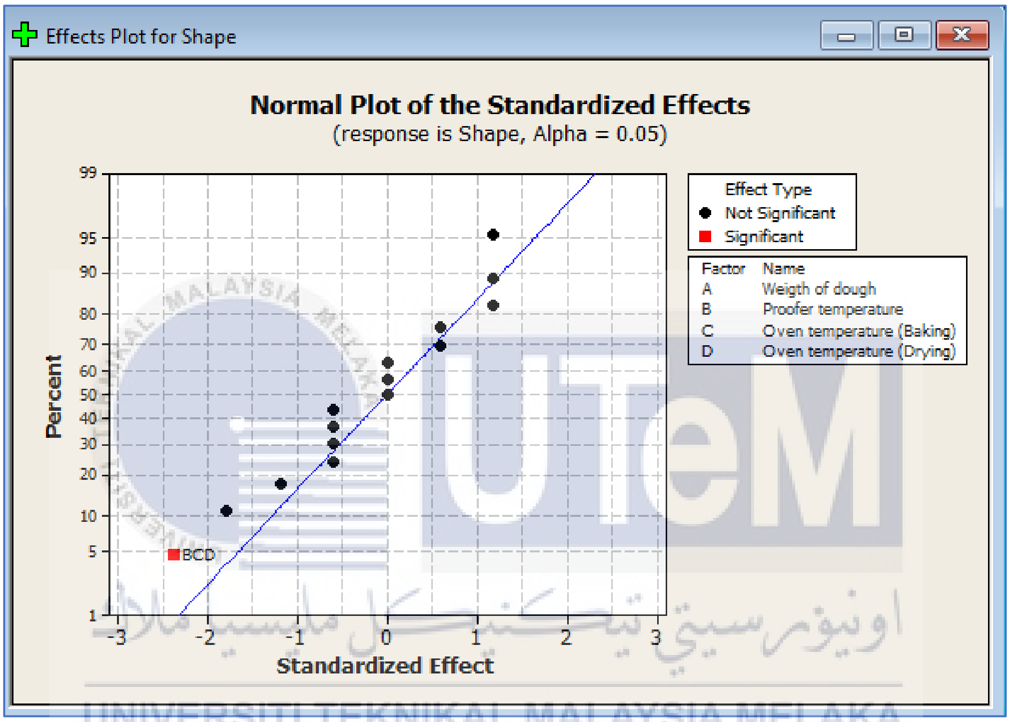


Figure 4.9: Normal plot of the standardized effects

Overall, based on the DOE result, the main factor affecting the shape quality of the biscuits are the relationship between the proofer temperature, oven temperature (baking) and oven temperature (dying). Besides that, weight of dough is second major factor effecting the shape of biscuit. A new set of input variable settings that will optimize the shape response. Based on Figure 4.10, the optimal factors and levels based on the higher magnitude of the mean value is achievable by setting up weight of dough at 24g, proofer temperature at 36ºC, oven temperature (baking) at 190ºC and oven temperature (drying) at 124ºC.

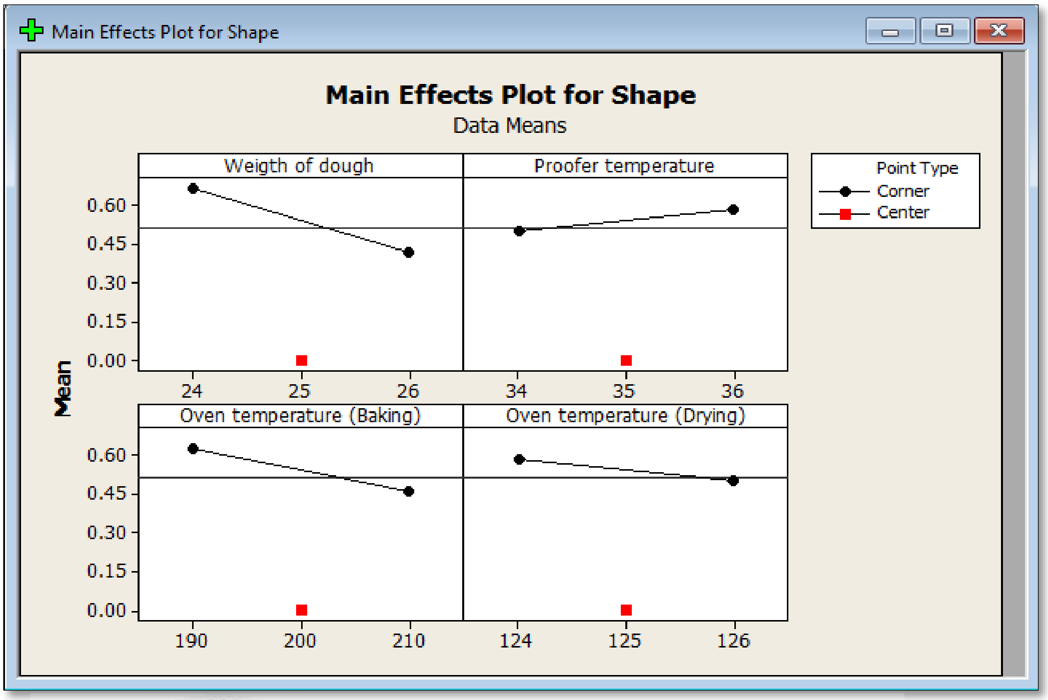


Figure 4.10: Main effects plot of the standardized effects

There are several issue related to the temperature of oven and proofer. The first issue was the machine's condition, which had an inconsistent internal temperature and condition during production. Moreover, the timer and temperature setting might be an issue because the machine is use for several type of biscuit. The worker may have incorrectly set the timer and temperature, or the machine itself may have broken during production, affecting the parameter. The cleaning activity for oven and proofer only be done once a month. Also, maintenance is only scheduled when the machine fails. This problem could be affecting the condition of the oven and proofer.

Furthermore, the weight of the dough influences the shape and size of the biscuit ‘tongkat'. The manual method of cutting the dough with a scraper requires good technique and training to reduce the time required and improve the consistency and weight of the dough. This is a problem, especially when a new employee begins the process without training. The size of the rounded dough influences how it is arranged in the tray before being placed in the proofer machine. It will have a minor impact on the rising process of the dough.

4.4.2 Improvement Implementation

Two solutions are proposed to improve the quality of biscuits in terms of machine temperature and weight of dough. First, a new dough cutting technique was introduced to improve weight consistency and reduce the process time. Then, a Total Preventive Maintenance (TPM) schedule is created to ensure that the machine is in good working condition during production to ensure the quality of the biscuit.

4.4.2.1 Schedule of Maintenance Practice

Total Productive Maintenance (TPM) is the process of maintaining and improving production effectiveness through the use of machines, employees, and processes that optimize equipment availability. To maintain the overall productivity and quality, TPM requires constant observation and action. Following that, a systematic approach is required to establish good maintenance practices. The preventive maintenance schedule is developed with the participation of all workers in maintenance activities. Training all workers in relevant maintenance skills related to operating and maintenance responsibilities requires that each has all of the necessary skills to carry when needed.

All procedures and activities performed to maintain the initial operating conditions of an oven and proofer are referred to as machine maintenance. The following aspects should be prioritized in maintenance activities:

i. Pre-scheduled inspection of the machine's overall condition.
ii. Replacement of components that are loose/flaking, worn, rusted, damaged, or broken.
iii. Check the important element of machine such heating elements, timer, setting and others.
iv. Cleaning process before and after production process.

The preventive maintenance schedule shown in Appendix C. Maintenance practice involving all the workers is schedule once a week. During the deep cleaning sessions, inspect the machines and check all visible parts. If any of the pieces are worn, loose, or require oiling, take care of them right away. Keeping up with repairs on a regular basis will also help to reduce breakdowns. Taking care of minor issues will aid in the prevention of larger problems.

Furthermore, the expected outcome of implementing a preventive maintenance schedule is to prevent changes to the machine breakpoint, which could result in inconsistent temperature and condition during production. Then, by reducing the temperature issue, the machine's efficiency improves, allowing the biscuit's quality to be maintained. This practice can keep the machine running more efficiently for a longer period of time.

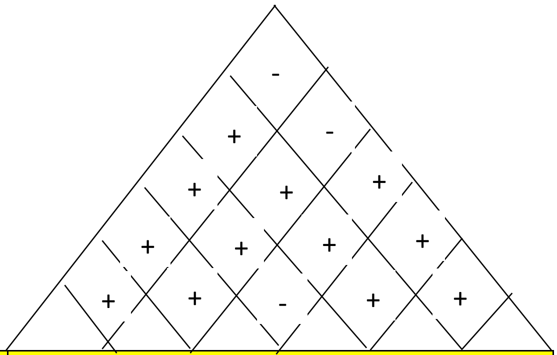
4.4.2.2 Analysis on New Dough Cutting Technique

The weight of dough is one of the factors influencing the shape of the biscuit 'tongkat'. It is important to improve the dough cutting technique in order to reduce the inconsistent weight of the dough. In addition, the technique can shorten the time required for the process. Furthermore, the consistency weight of the dough, resulting in rounded dough with the same size. As a result, this will help the dough arrangement in the tray to be in line.

A concept is recommended for dough cutting technique to reduce the time taken and improve the consistency weight of dough. The concept is chosen by putting the Quality Function Deployment (QFD) into action. QFD is used to effectively define and transform customer requirements into detailed engineering specifications. Finally, the data is planned to produce products that meet those requirements.

Initially, the House of Quality (HOQ) was defined as a product planning matrix designed to demonstrate how customer requirements are directly related to the ways and methods that companies can use to meet those requirements. Figure 4.11 depicts a House of

Quality perform based on information from customers on product improvement requirements. Five main significant criteria focused on the design concept, which is design, material, function, ease of manufacture, and cost.



Customer Requirement	Importance	Quality characteristic: Weight of part	Size	Ease of use	Ease to clean	Material Suitability	Price range	Competitive Evaluation/ Customer Assessment
Design	5	3	3	5	3	3	3	3
Material	3	3			1	5		3
Function	4	3	3	5				3
Easy to manufacture	3		3	3		1		3
Cost	4		1				5	3
Technical Importance		36	40	54	18	33	35	
Rank		3	2	1	6	5	4	

+	Supporting
-	Trade Off

5	Strong Correlation
3	Medium Correlation
1	Weak Correlation

Figure 4.11: House of quality (HOQ)

The technical specification for the design concept is important based on the HOQ. Refer at Figure 4.11, the first rank of technical importance is ease of use of the product for cutting process of the dough. The size of the product is then ranked second, followed by its weight. The final product specification is based on the voice of the customer and the house of quality with regard to the customer's requirements, which correlate with engineering specifications.

4.4.2.3 Concept Selection of Product

Concept selection is the process of evaluating concepts that meet the needs of the customer in relation to the critical specifications. Concept selection compares the relative strengths and weaknesses of various product concepts. The best conceptual design was then chosen to manage the rest of the design and manufacturing processes.

There are two methods for selecting concepts: concept screening and concept scoring. Screening is a quick, rough evaluation with the goal of producing a few variable alternatives, whereas scoring concept is a more thorough analysis of a few relative concepts with the goal of selecting the single concept design.

After all of the significant criteria are identified from the customer, all of the criteria must meet the specifications, and the first thing that is developed is the conceptual design, where the activities of selecting between concepts to find the most suitable concept are carried out. Table 4.6 depicts a concept selection table in which the shape of the concept, holes, and material for the part are all taken into account when selecting a concept.

Table 4.6: Concept selection table

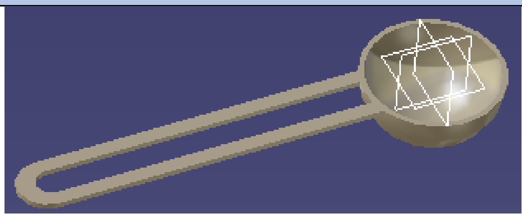
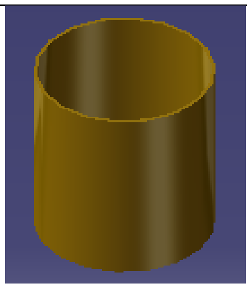
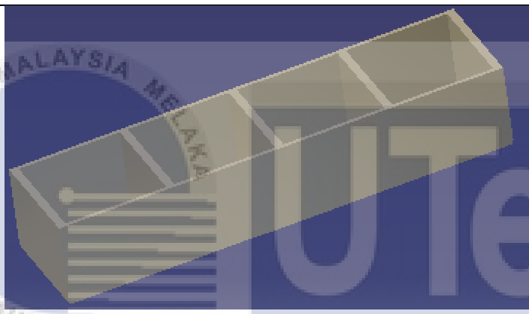
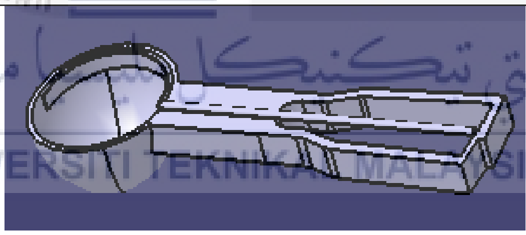
	Concept	Material
Concept 1		Plastic
Concept 2		Aluminium
Concept 3		Plastic
Concept 4		Stainless steel

Table 4.7 shows the four concept that are stated in the selection matrix being choose according to their importance. The existing cutting dough concept become the reference and all its selection criteria is rank 0, so that it become a natural benchmark to be compared with other concepts. The screening analysis show the concept 1 and concept 2 is continue for scoring analysis while the concept 2 and concept 3 is combined.

Table 4.7: Concept screening

Selection Criteria	Concept 1	Concept 2	Concept 3	Concept 4	References
Design	+	-	-	++	0
Material	-	+	-	+	0
Function	+	-	-	++	0
Ease to manufacture	+	++	++	+	0
Cost	++	++	++	+	0
Sum of +	5	5	4	7	0
Sum of 0	0	0	0	0	0
Sum of -	1	2	3	0	0
Net score	4	3	1	7	0
Rank	2	3	4	1	0
Continue	Yes	Combine	Combine	Yes	No

Concept scoring analysis was carried out for concept 1, concept 4, and the combination of concepts 2 and 3. The weightage for each selection criteria in Table 4.8 is based on the importance to be applied in the concept selected. The scoring is done using the scale shown in Table 4.9. The result from the scoring analysis shows that the design concept 4 is selected for dough cutting technique to improve consistency weight of dough with the highest score which is 3.75 marks.

Table 4.8: Concept scoring

Selection Criteria	Weight	Concept 1		Concept 4		Concept 2 & 3	
		Rating	Score	Rating	Score	Rating	Score
Design	30	3	0.9	5	1.5	1	0.3
Material	15	2	0.3	4	0.6	3	0.45
Function	20	2	0.4	4	0.8	1	0.2
Ease to manufacture	15	2	0.6	3	0.45	4	0.6
Cost	20	3	0.6	2	0.4	4	0.8
Total	100%	2.8		3.75		2.35	
Rank		2		1		3	
Continue		NO		YES		NO	

Table 4.9: Scoring scale

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Figure 4.12 depicts the dough cutting technique concept before and after the implementation of improvements. The current dough cutting technique only utilizes the use of a plastic dough scraper and manual weighting of the dough. The size of the dough is inaccurate, and you may need to add or subtract dough to achieve 25g. This technique is not very accurate and requires practice to avoid wasting time.

The stainless-steel scoop is a new concept dough cutting technique. The custom-sized scoop precisely measures 25g of dough. The worker did not have to weigh the dough, which increased the productivity of the cutting process. Dough scooping technique makes the process of rounding the dough easier and improves the consistency and weight of the dough. The arrangement of dough in the tray makes it easier to work with. The arrangement of dough in tray is easier to be in line order.

Heavy-duty spring action of the stainless-steel scoop allows for easy dough release without fatiguing someone hand. A cushioned Santoprene handle provides a more stable and comfortable grip for repeated scooping. Hand washing this tool is the best way to keep it in top condition.

Before Improvement Implementation	After Improvement Implementation
 	

Figure 4.12: Dough cutting technique concept before and after improvement implementation

Furthermore, the new dough cutting technique is expected to improve the consistency weight of the dough. It aids in the arrangement of the dough in the tray prior to placing it in the proofer. Furthermore, the new technique can reduce the time required for the cutting process. As a result, it can boost productivity while also improving biscuit quality.

4.4.3 Verification From Industry

Regarding the pandemic Covid-19, it is impossible to implement a solution to determine the improvement in biscuit quality. A proposal has been submitted to the founder of Biscuit Company in order to obtain feedback on the proposed solution to the issue affecting the quality of biscuits. The proposal and verification by industry are shown in the Appendix D, along with feedback for each solution.

The Total Preventive Maintenance (TPM) schedule is only appropriate for monthly checks and is impractical for weekly checks. Preventative maintenance is essential for keeping the machine running at peak efficiency for as long as possible. The TPM plan can be scheduled for daily, weekly, monthly, and annual maintenance checklists for good maintenance practice in production. It will take more time from the worker, but the benefits will save the money on costly downtime, leaks, and machine damage.

The new dough cutting technique based on the scoop concept is not suitable or practical for use in production. The scoop concept is rejected for two reasons: the dough contains yeast and is chewy, making it unsuitable for scooping. The current method of cutting the dough with a scraper is the best. The worker will receive training in order to master the technique.

4.5 Control Phase

The primary goal of the control phase is to ensure that the improvements made during the improve phase are maintained long after the project is completed. The implemented solution is checked, and performance is measured during the control phase to ensure the level of improvement. During this phase, we must ensure that the full-scale implementation of the improvement action plans takes place.

4.5.1 Work Standardization

After implementing the changes, it should be monitored to see if the improvement has a positive impact on the production process and brings any profits to the company. It can be done by developing a control plan that specifies what data should be controlled, how it should be controlled, how frequently it should be controlled, and who should control it. If a nonconformance is discovered, instructions are given on what actions must be taken. Such a plan should be updated over time based on post-implementation evaluations. If the improvement is achieved through process management methods such as process simplification, a new process standard must be established. If the improvement is made by removing the root causes of poor performance, it is necessary to monitor process performance after the improvement. Appendix E show the standardize operation worksheet for production in Biscuit Company.

4.5.2 Total Productive Maintenance (TPM) schedule

Total preventive maintenance ensures machine quality by preventing failures and thus improving the production cycle. The preventive maintenance schedule must be updated on a regular basis. Appendix F is the TPM schedule for monthly checklist. If the checklist hasn't been thoroughly updated in a while, it's likely that the appropriate activities are no longer included. In addition, without the proper content, preventative maintenance routines will fail to produce the desired results. All workers must be able to see the TPM schedule in the production area. Keep the TPM checklist document near the machine to ensure that the maintenance activity is kept up to date.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter discusses the results obtained in Chapter 4 based on the project's objective. It will provide a summary of the project's DMAIC application in the manufacturing industry. Furthermore, there is a discussion about future project recommendations.

5.1 Conclusion

The study focused on the application of DMAIC methodology in the manufacturing industry to reduce product defects. Several Six Sigma quality improvement tools are used in each phases to solve the problems in production. The first objective is achieved in define and measure phase. In Define phase, the project's scope and goals in terms of customer requirements are defined. Then, SIPOC diagram is created to give a clear understanding of process flow start from the supplier till the customer receive the product. In Measure phase, the current situation data was gathered, which included the average number of customer complaints and a cost analysis of rejected products.

The second objective has been accomplished in Analyse phase. In Analyse phase, the discussion on finding the root causes affecting the texture of the biscuit. There are two method use to evaluate the possible factor affecting the shape and size of the biscuit which is the why-why method and cause-and-effect diagram. Four factors effecting the quality of biscuit are identified. The factors are analyse using the why-why method and cause-and-effect diagram. The probable reasons for cause-and-effect diagram taking into account five factors: raw material, measurement, machine, manpower, and method. In Why-Why analysis, a countermeasure for each factor is determined for the improvement strategy.

In Improve phase, the idea to reduce the defect based on the root cause in Analyse phase. Third objective is accomplished by introduce two strategy to reduce the defect related to quality of biscuit. One set of proposal about the suggested improvement was given to the founder of Biscuit Company to evaluate and approve the strategy to be implemented. First, the idea of Total Preventive Maintenance (TPM) for machine is accepted but need to update the schedule to monthly checklist for maintenance practice. Then, the suggested idea on new dough cutting technique is rejected to replace the manual technique by using scrapper. The scooping concept is not too suitable to be implement because the dough is using yeast and chewy. However, due to Movement Control Order (MCO) to all district in Malaysia, the cost reduction analysis after improvement implementation cannot be achieved. Lastly, the work standardization and Total Preventive Maintenance (TPM) schedule is introduced in Control phase to sustain the result for long after the project completed.

5.2 Recommendation

This research can be expanded in the future as more improvements to the Small and Medium Enterprise (SME) industry can be made using the recommendations listed below:

1. Further improvement and update the Total Preventive Maintenance (TPM) schedule include the daily, weekly, monthly, and annual maintenance checklist.
2. Create One Point Lesson (OPL) for the entire process of biscuit 'tongkat'.
3. Proper studies on dough cutting technique to improve quality of biscuit.
4. Further studies about cost reduction in Biscuit Company.

5.3 Sustainable Design and Development

The sustainable manufacturing industry always considers product quality, waste elimination, low-cost involves, and customer requirements. Total Preventive Maintenance (TPM) implementation that is effective and sustainable contributes to significant improvements in machine performance and product long life. The schedule and checklist are updated over time to achieve more sustainable performance, reduce resource consumption, and have a positive impact on the environment. To achieve a zero-defect product, the machine must be durable enough to last a long time. Constant maintenance and good standard operating procedures improve sustainability design and development.

5.4 Complexity

The complex activities in this project occurred during the Measure phase, when data for the current situation was collected based on a customer complaint. The data is required to identify the type of defect and analyse the root causes affecting product quality. The average number of complaints must be precisely recorded to ensure that the determinate defect has a significant impact on the quality issue. So, the improvement strategy will solve the problem in the long run.

5.5 Life Long Learning

Life-long learning help in development and maintain of a positive attitude toward learning for both personal and professional development. The industrial based project gives an experience in real world project by implementing and demonstrate the skills and knowledge acquired in classroom. The project involvement provides real-world experience by reviewing the company's issues, developing a proposal and solutions, and then presenting the proposed improvement to company. Furthermore, the company can continue to look into developing SOP with other processes and continuously improve over time. As a result, more One-Point-Lessons (OPL) will be developed to standardize the working instructions given to workers to perform routine operations. Moreover, the maintenance schedule can be updated over time to update the checklist. Continuous maintenance practices in the workplace will save money on costly repairs, downtime, and machine damage.

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Appendix A: Gantt Chart for PSM 1

DMAIC Application for The Reduction of Defect in Manufacturing Industry																
Chapters	Activity	Weeks														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Choose Title															
Chapter 1	Introduction															
Chapter 2	Literature Review															
Chapter 3	Methodology															
	Submission of Logbook															
	Submission of Draft FYP report															
	Amendment on final Report															
	Presentation															
	Submission of Final Report															

Appendix C: Total Preventive Maintenance (TPM)

ABC Enterprise					
Total Preventive Maintenance Schedule					
Equipment : Oven	Month: August 2021		Issue by:	Staff	
Description	Week 1	Week 2	Week 3	Week 4	Remarks
1. Earthing - Should be proper					
2. Extension cord - burn, cut in wire to be checked					
3. Heating element - Loose & burn electrical connection to be checked					
4. Timer - Operation and time setting to be checked					
5. Thermostat - Operation and setting to be checked					
6. Lights - Fused light to be checked					
7. Door operation - Hinges on door and closing of the door to be checked					
8. Check the rating of heating element					
9. Check thermostat rating					
10. Clean the internal spaces of oven					
11. Check setting and operation of low and high temperature limit devices					
12. Check if any loose/flaking, worn, rusty, damaged, or broken components					
13. Check Operation of ventilating equipment/air extraction fans or blowers					
Signature					

Appendix D: Verification From Industry

Verification by Industry

VERIFICATION FORM		
Company: Delima Ain Enterprise		
Prepared by: Nik Muhammad Ibrahim B Nik Rezali		**Issue date:** 11 August 2021
No.	**Idea of Improvement**	**Comment(s)**
1.	New concept dough cutting technique	Reject !! not practical at all !!!
2	Total Preventive Maintenance (TPM)	Just suitable for monthly checked. not practical for weekly check.
Checked by: Mrs. Yushita Binti Rahmat (Founder of Delima Ain Enterprise)		Date: 13-8-2021. Company Stamp: DELIMA AIN ENTERPRISE (MA0095809-T) JC3435, JALAN SB 5/4A/1, SYEKSYEN 4, BANDAR JASIN BESTARI, 77200 MELAKA. 017-8770304

Appendix E: Standardized Operation Worksheet

ABC Enterprise		
Standardized Operation Worksheet		
Product: Biscuit 'Tongkat'	Date: 25 August 2021	Issue by: Staff
Process	No.	Work Elements
	1	Grab a yeast mixture bowl and jug
	2	Fill the water from pipe in the jug
	3	Pour the water in yeast mixture bowl
	4	Grab the yeast jar
	5	Open the yeast jar lid
	6	Pour the yeast into yeast mixture bowl
	7	Close the yeast jar lid
	8	Place back the yeast jar
	9	Stir yeast and water
	10	Put yeast mixture bowl aside
	11	Grab the egg
	12	Crack the egg in the mixer basin
	13	Throw the egg shell
	14	Grab a small bowl
	15	Open the salt jar
	16	Put salt in small bowl
	17	Close the salt jar
	18	Keep small bowl salt content aside
	19	Place a big bowl on table
	20	Grab the sugar jar
	21	Open the sugar jar lid
	22	Put sugar in big bowl
	23	Close the sugar jar lid
1. Prepare raw materials	24	Put back sugar jar in the place
	25	Grab the margarine packet
	26	Pour the margarine in big bowl
	27	Put back the margarine packet
	28	Grab the shortening jar
	29	Open shortening jar lid
	30	Put shortening powder in big bowl
	31	Close shortening jar lid
	32	Place back the shortening jar
	33	Keep the big bowl aside
	34	Grab the flour packet
	35	Cut the flour packet
	36	Put the flour in mixer basin
	37	Throw the empty flour packet
	38	Grab the big bowl to pour in mixer basin
	39	Pour the mixture from big bowl into mixer basin
	40	Place the empty big bowl aside
	41	Grab the yeast mixture bowl
	42	Pour the yeast mixture into mixer basin
	43	Place the empty yeast mixture bowl aside
	44	Grab a salt content bowl
	45	Put the salt from the small bowl into mixer basin
	46	Grab water jug
	47	Pour water inside mixer basin
	48	Keep the jug aside

2. Mix raw materials	49	Grab the spatula
	50	Mix roughly the raw material in mixer basin
3. Dough making process	51	Grab the mixer basin
	52	Install the mixer basin on the machine
	53	Grab the spiral part
	54	Insert the spiral part to the mixer machine
	55	Turn on the machine
4. Collect dough from preparation	56	Turn off the mixer machine
	57	Uninstall the spiral part
	58	Grab the mixer basin
	59	Take the flour plate
	60	Sprinkle flour on the table
	61	Lay aside the flour plate
	62	Take the dough cutter
	63	Clean the spiral part using dough cutter
	64	Take out the spiral part
	65	Take out the dough using dough cutter
5. Cut dough into small pieces	66	Shaping the dough
	67	Grab the bread cutter
	68	Cut the dough into a long pieces
	69	Cut the dough into small pieces
6. Weight the dough approximately 25 g	70	Grab the dough
	71	Put the dough in weigh machine
	72	Observe the readings
	73	Collect the dough from weigh machine
7. Shaping the dough into round shape	74	Shape the 25g dough into round shape
	75	Take aluminium tray from shelf
8. Arrange dough in tray	76	Arrange round dough line by line in tray
9. Keep tray in proofer (1h 45minutes)	77	Take the tray filled with dough
	78	Open the proofer
	79	Put the tray in proofer
	80	Close the proofer
10. 10.Take out the tray from proofer	81	Open the proofer
	82	Take tray and put on the rack
	83	Close the proofer
11. Bake dough in oven (200ºC, 30 minutes)	84	Open the oven
	85	Take tray contain already rise dough
	86	Put tray into oven
	87	Close oven
12. Take out tray from oven	88	Open oven
	89	Take out the tray
	90	Close oven
13. Cool the bread in room temperature	91	Put tray on cooling table (only room temperature)

14. Split the bread into pieces	92	Prepare one empty tray
	93	Divide bread to 4 parts
	94	Take one part
	95	Split piece
	96	Put into empty tray
	97	Fill up tray with pieces
15. Reheat bread (125ºC, 5 hours)	98	Pick up tray
	99	Open oven
	100	Put tray into oven
	101	Close oven
16. Flip rusk in oven every 30 minutes	102	Open oven
	103	Flip rusk using spatula
	104	Close oven
17. Take out tray and allow biscuit to cool in room temperature	105	Open oven
	106	Take out the tray
	107	Left tray of rusk cool on rack
	108	Close oven
18. Packaging biscuits	109	Take tray of rusk
	110	Prepare packaging bag
	111	Put pieces by pieces of biscuits in bag
	112	Put bag on weight balance
	113	Weight bag approximately 250g
	114	Seal biscuit's bag

Appendix F: Total Preventive Maintenance (TPM) Schedule

ABC Enterprise													
Total Preventive Maintenance Schedule													
Equipment : Oven	Year:2021										Issue by:		Staff
Description	Jan	Feb	Mac	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Remarks
1. Earthing - Should be proper													
2. Extension cord - burn, cut in wire to be checked													
3. Heating element - Loose & burn electrical connection to be checked													
4. Timer - Operation and time setting to be checked													
5. Thermostat - Operation and setting to be checked													
6. Lights - Fused light to be checked													
7. Door operation - Hinges on door and closing of the door to be checked													
8. Check the rating of heating element													
9. Check thermostat rating													
10. Clean the internal spaces of oven													
11. Check setting and operation of low and high temperature limit devices													
12. Check if any loose/flaking, worn, rusty, damaged, or broken components													
13. Check Operation of ventilating equipment/air extraction fans or blowers													
Signature													