A SURVEY AND IMPROVEMENT OF QUALITY AT DATARAN SETAR SDN BHD

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A SURVEY AND IMPROVEMENT OF QUALITY AT DATARAN SETAR SDN BHD

SEOW WENJIA

Report submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Engineering in Manufacturing Engineering

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EXAMINER APPROVAL DOCUMENT

We certify that the thesis entitled "A SURVEY AND IMPROVEMENT OF QUALITY AT DATARAN SETAR SDN BHD" is written by SEOW WENJIA. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award B.Eng (Hons) of Manufacturing Engineering. We are here with recommend that it be accepted in fulfilment of the requirement for the B. Eng (Hons) of Manufacturing Engineering.

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Position	: LECTURER
Date	: 1 JUNE 2016

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I hereby declare that the work in this thesis is my own except for quotation and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :
Name : SEOW WENJIA
ID Number : FA12057
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ABSTRACT

Define, Measure, Analyse, Improve and Control (DMAIC) is one of the problems solving methodology of Six Sigma that used to improve quality. This research presents a case study of surveying quality problems in small scale industry by using Six Sigma approach within a production department. The goals of this research are to improve the quality of services to meet customer demand using DMAIC methodology. This research had shown how the root causes being identified and how the quality of service is being improved and meet customer satisfaction. The defect of quality of service detected is the garment could not complete on time. The analysis from adopting DMAIC indicated that number of workers and machines' capability influenced the production of the garment. In particular, some calculation using formula has been done to calculate the number of workers needed and change the type of the machines. Six Sigma implementation resulted significant increases in number of workers to produce improvements in productivity. The number of workers has been increase from 15 to 24 workers. As a result, when the productivity of garment increases, customer could get their products on time.

ABSTRAK

Define, Measure, Analyse, Improve and *Control* (DMAIC) adalah salah satu metodologi Six Sigma yang digunakan untuk meningkatkan kualiti. Kajian ini membentangkan kes pengukuran masalah kualiti dalam industri kecil dengan menggunakan pendekatan Six Sigma dalam jabatan pengeluaran. Matlamat kajian ini adalah untuk meningkatkan kualiti perkhidmatan untuk memenuhi permintaan pelanggan menggunakan metodologi *DMAIC*. Kajian ini telah menunjukkan bagaimana punca-masalah dapat dikenal pasti dan bagaimana kualiti perkhidmatan bertambah baik dan memenuhi kepuasan pelanggan. Keburukan kualiti perkhidmatan yang telah dikesan adalah tidak dapat menghantar produk pada masa yang ditetapkan. Analisis menggunakan *DMAIC* menunjukkan bahawa bilangan pekerja dan keupayaan mesin telah mempengaruhi pengeluaran pakaian. Pengiraan jumlah pekerja dan mengganti jenis mesin telah dilakukan. Penggunaan Six Sigma menunjukkan bahawa untuk meningkatkan produktiviti perlu dilakukan penambahan jumlah pekerja dari 15 menjadi 24 orang pekerja. Hasilnya, apabila produktiviti pakaian meningkat, pelanggan boleh mendapatkan produk mereka pada masa yang ditetapkan.

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LIST OF ABBREVIATIONS

AD	Anderson- Darling
ANOVA	Analysis of Variance
CTQ	Critical to Quality
DMAIC	Define, measure, analyse, improve, control
DPMO	Defects per Million Opportunities
ECDF	Empirical Cumulative Distribution Function
FMEA	Failure Mode of Analysis
GDP	Gross Domestic Product
LSL	Lower specification limit
NSDC	National SME Development Council
OP	Opportunity
PPM	Parts per million
SME	Small and Medium Enterprise
USL	Upper specification limit
Z bench	Sigma level

CHAPTER 1

INTRODUCTION

Chapter 1 explains about the background, problem statement, objectives and project scope of this research.

1.1 Background

Manufacturing industry is the backbone of industrialised nation. The level of manufacturing activities of a country directly concerned the economic health. The standard living of people will be higher if the country practices more on manufacturing activities. In Malaysia, manufacturing industries are the second contributor which contributes about 40.6% compare to 48% of services and 11% of agriculture for Malaysia's GDP in 2015 (Index Mundi, 2015).

Over the years, quality management of an organisation has been spotted as the most important key ingredient to success and competes in this global market (Fening, 2012). Many researchers, professionals and organisations have focused on customer satisfaction. The main objective of a company is to increase the profits and to lower down the cost and the factor that can help the company to enhance the sales is by customer satisfaction as this factor can lead to customer loyalty to the company, recommendation and repeat purchase. Customers always have the right to get the maximum satisfaction either in products or in services from a company. The competition of every company nowadays not only building the products but also needs to create a great relationship with the customer.

For a garment industry, many sewn product firm are finding some ways to increase the customer satisfaction in terms of services. Quality in terms of presales and post sales service, delivery, and pricing are necessary for garment manufacturer. In order to improve the quality, the factors causing customer dissatisfaction have to indicate. Six Sigma methodology is used in manufacturing industry for the quality improvement as it has been widely recognised over the past few years.

Therefore, in the research of Dataran Setar Sdn Bhd, a garment industry, Six Sigma is used to improve the quality of the company.

1.2 Problem statement

Although garment industry contributes a lot to the nation, there are still a lot of problems occur like low quality in products, too much product defects, customer dissatisfaction and many others. Quality services of the company are very important to survive in the global market as it may affect the sales of the company. This is because a good customer service will definitely help to sell even a low quality product and bad service may even produce difficulty to sell a good quality product. Therefore, in this research, Six Sigma approach is used to improve the quality of services in Dataran Setar Sdn Bhd in order to achieve customer satisfaction.

1.3 Objectives

The objectives of this research are:

1. To understand the manufacturing process and the problems in Dataran Setar Sdn Bhd.
2. To identify the root cause of poor performance of the Dataran Setar Sdn Bhd.
3. To improve the quality of services of Dataran Setar Sdn Bhd using Six Sigma approach.

1.4 Project Scope

This research uses Six Sigma methodology to improve the performance or efficiency of the organisation by identifying the root cause of the poor performance of the industry and also eliminating the wastes. Waste and causes of the poor performance of the industry will be identified.

1. The case study is conducted at Dataran Setar Sdn Bhd, located at Pekan, Pahang.
2. The wastes and root causes will be identified using DMAIC: Define, Measure, Analyse, Improve and Control.
3. In DMAIC, Failure Mode and Effect Analysis (FMEA), Cause and effect diagram, Process map, Pareto chart and control charts will be using.
4. Minitab® 15 will be used to analyse the data.

CHAPTER 2

LITERATURE REVIEW

Chapter 2 presents the literature review on the definition of SME profile, definition of quality. Background, definition and philosophy of Six Sigma, company's background as well as the statistical tools and technique used are discussed in this chapter.

2.1 Definition of SME Profile

The competitive of business world in this modern era makes Small and Medium enterprise (SME) play an important role to the nation's economy as they have been considered as the backbone of the industrial development in the Malaysia (Sidek, 2014). There are a lot of contributions from SMEs, for instance, SMEs contribute to employment creation, Gross Domestic Product (GDP), poverty mitigation, export performance, domestic savings and entrepreneurial development of an economy (Sidek, 2014). In 2005, National SME Development Council (NSDC) has defined SMEs as (National SME Development Council, 2013):

i. Manufacturing sector: Sales turnover must less than RM25, 000,000 or full-time employees of less than 150.
ii. Services or other sector: Sales turnover must less than RM5, 000,000 or full time employees of less than 50.

However, new SMEs definition has been endorsed in 14th July 2013 as:

i. Manufacturing sector: The sales turnover must not more than

RM50,000,000 or full-time worker not more than 200 workers.

ii. Services or other sectors: The sales turnover must not more than RM20,000,000 or full-time workers not more than 75 workers.

For a business, it will be considered as SME if it has either one of two specified qualifying criteria, where the sales turnover or full-time employees are lower. Table 2.1 shows the definition by size of operation.

Table 2.1 Definition by Size of Operation

Category	Micro enterprise	Small enterprise	Medium enterprise
Manufacturing sector	Sales turnover <RM300,000 or employees of <5	Sales turnover RM300,000 – RM15,000,000 or employees 5-75	Sales turnover RM15,000,000-RM50,000,000 or employees 75-200
Services and other sectors	Sales turnover <RM300,000 or employees of <5	Sales turnover RM300,000 – RM3,000,000 or employees 5-30	Sales turnover RM3,000,000-RM20,000,000 or employees 30-75

2.2 Definition of Quality

Juran states that quality has two dissimilar meaning. The first definition is product features must meet customer needs as the definition of quality is oriented to income. The higher the quality, the greater is the customer satisfaction. In this sense, quality usually “cost more”. While the second definition is free from defects as the defects can be defined as errors during rework, customer dissatisfaction, and also customer claims (Juran & Godfrey, 1998).

Quality of service is defined based on the degree of satisfaction receiving the service by the customer. For a product, customer rated quality according to fit, finish, appearance, function, and performance (Chandrupatla, 2009).

Based on the definition by the Shewhart and Juran, quality can be defined and measured in many ways. They view the term “quality” from different perspectives and perceptions. Consequently, the definitions of quality are depending on personal point of view.

2.3 Previous Researches on Quality Improvement

There are a lot of researches such as Patel & Thankkar, Deshpande et al., Sambhe, Ansari et al and Ogus et al on quality improvement in an industry. Regarding previous researches, there are a lot of methods can be done to improve either quality of services, processes or products.

Patel & Thakkar (2014) used 5S implementation in their research. The objectives of their paper are to maximise the efficiency of all processes and remove losses of the company by removing wastes, smoothing the process flow, upgrade the storage facilities, security, safety and cost savings of the company. Before applying the 5S methodology, the storage areas are very untidy and unorganised. In their research, unneeded item are identified by red-tagging and then remove them. It gave the result 12.91% of space has been saved and some waste of the process has been removed.

Deshpande et al. (2015) used 5S implementation to increase the productivity, efficiency and safety. Effective workplace management has been magnified in this research to achieve the goal. Their research focuses on the staff and the operators, by strengthening their work ethic. They reported that the 5S implementation has successfully transformed the organisation from working conditions to employees working satisfaction.

Sambhe (2012) presented a case of a medium industry to increase the SS quality level. Six Sigma has been implemented in his paper. His paper first indicate the critical to quality of the products, after that, DMAIC methodology is applied to further analysis and provide solution to the defects. The implementation has results in the stratum improvement. The results can further upgraded by employing tool viz, design of experiment and also the Minitab software.

Ansari et al. (2011) implemented Six Sigma to streamline the establishment and maintenance of costing and planning for business activities within the current financial management process in financial department. The paper had explained how the Six Sigma Methodology was implemented between the finance function of a major division within a de fence contractor. The implementation has resulted an important reduction in the cycle time and cost saving.

Oguz et al. (1916) used Lean Six Sigma to enhance the process by removing the variations and creating workflow in process. Their paper had explained how to improve the production rate of concrete panel by using Lean Six Sigma tools. Moreover, the paper also uses the variation of panel production as CTQ to indicate the performance of Six Sigma system. The implementation has resulted in minimising the variability of daily panel production rate.

5S methods basically improve the quality of the factory using terms Sort, Shine, Set in order, Standardise and Sustain. Six Sigma methodology improves the quality using Define, Measure, Analyse, Improve and Control (DMAIC) while Lean Six Sigma combines both lean principles and Six Sigma to search for the defects and improve the quality of the factory. However, Six Sigma has been selected to improve quality problems in Dataran Setar Sdn Bhd as it is the simplest methodology that has only five phases to identify and to solve the quality problems in the company.

2.4 Six Sigma Background

In 1985, Bill Smith launched the foundation of Six Sigma quality improvement movement in Motorola. They are success in reducing defects on semi-conductor devices by 94% from 1987 to 1993. Six Sigma is now one of the most popular quality management systems in the world as it is also adopted in world-class companies like General Electric, Johnson& Johnson, Honeywell and many others. Six Sigma helps them a lot to transform their organisation in certain ways. They claim that Six Sigma is a very powerful system that can speed up the improvement by getting the right projects conducted in the correct way (Raghunath & Jayathirtha, 2012).

There are some key concepts of Six Sigma (General Electric 2013):

i. Critical to Quality: Customer satisfaction is the most vital.
ii. Defects: Fail to deliver what the customer needs.
iii. Process capability: What your process can deliver to the customer.
iv. Variation: What the customer can see and feels.
v. Stable Operations: Makes sure the process is consistent, predictable to improve the variation.

vi. Design for Six Sigma: Designing to meet customer demand and process performance.

2.5 Definition and Philosophy

The term "Six Sigma" is being defined by various experts and authors. Firstly, Six Sigma is implemented to achieve great quality result where it achieves customer requirements and satisfaction, defects reduction and also to make sure the level of quality is being maintained (Sareen et al. ,2000).

Six Sigma has also been defined as quality improvement methodology at Motorola where it can reduce the number of defects to 3.4 parts per million opportunities (Utem, 2010.).

In other research paper, Six Sigma Methodology is being used for errors, excessive cycle time's reduction, and also to reduce the inefficient processes and cost overruns (Sharma et al, 2012.).

Six Sigma measures the distance of a given process deviates from perfection. It is named based on the process that has six standard deviations. The main idea is to measure the number of defects in a process, to figure out the way to eliminate the defects and probably can remove the defects as close as zero defects (Sharma et al, 2012). The precision of sigma level is shown in Table 2.2.

Table 2.2 Precision of Sigma Level

Sigma Performance Levels- One to Six Sigma		
Sigma level	Defects Per Million Opportunities (DPMO)	Precision
1	690,000	68.27%
2	398,537	95.45%
3	66,807	99.73%
4	6,210	99.9937%
5	233	99.9994%
6	3.4	99.9999998%

At Wipro, Six Sigma is defined as a measure of quality that achieve for near perfection. It means to have products and services that meet global benchmarks, to make sure the robust processes between the organisations, meet or exceed customer satisfaction and make quality a culture within.

Other than that, Six Sigma approach is actually based on customer. Sigma capability is a metric that identified the performance of a process. It is better if the sigma capability is higher. This is because it measures the process capability to get a zero defect work to achieve customer satisfaction. Therefore, it is said to be customer-driven.

Six Sigma approach is also based on data. It concentrates on process variation reduction, centring the process and on optimizing the process. The main point is on the process capability improvement rather than the product quality control. Therefore, it is said to be data- driven (Murugappan & Keeni, 2000).

To accomplish Six Sigma goals, define, measure, analyse, improve and control (DMAIC) methodology is used. DMAIC methodology is a tool that used five phases to solve problem. It is typically used on the process that fails to meet customer demand. Every phase in DMAIC must follow accordingly which is shown in Figure 2.1.

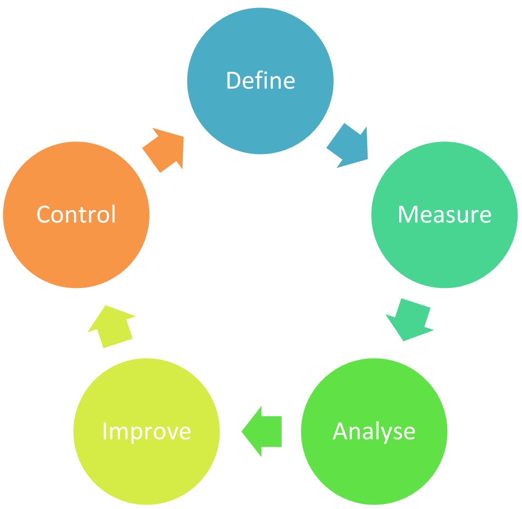


Figure 2.1 DMAIC Methodology

Every phases in DMAIC has it owns definition and functions (Oguz et al., 1916):

i. **Define** phase: To define and understand the customer's requirements and expectations which will affect the output of the process.

ii. **Measure** phase: Select the relevant measurement factors through Six Sigma metrics.

iii. **Analyse** phase: To determine the factors of the defects through various statistical quality control tools.

iv. **Improve** phase: Focus on analysis through some experimentation and statistical techniques to generate improvements.

v. **Control** phase: to control and to monitor the process variations using statistical process strategy to ensure that improvements are sustained.

2.6 Company Background

The research was done in a garment industry, Dataran Setar Sdn Bhd which located in Pekan, Pahang. Dataran Setar Sdn Bhd is a make-to-order company which provide the services of clothing manufacturing. There are about 15 employees in this company, and have the sales turnover less than RM500,000, it is considered as small scale industry. There are many types of garment produced in this company which are coats, trousers, jackets, T-shirt and many more. They provide attire mainly for the students which participated in the National Service Malaysia and also some attire to the government office. Moreover, they also produce some clothing according to customer requirement. They wish to improve their quality services to meet customer satisfaction. Therefore the company has been selected for research as it suits the title.

2.6.1 Overall Process of the Production

The process flow of fabrication of clothes will be shown in the Figure 2.2.

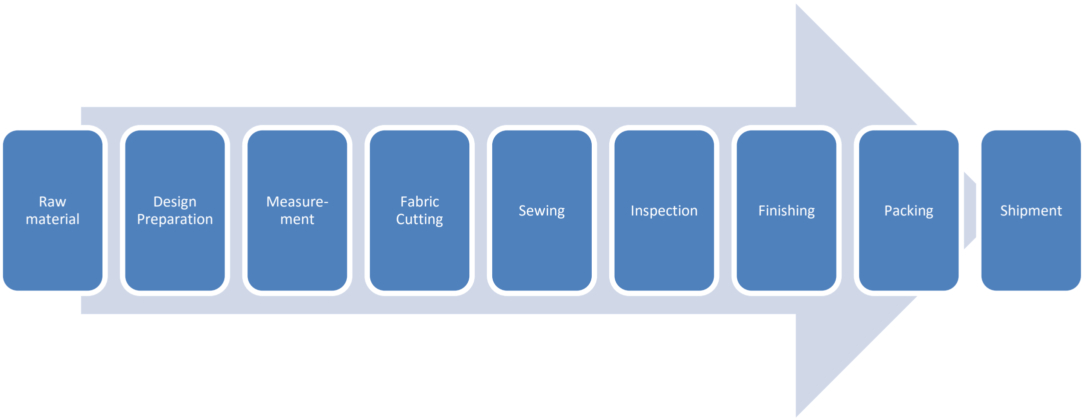


Figure 2.2 Process flow of fabrication of clothes

i. Raw Materials

In this garment industry, the raw material like fabric, thread, buttons and zips is ordered online or through phone calling. After confirming the order, the supplier will deliver the raw materials to the industry. If there happen urgent used in materials but inadequate of stocks, the employee will buy at the nearer fabric shop with higher price.

ii. Design Preparation

The sketch of the design normally will be given by the customer. For some other case, the employee of the industry will make a rough sketch after listening to customer's idea.

iii. Measurement

After having the sketch of the design, size of the body must be measured. However, for high order, the size of the clothes is standard for instance, size XS, S, M, L, XL, XXL and XXXL.

iv. Fabric cutting

After the measurement, fabric is cut with the help of cloth cutting machine.

v. Sewing

Sewing process is done after fabric cutting. It is a process sewing various parts of the cut pieces. There are many employees perform single operation in the workplace. For instance, one of the employee sew the waist seams or make button holes while another employee make only straight seams and make sleeve insets. They have their own responsibilities on the operations. Lastly, the part that had sewn like sleeves or pant legs is assembled to form clothing.

vi. Inspection

Quality control is a very important process before deliver to the customer. All the section of the clothing needs to be checked to prevent defects like open seams, wrong stitching techniques, non-matching threads and missing stitches.

vii. Finishing

Basic molding processes like pressing, pleating and creasing have to be done in the finishing stage.

viii. Packing

The finished garments are packed based on the size, design and colour.

ix. Shipment

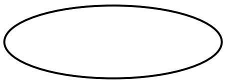
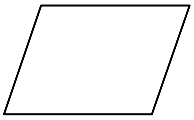
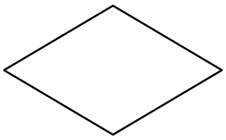
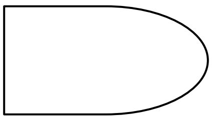
Finally, the bundle has been delivered to the customer through courier.

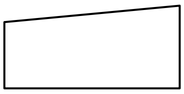
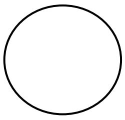
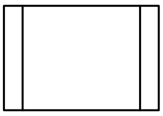
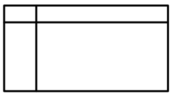
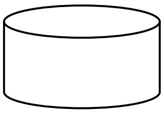
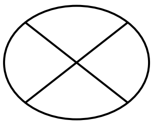
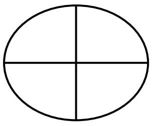
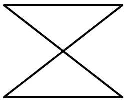
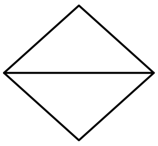
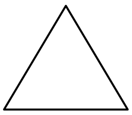
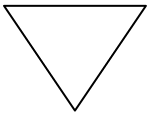
2.7 Statistical Tools and Techniques Used

2.7.1 Process Flow Chart

Process flow chart is also known as process flow diagram. It shows the steps of a process are in sequential order by applying different symbols. Table 2.3 shows the functions of each symbol (Tools & Improvement, 2015).

Table 2.3 Flow Chart Symbols and their Functions

Symbols	Name	Functions
	Start/ End	It represents start or end point.
	Arrows	It is a connector that show relationship between the representatives shapes.
	Input/ output	It represents input and output.
	Process	It represents a process.
	Decision	It indicates a decision.
	Document	Data that can be read by people.
	Delay	Indicates a delay in a process
	Multiple document	Indicates multiple documents.
	Preparation	Indicates a modification to a process, such as setting a switch or initializing a routine.

	Manual input	Indicate any operation that is performed manually by a person.
	Manual loop	Determine a sequence of commands that will continue to repeat until stopped manually.
	Connector	Determine an inspection point.
	Subroutine	Indicates a named process, like a subroutine or a module.
	Internal storage	Indicates an internal storage device.
	Database	Determine a list of information with a standard structure that allows for searching and sorting.
	Summing junction	Logical AND
	Or	-
	Collate	Determine a step that organises data into a standard format.
	Sort	Determine a step that organises items list sequent.
	Inventory	Finished goods storage
	Inventory	Raw material storage

When the flow chart is used?

- To understand the steps of the process.
- To study the improvement of a process.
- To ensure the process is recorded in details.
- To plan a project.

Procedure:

i. Define the process that needs to be designed.
ii. Decide the process of the boundaries of the process and also the detail that included in the diagram.
iii. Brainstorm the activities that take place.
iv. All the activities are arranged in proper sequence.
v. After all the activities included and the sequence is correct, arrows are draw to figure the flow of the process.

The example of a flow chart is shown in Figure 2.3.

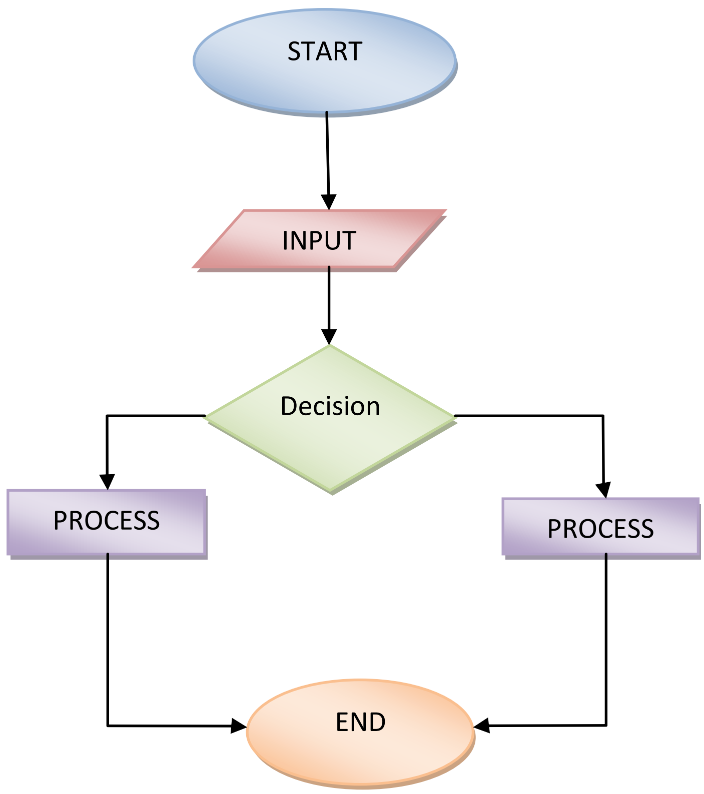


Figure 2.3 Example of Flow Chart

2.7.2 Pareto Chart

Pareto chart is also named as Pareto analysis or Pareto diagram. It is a graph that ranks data classification from left to right in descending order. It is used to analyse the data on frequency of problems or causes or defects in a process. It shows the most significant defects to focus on. Figure 2.4 shows an example of Pareto chart (Meran et al., 2013).

When should Pareto Chart be used?

i. To break big problems into smaller pieces and identify major contributors.
ii. To prioritise the problems or defects.
iii. To focus on the most important part when there occur many problems or reasons.
iv. To analyse the frequency of the causes and reasons.
v. To identify the amount of incidents in each category.

Goals

i. Indicate the presence of the 80/20 rule in the data.
ii. Reveal the categories that provide the most to an issue and pivot on that.
iii. Discrete data is shown by category displaying cumulative impact of every category.

Procedure

i. Represent the data in categories.
ii. Sum up the frequency of every category to choose the right scale on the Y-axis of the Pareto Chart.
iii. Represent the bars according to the categories in descending order from left to right based on their frequency.
iv. One of the categories will be named “others” when various categories role up the last five percent of frequency.
v. Display the curve that shows cumulative percentage by using Y2-axis.

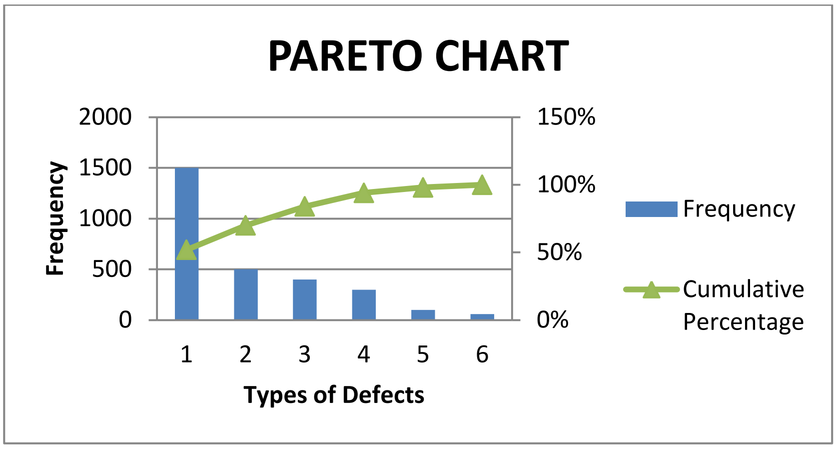


Figure 2.4 Pareto Chart

2.7.3 Cause and Effect Diagram

The cause and effect diagram is also known as Ishikawa diagram. It is used to identify possible causes. It shows the relationship between the causes and the effects. It is a very effective tool that can immediately sort ideas of causes into categories which shown in hierarchy form. Figure 2.5 shows the example of Ishikawa diagram (Meran et al., 2013).

When should cause and effect diagram is used?

i. To collect possible causes, before further analyses.
ii. To sort out some relationships between the factors affecting the effect.
iii. To analyse problems so that right action can be taken.

Goal

i. Provide an organised framework during brainstorming on potential causes.
ii. Visualize the interactions between the possible causes.
iii. A basis will be generated for further analysis.

Procedures

i. Draw up the problem as question, and then insert the problem to the fish heard for example late in deliveries.

ii. From the question, brainstorm the possible causes. Enter the possible problems to the fish bone using 6M which are Man, Material, Machine, Measurement, Method and Mother of Nature.

iii. Asking "why" to clarify the ideas.

iv. Continue working until all the potential causes are identified.

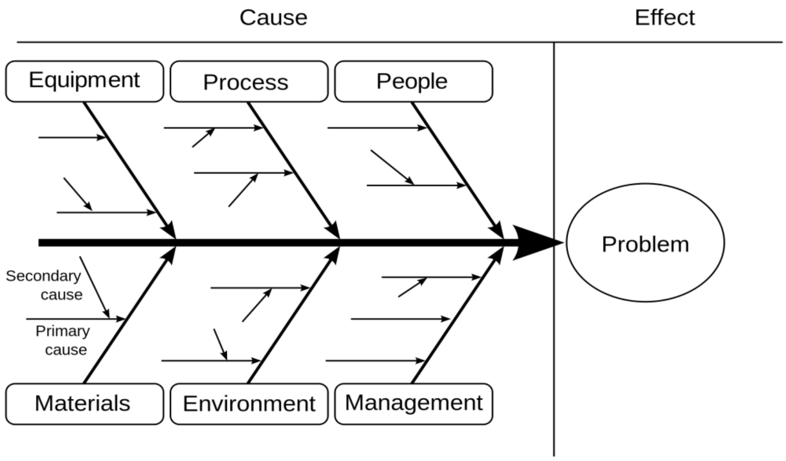


Figure 2.5 Ishikawa Diagram

2.7.4 Cause and Effect Matrix

A cause and effect matrix is a tool that relates process steps and the process inputs and also correlates to the process outputs. The step is scored to identify relative impact. It decides which inputs should be addressed first from process map. It is used to relate and emphasize X's to customer Y's through numerical ranking. X is rated where it relates to the output while the score for Y is according to the importance of the customer. Figure 2.6 shows an example of Cause and Effect Matrix (Meran et al., 2013).

When Cause and Effect matrix be used?

i. To narrow a list of X, inputs to a more practicable one

ii. To relate and emphasize X's to customer Y's through numerical ranking.

Procedure

i. First, the key of customer requirement, namely outputs are identified using process map or other tools
ii. After that, all the output are ranked using 1 to 10 scales and assigned to prioritise the factor.
iii. Inputs like all the process steps and materials are identified through process map or other tools.
iv. Evaluate the correlation for every inputs and outputs.
v. Calculate the score by multiplication.

Coffee Delivery at Diner		Temp of Coffee	Taste	Strength		Customer Requirements / Process Outputs
		8	10	6		Importance
Process Step	**Process Input**	**Correlation of Input to Output**				**Total**
1. Clean Carafe		0	3	1		36
2. Fill Carafe with Water		0	9	9		144
3. Pour Water into Maker		0	1	1		16
4. Place Filter in Maker		0	3	1		36
5. Put Coffee in Filter		0	9	9		144
6. Turn Maker On		3	1	0		34
7. Select Temperature Setting		9	3	3		120
8. Receive Coffee Order		0	0	1		6
9. Pour Coffee into Cup		3	1	3		52
10. Offer Cream & Sugar		3	9	3		132
11. Complete Transaction		1	1	1		24
12. Say Thank You		0	0	0		0

Figure 2.6 Causes and Effect Matrix

2.7.5 Failure Mode and Effect Analysis (FMEA)

Failure Modes and Effects Analysis (FMEA) is called Failure Modes, Effects, and Critically Analysis (FMECA). It is an organised tool that can identify, analyse and document a product and process design. Once the failure is identified, the effects of those failures on performance are recognised, and some appropriate actions will be taken to remove or minimise the effects of those failures. It is a pivotal reliability tool that helps to keep away cost incurred from product failure and liability.

FMEA basically very useful in three areas, namely design, manufacturing and service. It aims to examine product failure and also the effect of the failure to the user in design area, while in manufacturing area, it examines the factors that affect a lot to the quality of a process. Moreover, in service area, it is use to avoid the wrongly use of the tools and materials in servicing a product (Meran et al., 2013).

There is actually having three elements in FMEA,

i. Failure Mode: It describes the method where a design fails to perform according to their specification.
ii. Effect: It is the impact on the customer from the failures.
iii. Cause: The element that result in failure mode.

When should FMEA be used?

i. It is used when identifying potential causes for further investigation.
ii. It is used when identifying the risk and weak points in process.

Goals

i. To identify potential failures and weak points.
ii. To identify the priorities for further investigation.
iii. To evaluate the risk faced by the customer from a process.
iv. To reduce and mitigate the risks by deriving actions.

FMEA is shown in Table 2.4

Table 2.4 Failure Mode and Effect Analysis

Process or product name:									
Process step	Potential Failure Mode	Potential Failure Effects	SEV	Potential causes	OCC	Current Control	DET	RPN	Action recommended

2.7.6 Process Map

Processes are the steps of actions designed to transform X's, namely inputs into Y's, outputs. Process map is actually a tool use to determine all steps and decisions in a process within a diagram. Process map is shown in Figure 2.7 (Meran et al., 2013).

Goals

i. To describe the flow of materials, information and documents in a process.
ii. To display multiple tasks contained between the processes.
iii. To display the inputs transform into outputs.
iv. To determine the decisions made along the chain.

Procedure

i. First, process boundaries are established.
ii. Process in operation is observed.
iii. Outputs, customers and the key requirements are listed out.
iv. Inputs, Suppliers, and the key Requirements are listed out.

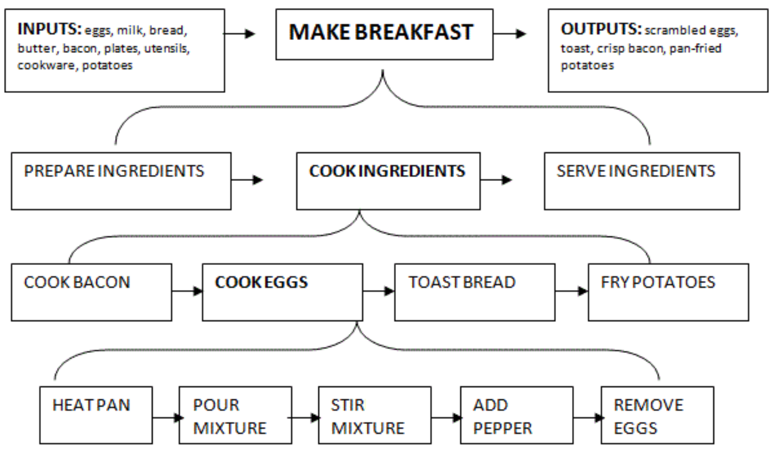


Figure 2.7 Process Map

2.8 Data type

There are two types of data namely (Meran et al., 2013):

i. Discrete data means qualitative data for example the value of the data can only be “zero” or “one”, or “good” or “bad”. Table 2.5 shows the example of the discrete data and continuous data.

ii. Continuous data are the data that can be measured to any degree of precision for example the data characterised by volts, size, weight and others.

Both types of data are used for measuring process capability.

Table 2.5 Example of Discrete Data and Continuous Data

CTQ TYPE	CONTINUOUS	DISCRETE
Dimension	Actual dimension	Good or bad; Pass or fail
Time	Actual time	Under/ Over estimate
Money	Actual cost	Under/ Over budget
Completeness	% Completeness	Present/ Absent
Accuracy	Number of errors	Good/ Bad

2.9 Process capability

Process capability is a tool that compares the output of under control process to a specification limits by conducting capability indices. There are different method to see the process capability between discrete data and continuous data. Table 2.6 shows the method to calculate the process capability.

Table 2.6 Process Capability Method

<table>
<tr><th>Discrete Data</th><th>Continuous Data</th></tr>
<tr><td>Defects per Opportunity</td><td>Six Sigma Process Report</td></tr>
<tr><td rowspan="2">Defects per million Opportunities</td><td>C_p and C_{pk}</td></tr>
<tr><td>$Z_{longterm}$, $Z_{short\ term}$ and Z_{shift}</td></tr>
</table>

2.9.1 Defects per million opportunities (DPMO)

A defect per million opportunities is used to calculate the process capability in discrete data. There are three important aspects (Meran et al., 2013):

i. Unit (U): Units mean the number of parts, assemblies or sub-assemblies inspected or tested.
ii. Opportunity (OP): Opportunity means a characteristic where you inspect or test.
iii. Defects (D): Defects are where the result in customer dissatisfaction or a non-conformance to specifications.

Calculation for DPMO:

i. Defects per unit
   = D/U
   = total number of defects/ total number of units
ii. Total opportunities (TOP)
   =U*OP
   =total number of units x number of characteristics per unit
iii. Defects per opportunity(DPO) = D/TOP
iv. Defects per million opportunities (DPMO)= DPO x 1,000,000

After obtaining DPMO, convert DPMO into Z-score. The sigma table is shown in Table 2.7.

Table 2.7 Sigma Table

Long term DPMO	Actual Sigma (long term)	Reported Sigma (short term)
500,000	0	1.5
460,172	0.1	1.6
420,740	0.2	1.7
382,089	0.3	1.8
344,578	0.4	1.9
308,538	0.5	2.0
274,253	0.6	2.1
241,964	0.7	2.2
211,855	0.8	2.3
184,060	0.9	2.4
158.655	1.0	2.5

Table 2.7 Sigma Table (continued)

135,666	1.1	2.6
115,070	1.2	2.7
96,801	1.3	2.8
80,757	1.4	2.9
66,807	1.5	3.0
54,799	1.6	3.1
44,565	1.7	3.2
35,930	1.8	3.3
28,716	1.9	3.4
22,750	2.0	3.5
17,864	2.1	3.6
13,903	2.2	3.7
10,724	2.3	3.8
8,198	2.4	3.9
6,210	2.5	4.0
4,661	2.6	4.1
3,467	2.7	4.2
2,555	2.8	4.3
1,866	2.9	4.4
1,350	3.0	4.5
968	3.1	4.6
687	3.2	4.7
483	3.3	4.8
337	3.4	4.9
233	3.5	5.0
159	3.6	5.1
108	3.7	5.2
72	3.8	5.3
48	3.9	5.4
32	4.0	5.5
21	4.1	5.6
13	4.2	5.7
9	4.3	5.8
5	4.4	5.9
3.4	4.5	6.0

2.9.2 Continuous Capability

For continuous capability, continuous data is used to describe the process by using average, standard deviation and normal curve. Some relevance specifications is created from the process, they are target values, upper and lower specification limits. A statistical principle of standard normal probability distribution is applied to determine the probability of process capability (Meran et al., 2013).

i. C_p value: The upper (USL) and lower specification limit (LSL) are used to determine the C_p value. After that, the distance is divided between USL and LSL by six standard deviation of the process.

Formula: C_p= USL-LSL/6s

ii. C_{pk} value: to indicate C_{pk}, the distance between the nearest SL and mean is divided by 3 standard deviation of the process.

Formula: C_{pk}=min [USL-bar X/3s; barX-LSL/3s]

2.10 Run Chart

Run chart is also called run-sequence plot where it is a graphical display that display the data in a time sequence. It is an analytical tool that often used for quality improvement. A good deal of the performance of the process with minimal mathematical complexity can be obtained. The data represent the output or the performance of a manufacturing process. It shows cycles, trends, shifts or non-random patterns. It can help to determine defects and the time occurred and controls the progress when there are solutions implemented. Figure 2.8 shows an example of a run chart (Meran et al., 2013).

There are some advantages and limitations of run chart. Advantages of run chart are:

i. Can observe the differences of the displayed data easily.
ii. Can use to find the critical time period when there are many problems occur.
iii. The trend displayed in the run chart is used as a baseline for continuous improvement.

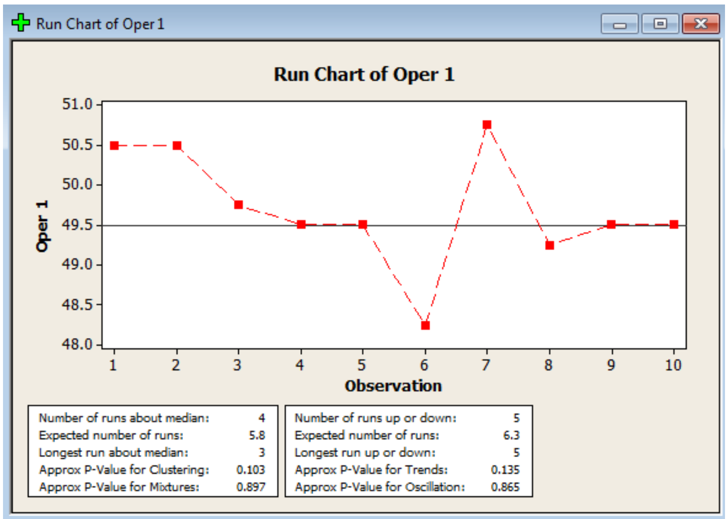


Figure 2.8 Run Chart

2.11 Types of Normality Tests

The test results determine whether null hypothesis should be rejected or not rejected where the data come from normally distributed population. Normality test can be done and create a normal probability plot in the same analysis. The normality test and probability plot are the best tools for judging normality. Following are the types of tools to perform normality tests.

2.11.1 Anderson-Darling

The Anderson-darling test compares the empirical cumulative distribution function (ECDF) of the sample data with the distribution expected if the data were normal. If the observed is largely different, the null hypothesis of population normality will be rejected.

2.11.2 Ryan-Joiner

The Ryan-Joiner test evaluates normality by calculating the correlation between the data and the normal scores of the collected data. If the correlation coefficient is near to 1, the population is possibly to be normal. The Ryan-Joiner statistic judges the strength of this correlation; if it is smaller than the suitable critical value, the null hypothesis of population normality will be rejected. Present test is alike to the Shapiro-Wilk normality test.

2.11.3 Komogorov-Smirnov

The Komogorov-Smirnov compares the ECDF of the sample data with the distribution expected when the data were normal. If this observed is largely difference, the null hypothesis of population normality will be rejected. If the p-value of this test is less than the chosen α, that's mean null hypothesis should be rejected and population is concluded not normal.

2.11.4 Comparison of Anderson-Darling, Ryan-Joiner and Komogorov-Smirnov

Anderson-Darling and Kolmogorov-Smirnov tests are based on the empirical distribution function. Ryan-Joiner (similar to Shapiro-Wilk) is based on regression and correlation. All three tests are working very well in identifying a distribution as not normal when the distribution is skewed. All three tests are less distinguishing when the underlying distribution is a t-distribution and non-normality is due to kurtosis. Usually, between the tests based on the empirical distribution function, Anderson-Darling tends to be more effective in detecting departures in the tails of the distribution. Usually, if departure from normality at the tails is the major problem, many statisticians would use Anderson-Darling as the first choice.

CHAPTER 3

METHODOLOGY

In this chapter, methodology of this research is being described. Flowchart and also other techniques were used during the research. DMAIC cycle of Six Sigma is being used in this research. This method was chosen as many of the researchers consider that DMAIC methodology is highly suitable to execute the quality improvement projects.

3.1 Flow Chart

Figure 3.1 shows the flow chart of this research.

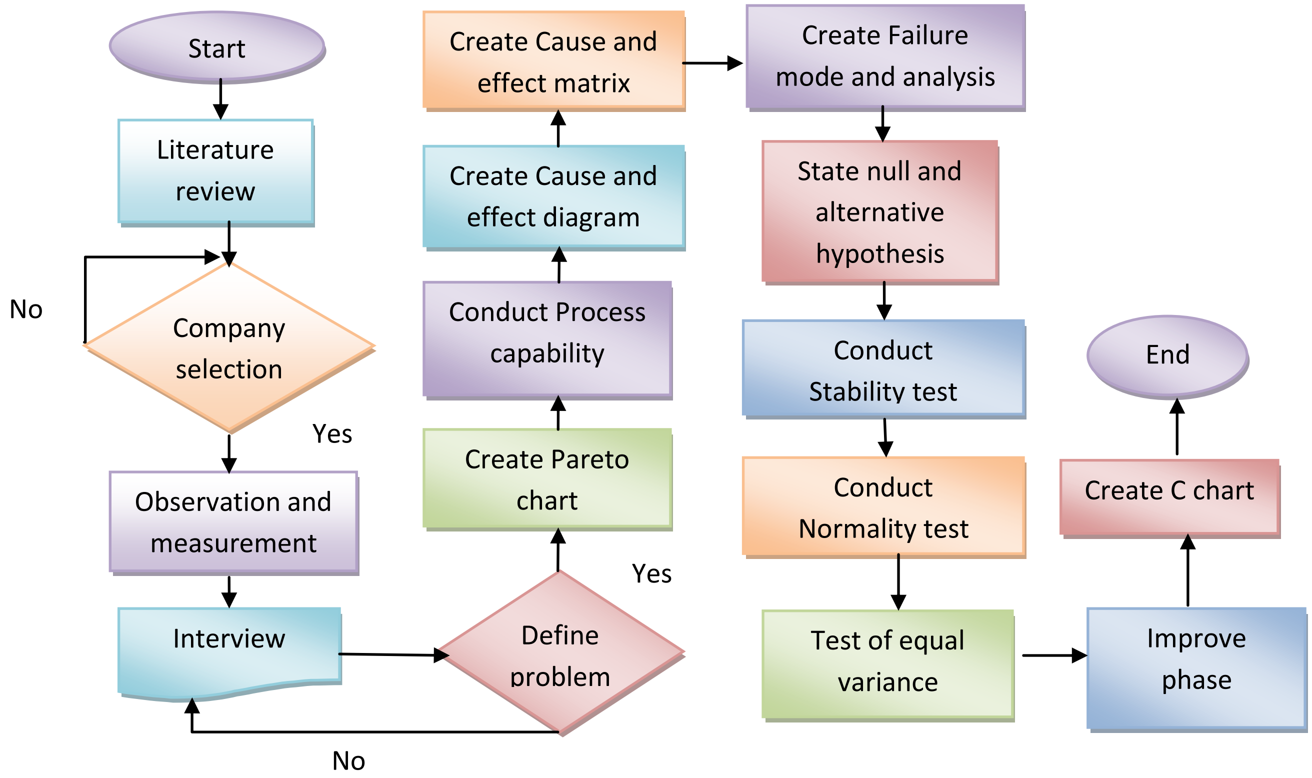


Figure 3.1 Flow Chart

3.2 Literature Review

In the beginning of the research, literature study like journals, website, books and several other references was performed in order to search theory that can be applied to the research. Literature on Six Sigma was studied especially on the quality improvement of manufacturing industries. Moreover, there are also another parts of theory is being investigated specifically for example the statistical tools being used in Six Sigma. This is to ensure the functions of every tool are understood and easy to coordinate while using.

3.3 Company Selection

Company has been selected according to their performance of the organization. Among all the companies, Dataran Setar Sdn. Bhd, a garment manufacturer which located in Pekan, Pahang, has been selected as they have more specific performance on the organization. Dataran Setar Sdn Bhd is a make-to-order company which provide the services of clothing manufacturing. There are about 15 employees in this company, and have the sales turnover less than 500,000, therefore it is considered as small scale industry. They wish to improve their quality services to meet customer satisfaction. Therefore the company has been selected for research as it suits the title.

3.4 Observation

After the selection of the company, observations had been done in the production department of the company in order to understand the process of garment to be produced. A simple standard operating procedure (SOP) was given to provide easy understandings on the process and get an introduction on the work performed. First, the company will get the raw material from the supplier. Then, a design is prepared, can be designed by the designer of the garment factory or provide by the customer. After that, a measurement will be done if the customer needs the clothes to be fit or measurement according to standard size, S, M, L, XL, XXL and XXXL. Then, will be the fabric cutting, sewing, quality checking, finishing, packing and shipment.

3.5 Interview

A few interviews have been done to the employees of the selected company in order to understand the process thoroughly. More detailed information on certain process has been given by the employees to ensure the research get along smoothly. Some critical issues on the performance of the organization from the customers are delivered to the researchers from the employees in the interviews. Improvement suggestions were discussed in the interviews in order to get the inputs from the employee on how feasible the ideas were and develop some other suggestions in the future.

3.6 Define

Critical to Quality (CTQ) is selected to identify what is significant to the quality of the services to verify things that are important to the customer. It can identify the critical needs of the customer, determine the quality of requirement and identify the performance requirement. Example of CTQ is shown in Table 3.1. A survey form will be created and distribute to the customer.

Table 3.1 Critical to Quality

Voice of customer	Key customer issue	Critical to quality
Clothes were not ready as the time promised.	Get the clothes on time.	Service's quality- Requires producing the products on time.
Need to wait long to get the clothes	No need to wait long to get the shirt.	Service's quality – Shorten the time of producing the clothes.

After that, the survey form will be collected back to indicate the critical of quality. Then, a few CTQ will be detected and it will be summarised out. Then, a Pareto Chart, a graph that ranks data classification from left to right in descending order will be used to prioritise the root cause that causing customer dissatisfaction which is shown in Figure 3.2.

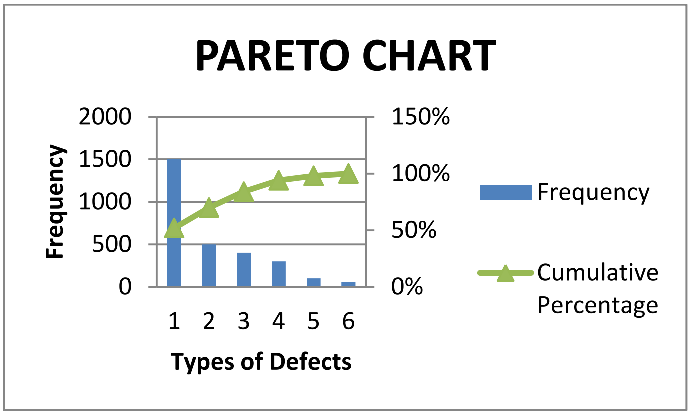


Figure 3.2 Pareto Chart

3.7 Measure

Process capability is used to compare the output of under control process to a specification limits by conducting capability indices. There are different methods to see the process capability between discrete data and continuous data. For the discrete data are the defects per million opportunity (DPMO) while for the continuous data are C_p and C_{pk}.

Some of the equation will be used to calculate DPMO:

i. Defects per unit = D/U

= total number of defects/ total number of units

ii. Total opportunities (TOP)=U×OP

=total number of units × number of characteristics per unit

iii. Defects per opportunity(DPO) = D/TOP

iv. Defects per million opportunities (DPMO)= DPO × 1,000,000

While for the continuous data, the upper (USL) and lower specification limit (LSL) are used to determine the C_p value. After that, the distance is divided between USL and LSL by six standard deviation of the process.

Formula: C_p= USL-LSL/6s

To indicate C_{pk}, the distance between the nearest SL and mean is divided by 3 standard deviation of the process.

Formula C_{pk}=min [USL-bar X/3s; barX-LSL/3s]

Easier way to see the process capability, Minitab software will be used to conduct the process capability. Everything includes the Cp and Cpk value, sample mean and standard deviation will be shown in the graph. An example of process capability using Minitab software is shown in Figure 3.3.

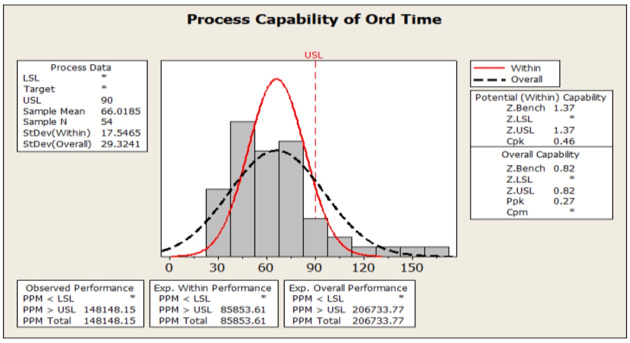


Figure 3.3 Example of Process Capability

After the process capability, cause and effect diagram is created to identify the possible causes. It will show the relationship between the causes and the effects. It is a very effective tool that can immediately sort ideas of causes into categories which shown in hierarchy form. It will provide an organised framework during brainstorming on potential causes and also visualise the interactions between the possible causes. First, formulate the problem as question and insert the problem into the fish head for example late in deliveries. After that, brainstorm all the possible causes. Enter the possible causes to the fish bone using 6M which are Method, Man, Machine, Material, Measurement and Mother of Nature and continue working until all the potential causes are identified. Figure 3.4 shows then cause and effect diagram.

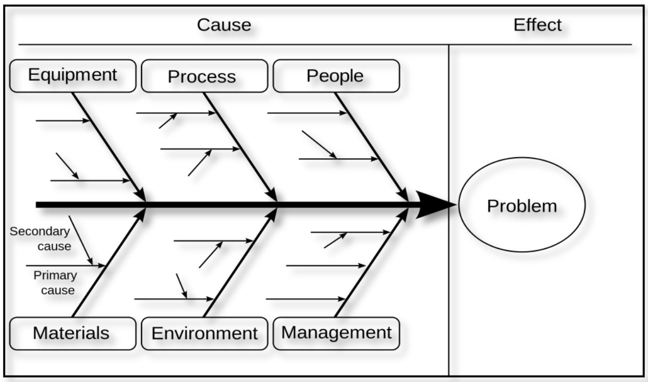


Figure 3.4 Cause and Effect Diagram

Next, process map is created to understand, analyse and document processes and activities and to list out the outputs and inputs. It describes the flow of materials, information and documents in a process, display multiple tasks contained between the processes, display the inputs transform into outputs and determine the decisions made along the chain. First, process boundaries are established and process in operation is observed. After that, list out the output, customers and the key requirement. Lastly, inputs, supplier and key of requirement will be listed out.

Cause and effect matrix is used to discover which factors that affect the outcomes. A cause and effect matrix is a tool that relates process steps and the process inputs and also correlates to the process outputs. The step is scored to identify relative impact. It decides which inputs should be addressed first from process map. It is used to relate and emphasize X's to customer Y's through numerical ranking. X is rated where it relates to the output while the score for Y is according to the importance of the customer. First, the key of customer requirement, namely outputs are identified using process map. After that, all the output are ranked using 1 to 10 scales and assigned to prioritise the factor. Inputs like all the process steps and materials are identified through process map or other tools. After that, evaluate the correlation for every input and output, and then calculate the score by multiplication. Table 3.2 has shown the example of cause and effect matrix.

Table 3.2 Example of Cause and Effect Matrix

Coffee Delivery at Diner		Temp of Coffee	Taste	Strength		Customer Requirements / Process Outputs
		8	10	6		Importance
Process Step	**Process Input**	**Correlation of Input to Output**				**Total**
1. Clean Carafe		0	3	1		36
2. Fill Carafe with Water		0	9	9		144
3. Pour Water into Maker		0	1	1		16
4. Place Filter in Maker		0	3	1		36
5. Put Coffee in Filter		0	9	9		144
6. Turn Maker On		3	1	0		34
7. Select Temperature Setting		9	3	3		120
8. Receive Coffee Order		0	0	1		6
9. Pour Coffee into Cup		3	1	3		52
10. Offer Cream & Sugar		3	9	3		132
11. Complete Transaction		1	1	1		24
12. Say Thank You		0	0	0		0

Lastly, FMEA is created at the end of the measure phase. It is an organised method that can identify, analyse and document a product and process design. Once the failure is identified, the effects of those failures on performance are recognised, and some appropriate actions will be taken to remove or minimise the effects of those failures. Table 3.3 shows the example of FMEA.

Table 3.3 FMEA

Process or product name:									
Process step	Potential Failure Mode	Potential Failure Effects	SEV	Potential causes	OCC	Current Control	DET	RPN	Action recommended

Specific factors causing the problems happened will be determined after constructing FMEA. After FMEA, data collection will be done based on the specific factors.

3.8 Analyse

After the measure phase, analysis will be conducted. First, state null hypothesis and alternative hypothesis. Then use a run chart to conduct a stability test. If the P-value is more than 0.05, the data is stable. If the P-value is smaller than 0.05, the data is not stable. After that, a normality test will be conducted using Anderson-Darling test. For the normality test, if the P-value is larger than 0.05, the data is normal whereas if the P-value is smaller than 0.05, the data is not normal. Lastly, the homogeneity of variance test will be conducted. When the P-value is larger than 0.05, H_o will be accepted and H_a will be rejected, the variances are equal. If the P-value is smaller than 0.05, H_a will be accepted and H_o will be rejected, the variances are different.

After that, Table 3.4, input and output method will be used to identify which final test will be conducted to see whether or not the input is significant to the output. For example, if the data collected are continuous X and continuous Y, which mean regression, will be used. If the data are continuous Y and discrete X, either T-test, ANOVA or homogeneity of variance will be used. Lastly, if the data are discrete Y and discrete X, either Goodness of fit or test of independence will be used.

Table 3.4 Input and Output Method

	Continuous X	**Discrete X**
Continuous Y	Regression	t-test ANOVA Homogeneity of variance
Discrete Y	**-**	Goodness of fit Test of independence

3.9 Improve

From analyse phase, the factors that have significant impact to the detected problem will be detected. Therefore, in this phase, brainstorming to fix the problems might be done. FMEA in measure phase had stated the solution to fix the problems. However, the solution might change base on the factors detected. The solution will be discussed in Chapter 4 after detected the factors in analyze phase.

3.10 Control

After the improved phase, control phase will be conducted. In this control phase, statistical process control tools will be used. Statistical process control consists of control charts or Shewart chart. First, the sampling strategy will be determined. Samples have to be collected when the control charts are used. The correct sampling is very important to producing valid control charts. The sampling strategy actually not only contains the size of the sample but also frequency of the sampling. After that, a suitable control chart will be selected according to the sample size and data type. The suitable control chart is shown in Table 3.5. After that, data will be collected and statistics and control limits will be calculated.

Table 3.5 Control Chart Selection based on Data Type

Data type		Sample size (subgroup)	Control Chart
Continuous data		1	IMR Chart
		<10(usually 3-5); constant	Xbar-R chart
		>10; variable	Xbar-S chart
Discrete data	Defect per part	Constant (usually larger than50); Number of defects larger than 5	c- Chart
		Variable (usually larger than 50) Number of defects larger than 5	u- Chart
	Defective parts	Constant (usually larger than 50)	np- Chart
		Variable (usually larger than 50)	p-Chart

CHAPTER 4

RESULT AND DISCUSSION

In this chapter, results will be obtained and will be discussed in details. Data was collected phase by phase at Dataran Setar Sdn Bhd by observing and recording the daily production. Minitab® software is using to obtain the results.

4.1 Define Phase

In define phase, survey form is first created. Then, the survey form is given to the customer to fill it to know the customer needs. Before created the survey form, interview has been done to employee in Dataran Setar Sdn Bhd to know which failure of service is most happening in their company. After the interview, types of failure service are concluded for example, garment unable to complete on time, wrong orders, employee's attitude, product failure, incorrect delivery, lack of responsiveness to the customer and price of the product is too high. Survey forms are then arranged properly after collected back. Then, Pareto chart is created using Minitab software which data is classified from left to right in descending order to prioritize the root cause that causing customer satisfaction. Pareto chart created is shown in Figure 4.1. Pareto chart shown that garment unable to complete on time is the critical issue in that company with 6 votes, follow by lack of responsiveness and wrong orders with same votes of 2, employee's attitude and price of product of 1 votes.

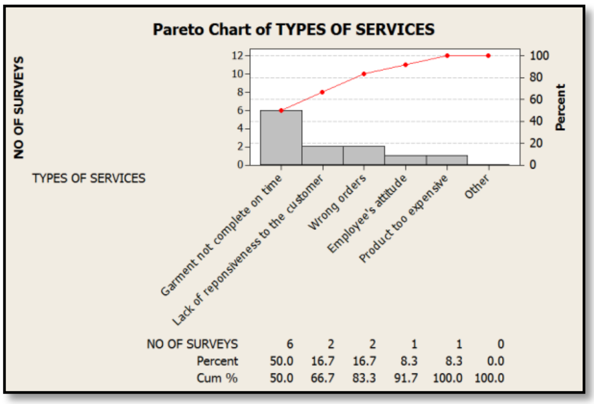


Figure 4.1 Pareto Chart

4.2 Measure phase

After the most critical issue has been found, process capability is needed to compare the output of under control process to a specification limit. Before creating process capability, data has to be collected first. Data collection is taken based on apron making. Number of apron produced daily is collected for two weeks. As the data is continuous data, sigma level (Z bench) is used to see process capability of the company.

Capability analysis is to determine whether a process is capable of producing output that meets customer requirements, when the process is in statistical control. Usually, the capability of a process is determined by comparing the width of the process spread to the width of the specification spread, which defines the maximum amount of variation allowed based on customer requirements. When a process is capable, the process spread is smaller than the specification spread. Process capability of production of apron is created using Minitab® software and is shown in Figure 4.2. It shows that the spread is wider than specification spread (line with red colour).

Z-bench is usually used to estimate the sigma level of a process. Using the Z-bench values, capability measures for the process can be determined. This table 4.1 shows the relationship between Z-bench values and other capability measures. From Figure 4.2, the Z bench value shows 0.57 when 90% of completeness is set as lower specification limit (LSL) to achieve the customer demand. From there, the PPM defective is shown very high. It means that the company has a very bad process capability because the production of apron is frequently below 90% completeness. USL has not been set because there are a lot of places to store the inventory.

Table 4.1 Relationship between Z-bench values

Z bench	Sigma level	PPM defective
1	2.5δ	158,655
2	3.5 δ	22,750
3	4.5 δ	1,350
4	5.5 δ	32
4.5	6.0 δ	3.4

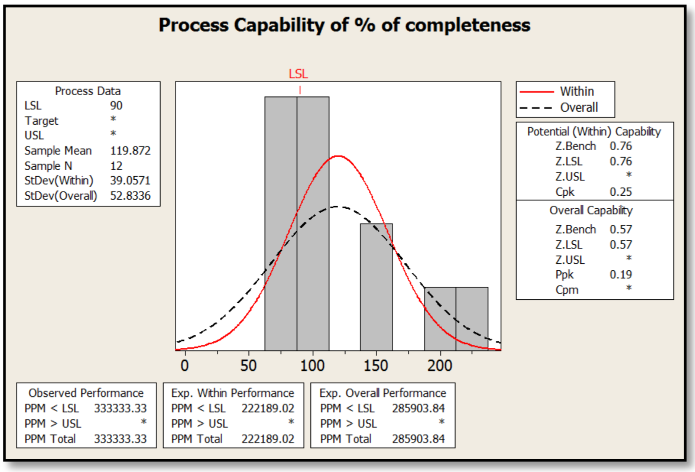


Figure 4.2 Process Capability of Production of Apron

After process capability is done, cause and effect diagram is created to identify the possible causes and brain-storming. Cause and effect diagram is shown in Figure 4.3. All the possible causes have been identified for further brainstorming.

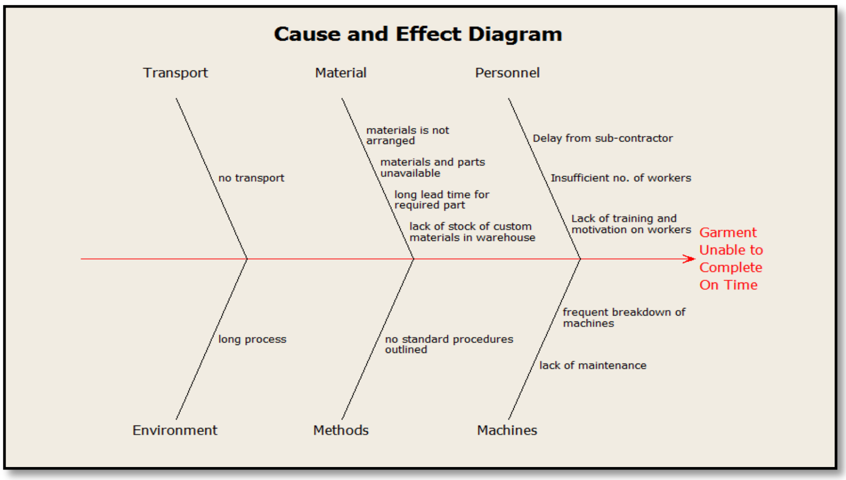


Figure 4.3 Causes and Effect Diagram

Next, process map is created describe the flow of the process and display the inputs and outputs. Process map is displayed in Table 4.2.

Table 4.2 Process Map

Process Input	-Thread -Fabric -Buttons -Zips -Needle -Sewing machine -Ruler	-Idea from customer -Workers experience	-Workers -Knowledge -Tools	-Materials -Knowledge -Workers -Tools -Machine	-Tools -Materials -Workers -Knowledge -Machine -Sub-contractor	-Workers	-Workers -Knowledge	-Workers
Process	**Materials and tools preparation**	**Design preparation**	**Measure -ment**	**Fabric cutting**	**Sewing**	**Inspection**	**Finishing**	**Packing**
Process output	Tools and materials are prepared	Design is prepared	Done measure -ment	Fabric cut	Done sewing	Done inspection	Done finishing	Done packing

Cause and effect matrix is then created to discover which factors affect the outcomes. Cause and effect matrix is shown in Table 4.3. From the table, the condition of the machine is the most critical one to affect the production since it has the highest rating in the cause and effect matrix of 308 scores, followed by subcontract and number of workers with rating of 303 and 269 respectively. Next is the workers' experience of 265 scores. Number of tools and materials in the warehouse has the same rating of 227. After that, will be the location of tools and materials placed with 178 rating and standard operation procedures of 158 rating. Therefore, four factors which have the higher rating will be considered in FMEA are condition of the machine, sub-contractor, number of workers and worker's experience.

Table 4.3 Cause and Effect Matrix

Garment completed on time		**Delay time**	**Processing time**	**Takt time**	**Lead time**	**Customer requirement**
		9	10	7	8	Importance
Process Input		**Correlation of input to output**				**Total**
1	Number of workers	7	8	10	7	269
2	Worker's experience	7	9	8	7	265
3	Number of tools	6	6	7	8	227
4	Amount of materials in warehouse	6	6	7	8	227
5	Condition of the machine	10	9	8	9	308
6	Location of tools placed	3	6	5	7	178
7	Location of materials placed	3	6	5	7	178
8	Standard operation procedures	2	8	4	4	158
9	Sub-contract	10	10	7	8	303

Lastly, FMEA is created at the end of measure phase which is use to identify, analyze and document a process. FMEA is shown is Table 4.4. Table 4.5, 4.6 and 4.7 show the severity scoring, occurrence scoring and detection scoring respectively. The RPN value is calculated using production of severity scoring, occurrence scoring and detection scoring.

Table 4.4 FMEA

Process or product name: Garment manufacturing									
Process step	Potential failure mode	Potential failure effects	SEV	Potential causes	OCC	Current control	DET	RPN	Action recommended
Materials and tools preparation	Materials and tools are not well prepared	Takt time increased	5	Lack of materials and tools in the warehouse	6	Buy the materials at nearer shop if urgent.	4	120	Order the materials early before used
Design preparation	The design is wrongly draw	Processing time increased	4	Workers lack of skills and experience	3	Let experience workers to design the clothes	4	48	Hire more skilled workers or provide training to present workers
Measure-ment	Workers do not measure the fabric correctly.	Processing time increased	7	Lack of skills and experience	5	Let experienced worker do the measurement	5	175	Hire more skilled workers or provide training to present workers
Fabric cutting	Workers do not cut the fabric correctly	Processing time increased	7	Lack of skills and experience	5	Let experienced worker do the cutting	5	175	Hire more skilled workers or provide training to present workers
Sewing	Lack of workers, machine problems	Takt time and delay time increased	9	Machine lack of maintenance, some machine too old, lack of workers	9	Sewing by hand instead of machine	2	162	Buy new machine and make a maintenance schedule biweekly
Logo sewing	Send to subcontractor	Delay time increased	5	Sub-contractor always delay	9	Just wait until they done sewing logo just proceed the next step	4	180	Hire skilled workers doing logo sewing
Inspection	Lack of workers	Lead time increased	2	Only one workers for inspection, finishing and packing	4	The only workers do all the inspection, finishing and packing	7	56	Hire more workers
Finishing	Lack of workers	Lead time increased	1	Only one workers for inspection, finishing and packing	4	The only workers do all the inspection, finishing and packing	7	28	Hire more workers
Packing	Lack of workers	Lead time increased	2	Only one workers for inspection, finishing and packing	4	The only workers do all the inspection, finishing and packing	7	56	Hire more workers

Table 4.5 Severity Scoring

Severity scoring	General evaluation criteria
Very high 10-8	It endangers the company's existence. Product cannot complete on time. Unacceptable excess of costs.
High 7-6	Large delay on completion time. High excess of costs.
Moderate 5-4	Delay on completion time. Moderate excess of costs.
Low 3-2	Small delay on completion time. Low excess of costs.
Very low 1	No delay on completion time. Minor excess of costs.

Table 4.6 Occurrence scoring

Occurrence scoring	General evaluation criteria
Very high 10-8	Products cannot complete on time is inevitable.
High 7-6	Products is highly cannot complete one time.
Moderate 5-4	Products is occasionally cannot complete on time.
Low 3-2	Products is relatively cannot complete on time.
Very low 1	Products can complete on time.

Table 4.7 Detection scoring

Detection scoring	General evaluation criteria
Very high 10-8	Very low probability that any failure would be detected.
High 7-6	Low probability that any failure would be detected.
Moderate 5-4	Moderate probability that any failure would be detected.
Low 3-2	High probability of detecting any failure by tried.
Very low 1	Very high probability of detecting any failure

From FMEA, the time delay by subcontractor has the highest rating of 180 scores followed by lack of skilled workers with 175 scores and condition of the machine of 162 scores. Lack of tools and materials is also one of the failures identified. Those problems also identified in cause and effect matrix as FMEA shows more detail information and provided with the actions recommended. Therefore, in analyze phase later, three factors will be considered which are, number of skilled workers, sub-contractor and condition of machine.

4.3 Analyse phase

Analysis of the data will be conducted after measure phase. Again, data will be collected base on the productivity of aprons. As in the measure phase, three factors have been identified which are number of workers, type of sub-contractor and condition of the machine. So, for the factors of number of workers, two teams have been divided, which are 8 workers and 5 workers for each team. Second, data will collected based on types of sub-contractor, sub-contractor 1 and sub-contractor 2 and third, types of machines, new machines and old machines.

First, null hypothesis and alternative will be stated. Null hypothesis (H_o) in this phase means the data is stable whereas alternative hypothesis (H_a) means the data is not stable. After that, run chart is created using Minitab® software to conduct stability test. Run chart is an analytical tool which the data represent the output or the performance of a manufacturing process. It will show clustering, trends, mixtures and oscillations. This test is based on the number of runs up or down, increasing or decreasing. As defined by this test, a run is one or more consecutive points in the same direction. A new run starts each time there is a change in the direction either ascending or descending in the sequence of data.

The test for the number of runs up or down is sensitive to two types of non-random behaviour—oscillation and trends. The two tests for randomness (Test for number of runs up and down and Test for number of runs about the median) detect trends, oscillation, mixtures, and clustering in the data. When the observed number of runs is greater than the expected number of runs, then oscillation is indicated. When the number of runs is less than the expected number of runs, then a trend is indicated.

For clustering, if the P-value is less than 0.05, it can be concluded that special causes are affecting the process, and investigation on possible sources should be done. Clusters may indicate sampling or measurement problems. A mixture is characterized by an absence of points near the centre line. Mixtures often indicate combined data from two populations, or two processes operating at different levels. If the p-value for mixtures is less than 0.05, there are mixtures in the data. A trend is a sustained drift in the data, either up or down. Trends may warn that a process will soon go out of control. If the p-value for trends is less than 0.05, there are trend in the data. In this case, the upward trend is circled and easily visible.

4.3.1 Run chart

4.3.1.1 Run Chart of Types of Machines

Run chart for types of machine has been created and shown in Figure 4.4 and Figure 4.5. Two types of machines, old machine and new machine have been used to compare their performance to the production. From Figure 4.4, P-value for clustering, mixtures, trends and oscillations is 0.5, 0.5, 0.17 and 0.83 respectively. Since all the P-value is greater than 0.05, Therefore, there is no indication of special causes variation or non-randomness.

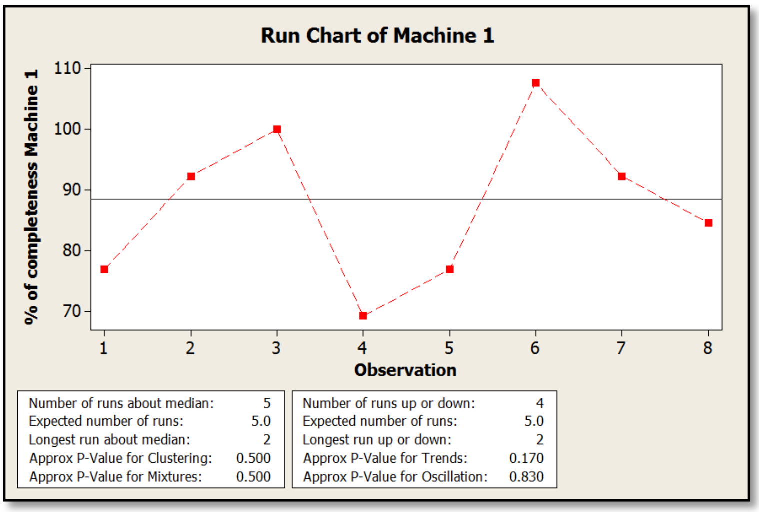


Figure 4.4 Run Chart of Machine 1

Figure 4.5 shows the run chart of machine 2, where the P-value of clustering, mixtures, trends and oscillations are 0.110, 0.890, 0.296 and 0.704 respectively. They are all greater than 0.05, therefore, it means there is no indication of special causes variation or non-randomness.

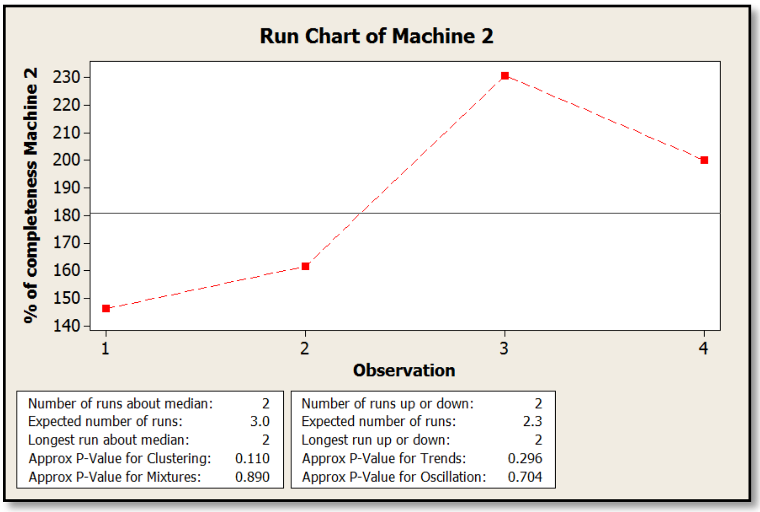


Figure 4.5 Run Chart of Machine 2

4.3.1.2 Run Chart of Types of Subcontractor

Run chart of types of subcontractor has been created and shown in Figure 4.6 and Figure 4.7. Two sub-contractors from different companies have been compared according to production. From Figure 4.6, the P-value for clustering is 0.181, mixtures 0.819, trends 0.027 and oscillations of 0.973. All P-value is greater than 0.05 except P-value of trends. Therefore, there is trend in the data. It is an upward trend. However, it is a good sign in this case because the percentage of completeness in the product is getting faster.

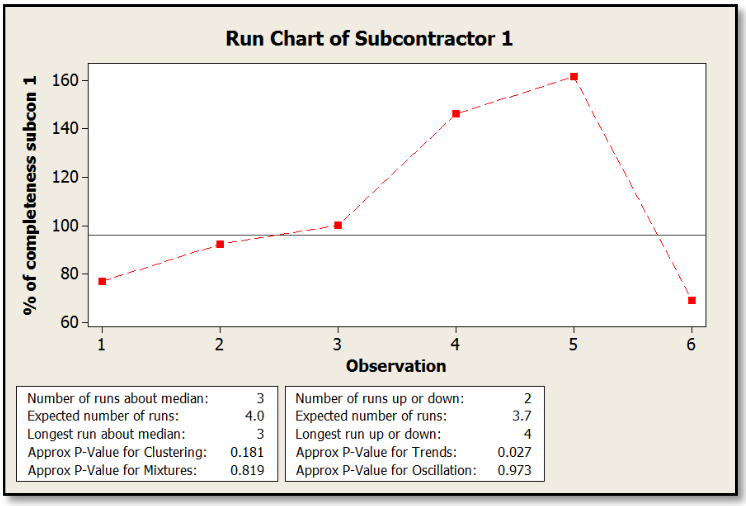


Figure 4.6 Run Chart of Sub-contractor 1

From Figure 4.7, the P-value for clustering is 0.181, mixtures 0.819, trends 0.027 and oscillations of 0.973. All P-value is greater than 0.05 except P-value of trends. Therefore, there is trend in the data. It is same with Sub-contractor 1. However, it is a downward trend. The % of completeness is getting lower and lower. There must be soon a process go out of control in their company. For example, maybe there are worn tools or a failure of a machine.

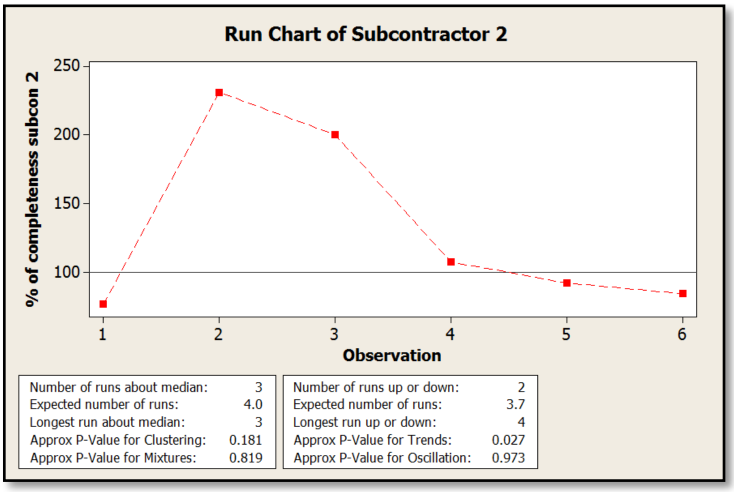


Figure 4.7 Run Chart of Sub-contractor 2

4.3.1.3 Run Chart of Types of Team

Run chart of types of team has been created and shown in Figure 4.8 and Figure 4.9. Two teams of Dataran Setar Sdn Bhd have been compared according to production. from Figure 4.8, the P-value for clustering, mixtures trends and oscillation are 0.034, 0.966, 0.220 and 0.780. P-values are all greater than 0.05 except P-value for clustering. Clustering can be seen in the figure which is first point to third point. Clusters may indicate variation due to special causes for example it is because the level of skill of every workers is different.

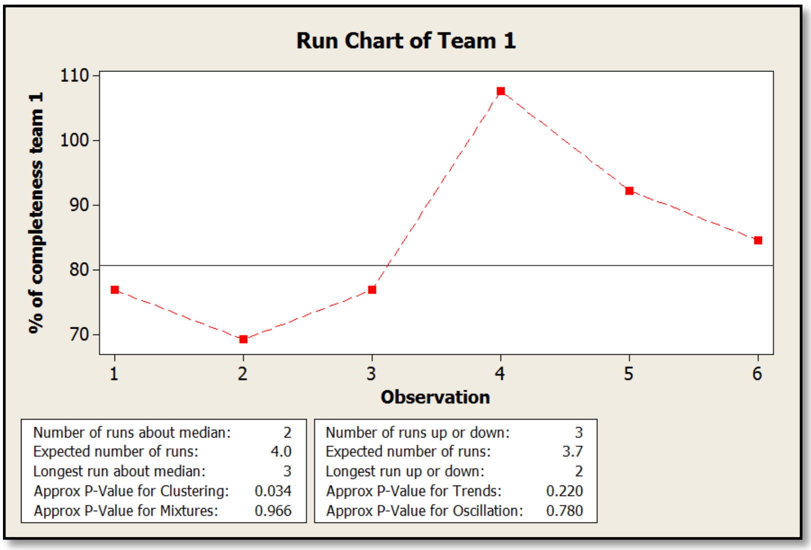


Figure 4.8 Run Chart of Team 1

Figure 4.9 shows run chart of team 2 which the P-values for clustering, mixtures, trends and oscillations are 0.034, 0.966, 0.027 and 0.973 respectively. P-values for clustering and trends are lower than 0.05. From the figure trends can be seen from point 1 to point 5. It is an upward trend. In this case, upward trend does not bring big deal because the percentage of completing the product is increasing. However, there occurs cluster pattern at point 4 to 6. This is because of the level of skill worker are slightly different.

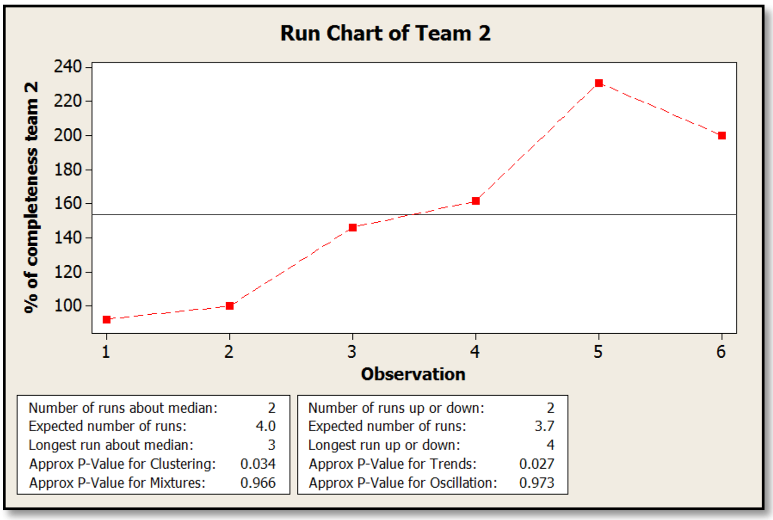


Figure 4.9 Run Chart of Team 2

4.3.1.4 Summary Table for Run Chart

Table 4.8 Summary Table for Run Chart

Factors	Types of machine		Types of Sub-contractor		Types of team	
	Machine 1 (old)	Machine 2 (new)	Sub-contractor 1	Sub-contractor 2	Team 1	Team 2
P-value for clustering	0.500	0.110	0.181	0.181	0.034	0.034
P-value for mixtures	0.500	0.890	0.819	0.819	0.966	0.966
P-value for trends	0.170	0.296	0.027	0.027	0.220	0.027
P-value for oscillations	0.830	0.704	0.973	0.973	0.780	0.973
Comments	Since all the P- value is greater than 0.05, Therefore, there is no indication of special causes variation or non-randomness.	Since all the P- value is greater than 0.05, Therefore, there is no indication of special causes variation or non-randomness.	Since P-value for trends is smaller than 0.05, that's mean there may have trend in the data. P-value for clustering, mixtures and oscillations are all greater than 0.05	Since P-value for trends is smaller than 0.05, that's mean there may have trend in the data. P-value for clustering, mixtures and oscillations are all greater than 0.05	Since P-value for clustering is smaller than 0.05, that's mean there may have cluster in the data. P-value for mixtures, trends and oscillations are all greater than 0.05	Since P-value for clustering is smaller than 0.05, that's mean there may have cluster in the data. P-value for mixtures, trends and oscillations are all greater than 0.05

4.3.2 Normality test using Anderson-Darling

The Anderson-Darling statistic measures how well the data follow a particular distribution. For a specified data set and distribution, the better the distribution fits the data, the smaller this statistic will be. For example, Anderson-Darling statistic can be used to determine whether data meets the assumption of normality. To start Anderson-darling test, hypotheses must be stated first. The hypotheses for the Anderson-Darling test are:

H_o: The data is normally distributed.

H_a: The data is not normally distributed.

Use the corresponding p-value to test if the data come from the chosen distribution. If the p-value is less than a chosen alpha which is 0.05, then reject the null hypothesis that the data come from that distribution. Anderson-Darling statistic also can be used to compare the fit of several distributions to determine which one is the best. However, in order to conclude one distribution is the best, its Anderson-Darling statistic (AD) must be substantially lower than the others. When the statistics are close together, additional criteria, such as probability plots, should be used to choose between them.

In this analysis, P-value will be used to analyse the distribution as it is much easier and does not need additional criteria.

4.3.2.1 Normality Test of Types of Machines

Figure 4.10 shows the normality test of Machine 1. The P-value for machine 1 is 0.816, it is greater than 0.05. From the figure, the points are all close to the straight line. Therefore the data is normally distributed and able to continue to conduct homogeneity of variance test.

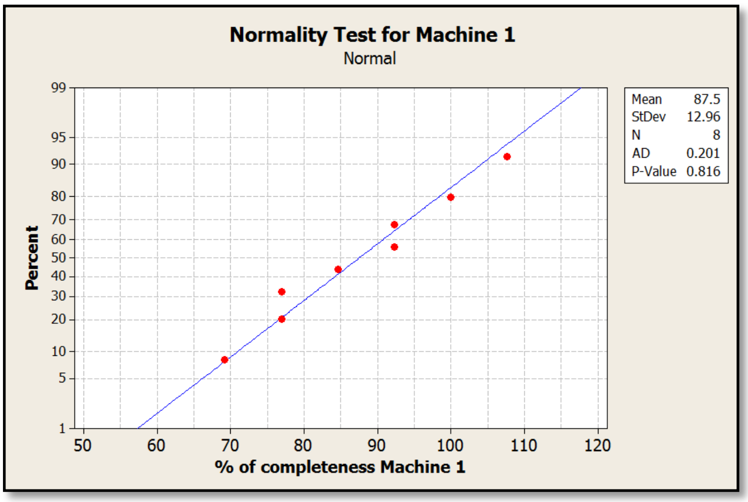


Figure 4.10 Normality test of Machine 1

Figure 4.11 shows the normality test of Machine 2. The P-value for machine 1 is 0.621, it is greater than 0.05. From the figure, the points are all close to the straight line. Therefore the data is normally distributed and able to continue to conduct homogeneity of variance test.

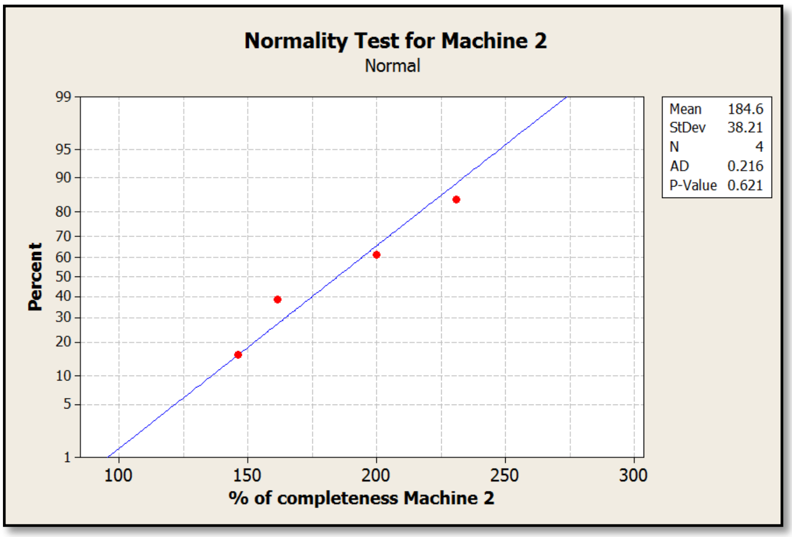


Figure 4.11 Normality test of Machine 2

4.3.2.2 Normality test of Types of Sub-contractor

Figure 4.12 shows the normality test of Sub-contractor 1. The P-value for subcontractor 1 is 0.304, which is greater than 0.05. From the figure, the points are all close to the straight line. Therefore the data is normally distributed and able to continue to conduct homogeneity of variance test.

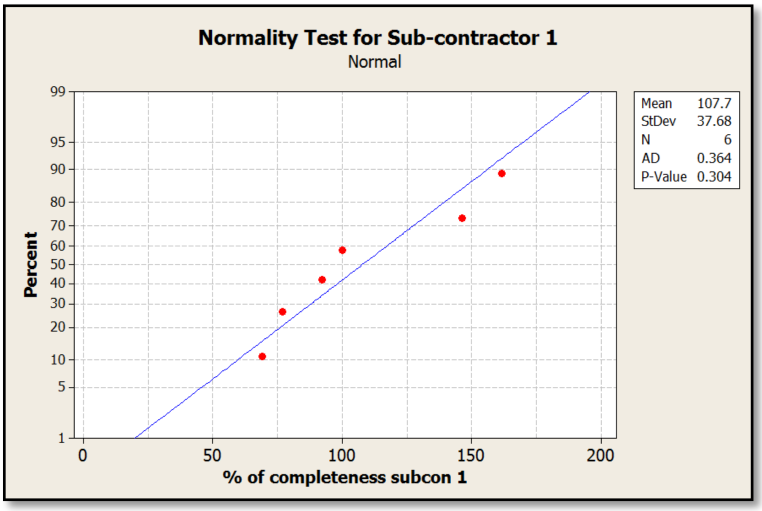


Figure 4.12 Normality Test for Sub-contractor 1

Figure 4.13 shows the normality test of Sub-contractor 2. The P-value for subcontractor 2 is 0.064, which is greater than 0.05. From the figure, the points are all close to the straight line. Therefore the data is normally distributed and able to continue to conduct homogeneity of variance test.

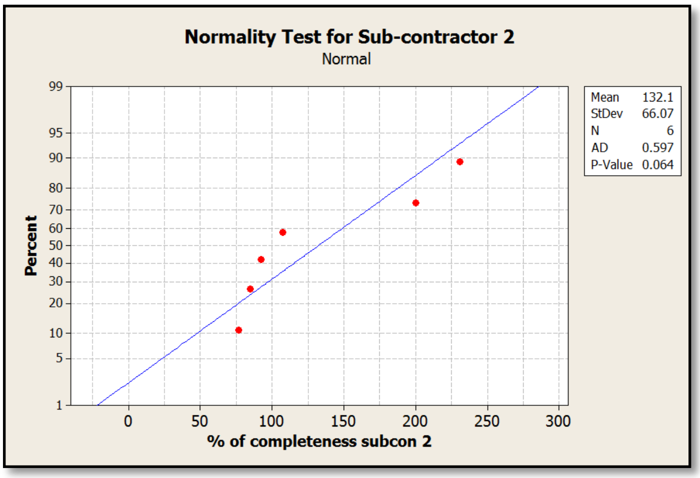


Figure 4.13 Normality Test for Sub-contractor 2

4.3.2.3 Normality Test of Types of Teams

Figure 4.14 shows the normality test of Team 1. The P-value for Team 1 is 0.513, which is greater than 0.05. From the figure, the points are all close to the straight line. Therefore the data is normally distributed and able to continue to conduct homogeneity of variance test.

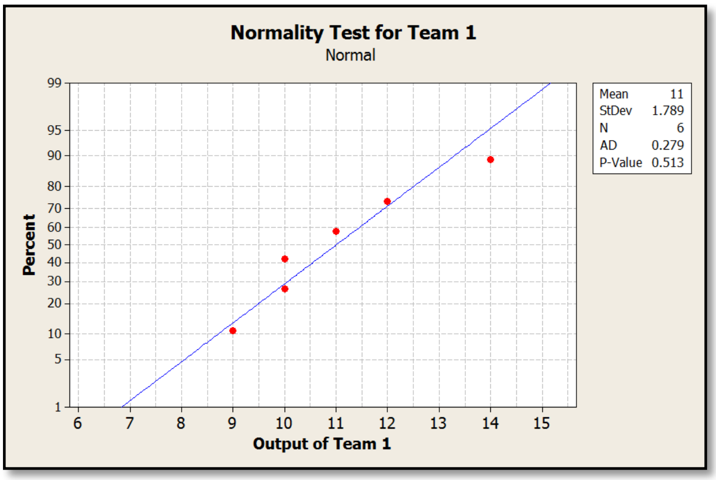


Figure 4.14 Normality Test for Team 1

Figure 4.15 shows the normality test of Team 2. The P-value for Team 1 is 0.513, which is greater than 0.05. From the figure, the points are all close to the straight line. Therefore the data is normally distributed and able to continue to conduct homogeneity of variance test.

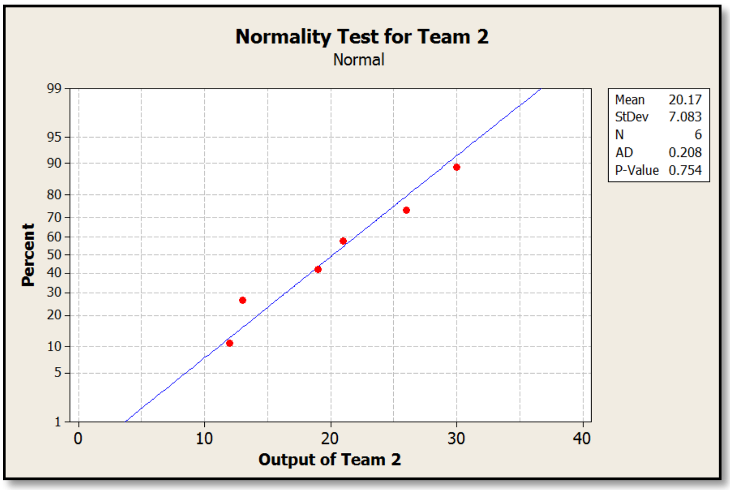


Figure 4.15 Normality Test for Team 2

4.3.2.4 Summary Table of Normality Test

Table 4.9 Summary of Normality Test

Factors	Types of machine		Types of Sub-contractor		Types of team	
	Machine 1 (old)	Machine 2 (new)	Sub-contractor 1	Sub-contractor 2	Team 1	Team 2
P-value	0.816	0.621	0.304	0.064	0.513	0.754
Comments	All P-value is greater than 0.05, so all the data is normal. Therefore, can proceed to next step which is homogeneity of variance.					

4.3.3 Homogeneity of Variance Test

Homogeneity of variance test is used because the input data is discrete data and output data is continuous data. Test for equal variances is to test the equality of variances between populations or factor levels. Many statistical procedures, such as analysis of variance (ANOVA) and regression, assume that although different samples can come from populations with different means, they have the same variance. Before doing homogeneity of variance test, hypotheses must first be stated. H_o means all variances are equal while H_a means not all variances are equal.

Test for Equal Variances displays results for Levene's test and the multiple comparisons method. For most continuous distributions, both methods give type I error rate that is close to the specified significance level which is alpha level. If the p-value for the multiple comparisons method is significant, then summary plot can be used to identify specific populations that have standard deviations that are different from each other.

Instead of Levene's method, results for the test can be based on the normal distribution. If there are only 2 groups or factor levels, then Minitab performs the F-test. If there are 3 or more groups or factor levels, then Minitab performs Bartlett's test. However, the F-test and Bartlett's test are accurate only for normally distributed data. Any departure from normality can cause these tests to yield inaccurate results.

In this analysis of homogeneity of variance test, levene's test will be used although the data are all normally distributed in previous normality test because there occurs some the P-value is almost nearer to 0.05. Therefore, levene's test is safer to be used in this case. When P-value is larger than 0.05, H_o will be accepted and H_a will be rejected, the variances are equal. If P-value is smaller than 0.05, H_a will be accepted and H_o will be rejected, variances are different.

4.3.3.1 Homogeneity of Variance Test of Types of Machine

Test of equal variance of types of machine is shown in figure 4.16. From the figure, the p-value is 0.007 which is lower than 0.05. Therefore, H_a will be accepted and H_o will be rejected, variances are different. This means that machines in Dataran Setar Sdn Bhd are affecting the production. This is why customer could not take their products on time.

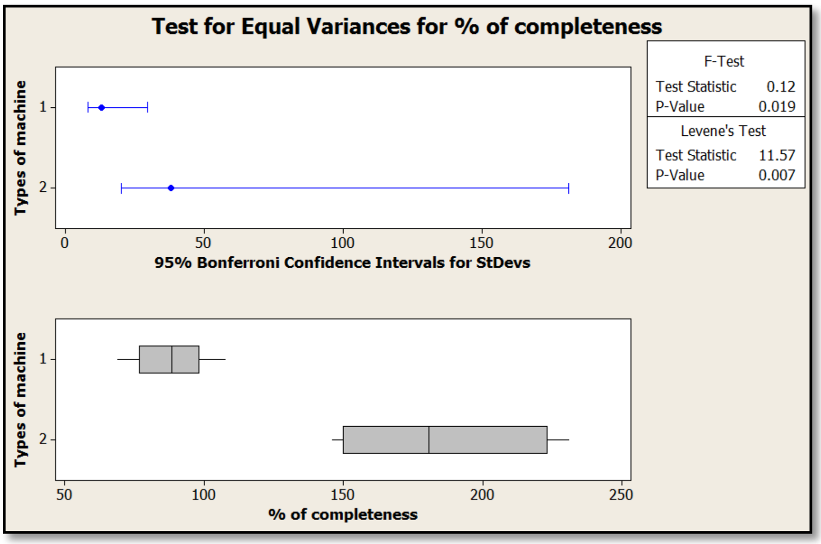


Figure 4.16 Tests for Equal Variance for Types of Machines

4.3.3.2 Homogeneity of Variance Test of Types of Sub-contractor

Test of equal variance of types of machine is shown in figure 4.17. From the figure, the p-value is 0.446 which is greater than 0.05. Therefore, H_o will be accepted and H_a will be rejected, variances are equal. This means that sub-contractor which Dataran Setar Sdn Bhd taking are not affecting the production.

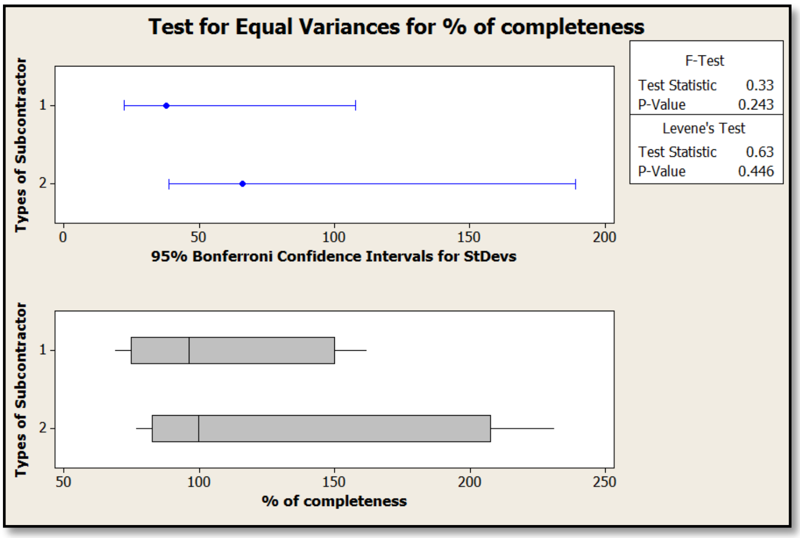


Figure 4.17 Test for Equal Variance for Types of Sub-contractor

4.3.3.3 Homogeneity of Variance Test of Types of Team

Test of equal variance of types of machine is shown in figure 4.18. From the figure, the p-value is 0.026 which is smaller than 0.05. Therefore, H_a will be accepted and H_o will be rejected, variances are different. This means that teams in Dataran Setar Sdn Bhd are affecting the production. This may be due to the number of workers is uneven. This is the reason why customer could not take their products on time.

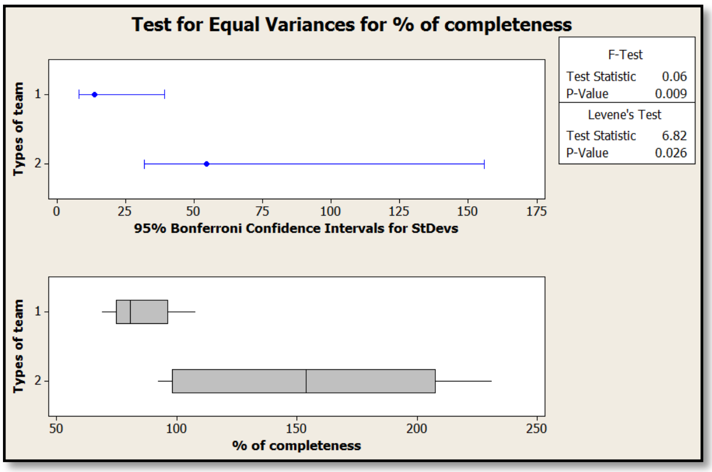


Figure 4.18 Tests for Equal Variance for Team

4.3.3.4 Summary Table of Homogeneity of Variance Test

Table 4.10 Summary of Homogeneity of Variance Test

Factors	**Types of Machine**	**Types of Sub-contractor**	**Types of Team**
P-value	0.007	0.446	0.026
Comment	Since P-value is smaller than 0.05, accept H_a and reject H_o	Since P-value is greater than 0.05, accept H_o and reject H_a	Since P-value is smaller than 0.05, accept H_a and reject H_o
Justification	Variances are different. Therefore, types of machine are significant to production.	Variances are equal. Therefore, sub-contractors are not really significant to production.	Variances are different. Therefore, types of team are significant to production.

4.4 Improve Phase

From previous analyse phase, types of machines and teams have big impact on the production. Therefore in this phase, brainstorming to fix the problems might be done. FMEA in measure phase had stated the solution to fix the problems. However, the number of machines and number of workers required need to be calculated according to factory efficiency and target to produce.

4.4.1 Improvement on Machines

Number of machines and types of machines need to be estimated in garment industry. The primary information needed to calculate numbers of machines are daily production target, number of hours in a shift, standard minutes for each operation and present efficiency of the factory.

First, a normal crew neck tee is selected to calculate machine requirement because there are many process operation to make crew neck tee as it may provide a more accurate calculation. Analysis of the operations to sew the garment has been surveyed in the factory. Table 4.11 shows the operation to make crew neck tee. Secondly, types of machine have to be identified which the factory using according to every operations. Then, record the standard minutes of every operation. After done collecting the standard minutes operation, daily production target of 50 pieces of crew neck tee has been set by the company manager. With all the information provided, theoretical machine requirement can be calculated using formula:

$$\textbf{number of calculated machine} = \frac{\text{target quantity in pieces} \times \text{individual operation of SMO}}{\text{working hours per shift} \times 60 \times \text{desired efficiency}}$$

Table 4.11 Operation to Make Crew Neck Tee and Number of Calculated Machines

Production target/ day=50 pieces		**Hours per shift=8 hours =480 mins**		**Factory efficiency=50%**	
No	**Description**	**Types of machine**	**Standard minutes of every operation (mins)**	**Number of calculated machines**	**Round-off number of machine**
1	Fabric cutting	Fabric cutting machine	15	3.1	3
2	Make neck rib and run stich	Sewing machine	5	1.0	1
3	Join shoulders	Sewing machine	3	0.6	1
4	Insert neck rib	Sewing machine	2	0.4	0
5	Serge margin	Sewing machine	4	0.8	1
6	Top stitch on neck rib	Sewing machine	8	1.7	2
7	Attach sleeve	Sewing machine	7	1.5	2
8	Sew side seam with labels	Sewing machine	7	1.5	2
9	Hem sleeves	Sewing machine	7	1.5	2
10	Bottom hem	Sewing machine	6	1.3	1
11	Button sewing	Button sewing machine	10	2.1	2
12	Logo sewing	Logo sewing machine	20	4.2	4
13	Packaging	Packaging machine	3	0.6	1

From the theoretical calculation in Table 4.11, Dataran Setar Sdn Bhd basically needs 3 fabric cutting machines, 12 sewing machines, 2 button sewing machines, 4 logo sewing machines and 1 packaging machines. According to present condition, the factory only have 1 fabric cutting machine, 15 sewing machines and 1 button sewing machine. They have none logo sewing machine because they do not have enough skilled workers to do logo sewing, therefore, they send it to subcontractor to do logo sewing. However in this solution, to achieve 50 pieces crew neck tee target, logo sewing machine is needed. To solve the number of skilled workers will be discussed later on in section 4.4.2. From table 4.11, can be seen that the factory have 15 sewing machines but the calculation only shows 12 are needed. Production with 15 sewing machines could not achieve 50 pieces product; however 12 sewing machines can achieve the target of 50 pieces this is because the factory's machines are old and never do any maintenance on that. Therefore, as a suggestion to the Dataran Setar Sdn bhd, they can try to trade in half number of sewing machines to new machines if they do not have enough money. If they have money they can trade in all of the sewing machines. However, the workers should do some service maintenance every week to the sewing machine.

4.4.2 Improvement on Number of Workers

From previous phase, types of teams have a very big impact to production. The team has different level of skill workers and different number of workers. Therefore, in this phase, number of skilled workers will be calculated and some solution provided to the factory to solve current problems. Dataran Setar Sdn Bhd working days are 5 days per week and 8 hours per shift. The factory only has one shift. The following Table 4.12 shows every processing step to make crew neck tee.

Table 4.12 Processing steps

No	Process	Operation time (T_o) /mins
1	Raw materials preparation	5
2	Design preparation	45
3	Measurement	30
4	Fabric cutting	15
5	Make neck rib and run stich	5
6	Join shoulders	3
7	Insert neck rib	2
8	Serge margin	4
9	Top stitch on neck rib	8
10	Attach sleeve	7
11	Sew side seam with labels	7
12	Hem sleeves	7
13	Bottom hem	6
14	Button sewing	10
15	Logo sewing	20
16	Inspection	20
17	Finishing	15
18	Packing	20
Total		229

These are the formulae to calculate the number of workers needed:

Total number of products unit annually, Q_f

=50 x 5 x 52

=13,000 units/ year

Number of processing steps, n_o=18

Number of components in products, n_p=13

Production operation, n_{of}

$=P\bullet Q\bullet n_o\bullet n_p$

=(13,000)(18)(13)

=3,042,000 operation/year

Number of hours needed, hr

= n_{of}(1/60)

=50,700hr/ year

Number of workers, w

=number of hour needed/ (8hr/day)(260days/year)

=24 workers

24 workers are needed in Dataran Setar Sdn Bhd after the calculation; however the present number of workers in the factory is 15 workers. Therefore, another 9 workers should be hired to achieve the target. Besides that, the company should provide training to their workers to improve their skills so that every of their workers are of the same skill level to avoid delay by lower skill workers.

If the company do not have enough money to hire another 9 workers, maybe they can try to change working hours from 8 hours to 12 hours. Last two steps are repeated to calculate the number of workers if the shift hour changes to 12 hours. The workers calculated are 16 workers. The company only need to hire another 1 worker if increase the working hours.

Number of hours needed, hr

= n_{of}(1/60)

=50,700hr/ year

Number of workers, w

=number of hour needed/ (12hr/day)(260days/year)

=16 workers

4.5 Control phase

After the improved solution is obtained, control phase will be conducted. First, data or samples again being collected to create control chart. As the data collected is productivity of the crew neck tee, they are discrete data. Basically, if the data is a continuous data and sample size is 1, IMR chart will be used to see the process control.

The I-MR chart consists of two charts in one. The first graph is an Individuals (I) chart, which plots the values of each individual observation, and provides a means to assess process centre. The bottom graph is a Moving Range (MR) chart, which plots process variation as calculated from the ranges of two or more successive observations. The green line on each chart represents the mean, while the red lines show the upper and lower control limits. An in-control process shows only random variation within the control limits. An out-of-control process has unusual variation, which may be due to the presence of special causes. First, the MR chart as the control limits for the I-chart is derived from the Range. So, if the MR chart is out of control, then the process is out of control. If there are any points outside the control limits, then the process is not under statistical control.

IMR chart is shown in Figure 4.19. From figure 4.19, it shows that the mean of I-chart is 1.4567 while the UCL and LCL is 1.7758 and 1.1375 respectively. While the MR-chart, the mean is 0.12, the UCL and LCL are 0.3921 and 0 respectively. The points vary randomly around the centre line and are within the control limits. No trends or patterns are present. It shows that every point of MR chart is in control. Therefore the process is under statistical control. When the target is achieved where the production is more than 50 and is under control, this means that the customer of Dataran Setar Sdn Bhd able to collect their products on time.

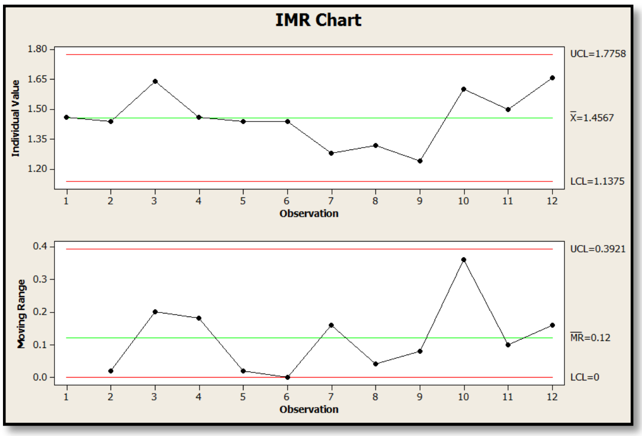


Figure 4.19 IMR chart

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter will be showing conclusion and recommendation. The result is concluded and some recommendation is given to the company to be applied in the future.

5.1 CONCLUSION

In a nutshell, after the garment industry adopting Six Sigma, a good result has been obtained. In this research, every steps of manufacturing process which are preparation of materials, design preparation, measurement, fabric cutting, sewing, inspection, finishing, packing and shipment is all understood by observing the company and interview the employee. The root causes of poor performance of the company have been identified in this research by making customer surveys and tools like Pareto chart, Cause and effect diagram, cause and effect matrix, FMEA and Minitab® software. The root cause identified is garment could not complete on time and the factors that affect the root cause are number of workers and types of machine. Dataran Setar Sdn Bhd has increased the number of workers from 15 workers to 24 workers. The company did not change their machines due to financial problem. However, the target of their daily production has achieved and this means that the garments are completed on time. Therefore, the quality of services using Six Sigma is improved.

5.2 RECOMMENDATION

5.2.1 General recommendation

The company should provide some training on regular intervals on employees' skills to help them increase their skill level. This might useful because when the employee very familiar using their skills, the lead time of every process will be increased. Besides that, the machines are highly recommended to have service maintenance once a week. Alongside this maintenance, total production maintenance where operators check and lubricate parts during cleaning after work can prevent machine breakdowns.

5.2.2 Specific Recommendations

After studying the current operating states of the productivity, some recommendation has been made to enhance the daily production in the future.

1. Increase the number of workers.
2. Increase the working hours of the operators.
3. Change the old machines into new machines.

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