ENHANCEMENT OF PRODUCT QUALITY THROUGH STABILITY IN GAGE REPEATABILITY AND REPRODUCIBILITY AT BEVERAGES INDUSTRY

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BACHELOR OF MANUFACTRUING ENGINEERING TECHNOLOGY WITH HONOURS

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2021

DECLARATION

I declare that this Choose an item. entitled " Enhancement of Product Quality Through Stability in Gage Repeatability and Reproducibility at Beverages Industry" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

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DEDICATION

To my dear father, mother, siblings, and friends, who have always been there for me spiritually and emotionally.

Ts. Dr. Amir Hamzah Bin Abdul Rasib, my supervisor, for mentoring, instructing, and assisting me in finishing my thesis.

ABSTRACT

Due to the numerous challenges competitors face in similar industries, particularly in the food business, industrial sectors focus their efforts on performance improvement. Measurement systems refer to a process's ability to provide a high-quality product or service that fulfills the standards of the client. The issue is that numerous small and medium-sized manufacturing enterprises are struggling to satisfy their customers while maintaining a high level of product quality. To improve product quality, the first objective of this research is to uncover issues with product quality related to the measuring method. Before initiating this study, a literature review using the GR&R technique was undertaken to acquire data and convert it to knowledge. When developing a collective term on a manufacturing system, it is necessary to collect production data from the selected food industry as an actual case study. Additionally, the second objective of this study is to undertake GR&R to improve product quality in the food and beverage business through stability. As a result, data collecting is critical to the study's completion. Interviews are conducted, photographs are taken, and measurement data is entered into a spreadsheet. The study's ultimate objective is to recommend an improvement activity based on the findings from the GR&R system analysis. The analysis is conducted utilising the data that has been gathered. This analysis is necessary to evaluate whether the measuring system is affected by Appraisal Variation (AV) or Equipment Variation (EV). Additionally, GR&R is utilised to decide whether the analysis is appropriate or not. These identify the most impacted element based on the GR&R evaluation and use it to make an improvement proposal. These ideas are discussed with the industrial representative concurrently with the research presentation for evaluation.

ABSTRAK

Disebabkan oleh pelbagai cabaran yang dihadapi pesaing dalam industri yang sama, terutamanya dalam perniagaan makanan, sektor perindustrian menumpukan usaha mereka pada peningkatan prestasi. Sistem pengukuran merujuk kepada keupayaan proses untuk menyediakan produk atau perkhidmatan berkualiti tinggi yang memenuhi piawaian pelanggan. Isunya ialah banyak perusahaan pembuatan kecil dan sederhana sedang bergelut untuk memuaskan hati pelanggan mereka sambil mengekalkan tahap kualiti produk yang tinggi. Untuk meningkatkan kualiti produk, objektif pertama penyelidikan ini adalah untuk mendedahkan isu-isu kualiti produk yang berkaitan dengan kaedah pengukuran. Sebelum memulakan kajian ini, kajian literatur menggunakan teknik GR&R telah dijalankan untuk memperoleh data dan menukarnya kepada pengetahuan. Apabila membangunkan istilah kolektif pada sistem pembuatan, adalah perlu untuk mengumpul data pengeluaran daripada industri makanan terpilih sebagai kajian kes sebenar. Selain itu, objektif kedua kajian ini adalah untuk melaksanakan GR&R bagi meningkatkan kualiti produk dalam perniagaan makanan dan minuman melalui kestabilan. Akibatnya, pengumpulan data adalah penting untuk penyiapan kajian. Temu bual dijalankan, gambar diambil, dan data ukuran dimasukkan ke dalam hamparan. Objektif utama kajian ini adalah untuk mengesyorkan aktiviti penambahbaikan berdasarkan penemuan daripada analisis sistem GR&R. Analisis dilakukan dengan menggunakan data yang telah dikumpul. Analisis ini perlu untuk menilai sama ada sistem pengukuran dipengaruhi oleh Variasi Penilaian (AV) atau Variasi Peralatan (EV). Selain itu, GR&R digunakan untuk memutuskan sama ada analisis itu sesuai atau tidak. Ini mengenal pasti elemen yang paling terkesan berdasarkan penilaian GR&R dan menggunakannya untuk membuat cadangan penambahbaikan. Idea ini dibincangkan dengan wakil industri serentak dengan pembentangan penyelidikan untuk penilaian.

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LIST OF SYMBOLS AND ABBREVIATIONS

GR&R	-	Gage Repeatability and Reproducibility
MSA	-	Measurement System Analysis
QA	-	Quality Assurance
QC	-	Quality Control
AIAG	-	Automotive Industry Action Group
GM	-	General Motor
AV	-	Appraiser Variance
EV	-	Equipment Variance
PV	-	Process Variation
TV	-	Total Variance
NDC	-	Number of Distinct Categories
K	-	Constant
UCL	-	Upper Control Limit
LCL	-	Lower Control Limit
EMP	-	Evaluating the Measurement Process
F&B	-	Food and Beverage
DMAIC	-	Define, Measure, Analyze, Improve & Control
SIRIM	-	Standard and Industrial Research Institute of Malaysia
Sdn. Bhd.	-	Sendirian Berhad
Mardi	-	Malaysian Agricultural Research and Development Institute
FAMA	-	Federal Agricultural Marketing Authority

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CHAPTER 1

INTRODUCTION

1.1 Research Background

In this technological era, the quality of a product is very important to satisfying and retaining their customer's trust in the product. So, when customers get a good product, they will return, make a repeat purchase and recommend it to others. In order to achieve a good product, a good measurement system must be emphasized. Al-Refaie et al., (2010) stated that to assess the precision and quality of goods, a variety of measurement methods have been developed, with the majority of them focusing on the total variance of measurement, also known as measurement uncertainty. In other words, to produce high quality product, variety of measurement method must be concern to ensure the productivity by the manufacturer.

Parts are weighed in certain production processes to ensure that such standards are met. These measures, however, can be deceiving if the measurement method is inadequate (Cox et al., 2013). The measurement instruments, appraisers, objects measured, and the measuring atmosphere may all contribute to measurement errors. Thus, this issue will lead to poor quality of product then will drop the production demand. In this sense, gauge variability is critical for quality improvement since the adequacy of a product's measurement process can only be calculated with a gauge that has reasonable repeatability and reproducibility.

1.2 Problem Statement

A good measurement system determines the product quality in the manufacturing company. A stepwise decision is the key to success to have a smart measurement system. Therefore, in a manufacturing factory, they keep on using Measurement System Analysis (MSA) to improve their manufacturing system. MSA is a comprehensive examination of a measurement process that usually involves a specially designed experiment to determine the sources of variance in the measurement process (Yeh & Sun, 2013). MSA also is one of the quality control methods that examines a set of instruments, processes, methods, software, and personnel that influence the assignment of a number to a measurement attribute.

Nevertheless, as technology advances, many small and medium manufacturing firms are finding it difficult to satisfy their consumers while maintaining high product quality. To help them thrive in this competitive society, they must keep evolving and improving especially in the measurement system to make it more productive and smoother. An evolving method exposes manufacturing companies to a certain amount of risk.

Until launching the new management, it's critical to ensure that the new system's enforceability generates a profit for the business. Therefore, the Gage Repeatability and Reproducibility (GR&R) is the best way in measurement system in enhancing the quality of the product in the manufacturing industry. GR&R can be used to determine the degree of uncertainty within a system of measurement and is an appropriate tool for gauges or instruments used to collect variable continuous data.

1.3 Research Question

Three research issues have been defined as a result of the problem statement.

RQ1: How to improve product quality in food and beverage industry?

RQ2: What are the method used in order to solve product quality?

RQ3: How GR&R helps in making sure that the measurement system process are stable and precise?

1.4 Research Objective

The main goal of this case study is to improve product quality through stability in manufacturing industry by using GR&R measurement system. This project has a set of underlying objectives:

i) To identify product quality issue that related to measurement system.

ii) To conduct the GR&R in order to enhance product quality through stability in food and beverage industry.

iii) To propose an improvement activity based on GR&R system study.

1.5 Research Scope

This study will focus on performance measurement or called the measuring system in manufacturing production. The primary task is to enhance the quality product of the measurement system in the industry. Gage Repeatability and Reproducibility is an approach for determining the amount of variance in measurement data caused by the measuring system. Therefore, the average and range method is used in this study to do the improvement of the product quality in the manufacturing industry.

1.6 Expected Result

The expected result for this study is to identify the factors that have an effect on product quality as a result of GR&R measurement system. After define and have solutions in ameliorating the production control, validate new ideas of improvement via GR&R system study. After done substantiation, present the improvement activity to the manufacturing industry. This study helps to gain an opportunity to apply the knowledge and study in a real case. This is a good chance to get the experience apart from learning in the school.

This study helps to determine the measurement system that used in the industry. Based on the measurement analysis system in the manufacturing industry, identify the weakness of measurement analysis then do the improvement based on the finding. Apart from these, the expected result for this study is to enhance quality product using GR&R system through stability to the manufacturing company.

1.7 Thesis Frame

The first part of the chapter is devoted to its introduction. This chapter describes the research history that informed this report. In this chapter, the study's problem statement is discussed. Following that, the research issue is developed based on the three problem statements. While from the research question, the research objectives are also written down in this chapter, and yet the research scope also explained in this chapter by using K-chart. This study's expected outcome as well as the thesis framework are mentioned. Finally, in this chapter, the study's description is presented.

Next, the second chapter is all about preparing the study's literature review. In this chapter, all the related knowledge about this study which are product quality, Measurement System Analysis (MSA), measurement variation and Gage Repeatability and Reproducibility (GR&R) were found and read to prepare the writing of this chapter. Method of writing this chapter is finding the past journals and articles, gain information from these past journals and articles. Then write down the finding knowledge to this chapter topic by topic. Therefore, in this chapter, there will have many subtopics and each topic is relating to this study.

Moreover, in chapter three, the methodology launch in this study is implemented. In this chapter, the tools and techniques were defined and had the guideline on doing this study. The tools and techniques will give a detailed explanation in this study. The problem-solving techniques are also explained in this chapter.

After that, chapter four will show the result and discussion of this study. In this chapter, the tools and techniques explained in chapter three will be used in this study. Further information on applying the tools and techniques is described. Next, the result of using these tools and techniques will be discussed in this chapter. The discussion will base on the findings result and achieve the objectives of this study.

Lastly, in chapter five, the conclusion of this study will be implemented. In this chapter, the finding of the entire study will summarize in this study. The improvement of this study will present. The future proposals on enhancing the quality of product through stability are presented. The enhancement will illustrate and the overall conclusion is written in this chapter as concluded in the thesis.

1.8 Summary

To summaries, for a manufacturing company to produce high-quality products, continuous improvement, especially in the measurement system, is important. Measurement System Analysis (MSA) will help the improving measurement system more stable and accurate. Besides, the stability to conduct the measurement system are important to enhance the quality and productivity of the product of the company. The implementation of MSA such as GR&R technique is one of the solutions to improve the quality of product become well. The aim of GR&R is to improve measurement equipment efficiency. This technique is also used as a criterion for evaluating new measurement instruments.

CHAPTER 2

LITERATURE REVIEW

2.1 Preliminaries

Nowadays, manufacturers are constantly working to improve the quality of their products and processes, as well as to minimize part variation. Every production process contains some degree of variation. One of the key goals of manufacturing industries is to achieve good product quality (Papadimitriou et al., 2009). Controlling the stability of production processes is crucial in achieving these conditions. Assigning a tolerance range to their print dimensions is a standard way that many design engineers employ to deal with variance. Unfortunately, there is some fluctuation in all measurement data. The gap between real and observed values is referred to as variance. The variance represents the level of measurement imperfection.

In addition to measurement imperfection, there is the premium product or process volatility. The GR&R's purpose is to determine how much of the overall process variation is caused by the measurement system and how important it is in relation to part-to-part variation (Hawary et al., 2019). According to Bottani et al., (2021) was defined reproducibility is the variability caused by different operators using the gauge (or, more generally, various settings), and repeatability as the gauge's basic intrinsic precision.

2.2 Quality

As explained by Ma et al., (2017) defines the sum of various interconnected properties such as design, measurement, composition, durability, craftsmanship, adjustability, finishing, and color constitutes product quality. Similarly, Quality (2015) defined the amount through which a product satisfies specifications as well as craftsmanship requirements. Those definitions make it apparent that quality refers to a product's different features and their excellence. Quality is a subjective definition that has never been ideal and also is defined either by the original purpose of the products as well as the conditions under which it is used (Bhakhri & Belokar, 2017). All things related to quality are product quality, quality control, and quality assurance.

2.2.1 Product Quality

In general, whether the product satisfies the customer or client, it is said to be of satisfactory quality. Customers will indeed consume services or products if they fulfill their requirements. As a consequence, the marketing department initially analyses customer's demands before making a quality selection based on the statistics obtained. Product quality is a benefit that a product or service should provide to a potential customer (Suchánek et al., 2014). Similar to Hoe & Mansori (2018), in the manufacturing industry, product quality is crucial for maintaining competitiveness and providing remarkable customer service. Product quality refers to the incorporation of functionality that can satisfy consumer demands and provide customer loyalty by enhancing products (goods) and removing any flaws or defects.

In addition, Runje et al., (2017) found that more comprehensive idea of quality, which incorporates all of a product's or service's qualities and qualities. This may have an impact on its ability to achieve specified targets or implied customer requirements. It is possible to assume that quality is a critical factor that customers consider when evaluating goods or services. As a consequence, it's everybody's responsibility in a firm should fulfill the total demands of every customer. Regardless of who that customer is, which again is inspired by market considerations such as competitiveness and, most significantly, the customer.

Quality is defined as a product's ability to perform following the producer's promise to the customer. Such a commitment might be communicated directly or indirectly, for example, in a written agreement or terms of the quality control criteria of the typical product consumer. As identified by Crosby (1979), product quality is defined as conformance to a requirement or specification. Product output is concerned with the ultimate purpose and service that the product must provide to the final ways which are customers.

2.2.2 Dimension of Quality

Garvin (1996) proposes that eight dimensions for investigating product quality which are performance, features, reliability, compliance, durability, serviceability, aesthetics, and product attributes. Garvin's eight-dimensional framework had been initially published in 1984, but its importance in determining product quality is obvious, as proven by its continuous usage in this industry.

Pereira (2008) investigated that the impact of integrated quality control techniques on a firm's product quality in a study. The "product quality" construct was measured using four of Garvin's measurements (performance, reliability, conformance, and durability). The dimension of quality as shown as in figure 2.1.

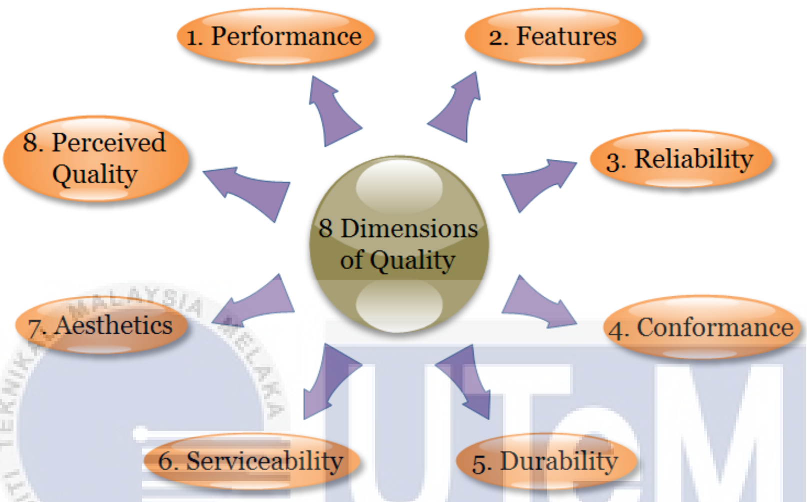

Figure 2-1: The 8 dimensions of quality (Bottani et al., 2021)

2.2.2.1 Performances

Performance is related to a product's key operational characteristics. Garvin (1996) showed that trademarks may usually be features offered on individual aspects of results since this dimension of quality comprises quantitative features. Overall performance rankings, on the other hand, are more impossible to create, particularly since they include benefits which were not necessary by those customers.

Similar to Pereira (2008), customers and suppliers frequently disagree over performance, especially when outcomes are not precisely stated within specifications. Although certain quality criteria are based on personal preferences, they influence an objective norm due to the universality of the preferences. Thus, a product's success has a significant impact on the end-profitability user's or credibility. As a result, many deals or specifications include clauses that provide for compensation in the event of poor performance.

2.2.2.2 Features

Features, the second pillar of quality that is sometimes overlooked in favor of efficiency, can be tackled in the same way. It is hardly important to recognize between primary and secondary output features. Although this dimension will seem to be self-evident, performance requirements seldom describe the features that a product must have (Pereira, 2008). As a result, manufacturers producing performance-based products or services must be conversant with the intended applications and retain close connections with end-users.

Here, features must have objective and observable characteristics. As a result, objective individual needs, rather than biases, influence their transformation into quality disparities (Garvin, 1996). Better quality, in the perspective of many consumers, refers to the overall number of options offered rather than the presence of specific characteristics.

2.2.2.3 Reliability

Pereira (2008) pointed out that most end-users regard reliability to be a basic feature of quality, and it contributes greatly to a brand's or company's profile. This indicator measures the chance of a good or service malfunctioning or performing poorly within a certain time range. The time to first breakdown, the average duration of errors, as well as the error rate per time unit is three of the most important reliability indicators.

Performance and dependability may be linked. For example, a product specification can include uptime or failure rate requirements. Because they allow a product to be used for a specific amount of time, these techniques are more appropriate toward long-lasting things than to products or services that are utilized on a regular basis. When downtime and maintenance become more costly, customers place a higher value on reliability (Garvin, 1996).

2.2.2.4 Conformances

Conformance, or perhaps the amount to which a product's design and technical specifications adhere to current norms, is a related component of quality. This measurement contributes even more to the management systems of the preceding generation (Hoe & Mansori, 2018). These requirements are typically portrayed also as purpose or "center," with departure again from center allowed within a certain range. Furthermore, because this methodology to conformity equates reasonable performance with operations within an acceptable limit, there seems to be no emphasis on exactly satisfying requirements. Most of the time, distribution within specified limits is neglected.

2.2.2.5 Durability

The terms "warranty" and "durability" are often used interchangeably. Pereira (2008) highlights that procurement contracts and specifications frequently contain durability requirements for products. Durability has always been a metric that measures both the industrial and cultural elements of a product's life. Longevity, in technical terms, relates to how long a product may be used before it deteriorates.

There are two significant consequences of this approach to durability. For starters, it indicates that dependability and durability are interchangeable terms. A product that breaks frequently is more likely to be rejected early than one that is more trustworthy, resulting in increased maintenance costs and the acceptance of buying a competing brand. Second, figures concerning durability should be taken with caution as a result of this method. Technical advancements or the use of longer-lasting products may not be the cause of an increase in product life. As identified by Garvin (1996) instead, the fundamental economic climate may have changed.

2.2.2.6 Serviceability

The sixth dimension of performance is serviceability. Pereira (2008) expressed the opinion that serviceability (together with reliability) is becoming a more important factor of quality and criterion for product selection. It has the same sense as speed, courtesy, competence, or serviceability.

Investors are aware not just about the failure of a product, but also about the time it takes to restore service and the punctuality with which service appointments are held. The quality of interactions with service workers, as well as the frequency with which service calls or repairs fail to resolve existing issues, are all factors that contribute to serviceability.

2.2.2.7 Aesthetics

Aesthetics is the most subjective of the quality dimensions. A product's aesthetics refers to how it looks, feels, plays tastes, or smells. It's simply an issue of self-preference and opinion. Because of aesthetics, the way a product looks is also incredibly important to end-users. The aesthetic aspects of a product lead to the identity of a company or brand. Pereira (2008) also wrote that defects or errors in a product that deviates from its aesthetic features but do not alter or change other quality of a product are frequently used as reasons for rejection.

2.2.2.8 Perceived Quality

Since customers may not always have complete information about a product's or service's attributes, indirect measurements may be the only method for them to evaluate products. Reputation is the backbone of perceived quality. Its power originates from an unspoken connection that today's product quality is equivalent to that of yesterday's product (Garvin, 1996). Furthermore, the commodities in a new product line have the equivalent quality to the company's existing products. Pereira (2008) confirmed that despite having adequate or even superior quality dimensions, a product or service can still struggle from negative consumer or public expectations.

2.2.3 Quality Control and Quality Assurance

A technique of procedures used to verify that a produced product or service fulfills a set of quality standards customer's needs is known as quality control (QC). Joubert & Meintjes (2015) maintained that quality control is the systematic management of the factors in the production process that influence the quality of the end product.

Xiang et al., (2017) also agreed that quality control encompasses all efforts aimed at recognizing, monitoring, and keeping quality. Quality control is comparable to quality assurance, but it is not identical. Quality assurance refers to the assurance that defined specifications have been satisfied by a product or service, whereas quality control refers to the actual inspection of these products.

During the production process, quality control refers to the monitoring of a product's quality. It aims to get a product to a predetermined standard of quality (Bhakhri & Belokar, 2017). QC, in other words, is concerned with minimizing the negative deviations that eventually affect a manufacturer's capacity to produce high-quality goods. The systematic management of factors in the production process that influence the end-quality goods is known as quality control (Quality, 2015). Suchánek et al., (2014) also found that quality control is an element of quality management that ensures that quality requirements are met. Quality control is mainly concerned with the inspection component of quality management, whereas quality assurance is concerned with how a process or a product is worked out.

Quality assurance and control (QA/QC) is a term that combines the terms quality assurance and quality control into a single word. Quality assurance is an element of quality management that ensures that quality specifications are satisfied. QA gives confidence to management on the inside, as well as investors, policymakers, authorities, certifiers, and other parties on the outside. As an alternate idea, all the planned and systematic practices conducted inside the quality framework can be proved to ensure that a product or service will meet quality standards.

2.3 Measurement System Analysis (MSA)

The method provided here is focused on the measurement system analysis (MSA) philosophy, which is an important tool in quality control engineering. It's frequently used to verify that data collected by measurement systems are of high quality. As explained by Yang et al., (2020), MSA is a systematic tool for evaluating the components of variation in the accuracy and precision evaluations of measuring equipment utilized in a meet required. Therefore, it appears obviously by using good system measurement will improve the quality of the product. Hence, many manufacturing industries will use this type of measurement system to achieve better production.

Based on the idea of Cox et al., (2013) with the multiple challenges that may arise during the manufacturing of high-tech, function-oriented, and ultra-precision commodities, the accuracy of measuring equipment has garnered increased attention from researchers. It means that this measurement system is very in high demand for most manufacturers today.

Thus, Jain (2017) claimed that stats and statistics were used by measurement system analysis (MSA) to carry out a basic experimental design, statistical analyses of measurement device error, evaluates difference measuring instrument and on-site inspector’s work. To sum it up, a good variety of system measurements will lead to produce high-quality product standards in manufacturing.

Table 2-1: Methods for evaluating measuring systems (Kuo & Huang, 2013)

Method / Item	Calibration	Measurement system analysis (MSA)	Correlation
Sample selection	Standard item could refer to international standard.	Sampling the actual product	Customer specified or customer and manufacturer agreed standard items
Measured result	International standard is available	Acceptable deviation and variation	Measurement consistency of the same sample with different measuring instruments
Measuring environment	Controlled laboratory	Manufacturing environment	Manufacturing environment
Method of judgment	Errors within 1/10 of measurement tolerance	Based on the AIAG MSA manual	Customer specified error range or 1/10 of measurement tolerance

2.3.1 Variation Measurement System Analysis (MSA)

MSA is specifically concerned with the differences in a measurement method. The two forms of variations are place variations, which represent the precision of a measurement system, and width variations. It represents a measurement system's precision.

Position variations include things like linearity, bias, and stability. Repeatability and reproducibility are two characteristics of width variations. Bias is the difference between their predicted expected value and the reference value. The term "stability" refers to the changes in bias over time. Ma et al., (2017) pointed out that linearity in measurement equipment refers to the maximum variance of bias within a gauge's operational range.

The purpose of measurement system operating systems is to determine what these differences are and whether they make the system of measurement capable (Aparecida et al., 2020). Whether it's related to the measuring equipment, the worker, or the nature of the component being tested, we may reasonably conclude that variance in measurement systems is natural.

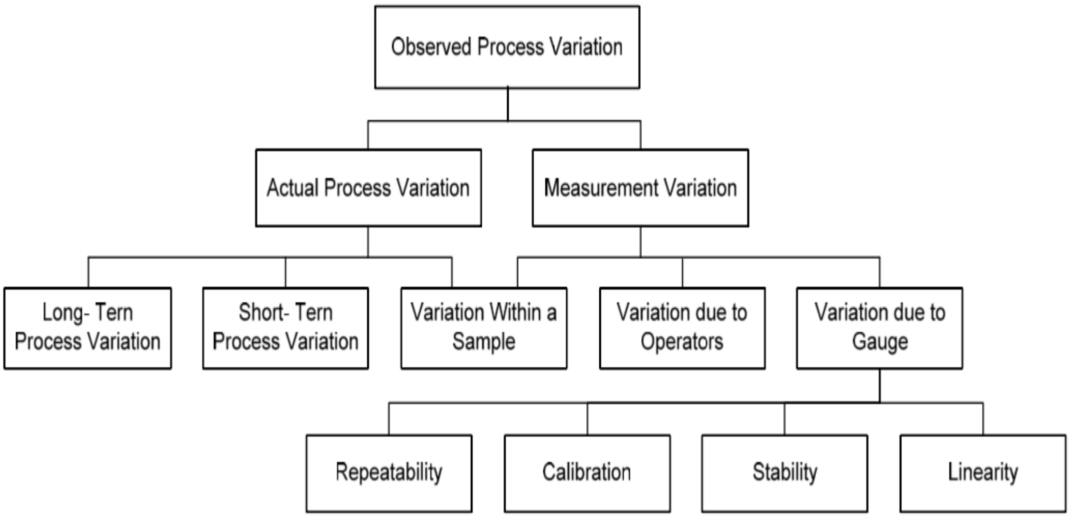

Figure 2-2: Analyses of process variation (Kuo & Huang, 2013)

2.3.1.1 Bias of Position Variation

Bias is defined as the difference between the obtained measurement average and the reference value. The recognized reference value, also known as the master value, is a value that is used as a standard for measuring values. A reference value can be calculated by averaging many samples with higher-level measurement equipment.

2.3.1.2 Stability of Position Variation

Stability refers to the total variation in measurements acquired with a measuring instrument (or drift). When measuring a single attribute, it's on the same master or section. It's often over a long period of time. Instrument aging, instrument calibration, and environmental drift are all potential causes.

2.3.1.3 Linearity of Position Variation

The linearity of a measurement system is a measure of how the size of the component influences the bias of the system. It's the difference between the observed bias values and the predicted measurement range.

2.3.1.4 Repeatability of Width Variation

Measurements taken with the same measuring tool by the same appraisers several times while measuring the same qualities on the same parts are referred to as variation. Common cause variation (random error) and within-system variation are two types of repeatability variation. Within-part variation, within-instrument variation, and within-appraisal variation are all potential causes.

2.3.1.5 Reproducibility of Width Variation

It is a variance measurement of different appraisals done with the same measuring instrument. When assessing identical properties on the same part, this method is utilized. The sort of repeatability variation, in this case, is an average variation amongst systems. This is especially true for manual devices that are influenced by the operators' abilities. The possible cause includes between-method variation and between appraisal variation.

2.4 Gage of Repeatability and Reproducibility (GR&R)

Measurement errors can be caused by a variety of factors, including assessment tools, measuring workers, measured products, and the measuring surroundings. Pan et al., (2015) hypothesized that without an accurate measuring method in estimation, inspection, and tracking, measurement data becomes unreliable, resulting in inaccurate assessments of process capabilities.

Thus, this problem will lose in terms of time, cost, and quality itself. GR&R research aims to quantify measurement errors (Peruchi et al., 2013). It seems that focusing more on measurement error is the best way to improve measurement accuracy.

Pan (2004), indicated that three assessment approaches are widely used in industry and academia to research GR&R. Pan (2004) also showed that employed anticipated mean squares to calculate the total variance of measurement, based on the concept of average and range. In the same way, Bottani et al., (2021) also suggested Classical GR&R as a second choice. Both of them were using this method to estimates the total variance of GR&R measurement using the mean and range, producing a standard deviation estimate for GR&R.

AIAG based on Cepova et al., (2018), they mentioned that three major American automotive firms, GM, Ford, and Chryler, established the Long Form concept outlined in the MSA manual. Hence, this approach was developed with specialists in mind rather than a statistical context, and it is used to estimate the overall measurement variance of GR&R as well as the precise valuation to tolerance (P/T) proportion. Overall, all these approaches are good enough to ensure the stability and the performance of the measurement.

Table 2-2: General proportions acceptable for precision width errors

(Cepova et al., 2018)

GR&R	Judgement	Evaluation
Less than 10%	it is generally considered as an acceptable measurement system	It is recommended when process reinforcement is required for arranging or classifying parts
10% -30%	It is considered acceptable in some applications	The corresponding importance, cost of measuring devices and maintenance are taken into account for accepting the error; or, it should be agreed by the customer.
More than 30%	It is considered unacceptable.	Efforts should be made to promote the selection of the measurement system. Some appropriate measuring strategies can be applied to solve the problems, such as utilizing the average eigenvalue to lower the final change in measurement.

There has some formula that involved to do the research of GR&R.

1. Firstly, we need to know how each appraiser's average of ten ranges is calculated for Ra , Rb , and Rc . Then, using the formula below, calculate R and XDIFF:

$$\bar{\bar{R}} = (\bar{R}_a + \bar{R}_b + \bar{R}_c)/3 \tag{2.1}$$

$$\bar{X}_{DIFF} = Max\bar{X} - Min\bar{X} \tag{2.2}$$

2. The equipment variance (EV) is computed by multiplying the average range (R) by a constant to get the repeatability (K1). K1 is the inverse of d2, which is calculated using the MSA and is proportional to the number of trials utilized in the gauge analysis. D2 is calculated using the trial number (m) and the component number multiplied by the appraiser number (g) (Yeh and Sun, 2013). Subsequently, EV is determined using the formula:

$$EV = \bar{\bar{R}}\ x\ K_1 \tag{2.3}$$

3. K1 and reproducibility are computed by multiplying the maximum average appraiser difference (DIFF X) by a constant, and appraiser variance (AV) are computed by multiplying the maximum average appraiser difference (DIFF X) by a constant, according to the MSA manual (K2). K2 is the inverse of d2, which is determined by the number of appraisers used in the gauge analysis and is obtained from the MSA manual. D2 is based on the appraiser number (m) and g = 1 because there is only one range estimate. Because the appraiser variation is polluted by the equipment variation, it must be altered by subtracting a proportion of the equipment variation (Yeh & Sun, 2013). Hence, AV is determined using the following formula:

$$AV = \sqrt{(X_{DIFF}\ x\ K_2)^2} - (EV)^2/(n\ x\ r) \tag{2.4}$$

4. The equation for determining the GR&R of a measurement system based on repeatability and reproducibility is:

$$GR\&R = \sqrt{(EV)^2 + (AV)^2} \tag{2.5}$$

5. To calculate the process variation (PV), multiply the mean of the sample parts by a constant (K_3). K_3, which is the inverse of d_2 in the MSA manual, is determined by the number of sample pieces used in the calculation. d_2 is determined by the number of appraisers and the number of sub-sets, as shown in the formula:

$$PV = Rp\ x\ K_3 \tag{2.6}$$

6. To calculate the process variation (PV), multiply the mean of the sample parts by a constant (K_3). K_3, which is the inverse of d_2 in the MSA manual, is determined by the number of sample pieces used in the calculation. d_2 is determined by the number of appraisers and the number of sub-sets, as shown in the formula:

$$TV = \sqrt{(GR\&R)^2 + (PV)^2} \tag{2.7}$$

7. The percentage of %GR&R in the total variance is given by the formula:

$$\%GR\&R = GR\&R/TV\ x\ 100 \tag{2.8}$$

8. Finally, make sure the measurement system's NDC (Number of Distinct Categories) is accurate. The number of categories of measured values that may be consistently distinguished is known as the NDC. It measures the number of times the gauge repeatability and reproducibility GRR fits within the real process variance. Hoffa & Laux (2007) demonstrated NDC is the number that includes the 97 percent consistent interval that is not filled by projected product variance, as in the formula:

$$ndc = 1.14 \, x \, (PV/GR\&R) \tag{2.9}$$

2.4.1 Gage

The term GR&R (Gage Repeatability and Reproducibility) refers to a gauge's repeatability and reproducibility. It's a tool for determining the repeatability and reproducibility of a measurement device. GR&R tests are carried out to see how much of the variance in the process is related to the measuring method (Bhakhri & Belokar, 2017).

In this case, a gage is a measuring instrument. A gage or gauge might be anything as plain as callipers and a ruler. It may also be a complicated piece of equipment. It's also possible that it's a piece of software. There are two components that are involved in gage. Precision in a measurement system is made up of two components: repeatability and reproducibility. Using a GR&R analysis (Stat > Quality Tools > Gage Study) to determine repeatability and reproducibility (Fabrício Alves de Almeida et al., 2018).

2.4.2 Repeatability

The variance caused by the measurement technique is known as repeatability. It refers to the variance that occurs when the same operator tests the same component several times with the same gage and under the same conditions. In other words, repeatability refers to the difference in measurements taken by the same individual using the same gage on the same component or characteristic (Ramana, 2016). The repeatability of the measurement system can be measured by measuring the component many times, and the gauge's variability is the source of the measurement system's variability (Asplund & Lin, 2016).

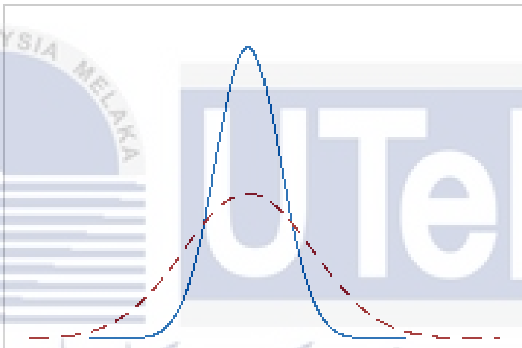

Figure 2-3: Repeatability in Minitab software (Bower & Touchton, n.d.)

2.4.3 Reproducibility

The variability caused by various operators measuring a component multiple times, different gauges, and changes in the environment can all be used to assess reproducibility (Asplund & Lin, 2016). Reproducibility is the variation due to the measurement system. It's the variance that occurs when several operators calculate the same component with the same gauge under the same conditions.

Based on the ideas of Ramana (2016), reproducibility is the difference mean of measurements obtained on the same component by various people using the same instrument when evaluating the same aspect.

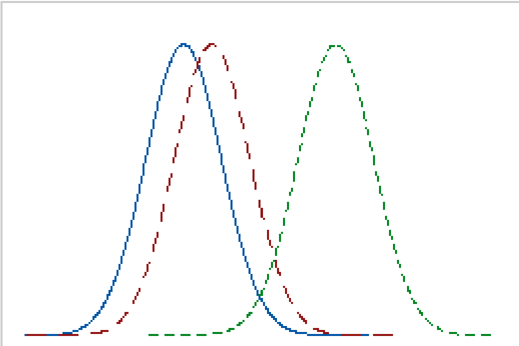

Figure 2-4: Reproducibility in Minitab software (Bower & Touchton, n.d.)

2.4.4 Relationship Between Repeatability and Reproducibility

Any industry that uses measurements can conduct repeatability and reproducibility studies. Pan (2004) investigated that the sealing technique used in the manufacture of high-resolution microscopes in Taiwan and discovered that it was repeatable and uniform. Joubert & Meintjes (2015), veterinarians, discovered that using ultrasound methods to calculate muscle thickness in horses is repeatable and reproducible. Hoffa & Laux (2007) found that latent fingerprint examiner conclusions were consistent and repeatable. In the field of chemical engineering, Cepova et al., (2018) also mention that the repeatability and reproducibility of two-chambered experimental microbial fuel cells.

Repeatability, also known as machine, variance or gauge error, is the error that happens as a result of the measurement system. It's calculated by comparing the measurements of one operator using the same measurement method and parts multiple times under the same conditions (Joubert & Meintjes, 2015).

Reproducibility refers to the error that happens as a result of the operator, also known as operator variance or failure (Pan, 2004). Operator error occurs when they do not receive enough instruction in how to use the measuring method or do not obey the basic protocols that have been explained to them (Joubert and Meintjes, 2015).

2.4.5 Method to Perform GR&R

GR&R can be accomplished using one of three approaches. In GR&R, there are three methods which are range method, average and range technique, and analysis of variance technique. The range method computes measurement device repeatability and reproducibility separately, but it does not provide a quick estimate of measurement variability. The average and range approach, on the other hand, provides repeatability, reproducibility, and component variance while characterizing the variability of the measuring system. The average and range approach can only be used for crossed GR&R.

The analysis of variance approach is the most widely used and trusted approach for verifying a device's repeatability and reproducibility. It also assesses the operator's variability in interaction with the equipment. The average and range can be used to perform GR&R (crossed, nested, and expanded). GR&R measures the amount of variation in measurements caused by the measurement equipment itself. Next, relate this variability to the overall variability to determine the true variability of the measuring system. Ramana (2016) explained that GR&R is crucial when new staff are assigned, new procedures are used, or big process changes occur.

2.5 Gage of Repeatability and Reproducibility Study Type

Crossed, nested, and expended are the three forms of GR&R. Each one has a distinct purpose. The amount of data provided and whether the measuring test is damaging decide which type of GR&R analysis should be performed.

2.5.1 Crossed GR&R Study

Each operator in this analysis calculates each component. The analysis is termed crossing because an operator tests the same components the same number of times. to perform an R&R study using crossed gauge To assess the analysis, go to Minitab's start menu and select quality tools. To determine how much of the current process variable is due to measurement instrument variation, GR&R studies with crossed gauges are typically used.

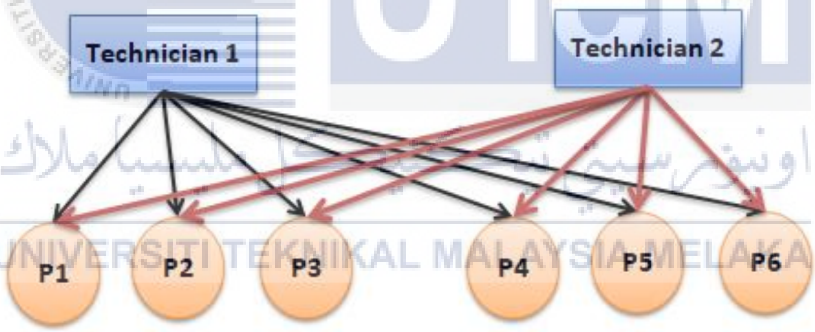

Figure 2-5: Crossed Study GR&R (Ramana, 2016)

2.5.2 Nested GR&R Study

Since the part are consumed by the nest, each part is weighed by a single operator. This research is referred to as nested since another factor nests one or more factors, resulting in the other factors not being crossed. To run a nested GR&R analysis in Minitab, repeat the steps above and choose GR&R from the drop-down menu (nested).

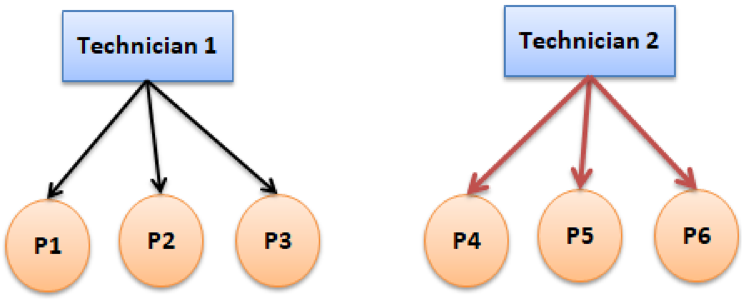

Figure 2-6: Nested GR&R Study (Ramana, 2016)

2.5.3 Expanded GR&R Study

Where there are more than two variables, such as appraisals, measuring instrument, and product, a study in which one or more of the following conditions are true. Then there will be a random or fixed factor. The design is then unbalanced due to both crossed and nested conditions. This research is referred to as extended since it can be seen in a variety of situations.

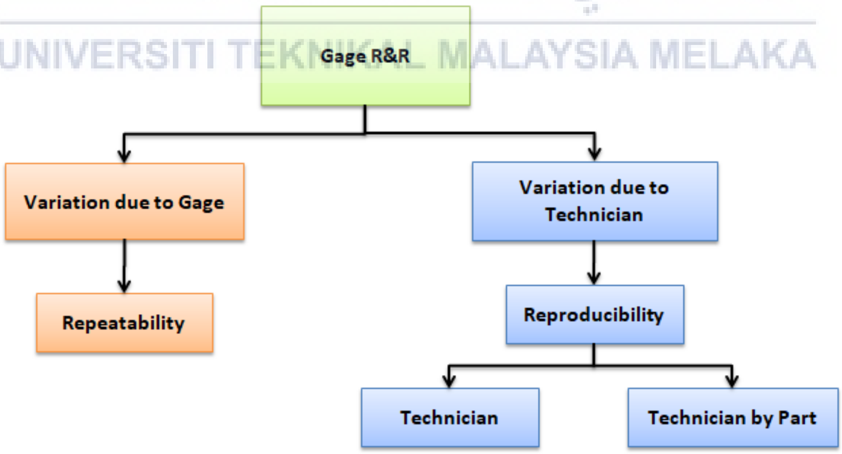

Figure 2-7: Expanded GR&R Study (Ramana, 2016)

2.6 Summary

In conclusion, product quality is referring to satisfaction for the customer that has been provided by product or service as mention by (Suchánek et al., 2014). In addition, the quality of a product means the ability to integrate functionality that can meet customer demand by enhancing products (good)s and eliminating any defects. To control the product quality, good measurement must be included. According to Yang et al., (2020), by using a systematic method which is MSA can identify the different components in accuracy and precision in measuring tools used in a measurement scheme.

Thus, variation in MSA must take note as well because there are several differences in a measurement method which are bias, stability, linearity, repeatability, and reproducibility. It means need to figure out what percentage of variation is due to the measurement method as quality professionals. GR&R is an example of determining a measurement system's capability. The repeatability of the equipment and the appraiser's reproducibility is examined in a GR&R analysis. Besides that, GR&R research aims to quantify measurement errors (Peruchi et al., 2013). Hence, it can more accurately forecast and analyze the complete measuring system.

CHAPTER 3

METHODOLOGY

3.1 Preliminaries

This chapter goes into the methodology used to achieve the study's goals in great detail. Moreover, methodological flow charts were created to map the sequence of the study from start to finish. This flow chart serves as a starting point for more data and knowledge research. In addition, each title's theory was interpreted in this chapter. Each title should be specific about how the approach would contribute to the project's success. Furthermore, the dominant theory makes it easy to choose an appropriate method or tool for this analysis.

Prominently, the data collection method will be discussed in this chapter as it is important for obtaining the data needed for this chapter. The process for gathering data is determined by the instruments used and the information obtained from the observations that will be used in the data analysis. The data obtained from the sectors explicitly for this project will be used to evaluate and analyze data later. Finally, data is gathered from the manufacturing and assembly industries.

3.2 Design of Studies

The design of studies is a term that refers to the qualitative and quantitative analysis methods that are used to collect and analyze data. These approaches are aimed at achieving the set goals. In general, quantitative research is associated with numbers and statistics, while qualitative research is associated with theories and ideas. Using the interview and literature analysis methods, qualitative researches on exploring ideas and formulating a theory or hypothesis that is evaluated by explanation, categorization, and interpretation.

Quantitative research, on the other hand, focuses on concepts and theories that are evaluated by mathematics and statistical analysis using the case study approach. Figure 3.1 shows the design of studies for this research.

(i) Research approach

There are two main research approach in this research which is qualitative and quantitative approach.

(ii) Process

The process to do research included identification, verification and propose

(iii) Method

The way how the data will be collected.

(iv) Source

The collection of origin data from research.

(v) Size

The value of journals, company and time taken.

(vi) Research objective

Based on the objectives that have complete.

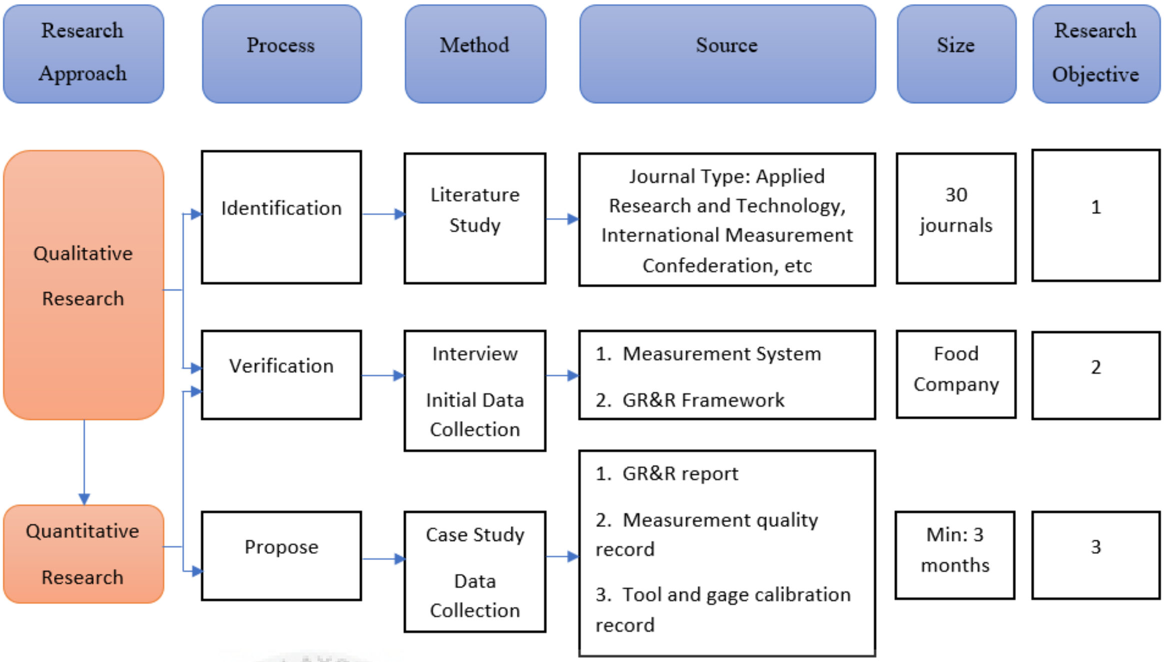

Figure 3-1: Design of Studies

3.3 Process Flow Chart

The detailed research methodology phase flow, which includes all of the steps to achieve the research goals, is depicted in Figure 3.2. The flowchart's purpose is to provide a structure for the project's activities. This method will also explain how the selected method and methodology should be used to complete the study's key to the task dimension. This flowchart is created based on problem issues in manufacturing assembly to get the solution.

The first step is to identify research problems and concerns in order to determine the root causes of manufacturing assembly process issues. The information from the literature review is encrypted in order to improve awareness of manufacturing assembly.

Second, the factors that influenced quality output are established. Following that, the data collection process is carried out in order to confirm all of the information found in the previous literature review. There are three techniques for collecting data: using Microsoft Excel spreadsheets, photographing a problem that occurs in the industry to collect data. All three methods can be used together.

The data is then analyzed to determine the solution in the measurement system. The result can be reached after gathering all of the data and performing some calculations. The next step is to analyze to see whether anything needs to be modified or replaced. Once the entire study has been completed, propose and submit the improvements to the panels and industry.

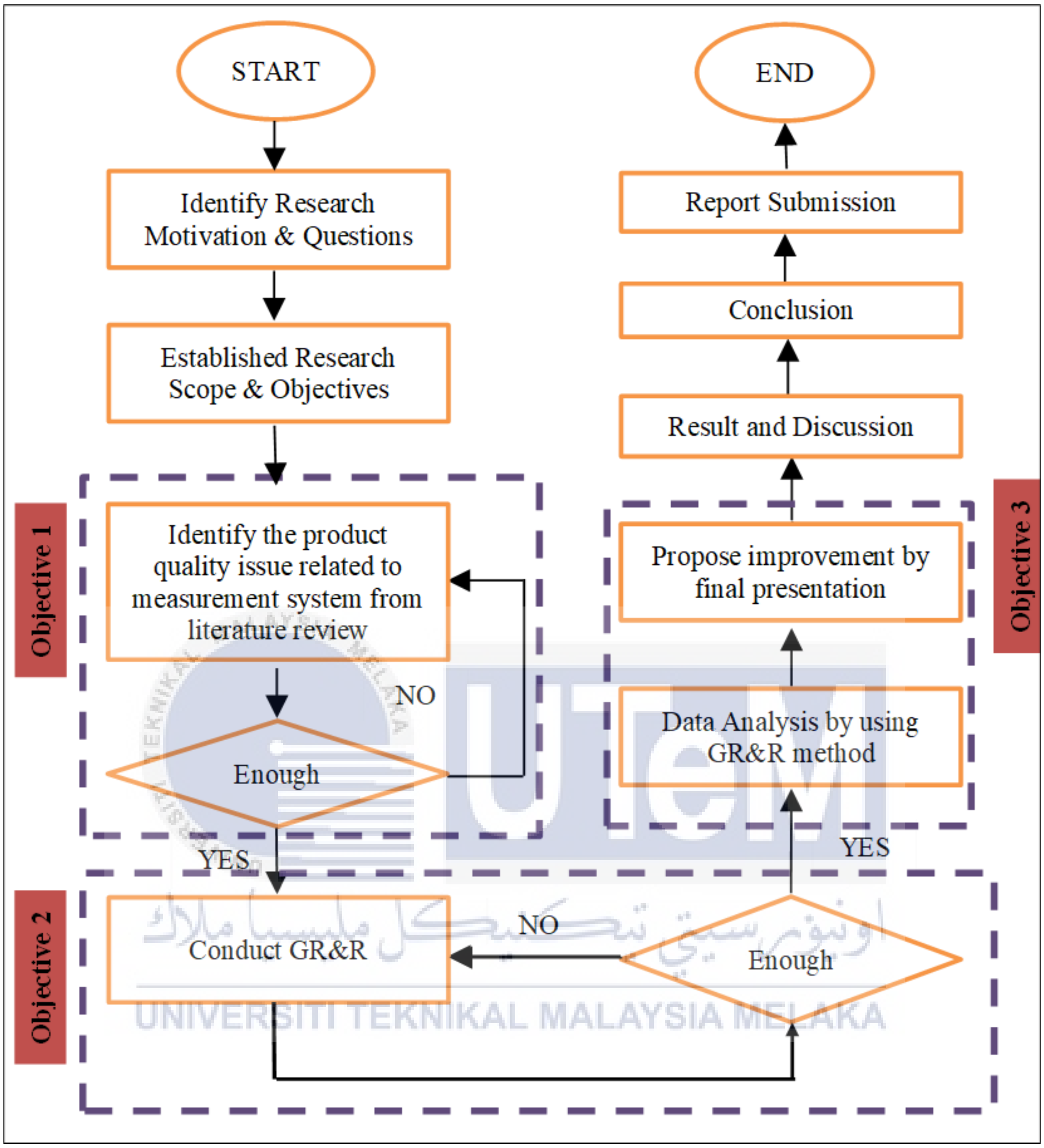

Figure 3-2: Detailed Process Flow of Research Methodology

3.3.1 Identify Research Problem and Question

The first step in completing this project is to establish a research problem and questions concerning the GR&R measuring system and how it relates to product quality in the manufacturing industry. This is the first step toward accomplishing the project's goal.

Depending on how it is implemented and whether it is appropriate for the related field, the current quality plan may have advantages and downsides. One of these projects will concentrate on the drawbacks of reducing the current quality issues. GR&R will strive to come up with a solution and recommendations on how to improve the quality of the product with GR&R.

3.3.2 Established Research Scope and Objectives

The next step is to identify the research scope and objectives, which entails expanding on the challenges that have been described and categorizing them into categories. Because the research scope and objectives are founded on the problems, establishing research scope and objectives comes after recognizing the research problems and questions.

Aside from that, create a research scope based on the problem identified. Reduce the issues to a specific subject and search for information depending on the scope. This makes performing the literature review easier because already know what to look for. Nevertheless, it also can be able to find more relevant and accurate information and save time by not having to guess.

3.3.3 Identify Product Reliability in ways Similar to Process Capability from Literature Review

The literature review is a summary of current research, such as journal articles or academic books, that was based on investigation and exploration. Its purpose is to obtain knowledge and information about the case study, and it can be used as a reference to strengthen the declaration of objectives. Furthermore, the literature review is a summary of other publications' compilations, and it may help research that is valid and relevant to this project's scope. Besides, to make task easier and more systematic, the Process Flow of Objective 1 is provided as shown in Figure 3.3. The first step is Search Journal from Sources which will be explained in the next session.

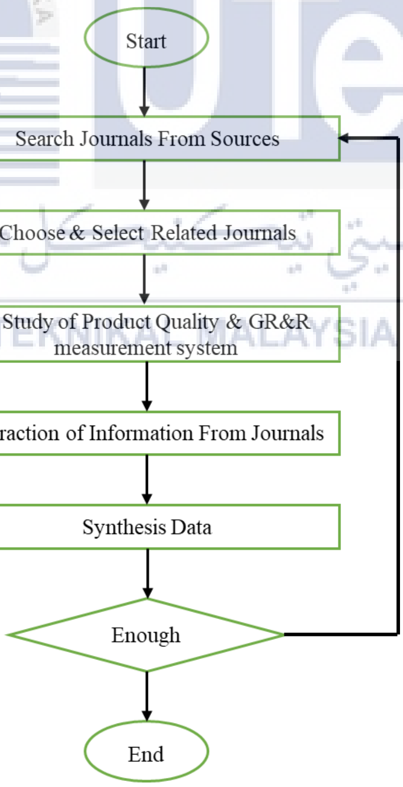

Figure 3-3: Process Flow for Objective 1

3.3.3.1 Search Journals from Sources

The literature studies target a maximum of 50 journals that published majority in the past 5 years. The journals that have been search focus especially on measurement system, product quality, industrial engineering and operation and production management.

3.3.3.2 Choose and Select Related Journals

The keywords of this project are a quality product, enhancement, and GR&R measurement. The main focus of the literature review is on how measuring system stability affects the quality of a manufacturing company's product. Aside from that, the literature review focuses on how the GR&R measuring system assists in improving product quality. In every industry's manufacturing system, achieving measuring system stability is important. It's because accurate measurements are essential for improving product quality. It assists in gaining an understanding of the strategies of appropriate measuring approaches in a system by examining associated articles.

3.3.3.3 A Study of Measurement System Analysis (MSA)

MSA is a method of determining how much variance the measuring system contributes. When using any statistical method that relies on data, it's critical to make sure the data collection systems are both accurate and precise. To examine the quality of measurement systems, a set of procedures known as "Gage Studies" is commonly utilised.

3.3.3.4 Extraction of Information from Journals

While GR&R is an example of a measurement methodology that aids in the effective production of high-quality products in manufacturing. The information concerning GR&R studies can help improve product quality and can be used to develop the proposal of employing the GR&R method.

After finishing the research, gather the findings, summaries, organize them, and construct them as a literature review. In the qualitative method, all of the obtained data is referred to as data analysis. The literature review is the first step in preparing for the actual case study. The literature study can help to gain a better understanding of the project before conduct the real case study, and it can also assist avoid issues.

3.3.3.5 Synthesis Data

Literature reviews outline the sources used to research a specific thesis and explain how the literature is applied to a larger field of study to readers. A theoretical framework is a strategy for assessing and methodically analyzing past research. As a result, a literary review gives a definition, synopsis, and in-depth comprehension of specific publications on the research topic under consideration.

3.3.4 Conduct GR&R Average & Range

The Process Flow of Objective 2 is provided as shown in Figure 3.4 below. The first step is Search Journal from Sources which will be explained in the next session.

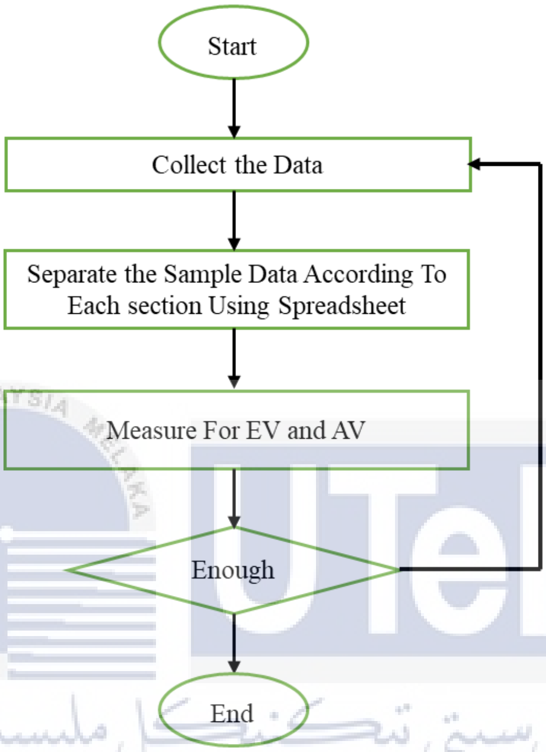

Figure 3-4: Process Flow for Objective 2

3.3.4.1 Collect the Data

Data collection is a strategy for gathering information from many sources, determining answers to research questions, putting scientific theories to the test, and evaluating the results. Furthermore, regardless of the research area, data gathering is the first and most important stage in each study.

The most important purpose of data collection is to obtain data that is both information-rich and accurate so that data-driven research decisions can be made. Daily production, monthly quality records, and tool calibration schedules were used to compile the data. In data gathering, there are two categories of data: (i) primary data, which is data that is not supplied by the organization or is self-compiled using current processes, and (ii) secondary data, which is data that is gathered or supplied by the organization.

i.Primary Data

Primary data is concerned with gathering qualitative information that cannot be counted. As a result, data will be gathered through interviews with industry practitioners and capture the measurement activity. The primary data will be obtained from the interviews, which will focus on the specifics of the measurement process.

ii. Secondary Data

Collecting quantitative data is what secondary data is all about. The accurate data of the industry, which is capturing the process input and output of the measurement process, is the primary focus data for secondary data. The prior record, such as monthly data and tool calibration, contributes to determining the production system's input and output resources.

3.3.4.2 Separate the Sample Data According to Each Section Using Spreadsheet

It is essential to get random data when doing a Gage R & R study. Multiple appraisers measuring the same set of parts in a random order is a typical procedure. It's standard to utilize two or three appraisers and five or ten sections. The goal of this study is to provide an example rather than an examination of the process.

Two appraisers or operators measured a set of 10 parts twice in random order and recorded the results in this investigation. The components were typical of the complete process output range. Digital calipers were used to obtain measurements for the study. Decimal inches are the measurement unit. Use the spreadsheet and capture photo to collect data to undertake additional studies. While the spreadsheet is often created with Microsoft Excel, the formula should be manually entered into Microsoft Excel. Table 3.1 illustrates an example of a Microsoft Excel spreadsheet.

Table 3-1: Microsoft Excel spreadsheet

DATA COLLECTION													
APPRAISER	NO. OF TRIALS / PARTS		1	2	3	4	5	6	7	8	9	10	GRAND AVERAGE
	OPERATOR A	1											
		2											
		3											
		AVERAGE (Xa)											
		RANGE (Ra)											
	NO. OF TRIALS / PARTS		1	2	3	4	5	6	7	8	9	10	GRAND AVERAGE
	OPERATOR B	1											
		2											
		3											
		AVERAGE (Xb)											
		RANGE (Rb)											
	NO. OF TRIALS / PARTS		1	2	3	4	5	6	7	8	9	10	GRAND AVERAGE
	OPERATOR C	1											
		2											
		3											
		AVERAGE (Xc)											
		RANGE (Rc)											

3.3.4.3 Measure for EV & AV

Equipment variation (EV) represents the repeatability of the equipment or measurement device. If the measurement result in the example is low, a high percentage, greater than 30%, would tell operators that they have issues with the measurement equipment itself that must be resolved. The gauge may need maintenance or perhaps the fixture holding the part for measurement is not adequate.

While Appraiser Variation (AV) represents the reproducibility of the system. A high percentage here, greater than 30%, indicates a large operator-to-operator difference. A possible cause could be operators not following proper measurement procedures, not being trained properly, or perhaps being trained in different methods.

3.3.5 Propose an Improvement Activity based on GR&R System Study

Propose Improvement is a process for determining all feasible ways to improve a system and making a recommendation to the current system. The goal of this study's improvement is to increase the manufacturing system's production smoothness. As a result, a quality product issue connected to the measurement system must be identified as part of the improvement process. Figure 3.5 below shows the Process Flow for Objective 3.

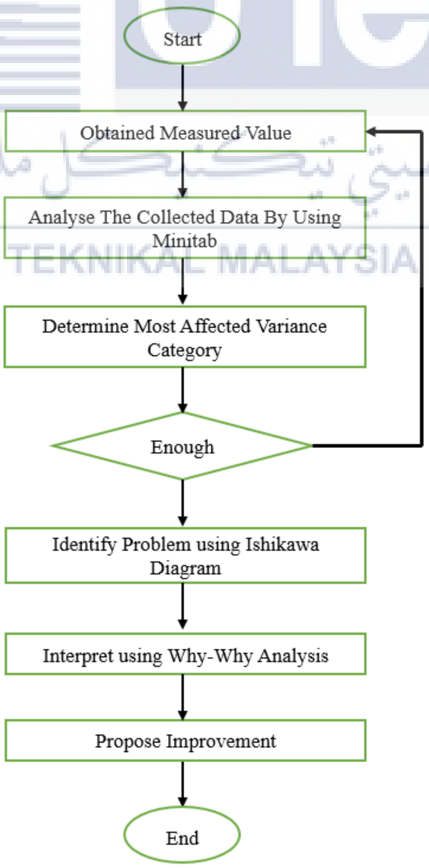

Figure 3-5: Process Flow for Objective 3

3.3.5.1 Obtained Measured Value

After calculating the data by using GR&R, make sure that values are being appropriately prepared. This method can also show the percentage of Total GR&R, which is vital to deciding whether the measurement is acceptable. It also will indicate the values of EV and AV to decide which more to contribute to the measuring quality problem. Next, the measurement data that has been recorded will be put in Minitab to do the Average and Range analysis under GR&R.

3.3.5.2 Data Analysis Using Minitab

Following data collection, data analysis is a continuous operation. The purpose of data analysis is to investigate the current situation, identify the issues, make improvements, assess the feasibility of the improvements, and put the suggested improvement actions into effect. As a result, data analysis is an important component of this research, which employs previously acquired expertise to identify, solve, and enhance the quality of a product. Figure 3.6 shows example of Minitab Software.

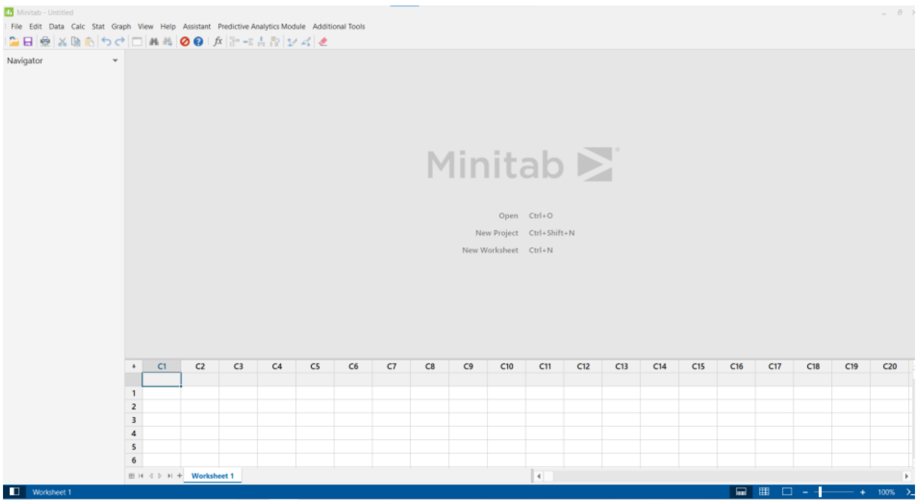

Figure 3-6: Minitab Software

3.3.5.3 Identify Problem using Ishikawa Diagram

A cause-and-effect diagram depicts the systematic relationship between a symptom of an effect and its likely causes. It is a helpful strategy for carefully creating and organising thoughts on the problem's causes. This tooling concept, often known as the Ishikawa Diagram, was developed by Dr. Kouro Ishikawa. Because of the overall structure's design, the tool is also known as the Fish-Bone Diagram, as the example illustrated in figure 3.7. In this case, the most effective improvement tool strategy for achieving customer satisfaction in manufacturing is to use a cause-and-effect diagram.

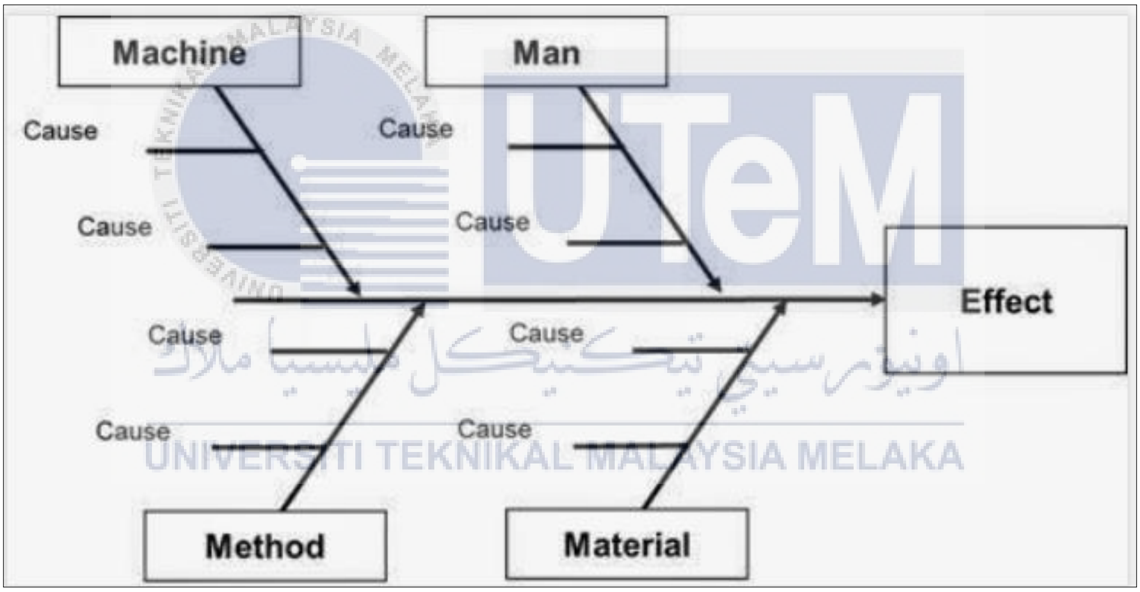

Figure 3-7: Ishikawa Diagram

3.3.5.4 Identify the Root Cause of Problem Using Why-Why Analysis

The Why-Why Analysis technique on process capabilities is one of the most efficient methods for identifying root causes in manufacturing. The Why-Why Analysis can be used to pinpoint the root cause of any problem and avoid a process from making the same mistakes and failing repeatedly. Even if the root of the issue is unpredictable, the Why-Why Analysis approach should go to the root of the problem and then solve it.

In actuality, what appears to be a technological difficulty turns out to be a human and process one. Therefore, the Why-Why Analysis method is a valuable and alternate technique to problem-solving. The primary goal is to determine the precise cause of an issue by asking a sequence of "why" questions, as illustrated in table 3.2 below.

Table 3-2: Example of why-why analysis template

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

3.3.5.5 Determine Most Affected Variance Category

It will already be able to detect differences in measurements. It also possible to pinpoint the fundamental cause of certain variances depends on the evidence. For example, if one thing is continuously larger than the others, it could be a manufacturing defect; if one tester frequently produces measurement errors, it could be a lack of ability; and if the errors are caused by a single machine or measuring device, you can pinpoint the source. However, the variations are likely to be inconsistent.

3.3.5.6 Propose Improvement

In this propose improvement section, it is to enhance the stability of GR&R measurement by suggested an idea or ways. It helps them to figure out and exposed to a better solution that could help them to improve their production of product quality to the next level. The improvement should be suggested through a final presentation to the industry.

Sometimes there are some suggested improvements which are not suitable for some company current condition regarding the limitation of cost, tools and operator's skill. Thus, they can choose whether to implement the proposed improvement into their production or request another method that appropriates with the capability of the company. So, by using Minitab software, it probably can helps to improve the product quality in better ways.

3.3.6 Result and Discussion

The results and discussion section demonstrates and examines the research's findings. The results will be discussed in this part, as well as how they relate to the Cp Cpk technique. Then, research to find a solution and techniques to tackle the problem will be discussed. Throughout this investigation, the process capability will be used to tackle difficulties that arise from this study. Furthermore, this section will demonstrate how the performance of the Cp Cpk approach is connected to the F&B industry.

3.4 Summary

In a nutshell, the methodology chapter of a research project is critical since it explains the project's detailed flowchart. This flowchart is really useful in a research project since it can make positive contributions in the step-by-step completion of the research and the avoidance of any misleading material that should not be included in the project's study. Study problem and questions, research scope and objectives, literature review, data collection, data analysis, and propose improvement are all items that should be included in the methodology.

The research problems and questions explain the issues that arise in the industries, leading to the researcher's investigation of a research project. Following that, the research scope and objectives must be provided in the project, as they are the elements that must be achieved at the end of the project. Besides that, a literature review is required because it can aid in gaining additional knowledge and understanding of the issues that must be covered to do the research. Then, in the quality control department, data collection and data analysis are used to collect any data and analyze the data from the measurement system. The spreadsheet and photos are used to gather data, and the GR&R method is performed to analyze the data.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Preliminaries

The case study for this project will be set up properly in this chapter based on the data acquired from the organization itself. The GR&R, in particular, will be clarified and used in this topic as a strategy to overcome difficulties that arise in the production of beverage drinks. Throughout the project, data analysis was used to suggest changes and effective approaches enhance the quality of their products.

For instance, the information was gathered through the use of primary data, the measurement value, and even interviews with high management and production employees. When all of the data has been collected, the study will be moved forward. The analysis helps to solve problems that reduce the variance of measurement in product quality by using Average and Range Method with Microsoft Excel.

Finally, the company would be advised to improve product quality in order to resolve the existing issue. This could be advantageous to the organization in terms of improving the beverage product. Finally, depending on their capabilities and requirements, the corporation can use this strategy in the development of beverage drinks.

4.2 Problem Definition

The soya manufacturing line in the food and beverage industry was chosen as the survey target in order to carry out this investigation. There have been certain concerns uncovered that impair the quality of food and beverage production. The performance of appraisers is the first issue. This error occurs when operators do not get sufficient training or do not measure a product according to standard procedure.

Moreover, the second product quality issue in tamarind drink production are many variances of measurement occur in the production system. In this case, the tamarind production process is not so smooth due to unstable measurement that have been handle by the different operators.

The third issue in this soya production line is gauge error. The gauge was been use many times under the same conditions, then several different values of measurement may occur. So, this problem will reduce the quality of product thus will make the customer not satisfy with their product. In conclusion, these three issues are the quality product issues and these problems need to be solved immediately to improve the quality of soybean production.

4.3 Data Collection

This section will record and compute all important documentation and information gathered from the company. It contains a flowchart of the process, a layout of the floor production plan, and prior production data of beverage food industries. This business career is in the food industry that produces beverages.

As a result, the information gathered is essential for making improvements or adjustments in manufacturing to address the company's product quality problem. In this part, soybean production information is collected in two ways. One is primary data and another way is secondary data which is by recorded the measurement part. Figure 4.1 shows the Soyabean drinks variation flavour.

Figure 4-1: Soyabean drinks

4.3.1 Primary Data

Employees will collect data for the soybean drinks manufacturing process. Details such as input, output, and the number of defects will be gathered in order to use the GR&R measuring system, which uses the approach. The purpose of this study will be to improve the product quality of soybean drink by assessing the samples and process stability.

4.3.1.1 Process Flow Chart of Soya Beverage

The process flow chart for the production of soybean drink in one of beverage food industry is shown in Figure 4.2. The manufacturing process begins with the preparation of the raw ingredient, soybeans. After that, the soybeans will be steeped in boiling water for about 240 to 300 minutes. The soaked soybean will then be sieved to remove the soybean outer coat, also known as the seed coat. Employees must pay more attention to removing all of the soybean seed coatings throughout this operation.

Following that, the outer coat of the soybean will be removed and cooked for around 60 minutes. It will be processed twice a day, with each batch capable of filling approximately 1,732 bottles. Following the heating process, the soybean drink is filtered again using the pumping machine. The pumping machine's apparatus is cloth, and the process is done manually. Employees must squeeze out as many soybean drinks as possible regularly. Soybean drinks have previously completed the process up to this point.

The next phase is to use an automatic machine to fill the soybean drink into bottles. As previously stated, these two batches of soybean drinks can fill approximately 3,464 bottles a day. Then it will begin manually foiling the cover on the soybean bottles.

The next step is the retorting procedure, which removes all of the air from the soybean flasks, allowing germs to remain inside. After finishing the retorting of the soybean drinks, the inspection process will begin. The soybean drinks will be divided into two categories: excellent and defective, with defective items being discarded.

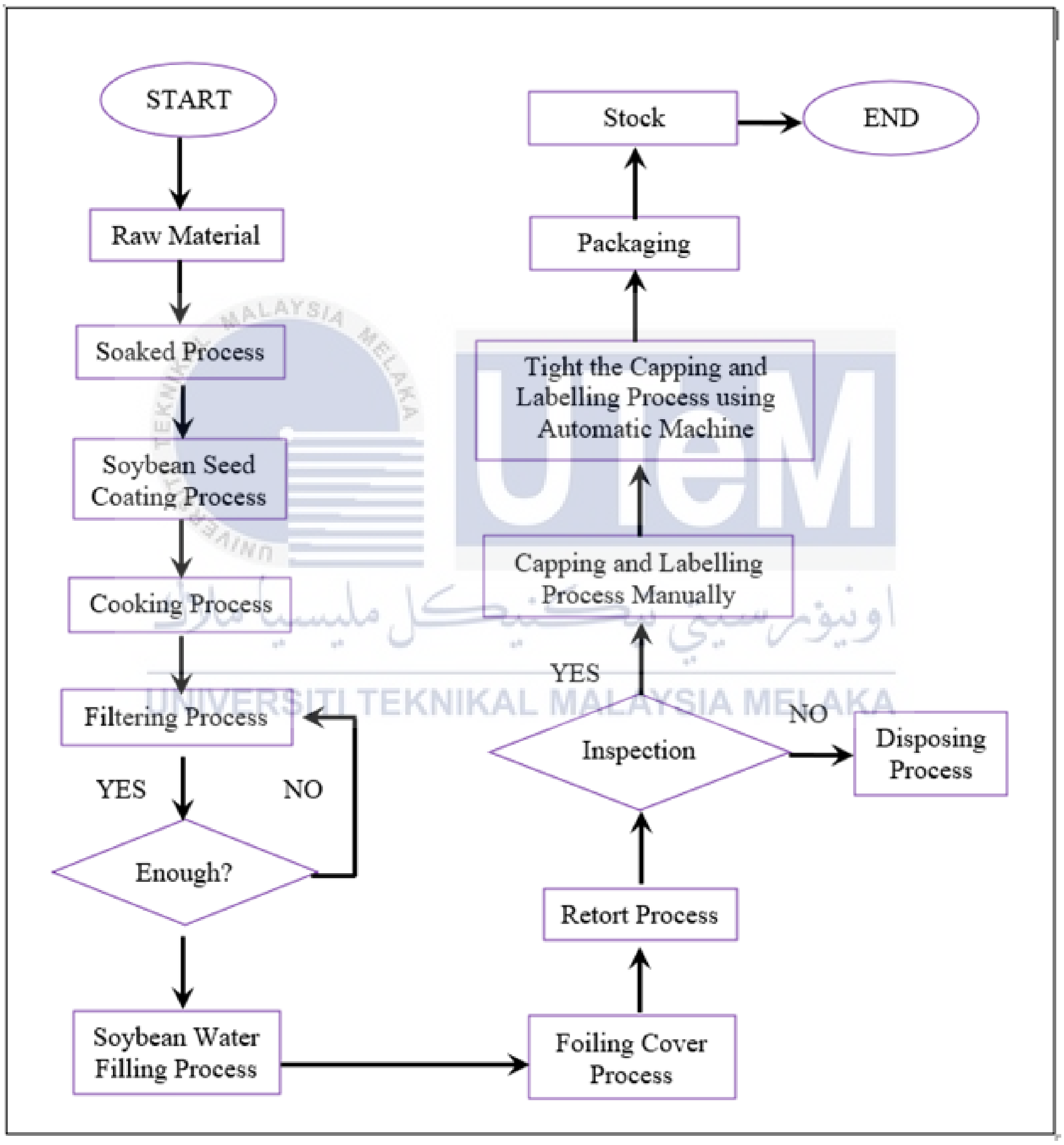

Figure 4-2: Process Flow Chart of production Soybean Drink

4.3.1.2 Process Layout

The process plan for the production of soybean drinks at F&B industry is shown in Figure 4.3. It represents two rooms, the first of which is the soybean drink manufacturing process, and the second of which is the soybean drink labelling and packaging process.

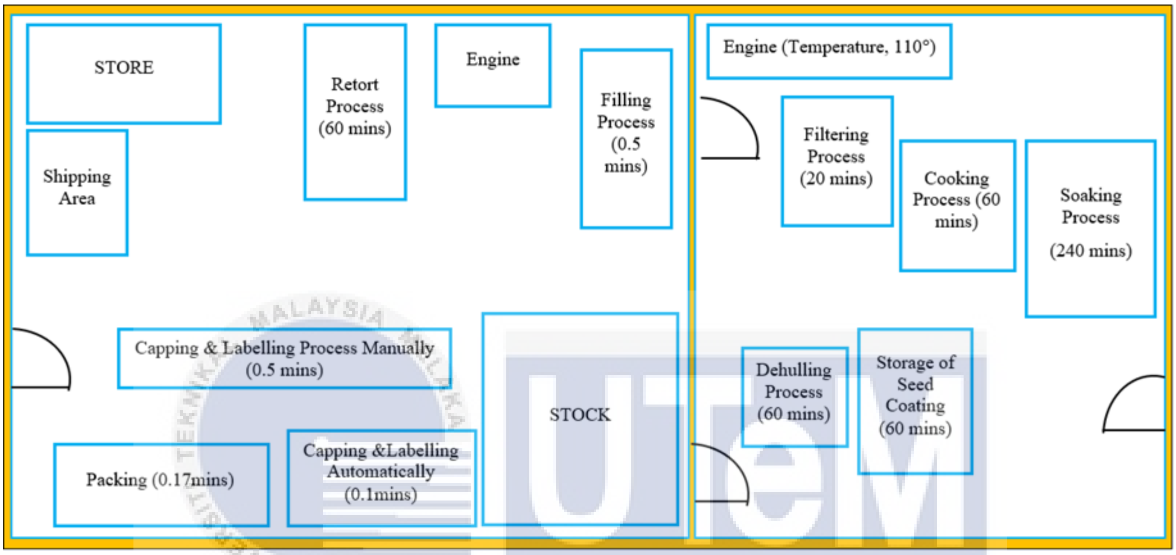

Figure 4-3: Process Layout of Soybean Production

4.3.1.3 Measuring Quality Data

In GR&R, measuring quality data is essential to analyze using Minitab software. Therefore, the data was collected at the F&B industry for 30 days with 10 samples for three operators in 3 trials. Based on table 4.1 below, the data have been recorded. Figure 4.4 shows the operator measure using calliper and diameter of bottles.

Table 4-1: Diameter of Bottle Measurement Data

DATA COLLECTION													
APPRAISER	**NO. OF TRIALS / PARTS**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**GRAND AVERAGE**
	OPERATOR A	1	20.23	20.40	20.30	20.22	20.42	20.19	20.38	20.26	20.32	20.20	20.29
		2	20.24	20.41	20.30	20.23	20.40	20.20	20.37	20.25	20.33	20.20	20.29
		3	20.24	20.40	20.29	20.23	20.41	20.20	20.37	20.26	20.32	20.21	20.29
		AVERAGE (Xa)	20.24	20.40	20.30	20.23	20.41	20.20	20.37	20.26	20.32	20.20	20.29
		RANGE (Ra)	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
	NO. OF TRIALS / PARTS		1	2	3	4	5	6	7	8	9	10	GRAND AVERAGE
	OPERATOR B	1	20.22	20.40	20.29	20.26	20.39	20.18	20.36	20.29	20.32	20.20	20.29
		2	20.23	20.41	20.30	20.25	20.39	20.17	20.35	20.28	20.33	20.19	20.29
		3	20.23	20.40	20.28	20.26	20.40	20.19	20.37	20.29	20.32	20.20	20.29
		AVERAGE (Xb)	20.23	20.40	20.29	20.26	20.39	20.18	20.36	20.29	20.32	20.20	20.29
		RANGE (Rb)	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01
	NO. OF TRIALS / PARTS		1	2	3	4	5	6	7	8	9	10	GRAND AVERAGE
	OPERATOR C	1	20.23	20.38	20.32	20.25	20.41	20.19	20.39	20.40	20.28	20.21	20.31
		2	20.24	20.39	20.31	20.23	20.40	20.18	20.38	20.40	20.29	20.21	20.30
		3	20.22	20.38	20.31	20.24	20.40	20.19	20.39	20.41	20.27	20.21	20.30
		AVERAGE (Xc)	20.23	20.38	20.31	20.24	20.40	20.19	20.39	20.40	20.28	20.21	20.30
		RANGE (Rc)	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.00	0.01

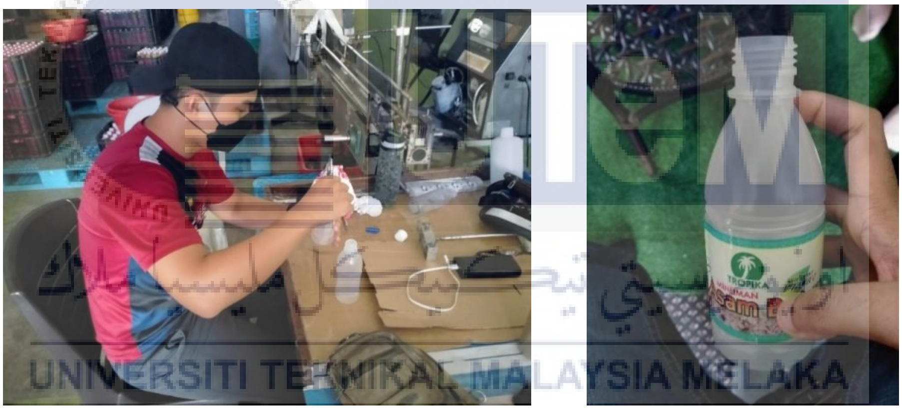

Figure 4-4: Operator measure using calliper and diameter of bottle

4.3.2 Secondary Data

Employees will collect data for the soybean drinks manufacturing process. Details such as input, output, and the number of defects will be gathered in order to use the GR&R measuring system, which uses the Average and Range approach. The purpose of this study will be to improve the product quality of soybean drink by assessing the samples and process stability.

4.3.2.1 Factor Affecting Product Reliability Production Based on Literature Review

This part explains how to complete the case study's goals, which include determining the elements that influence the production of the selected beverages industry. A literature study is used, as previously said, to better understand the factors that can influence production. Some of the material or references that have been read, used, and selected in connection with the case study being conducted. According to GR&R studies, the most influential aspects in the beverage sector are listed in the table 4.2 below.

Table 4-2: Examine factor of Product Quality

Factors Affecting Production Measurement	Literature References	Total Related Journal (%)
Man	*Al-Refaie & Bata (2009) Cepova, Kovacikova et al, (2018), Gerger, Yüksekokulu et al, (2021), Parente, Patel et al (2012), Peruchi, Balestrassi et al (2013), Wrzochal & Adamczak (2019), Xiang, Chen et al (2017), Yang, Wang et al (2020), Zanobini, Sereni et al (2016), Bhakhri, Belokar et al (2017), Cox, Garside et al (2013), Hoffa & Laux (2007), Yeh & Sun (2013)*	54
Machine/Equipment	*Jain & Abbash(2017), Saikaew & Charnnarong(2018), Asplund & Lin (2016), Almeida, Gomes et al (2018), Joubert & Meintjes (2015), Jeh & Pan (2004)*	24
Method	*Marques et al, (2020), Bottani & Montanari (2021), Hawary & Hoe (2019), Runje et al (2017),*	16
Material	*Almeida, Gomes et al, (2019)*	4

Based on the table 4.2, a significant number of the elements that influence production measurement in an F&B company are related to man, specifically the operators, followed by machine or equipment. Aside from that, the technique of handling has an impact on product quality. After that, the raw material has an impact because the majority of the materials used are defective due to environmental conditions and defective before they are processed.

4.4 Data Analysis

Data analysis in the qualitative approach is the process of evaluating data using logical tools or statistical processes that are used consistently. The data analysis will discuss in detail the difficulties that have been highlighted and will identify some potential sources of the problem. Data analysis is carried out in this integrated graph analysis, Ishikawa diagram, and why-why analysis.

Second, the Ishikawa diagram is utilized to determine the underlying source of a problem in the Soybean Drink inventory. In order to discover as many causes and effects as feasible, this approach is split into four primary causes: man, material, method, and machine. The brainstorming process is necessary for the completion of the Ishikawa diagram.

Eventually, the why-why analysis tool can be used to create a list of significant elements as well as particular causes and effects. It's a method of questioning that aids in the uncovering of possible underlying reasons of a problem. This why-why examination is extremely helpful in determining the true root cause and taking the necessary steps to solve the underlying issues.

4.4.1 Analysis by Average and Range (Minitab)

The graph analysis is created by using the primary of monthly inventory for November 2021. The data only took in one month because of Covid-19 pandemic. This is because the production is focused on customer requests and often the employees do not document the details. These graphs consist of Gage Evaluation, R chart and X Bar Chart, balance stock in the warehouse, and the minimum level of inventory in the warehouse.

Table 4-3: Gage Evaluation

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.0100194	0.060117	14.40	30.06
Repeatability	0.0074837	0.044902	10.76	22.45
Reproducibility	0.0066621	0.039973	9.57	19.99
Part-To-Part	0.0688536	0.413121	98.96	206.56
Total Variation	0.0695787	0.417472	100.00	208.74

Number of Distinct Categories = 9

The result is obtained using the Average and Range analysis method in Minitab software, as shown in Table 4.3. First, the percent Study Var must be observed to compare the measuring system variation to the total variance. It indicates that the percent Study Var for Total GR&R is 14.40%, more than 10%. According to AIAG guidelines, the measurement is acceptable if the percent of study is between 10% and 30%. As a result, the measuring system can be concluded to be satisfactory.

However, it may require modification, depending on the application, the cost of the measurement device, the cost of repair, and other considerations. The value for NDC is 9, which is the recommended amount for an adequate measuring system. Based on idea of AIAG, the NDC value should be equal to or greater than 5. Thus, this result indicates that its capable to separate the process into five unique groups of measured data.

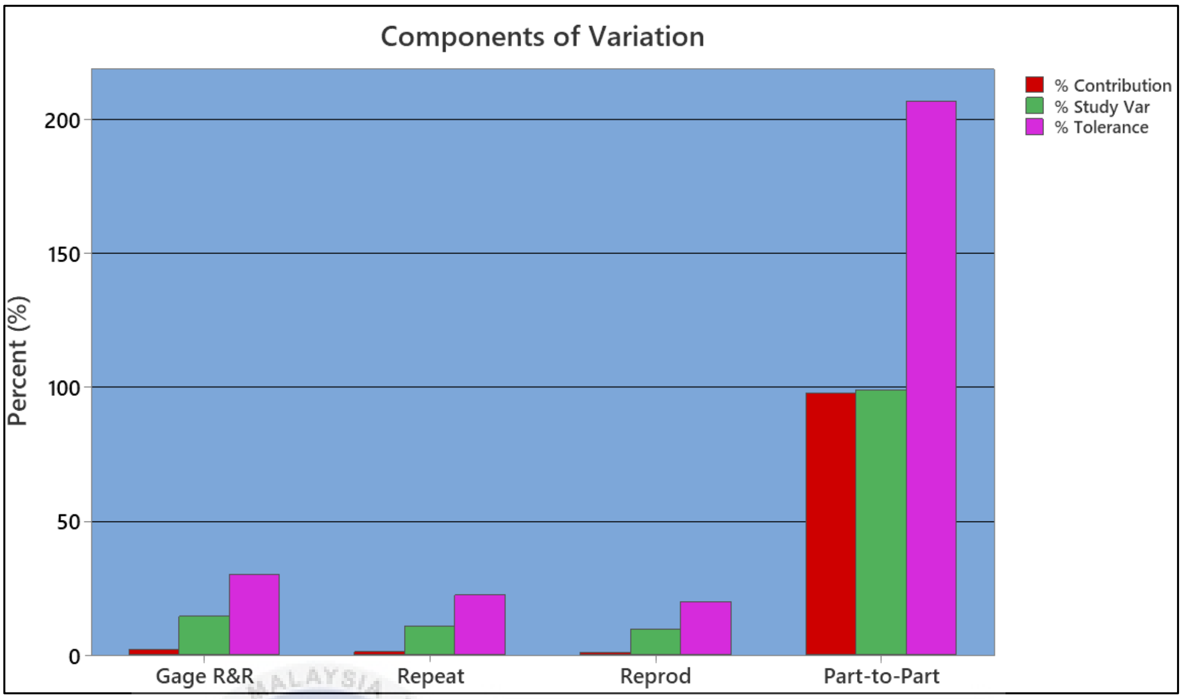

Figure 4-5: Component of Variance Graph

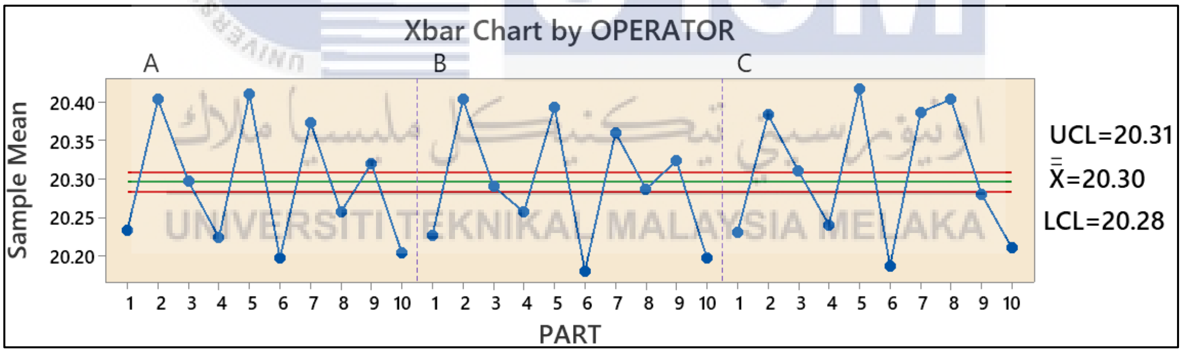

Figure 4-6: X Bar chart graph

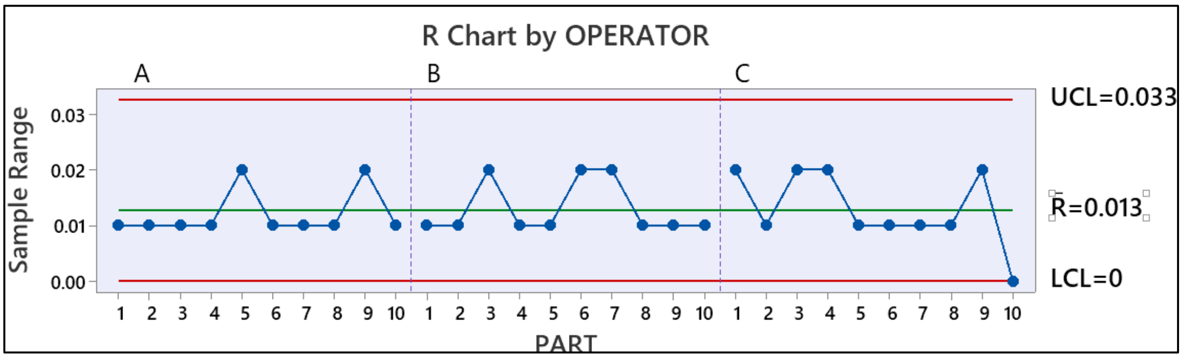

Figure 4-7: R chart graph

Subsequently,as shown in figure 4.5 above, the percentage contribution from part-to-part is higher than that of Total GR&R in the component of variation graph. Hence, it means that part-to-part variance contributes to a significant amount of the variation. Figure 4.6 illustrates that the graph compares the part-to-part variation to the repeatability component on the X-Bar chart. Because the part chosen for a GR&R study should represent the entire range of possible parts, this graph ideally shows a lack of controls. For these data, many points are above and below the control limits. Hence, this result indicates that part-to-part variation is much more significant than measurement device variation.

Meanwhile, in figure 4.7 indicates that the R chart is a control chart of ranges that graphically displays operator consistency. If any points on the R chart fall above UCL or below LCL lines, it means that the operators are not consistently measuring the parts. However, the R chart above shows that all the points fall within the center-line of control limits with a value of 0.013. Thus, it means that the operators are measured consistently.

4.4.2 Analysis by Ishikawa Diagram

By breaking down concepts into useable components, the Ishikawa diagram was used to find general underlying causes. The Ishikawa diagram also used in-depth in the investigations, and it was based on factor 4M, which stands for method, machine, material, and man. This diagram can help think about how to figure out what's causing the problem in the first place. The Ishikawa diagram, shown in Figure 4.8, were utilized to solve the problem.

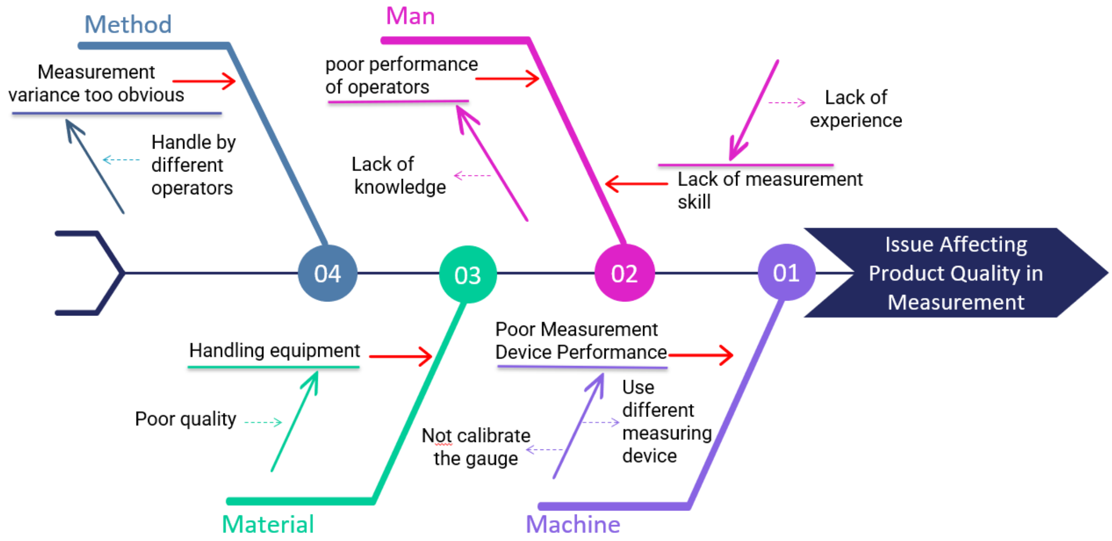

Figure 4-8: Ishikawa Diagram

The Ishikawa diagram is used in this case study to identify the significant cause using the 4M (Man, Machine, Method, and Material) factors. According to the diagram, Man is the most significant factor influencing product quality in measurement, followed by Method and Machine.

The justification can be found in table 4 above, where Man contributes the most (54%), followed by Machine (24%), and Method (16%). On the other hand, the Material has the lowest percentage, which means less impact than the other 4M components. As a result, Materials have been neglected from being discussed in Why-Why Analysis.

The first problem that is one of the major issues affecting production measurement is the poor performance of operators. This issue happens because the operators are not fully exposed to measurement knowledge. Moreover, this problem also contributes to poor measurement skills, leading to a lack of experience.

Furthermore, machines are also related to factors influencing product quality in measurement. The main root of this problem is the poor performance measuring device. This problem occurs because the workers or operators do not calibrate the measuring device. Thus, it will not give an accurate measurement. When the measurements are not accurate, the final results will also be inaccurate, and the quality of the product will be sub-standard.

Another problem related to poor performance measuring devices is using different tools. For example, an operator is measuring several parts using a vernier caliper, while another operator uses a digital caliper to make measurements. Based on this situation, it is clear that it will have a different measurement value because digital caliper will take a more accurate reading than vernier caliper. Hence, it will make a more extensive variation gap in measurement data.

Finally, the third factor affecting product quality in measurement is Method. In this issue, measurement variance is too obvious. This problem happens because different operators have taken the measurement data. Hence, the possibility of the operator not handling the measurement device properly is high due to not monitoring by the supervisor.

4.4.3 Why-why Analysis

A why-why analysis is used in the workplace to determine the reasons and underlying causes of a problem. The why-why analysis is a technique for examining and discovering the root causes of a problem. It will uncover the real reasons for failures and prevent them from happening again. Genichi Taguchi created this method, which is based on the innovative Fishbone diagram, to provide a simple and quick tool for finding the fundamental causes of a problem. Then, for each root cause, relevant behaviors are identified that lower the risk of the cause occurring or having a result.

Table 4-4: Why-why Analysis with root cause

Main factor	Problem	Why 1	Why 2	Why 3	Why 4	Root Cause
Man	**Poor performance of operators**	No proper planning	Lack of knowledge	Lack of theory	Lack of education	not been expose to measurement education
	Poor measurement skill	Lack of measuring experience	Not enough measurement training	No specific trainer	No place for training	Not have appropriate training center provided
Method	**Measurement variance too obvious**	Handle by different operators	Different handling measurement methods	No monitoring from supervisor	No have proper instruction	Not have proper guidance from immediate superior regarding the task
Machine	**Measurement tool (calliper) are not in good performance**	Poor precision & accuracy on tool measurement	Use different tool measurement (vernier & digital calliper)	No standard requirement to use measurement tool	-	Not have appropriate measurement tool provided.
			Device wear and tear	The calibration is not done properly	No system calibration in measurement department	Not have systematic calibration provided by management

Based on table 4.4, the first main factor that affects measurement quality is the man factor. The problem regarding Man is the poor performance of operators. It is because of their have proper planning to do their job. Besides that, they also lack knowledge and theory about measurement systems. Indirectly, it will contribute to the root cause, which is not exposed to measurement education. Another problem related to man is poor measuring skills. It happens because the operator has lacks measuring experience using callipers. Not enough measurement training and no specific training also affect the operator's performance. Hence, the root cause does not have an appropriate training center provided by the company.

The second main factor that affects product quality on measurement is the Method factor. The problem occurs when measurement variances are too prominent. This is caused by different operators handling the measurement system. At the same time, different handling methods and no monitoring from the supervisor could lead to variance measurement data. Thus, the root cause for this issue is the operators do not have proper guidance from the immediate superior regarding the task.

Finally, the Machine is the third leading factor related to product quality on measurement. Measurement tool, which is callipers are not in a good performance is the problem regarding Machine factors. This is caused by poor precision & accuracy on tool measurement. On this issue, it is divided into another two reasons that cause the problem. The first reason is that operators use different tool measurements, vernier & digital calliper. For this reason, it is no standard requirement to use a measurement tool that will create the root cause, which does not have the appropriate measurement tool provided. The second reason is the device's wear and tear because the calibration is not done correctly. As a result, not having systematic calibration provided by management is the root cause of the problem.

4.5 Improvement Proposal

The idea for improvement should be based on identifying the market's root cause, and it might be implemented in the F&B company. Furthermore, improvement is a necessary action to assist a firm in becoming more productive, and it is related to the study's core goal of improving product quality.

Table 4-5: The root cause and Proposed Action

No	Root Cause	Proposed Action
Man	not been expose to measurement education	Provide exposure to operators about the importance of stabilizing measurements
	Not have appropriate training center provided	Provide an appropriate training center that focuses on measurement
Man	Not have proper guidance from immediate superior regarding the task	Make proper guidance for the operators about measurement tool handling
Machine	Not have appropriate measurement tool provided.	Standardize the use of digital caliper as the primary measurement device
	Not have systematic calibration provided by management	Provide a calibration system by manual or automatic calibration

Based on table 4.5, the first improvement proposal that can be present is to provide exposure to operators about the importance of stabilizing measurements. While at the same time, the company also has to consider providing an appropriate training center that focuses on measurement. Furthermore, adequate operator training can be provided to lower the percentage of GR&R. For example; AV can be lowered by having a good training centre. As a result, it can improve operator knowledge and competence while still producing a high-quality product.

Next, another improvement related to measurement variance too obvious problem is making proper guidance for the operators about measurement tool handling. The company needs to ensure that the operator uses the calliper properly to get stable and precise data. Subsequently, the suggested idea to encounter the root cause for not having a specific measurement tool provided is that the company needs to standard the use of digital calliper as the primary measurement device.

For example, they can provide the operator with a digital calliper that is more precise to measure the bottle. Thus, it can also help them take more stable and accurate measures. Moreover, under the same problem, the company should also improve by making a calibration system by manual or automatic calibration. This is because calibration defines the accuracy and quality of measurements recorded using the equipment.

Over time, results and accuracy tend to 'drift' mainly when using technologies or measuring parameters such as temperature and humidity. Therefore, to be confident in the measured results, there is an ongoing need to maintain the calibration of equipment throughout its lifetime for reliable, accurate, and repeatable measurements.

4.6 Controlling the Improvement

The final phase of the study, based on the DMAIC concept, is to ensure that the proposed improvement ideas are implemented in a controlled and long-term manner for continuous improvement in manufacturing productivity. By using the Control concept, it will be able to ensure that the quality of the measurement can be well maintained. As a result, this ensures enhanced product quality and consistent measurement. Here are some suggestions for continuous improvement of F&B companies.

The first suggestion for improvement for the F&B company is to set a time for operator check for skill performance. The supervisor is responsible for ensuring that the operators are in a good performance. For example, the supervisor needs to provide a checklist regarding operator measurement skill performance and monitor it monthly.

Another suggestion is to provide a periodic scheduling table for internal calibration. The callipers must be maintained by calibrating them regularly and carefully to ensure the precision of measurements. For example, the management can make internal calibration for every six months. Thus, this can ensure that the measurement quality can be maintained well.

4.7 Summary

To summarise this chapter, the following steps are taken using the DMAIC concept, in which the study's problem is first defined. There is a problem with product quality that is linked to the measuring system, as indicated in the problem statement. The data was gathered by travelling to an F&B company and gathering primary and secondary data. The third DMAIC idea is to apply the collected data in the study's analysis. The GR&R analysis is used to estimate the percentage or probability of measurement error and identify the source of the variation, which is either equipment or the operator. According to the results, EV contributes to higher measurement system variation. The study is then examined further in the Improvement phase, using the Fishbone diagram and Why-Why analysis to uncover the fundamental cause of the product's poor quality. This phase is essential since it ensures that the company can improve its production process due to the suggestions offered. Finally, for the F&B company, the final aspect of DMAIC, Control, is presented. It's also critical for the company to maintain control over its manufacturing process after the improvements have been made.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The purpose of this study was to employ a measurement system used in the quality management sector to conduct an analysis of soya bean production in the food and beverage industries using the GR&R approach. Additionally, the methodologies provide a complete examination of the system's results. By examining the outcome, one can ascertain the system's constraints and limitations. Thus, the GR&R programmed enables the analysis of modified systems, which allows the examination of capital and system performance before investment or change.

Moreover, applying the GR&R technique can detect a few issues related to the manufacturing system in this study. Examples, in terms of workers, environment and machine itself that contribute the case. After investigating the manufacturing system in the industry, this project's first objective was to identify product quality issues associated with the measuring system.

A system simulation is conducted using the primary and secondary data obtained during the soybean production process. The simulation result aids in determining the system's constraints and limitations, as well as the underlying causes of specific system circumstances. As a result, the second purpose is also met, which is to conduct the GR&R in order to improve product quality in the food and beverage business through stability.

While the project's final purpose is to suggest an improvement activity based on the results of the GR&R system analysis, the Ishikawa diagram and why-why analysis methods are used to determine the root cause of problems in Lean management. Both are highly effective tools for determining the underlying cause of the issues. Thus, solutions are suggested in accordance with the manufacturing system's stated underlying causes. The enhancement is integrated into the existing simulation system, and the performance is monitored. The enhancement is then suggested to the food and beverage businesses.

5.2 Contribution

The primary contribution of GR&R in the manufacturing business is to regulate and optimize the current manufacturing system. By utilizing the GR&R, it is possible to discover issues with the measuring system. Additionally, it assists in determining the system measurement for any new investment in the existing system. As a result, it can help avoid ineffective implementation, which could result in significant financial loss.

Next, this study enables the F&B businesses to improve product quality, improving and optimizing production. Further, it will assist in efficiently producing high-quality goods and will pay attention to the employee's aptitude to complete tasks in a safe environment. Finally, they can effectively implement this strategy to increase and maintain the output of soya beverages.

5.3 Suggestion for Future Research

In conclusion, the recommendation for future research is that GR&R can be employed in processes other than food manufacturing. This methodology is a vital tool in this study since it visualises the entire process from raw material purchase to finished goods delivery to consumers or storage in stocks. Furthermore, GR&R involves calculating the AV and EV, which may be tracked and evaluated to determine the source of the variation. GR&R can also be used in other manufacturing or electronic industries because it is a part of a lean tool for improving measurement systems.

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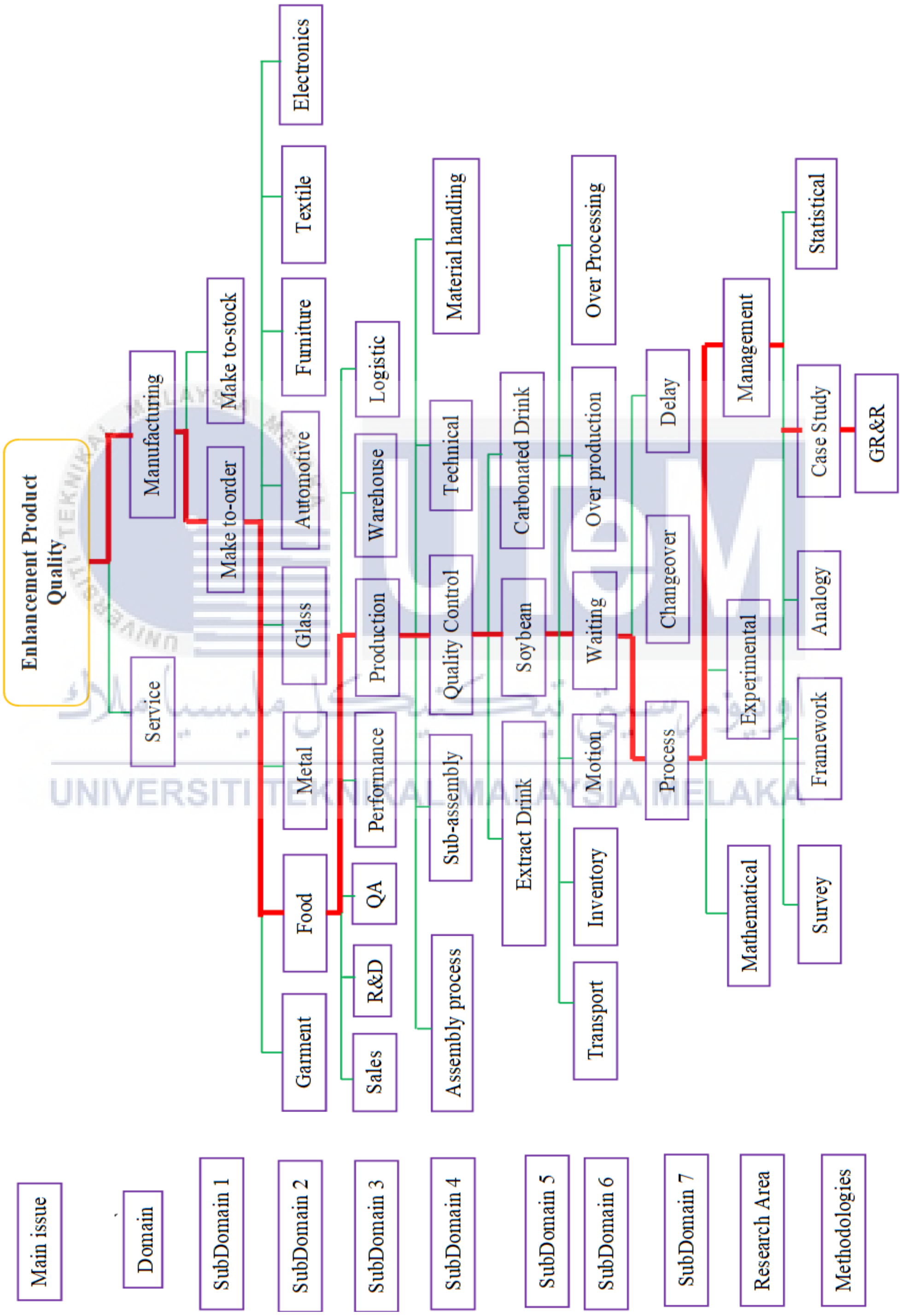
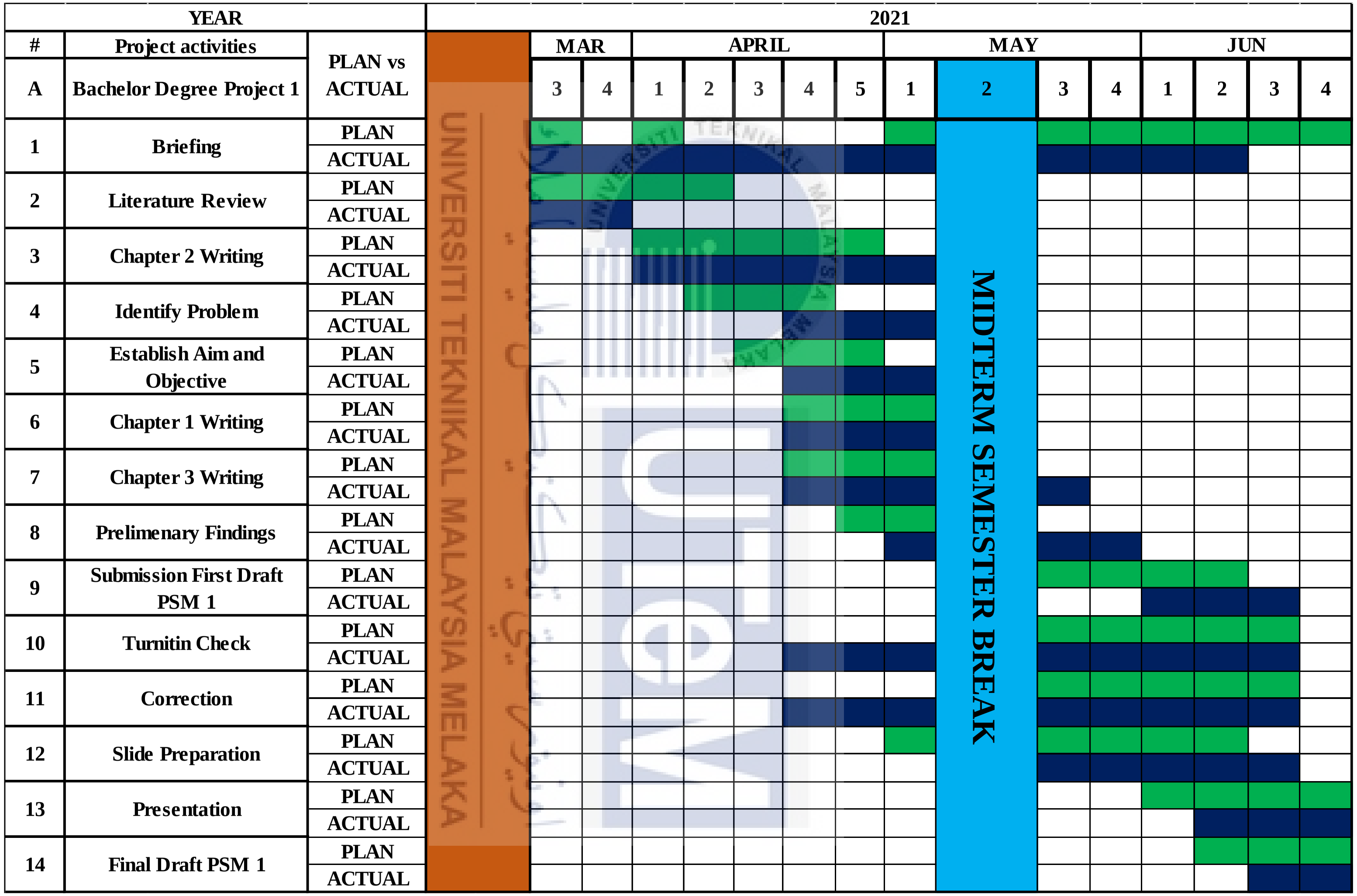
APPENDICES

APPENDICES

APPENDIX A K-Chart for Research Scope



APPENDIX B Gantt Chart PSM 1 & 2



Accomplishment Literature Review	W8
Accomplishment Introduction	W8
Accomplishment Methodology	W10
Accomplishment Preliminary Findings	W11

YEAR				2021													2022	
#	Project activities	PLAN vs ACTUAL		OCT				NOV				DEC					JAN	
B	Bachelor Degree Project 2			1	2	3	4	1	2	3	4	1	2	3	4	5	1	2
1	Briefing	PLAN									MIDTERM SEMESTER BREAK							
		ACTUAL																
2	Writing Chapter 4	PLAN																
		ACTUAL																
3	Data Collection	PLAN																
		ACTUAL																
4	Data Analysis	PLAN																
		ACTUAL																
5	Proposed Enhancement	PLAN																
		ACTUAL																
6	Submit Work Progress	PLAN																
		ACTUAL																
7	Chapter 5 Writing	PLAN																
		ACTUAL																
8	Executive Summary	PLAN																
		ACTUAL																
9	Submission First Draft PSM 2	PLAN																
		ACTUAL																
10	Turnitin Check	PLAN																
		ACTUAL																
11	Correction	PLAN																
		ACTUAL																
12	Final Draft PSM 2	PLAN																
		ACTUAL																
13	Slide Preparation	PLAN																
		ACTUAL																
14	Presentation	PLAN																
		ACTUAL																

Accomplishment Result and Discussion	W10
Accomplishment Data Collection	W8-W9
Accomplishment Data Analysis	W9-W10
Accomplishment Proposed Enhancement	W11
Accomplishment Conclusion and Suggestion	W12
Thesis Submition	W16

APPENDIX D Industrial Visit


2021.11.10 11:07

APPENDIX E Thesis Status Verification Form

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **ENHANCEMENT OF PRODUCT QUALITY THROUGH STABILITY USING GAUGE REPEATABILITY AND REPRODUCIBILITY IN BEVERAGES INDUSTRY**

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

Saya **MUHAMMAD KHAIRUL ASRAF BIN ZAINAL** mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

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☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

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Disahkan oleh:

Alamat Tetap:

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Perak Darul Ridzuan

Tarikh: 17 Januari 2022

Cop Rasmi:

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APPENDIX F Thesis Status Verification Form

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Tuan

PENGKELASAN TESIS SEBAGAI TERHAD BAGI TESIS PROJEK SARJANA MUDA

Dengan segala hormatnya merujuk kepada perkara di atas.

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

Nama pelajar: MUHAMMAD KHAIRUL ASRAF BIN ZAINAL (B091810056)

Tajuk Tesis: ENHANCEMENT OF PRODUCT QUALITY THROUGH STABILITY USING GAUGE REPEATABILITY AND REPRODUCIBILITY IN BEVERAGES INDUSTRY

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

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
"KOMPETENSI TERAS KEGEMILANGAN"

Saya yang menjalankan amanah,

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Penyelia Utama/ Pensyarah Kanan
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