APPLYING DMAIC FOR IMPROVING PRODUCTION YIELD IN TELECOMMUNICATION MANUFACTURING

By

SUREERAT SUPALEARKRATTANA

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT
Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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I, _Sureerat Supalearkrattana____

declare that this thesis/project and the work presented in it are my own and have been generated by me as the result of my own original research.

Applying DMAIC for Improving Production Yield in Telecommunication Manufacturer ____

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Date Cgrt -q01:3

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Finally, I would like to thanks my family, friends and my colleagues for all the guidance and support. I am grateful for their constant support and help throughout the period of this project.

Sureerat Supalearkrattana
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ABSTRACT

According to the goal of boosting up the company profits, most of the company will be focusing on effective cost reduction instead of price negotiation with suppliers. Internal cost becomes the significant factor, especially in electronic business which requires good quality and new technology at the lowest price. Therefore, in order to achieve customer satisfaction, the company recognizes that the competitive advantage will belong to the company who can offer the lowest price with good quality and responsiveness.

In order to gain a competitive edge in business, the company realizes that improving production yield by decreasing waste in production line is the priority. The result can be directly affected to company performance, lead time, and cost. With reference to the company strategy of high mix low volume product, this project focuses on the product by using criteria having the highest revenue and continuous demand for conducting the concept of DMAIC. This project finds that there are 4 main factors that cause low production yield, including false reject, missing part, solder bridging and connector misalignment. The root cause comes from machine and man. The analyze phase in this project, mainly using C-E analysis and team brainstorming requires an observation on the shop floor in order to define in-process actual issues at each process step. The result shows that implementing DMAIC can achieve the company target for improving the production yield.

However, this project is put into actual implementation at the ABC Company. Thus, the method, technique, and tool can be used in ABC Company only. It depends on products and reject criteria as well as company policies.

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CHAPTER I

GENERALITIES OF THE STUDY

Despite the highly-competitive electronics market, a company is not only required to improve product quality, services and processes, but also reduce costs in every activity in order to run an organization in the most profitable and sustainable manner. In reality, there are 4 elements in the current market which customers always are looking for, including good quality, speed, costs and reliability, and all of these become core competitive advantages that any business needs to achieve in order to enjoy the success.

1.1 Background of the Study

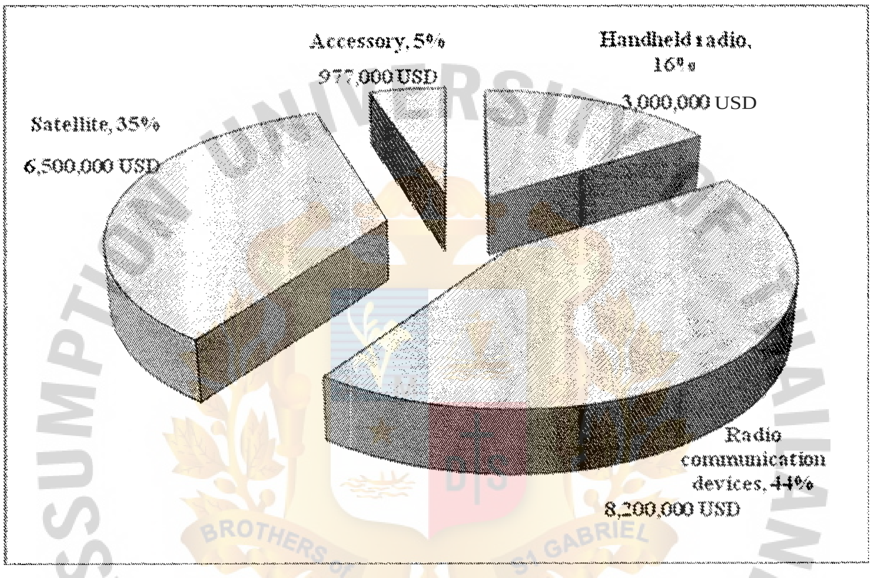
The company, which will be taken as a key part of this research, was established since 1985, is the ABC Company, located in Pathum-Thani The company itself strives to become one of the leading global providers of full turnkey box-build in Sea-telecommunication such as radio communication, handheld radio and accessory, contract manufacturing services to the industrial and high-end professional electronic sectors located in Europe and USA. Key capabilities of the company include advanced manufacturing technologies for surface-mounting devices, a wide range of research and development for new program, as well as a full range of supply chain service and distribution center.

According to the company's business policies, their business strategy designated to highly focus on hi-mix-low-volume production, meaning that the product has to be widely with a variety of product range while the supplied volume is low. The company also works through a product design stage collaboratively with customers in order to help them bring new products to market quickly and cost-effectively with the optimum degree of resources used.

1.2 Statement of the Problem

In an effort of the company to strive for the current competitive electronics market, there are a number of considerations made to reduce overall costs of production, and to understand possible hidden factories along the entire process.

Figure 1.1: Demand by product group in 2012



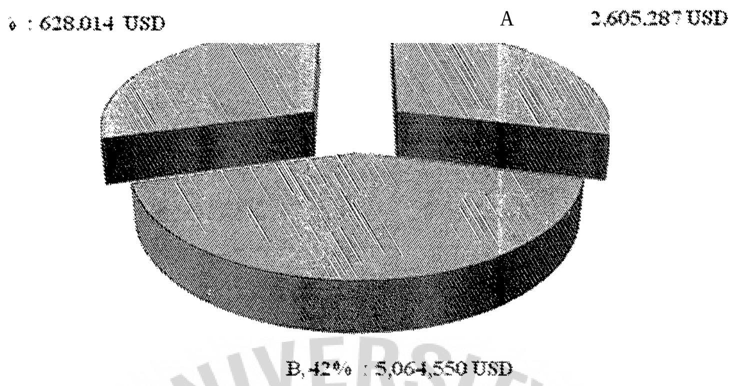
Source: ABC Company

Referring to Figure 1.1 (Demand by product group in 2012), there are 4 product groups which can be defined as follows.

- Handheld radio: the radio that can carry or be called a "Walkie Talkie"
- Radio communication device: a set of radio that is installed into a vessel control dashboard.
- Satellite: a group of communication products that use satellites such as a satellite transceiver.
- Accessory: Equipment or spare parts for supporting or being used with products such as a charger and a battery.

According to amount and demand, this case study will be focusing on the biggest product group: radio communication devices.

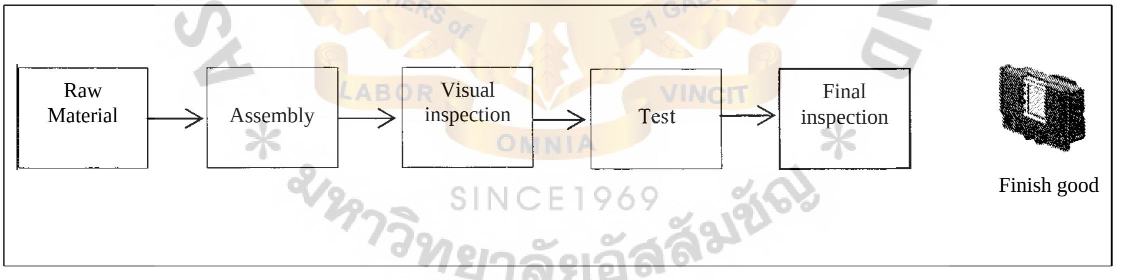
Figure 1.2: Demand by Model Group of Radio Communication Device in 2012



Source: ABC Company

Referring to Figure 1.2, radio communication devices include 3 models: A, B and C. Model B can be defined as a major portion in terms of production quantity and amount; therefore, this case study will focus on model B.

Figure 1.3: Process Flow Overview for Radio Communication Devices Model B



Source: ABC Company

Regarding Figure 1.3, the process flow overview for radio communication devices includes a 5-step process:

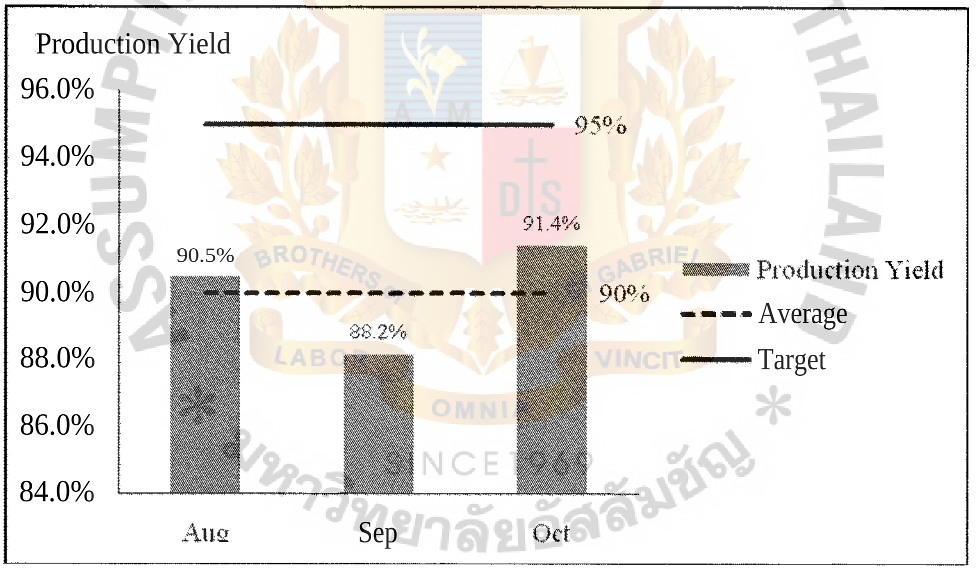
- Receiving raw materials through both local and oversea suppliers and then sending to productions.
- Production assembly raw materials based on specifications from customers.
- After completing the production process, the finished goods will be sent to visual inspection by operator for checking that all materials have been assembled into correct positions.

After passing the visual inspection process, the finished good will be sent for functional testing at test process in order to make sure that the product is usable.

The final inspection will be done as the last process for sampling inspection the overall appearance before being delivered to customers.

The study to be carried out in this project will be focusing on the test process. With reference to the production yield summary as shown in Figure 1.4, below the yield collected in the test process is reported at an average of 90% record during August-October 2012.

Figure 1.4: Production Yield Summary in Aug-Oct 2012



Source: ABC Company

The overall production will be done and its quality will be confirmed by the test process before arranging shipment to customers. It can be said that the test process is a significant step to make sure that the finished goods is usable based on specification from customers. By putting this into perspective, 10% of the rejected parts, if recovered, are equivalent to the estimated quantity of 156 pcs at the cost of 936,000 baht per month after being re-tested as good parts. With reference to the rejected cost, the main question of the project is related to "How to improve Production yield from 90% to 95% based on the company target?"

1.3 Research Objectives

Based on the problems found in ABC company, the objective of this case study is to improve the production yield from 90% to 95% by applying Define, Measure, Analyze, Improve and Control (DMAIC) techniques.

1.4 Scope of the Research

This research aims to study the product groups focusing on the radio communication device model B which is supplied for the big customer playing a key role of the telecommunication market. The data collection is carried out based on the engineering reports including analysis the yield and Pareto Analysis with reference to a weekly production status. DMAIC and Cause and Effect Analysis (C-E Analysis) will be used to find root causes of the rejections and part of the test process has to be improved versus each specific test failure categorized under the "Re-test process".

1.5 Significance of the Research

It can be said that the challenge of this project is about how to improve the production yield in order to reduce the significant reject rate, cost and production lead time with the use of DMAIC approach. The analysis for the whole process will have to be carried out to understand keys which the specific type of improvement is needed for individual failure groups.

1.6 Limitations of the Research

As business nature of the ABC Company relies on the high-mix-low-volume production strategy, the production for some products is not carried out periodically; hence, this gives an impact on a data collection and the number of data sets to be used in the related analysis. In order to gain an accurate data collection, it will take long period of time to complete the data collection as a demand is not stable and the correction is only carried out with a small production volume. For example, there are

300 pieces per shot in several-month period while actual production lead time is only 1-2 weeks to complete finished good production.

1.7 Definition of Terms

Cause and effect analysis	The diagram that identify potential cause has another name called a "Fish bone diagram" (Ghosh,2013).
DMAIC	The solving problem medthod consisting of 5 steps are defined: measure, analyze, improve and control (Leon, Perez, Farris, & Beruvides, 2012).
Failure mode and effect analysis (FMEA)	Activities that rate a potential failure and specify an action in order to reduce the likelihood of potential the failure (Estorilio & Posso, 2010).
Pareto	A 80-20 rule with 80 percent of the benefit will be obtained by 20 percent of the activities (Cervone, 2009).
Production Yield	The number of good parte compared with reject parts at the end of the process (Hammershoj, 1986).
Quality control	The process with techniques and activities to encourage and improve quality (Besterfield, 1998).

CHAPTER II

REVIEW OF RELATED LITERATURE

A key material in this case study is DMAIC consisting of 5 steps including define, measure, analyze, improve and control. In each step, there are many tools that can be adapted in order to find out a root cause of problems as well as a further action plan as part of production yield improvement by means of reducing wastes at the specific process, process optimization and human resources improvement through and effective training strategy. The root cause analysis will be done based on the process-specific focus.

2.1 **DMAIC**

This project using DMAIC is outlined for analyzing and improving the production yield. According to Kumar and Sosnoski (2009), DMIAC brings about manufacturer's successes in terms of cost saving, quality and process improvement. The framework consists of 5 steps which are define, measure, analyze, improve and control.

Referring to Gupta, Acharya and Patwardhan (2012), DMAIC used for handling a particular problem in order to reach high quality level consists of 5 steps as shown below.

- Define: Defining customers' requirement such as problem and solution priority.
- Measure: Process measurement.
- Analysis: Analyzing root causes of problems.
- Improve: Changing process or remodeling for betterment.
- Control: Keeping on new methodology from a process of improvement.

In each step, there are different approaches of Summers (2007) as stated in detail as follows:

Define: The significance of this process is defining all concerns with the problem study such as defining requirement and current condition, identifying the problem and setting the achievement target. With all of these, customers' feedback is a critical point for starting on defining the problem. The company is required to set objectives and targets according to the feedback or complaints from customers. In order to understand the process, the team is required to make use of the tools such as a process map and a flow chart (Arumugam, Antony, & Douglas, 2012).

Measure: In order to define the problem, the statistical data is needed to analyze the number of inputs, outputs and details of the key process in order to explore the problem. There are many tools of measurement that can be used in this phase such as why-why diagrams, Pareto diagrams, check sheet, process flow, and so on. In addition, the measurement of the direct activity is necessary as part of using tool as capability studies, process control and data collection in order to evaluate possible cause (Arumugam et al., 2012).

Analyze: This phase is aimed at identifying the key problems and finding out causes and effects that can be linked to the input and output process by selecting a few root causes. According to Arumugam et al. (2012), there are many tools that can be used such as Failure Mode Effect Analysis (FMEA), Design of Experiments (DOE), hypothesis testing, and regression. However, the tools implemented in this project can be given as C-E analysis and FMEA.

Improve: The proposed and implemented solution should be considered as criteria below.

- The solution should be simple and usable in a long term basis in order to prevent repeated problems in the future.
- The solution should be related to the root cause in order to fix the problem.
- The solution needs to be considered cost effective because some solutions can be costly and may not worth the results.

- The solution needs to be reasonable to implement and relate to the company's limitations such as period of the time.

Arumugam et al. (2012) suggested techniques that DOE and team brainstorming can help to find the solution.

Control: This phase is aimed to prove that the solution is effective and ensure that the implemented actions result in a consistent problem solving which consists of all control parameters for the process staying within control limits. The key method is based on the fact that the company is required to control an operation based on a new condition in order to solve the problem. In addition, a training program can be potentially helpful to have the operators and all related working staff familiar with the new working methods based on the implemented action plans.

2.2 Tool

There are many techniques that can be used in each step. Leon, Perez, Farris, and Beruvides (2012) stated that the tool used with DMAIC is unclear and not specified in each phase of DMAIC. The implementation for the effective technique needs to get cooperation, team involvement and team agreement towards the decision.

Ismyrlis and Moschidis (2013) stated that some of the various tools cannot be implemented with the current task and some tools are not concerned only about statistics. Table 2.1 is a summary of the common tools used in DMAIC.

Table 2.1: Common tools for DMAIC

Tool/Technique	Define	Measure	Analyze	Improve	Control
Pareto diagram	•	•	•	•	
Hypothesis test			•	•	
Analysis of variance			•	•	
Regression analysis			•	•	

Table 2.1: Common tools for DMAIC(Continued)

Tool/Technique	Define	Measure	Analyze	Improve	Control
Correlation analysis			•	•	
Design of experiments			•	•	
Non-parametric tests			•	•	
Flow chart			•	•	
Check sheet	•	•	•	•	•
Process map	•		•	•	
Process capability analysis	•		•		•
SIOPC diagram	•			•	
Critical to quality matrix	•	•		•	•
Quality function development (QFD)	•		•	•	
Benchmarking		•		•	
Statistical process control (SPC)		•	•		•
Failure Mode Effect Analysis (FMEA)			•	•	
Six sigma indicator	•			•	
Tree diagram	•				
GANTT chart	•				
SWOT analysis	•				
Voice of the customer	•				
KANO model	•				
Prioritization matrix	•				
Arrow diagram	•				
Matrix diagram	•				

Table 2.1: Common tools for DMAIC (Continued)

Tool/Technique	Define	Measure	Analyze	Improve	Control
Matrix dada analysis	•				
Control chart		•			
Descriptive statistic		•			
Histogram			•		
Run chat			•		
Pies, Bar charts			•		
Scatter diagram			•		
Cause-effect diagram			•		
Affinity diagram			•		
Brainstorming				•	
Mistake proofing (Poka yoke)				•	
Relation diagram				•	
Process decision diagram chart				•	

Source: Ismyrlis and Moschidis (2013, p. 9)

This part explains more details for the tools commonly used in this project.

2.2.1 SIPOC

Supplier-customer systems or SIPOC is known as Supplier, Input, Process, Output and Customer. The given tool can help to analyze tasks and variables in each operation (Nooramin, Ahouei, & Sayareh, 2011). In addition, Antony, Bhuller, Kumar, Mendibil, and Montgomery (2012), SIPOC is an interrelated process and relationship since suppliers, inputs, processes, output and customers applied for a business process and details in each step are extracted from team brainstorming.

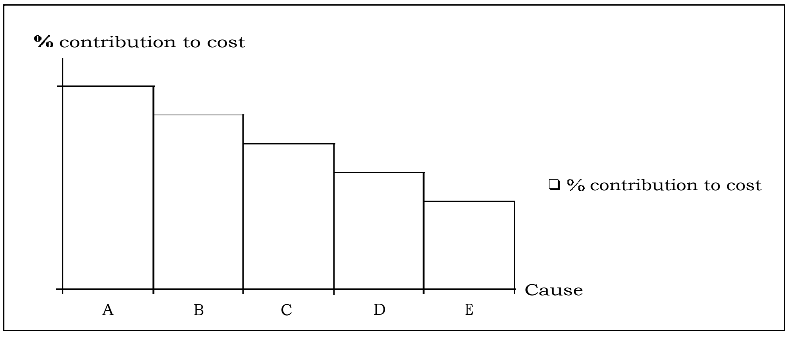
2.2.2 Check sheet

The detail of a basic tool for recording the data consists of a number of items and criteria. Normally users will be marked into a check sheet and this technique is used in a quality insurance (Summers, 2007).

2.2.3 **Pareto** diagrams

According to Villarreal and Kleiner (1997), the Pareto chart presents the frequency or effects of the problems regarding the highest values reference to the important problems that often occur and shows a few problems that are most effective to a company. This tool also helps to monitor performance of any changes that have been implement in a company. Summers (2007) stated that Pareto is the graphic ranking of most of the problems based on the concept of 80-20 rule means "80% of problem come from 20% of cause". However, there are some concepts that ponit to the cost effects with the quality issue such as Hutchins (1980). The Pareto can encourage cost effects concerning quality problems, as some companies will show the graph with the scarp cost instead of the frequency cause of quality issue as shown in Figure 2.1 below.

Figure 2.1: **Pareto** plotting by referring to cost effect from quality issue



Source: Hutchins (1980, p. 12)

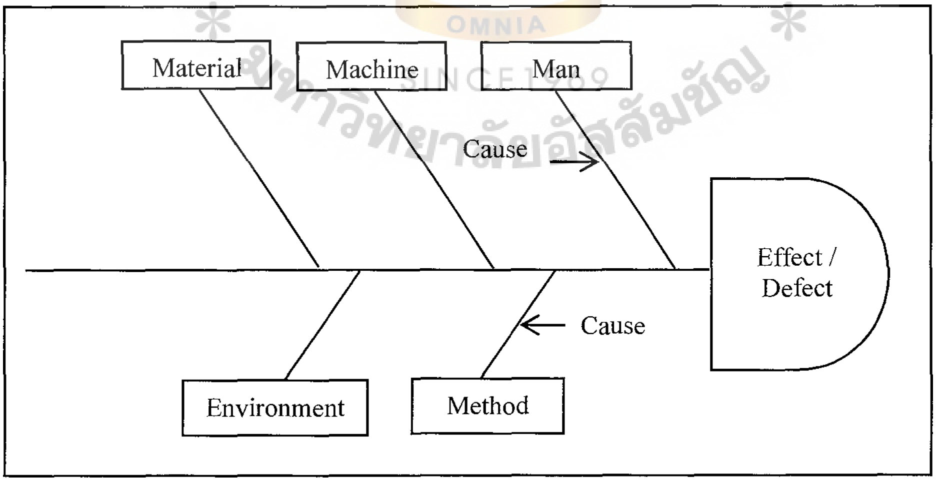
2.2.4 C-E Analysis

There are many names used for this technique such as an Ishikawa diagram and a fish-bone diagram. The main concept of this is to work through team brainstorming because it can help to organize ideas and shape them all into further causes and solutions of the problems. The method consists of the following steps:.

- Identify problems in the box at the end of the line.
- Specify causes of each problem by brainstorming for major causes and sub major causes.
- Build the diagram and input details.
- Find the solution by analyzing causes in the diagram and the decision that needs to be considered with cost-effectiveness.

In addition, C-E analysis can be used as an assistant to classifying the problems based on types of root causes; this creates a baseline for ideas and team brainstorming (Islam & Ahmed, 2012). Referring to Figure 2.2, this project applies 4M and 1E (Man, machine, material, method and environment) for the analysis.

Figure 2.2: C-E Analysis



Source: Gupta, Acharya, and Patwardhan (2012, p.201)

2.2.5 **FMEA**

The methods aim to prioritize failure risks in the future by evaluating risk priority number (RPN) to find out the action for solving the problem. The formula of RPN is S*O*D which stands for severity(S), Occurrence(O) and detection(D). The RPN rating has a number 1-10. A high number of S and 0 means high frequency of failure, but a high number of D indicates that the company can creating detect problems or failures. In conclusion, if RPN falls within high values, high priority or high failure risk will be likely to occur in the future and the company cannot detect the problems (Subburaman, Sawhney, Sonntag, Venkateswara Rao, & Capizzi, 2010).

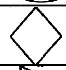
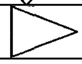
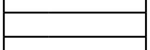
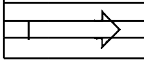
2.2.6 Brainstorming

The team presents opinions about the topic and discuss for agreements or new ideas. Each idea will be recorded, comments or reasons are not allowed in order to avoid depression from other participants. This technique can motivate team members to give new ideas and, at the end, the team will vote for selecting the most scored idea (Villarreal & Kleiner, 1997).

2.2.7 Flow chart

Villarreal and Kleiner (1997), basically makes use of the flow chart for analysing the process of simple business analysis. The chart consists symbols for identifying details in each process and make it easy to analyze causes or problems. This technique can link to the process flow which includes the detail in each step such as decision, process, start and stop as shown in Figure 2.3.

Figure 2.3: Flow chart symbol

Symbol	Detail
	Start/stop
	Delay
	Decision
	Inspection
	Process
	Transport/move

Source: Villarreal and Kleiner (1997, p. 95)

2.3 Summary

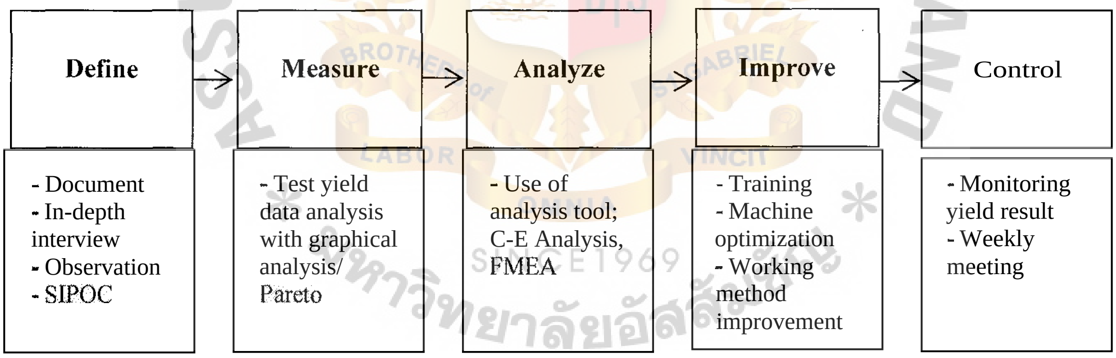
Many techniques and concepts are applied in this project. However, the theory used in the project is considered to give the most of the benefit and potential for improving production yield based on the project objectives. The concept is used as a guideline for mainly reducing waste. In addition, watse can be referred as a rejected part. Moreover, the DMAIC approch is used for improving the process in order to achieve good quality level which includes analysis tools applied in each step so the tools used can be adapted for other products which are not specified. This can largely depend on team members or appropriateness for each product/process. Using DMAIC for the analysis should be considered based on a type of possible root causes, a step-by-step analysis, record, control and mesurement technique as shown in Table 2.1.

CHAPTER III

RESEARCH METHODOLOGY

In order to find out the root cause and improve the production yield percentage, quantitative methodology is used as a tool to sort out the rejection percentage of each criteria of the ABC Company. The propose is literally designed to minimize the percentage of rejected part by improving the production yield from 90% to 95%. DMAIC will be applied for analyzing the data, finding sources of waste and further understand how to eliminate waste from process.

This project is conducted based on typical process understanding as shown in the DMAIC flow chart below. However, the DMAIC approach will be used as a tool for defining core problems, as well as providing a baseline for actions and controlling plans.



3.1 Defined problem

Regarding Chapter 1, the company found low production yield at a test station. In order to define the problem. The data was collected by integrating sources: documents, observations and in-depth interviews:

Document: Internal reports can be defined as production yield collected from the engineering department. All the data refers to the same period (from Aug to Oct, 2012).

- In-depth interview: All departments involve test station areas such as an operator who works at the test machine, an engineer and a production supervisor. All of them will give out the detail of actual practices being done in the relevant test process in order to understand the process constraints, frequency of the problem, in-process countermeasures when failing parts arise at the stations they are working at times.
- Observation: Testing needs a method test machine including an observation at the relevant test area in order to compare between the actual process actions and the data derived from the interview. The in-process observation is designed and carried out in order to understand actual process practices. Also, carrying out the operators included normal process routines, problem solving methods when issues happen. The study also try to understand the gap between to-do guidelines mentioned in Work Instruction and actual process practices. By understanding those gaps, this will help ironing out factors induced by operators not following their works according to the instruction given.

In addition to data collection, SIPOC (Supplier, Input, Process, Output and Customer) will also be used for defining problems in this project.

3.2 Measurement

Several control tolls for statistical process will be used for better understanding to the current process, key performance measurement indicators to the process performance such as production yield. As the problem is determined due to poor production yield, then tools and other quality analyzing techniques will be used to study and understand how the nature of the problems and how the process performance can be measured accordingly based on the problems seen and the action implemented. The key measures of production yield are carried out at the testing area based on the following criteria:

- Signal input and output
- Clarity and quality of the signal level

- Parameters of the circuit board and display
- Actual in-curcuit functionality

3.3 Analysis

In order to analyze the problem, this project is designed to collect statistical data for reviewing and identifying the problem.

3.3.1 Engineering report

In order to measure the degree of the problems, statistical data records are required. An engineering report shows details of production yield, criteria of reject, quantity and period of time. All of these represent to the problem occurred.

3.3.2 **Pareto** analysis

According to the engineering report during Aug-Oct 2013, the production yield of 90%. Pareto is used for reviewing and pointing out the significant problems in order to analyze and improve each criterion.

3.3.3 Cause and effect analysis (C-E analysis)

Problems from the Pareto analysis are considered by making use of the C-E analysis for further investigating the root cause and finding out specific solutions in each criterion of the reject part. The method of C-E analysis is that the researcher will conduct on observation at the test area by using the concept of 4M and 1 E (Man, machine, material, method and environment) in order to identify the problem in each group and plan for the improvement by using the target production yield at 95%.

3.4 Improvement

The C-E analysis which identifies causes of the problem allows clear understanding of the factors and variables that effect process performance. With this regard, changes will be made to the process accordingly based on the improvement plan in each specific criterion as 4M and 1E. Planning for implementing the improvement process is also performed in order to accommodate actions required for each specific problem area through the team meeting and brainstorming for finding the solution and action plan.

3.5 Control

As the action plan is carried out as part of the improvement done for the test process and production process, the results will be monitored carefully in order to maintain consistency of the result based on the improvement done in all process aspects. Necessary control measures will be put in place to monitor the process performance results through the percentage of production yield and reject part quantity. The departments concerned are operators, machines and test engineering.

3.6 Summary

Implementation of the concept should be explored based on the background and characteristic of the process. DMAIC is the step for analyzing since defining the problem, company target and customer expectation. The Company must establish the measurement in order to evaluate the result of the problem or the result after the improvement process. The analysis is used for finding out the root cause and the solution in order to solve the problem. After the team gets the result and gain understanding under the same target, the next step is to improve and control. Accordingly, the problem and implement continuous improvement will be managed.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

This chapter will explore the result regarding concepts applied in chapter 3. All data collection will be analyzed through the DMAIC technique explained in details in each step. A particular solution will be reported in order to fix the problem and control the result for continuing improvement. Various kinds of statistical tools will be implemented in order to obtain useful results for further applications to other models.

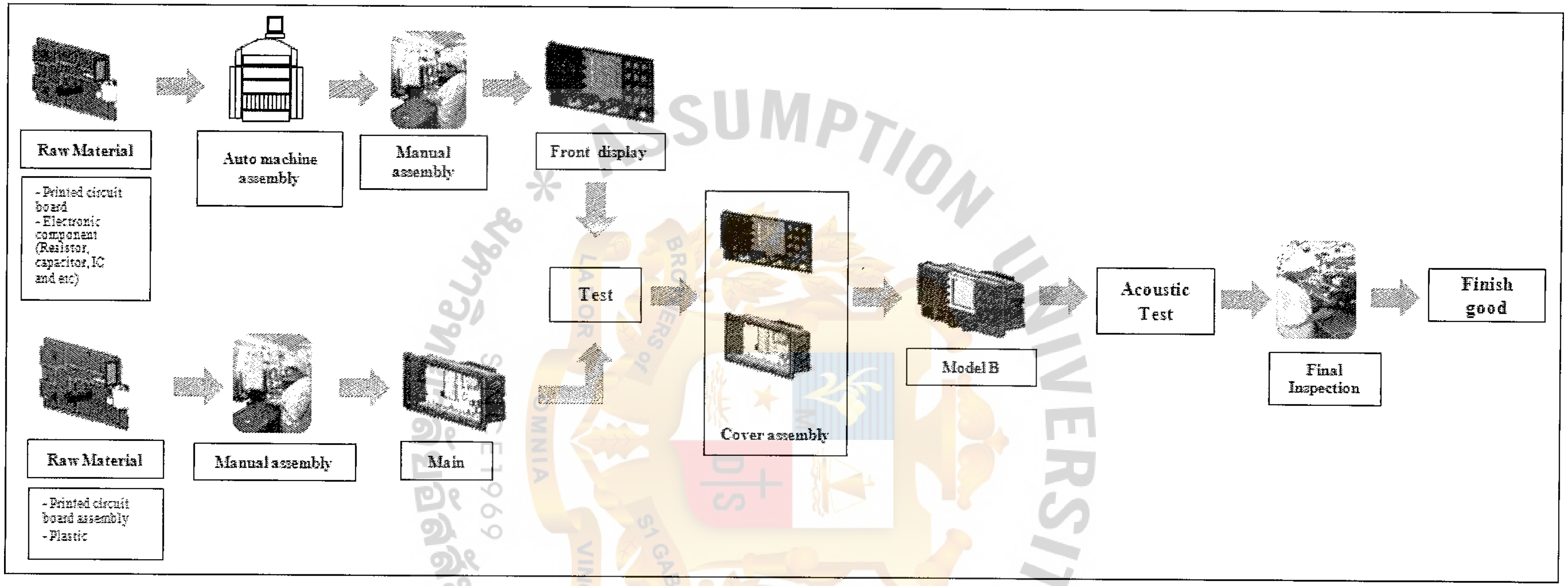
4.1 Defined problems

With reference to the define phase, a further study on an in-depth process flow is required to understand process characteristics and key parameters. According to Figure 4.1, Model B consisting of 2 parts; namely front display and main, which are designed to run as parallel processes. Upon the completion of the two processes, operators will further perform an assembly for front display and main into a single combined unit and finalize it as a final set of finished goods. In short, the front display and main are required as the two sets of input which will be processed in order to make an output, given as a finish good. Below is the explanation in more detail.

- Front display process: This begins from loading raw material onto automatic assembly machine. In the process, there are some raw materials that cannot be assembled by an automatic machine due to the size and limited machine capability itself These materials will be manually assembled by operators performing a self-visual inspection before the test process.
- Main: This process makes use of manual assembly as performed by operators with a self-visual inspection.
- Test: This step tests both a front unit and main in terms of functional parameters such as display and circuit working conditions.

- After the test process is identified as "pass", both parts will be sent to cover an assembly process which is performed using manual process in order to get a pre-finished model B and an acoustic test again.
- Final inspection will be done as a last process step for appearance check ready for a delivery to customers.

Figure 4.1: Model B process flow

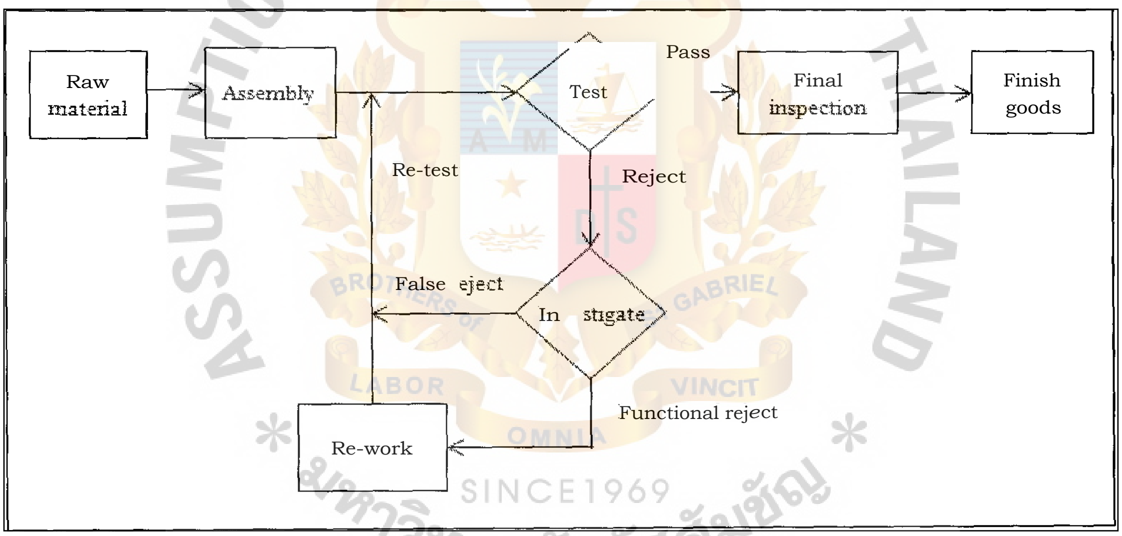


Source: ABC Company

After analyzing the process detail of process implemented to SIPOC for this phase, a simple model can be referred to Figure 4.2 below.

Figure 4.2: SIPOC analysis

Supplier	Input	Process	Output	Customer
Local suppliers Oversea suppliers	Raw material Packaging Machines Electricity Resources		Telecommunication Model B	Customers



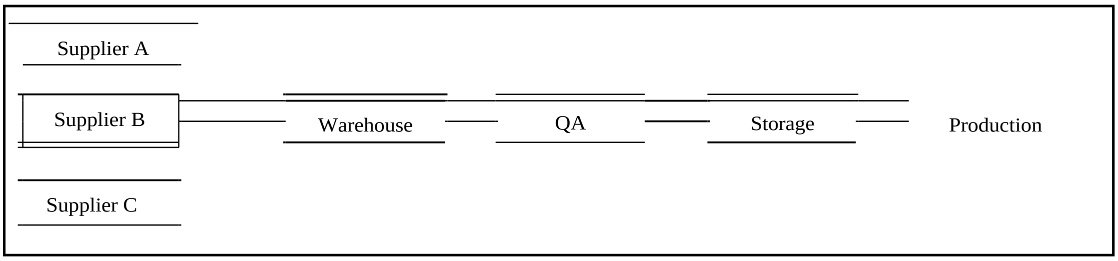
Source: ABC Company

Based on Figure 4.2, the SIPOC (Supplier, input, process, output and customer) analysis can be explained in more detail as follows:

4.1.1 Suppliers and input

There are 2 groups of suppliers, local and oversea, that supply raw materials and packaging. Approved vender list is qualified by customers and the ABC company itself.

Figure 4.3: Input process



Source: Author

The input process can be referred to Figure 4.3, starting from the ABC company receiving shipments at the warehouse through the receiving process in the system and it is processed at the QA for a sampling inspection. If the inspection result is qualified as "pass", materials will be sent to a storage in order to prepare for production. If the result is "reject", materials will be segregated for waiting team's feedback to be given to suppliers. Based on this process, it can be said that most materials used in the production is qualified as good quality materials ready for the production.

4.1.2 Process

In Figure 4.2 regarding the SIPOC analysis, after the assembly process, the product will be sent to the test process in order to check functions. If the rejected parts were found and it would be necessary have the parts re-worked and re-tested again in order to assure that they are truly good parts and can function the same as their original ones after the re-work process. In a general practice, a test-engineering team will confirm initial failures by using a re-test and bench analysis (Lab-scale Test with 100% accuracy) and confirm that most failed parts can become good parts after being reworked. The reject part is required to further investigate the root cause of failures contributing to the problems in order to reduce quantity of the rejected parts and to improve the production yield.

4.1.3 Output

After passing the test process, the company needs to perform the final inspection in order to make sure that there is not any problems about the appearance of finished goods. In case that the finished good is rejected, it will be quarantined by having a root cause investigation and an improvement plan. However, the quantity of the output depends on the production yield.

4.1.4 Customers

Finished goods will be sent to customers and the customers will check and giving feedback in case that the products cannot be used based on specification. In conclusion, problems can be observed from engineering reports are shown in Figure 1.4 (the graph of production yield). A significant number of 90% is required to identify problem areas analyzed by using the Pareto chart in order to know which one is the key problem.

4.2 Measurement

Measure is done by verifying the test results which are derived from testers designed to simulate application and working conditions of the products. The test is done and justified based on specification limits defined for specific parameters.

Testers will also have to go through the routine calibration process in order to make sure that they can give consistency while working on the mass-production basis. Calibration is done on every ship changed by performing golden samples in order to eliminate variations in both hardware and software manners of the testers themselves in order to maintain accuracy much as possible based on the specification.

Golden samples can be referred to as a master sample and can be used as references for conforming if testers can still judge good and non-good units based on these samples. Normally there are 3 sets of golden samples in each step of the test process.

The calibration will be applied based on the yes/no confirmation test basis with the use of the black-box tester which is solely controlled and released by customers. In case of the fact that a golden sample gets damaged, there are two other back-up sets which are ready to be used. The team will report customers in order to request for a new golden sample for the replacement in case of damage. Golden samples are provided and controlled by customers and the ABC company is not even authorized to adjust specification or create golden samples internally. Golden samples are created at customers' side based on their confidentiality regarding test and specification designs.

There is one set of tester sets at a test station (Main, Display and Acoustic Test) and each test station is handled by only one operator. However, the tester itself is controlled solely by customers including repairing, debugging and refurbishment.

The test process carried out in the given products includes the following conceptual tests that are designed to simulate the actual working conditions of the products as well as its associated functionality as applied by end customers according to its real applications:

- Signal input and output: It is the test of signal input and output level to determine whether they are sufficient for analog/digital signal processing as well as internal and external data transmissions.
- Clarity and quality of the signal level. It is the fact that no noise is associated during the data processing and transmission as well as the transmitted tone at the required quantity level with sufficient signal clarity required for communication.

  Parameters of the circuit board and display: Testing input and output signals is done to determine if the curcuit board can be function properly in relation to the results and displays presented on the display screen.

  Actual in-curcuit functionality: It is the test for test actual working modes of the products such as function of individual button, data transmission mode, singal searching mode.

Table 4.1: Summary of rejected quantity during August-October 2012

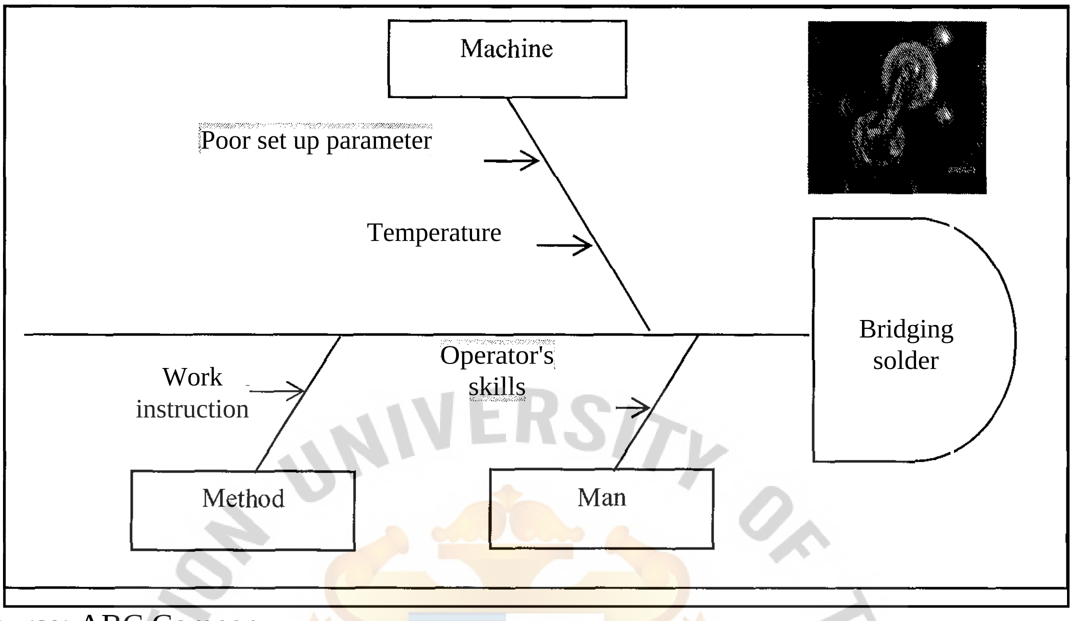
Criteria	Q'ty reject	Percentage
False reject	**228**	**30.0%**
-Tester false short circuit	200	26.4%
-Operator skill	25	3.3%
-Contamination at flex cable	3	0.4%
Missing part	**182**	**24.0%**
- Area 1	60	8.0%
- Area 2	61	8.0%
- Area 3	61	8.0%
Bridging solder	**167**	**22.0%**
- Area 1	55	7.3%
- Area 2	56	7.3%
- Area 3	56	7.3%
Connector misalignment	**107**	**14.1%**
Others	**75**	**10.0%**
Total	**759**	**100.0%**

Source: ABC company

Referring to Table 4.1, based on inpthe ut quantity of 8,283 pcs, there are rejected parts of 759 pcs which are be equivalent to 10% reject rate and false rejects can be regarded as a major problem. As for the criteria of missing parts and solder bridging, the reject rate is randomly contributed by all product areas because it depends on a personal skill of each operator. Referring to Figure 4.4, products can be separated into 3 areas for identifying test results. The area is helpful for engineers to verify in a specific portion instead of all product areas. It is also helpful for time-saving investigation.

This project analyzes the reject criteria by using the Pareto analysis by setting the priority of the reject criteria, the cause and effect matrix used for finding out root causes and potential causes of each reject criterion and FMEA for rating the risk level of reject criteria that will occur in the future and find out the action for preventing repeated problem in the future.

Figure 4.10: **C–E** Analysis for Solder Bridging



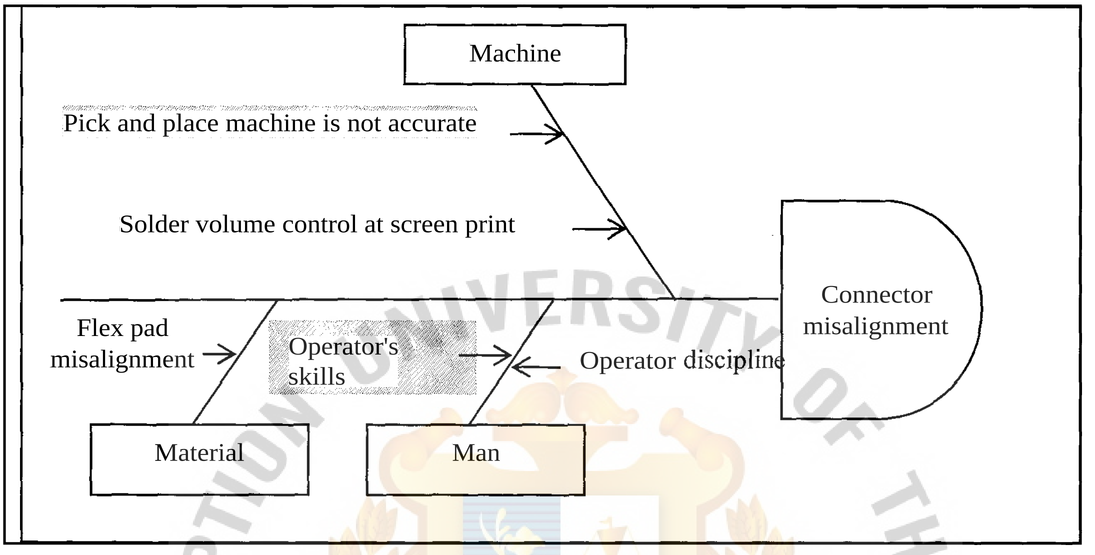
Source: ABC Company

After investigating the root cause by using the C-E analysis as shown in Figure 4.9, it is apparent that the problem should be resolved by optimizing and adjusting the set-up values at the test machine because most of the rejected parts are induced by touching-up manual solder. Upon the reject confirmation, most of the rejected parts are discovered from the manual solder, always confirmed as "false reject", the operators will skip or adjust the results by themselves. This helps to prevent real rejected parts that cannot be detected.

4.3.6 Connector misalignment

In Figure 4.10, there are potential causes. Pick and place machine, for example, is not accurate. Solder volume is controlled at screen print, flex pad misalignment of operators' skills as well as and operators' disciplines. These problems can be detected by first piece confirmation and an in-process inspection for a solder volume on pad. Based on the analysis of causes as shown in Figure 4.6, this problem occurs with 3 cases in general which are induced by machine errors, operators' skills and operators' disciplines.

Figure 4.11: C–E Analysis for Connector Misalignment



Source: ABC Company

As far as a machine's factor is concerned, an engineering team has concluded that further adjustment for the program needed to be re-engineered and optimized in order to come up with a more accurate "pick and place" process for the components. Some of the existing pick and place machines are investigated to have a poor pick and place performance by generating a misaligned placement of the component on the assembly circuit itself. As a consequence of component misalignment, further touch up and rework process will be established for misaligned units. By manually soldering and touching up the misaligned components, there is also a tendency which the complete alignment cannot be controlled; hence, this causes another subsequent component misalignment.

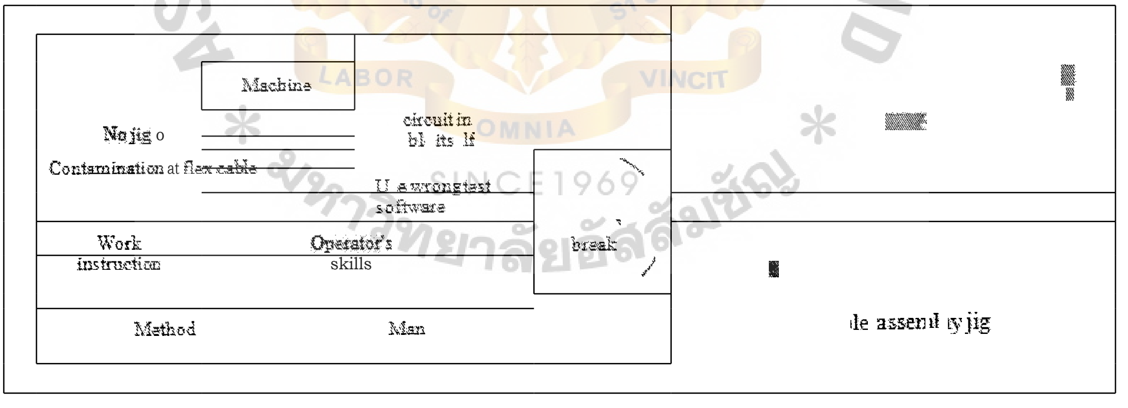
4.4 Improve

Upon understanding the factors and variables that effect a process of a performance test, changes will be made to the process accordingly based on a improvement plan in each criterion as shown below.

4.4.1 False reject

As shown in Figure 4.12, the solution for this problem can be explained in a way that a new jig design is created to support the Flex cable while being loaded for the test into the board. Jig can help to firmly strengthen and extend life time of a flex cable. As well as the importance of an operator's experience, in order to work under the same practice, the team needs to be method characterizing the standard of flex cable insertion for the operator. The correct handling of the flex insertion is required to be documented to minimize such incidents of the insertion of the flex direct onto the board, the insertion from any side of the board, or the insertion at other different angles onto the board which all in all can misjudge the test result due to poor misalignment between flex cables and a test board. The correct method is designed to address the proper method of the insertion with ease of operation and ergonomics. The method is also designed to address problems driven by human errors such as accommodating too much amount of force while inserting a flex cable onto a board.

Figure 4.12: Improvement for False Rejection



Source: ABC Company

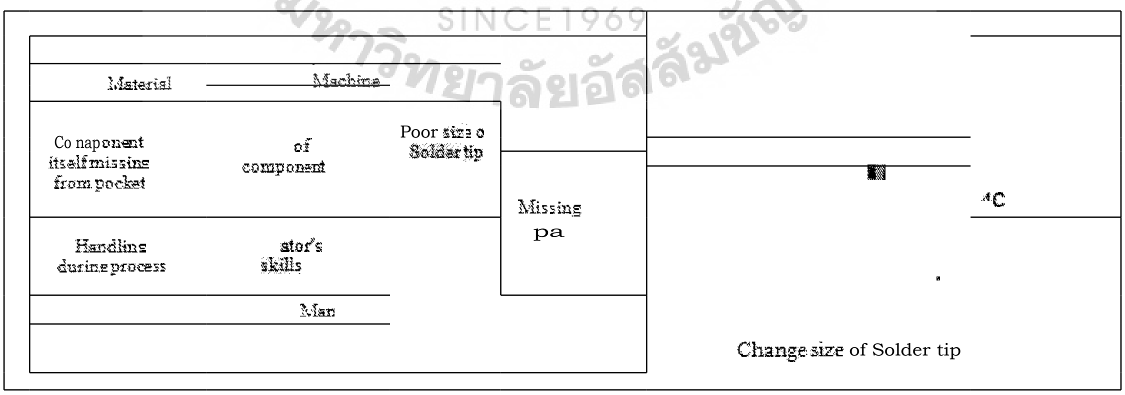
4.4.2 Missing parts

Due to the fact that this process demands high degree of difficulty for manual assembly, there are factors concerned such as size of components, positions and intervals of materials, tools and experiences. Therefore, this process needs to be incorporated with a highly-skillful operator who can be maintained towards re-training and re-certification.

According to size of a solder tip, this factor plays a very important role in manufacturing quality regardless of a proper training program to be organized for production operators. By taking proper solder tip size into account, an engineering team is required to verify the a component size as well as temperature, solder wettability characteristics in order to justify for the best-fit solder tip.

As shown in Figure 4.13, the solder tip size has been changed from 4C to 3C. The new size is smaller than the original one so that this can help operator to easily perform an assembly because the smaller size can prevent physical contact to other product components.

Figure 4.13: Improvement for Missing Parts



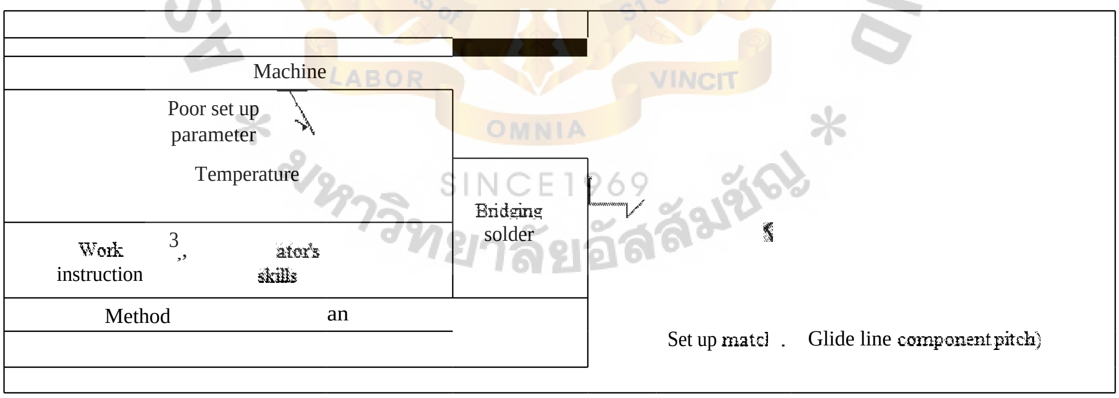
Source: ABC Company

4.4.3 Bridging Solder

In order to fix this problem, the company has to focus on the machine set-up for printing pressure in order to use an auto machine instead of a manual solder and set-up test machine optimization to have it as the most accurate testing process in order to prevent operators adjust the result by themselves together with that fact that the company needs to re-enforce to operator not adjust the result, then the solder bridging will be improved.

The current engineering team as shown in Figure 4.14 had set up a machine by recording the parameter which can help to track or scope the problem when the problem of bridging solder occurs. An operator needs to be trained about disciplines and awareness for inspections when the machine alerts the reject. They need to check and be recorded in the worksheet and wait for an engineering team to verify instead of skipping the test as previously done.

Figure 4.14: Improvement for Bridging Solder



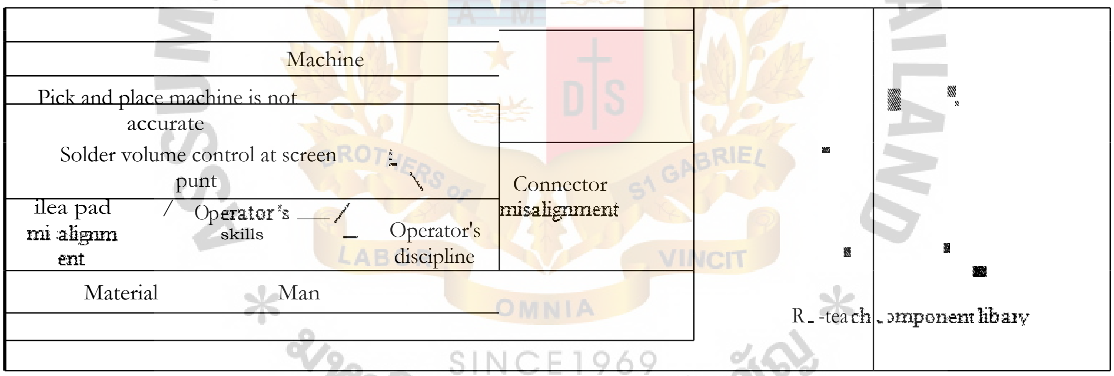
Source: ABC Company

4.4.4 Connector Misalignment

Referring to the observation and the interview conducted at a tester's area, there is no illustrative and comprehensive instructions for operators to precisely follow while a training program must be established in accordance with instructions to make sure that operators are well aware of a proper method and do/do-not guidelines when working on misaligned products as well as engineer also need to adjust a machine to be accurate for the pick and place method.

In Figure 4.15, the engineering team analyzed and discussed with suppliers who supply the machine for adjusting methods and the limitation of the machine itself. Checking, adjustment and shelf-life control of the machine need to be monitored on a routine basis in order to fix the problem. Also awareness and disciplines need to train when they perform a manual assembly and self-inspection. In order to reduce bias, the team will establish the award giving program to operator who is able to find and alert the problem.

Figure 4.15: Improvement for Connector Misalignment



Source: ABC Company

4.5 Control

As the action plan is carried out as part of improvement done for the test process, results will be monitored carefully in order to maintain consistency of the result based on improvement done in all process aspects. Necessary controlled measures are to be put in place of monitoring the process performance which results into the percent of yield at the test station and quantity of the rejected parts.

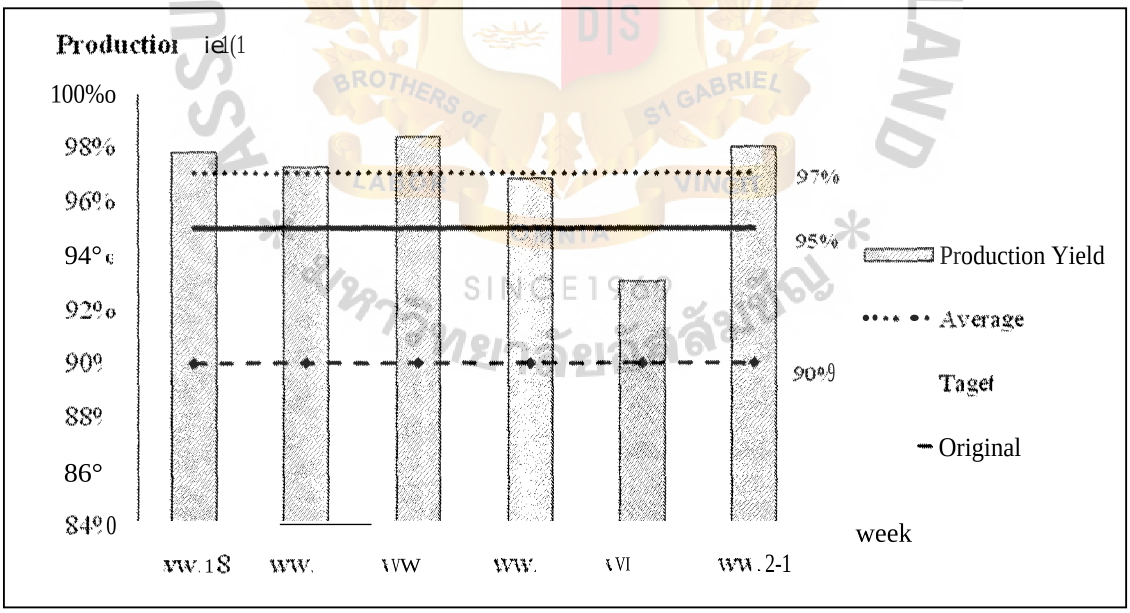
Table 4.5: Results of Implement Action on May- Jun 2013

Result Criteria	Q'ty reject	Percentage
False reject	20	14%
-Tester false short circuit	20	14%
-Operator skill	0	0%
-Contamination at flex cable	0	0%
Missing part	1	1%
- Area 1	1	1%
- Area 2	0	0%
- Area 3	0	0%
Bridging solder	7	5%
- Area 1	2	1.7%
- Area 2	2	1.7%
- Area 3	3	1.7%
Connector misalignment	9	6%
Others	102	73%
Total	139	100%

Criteria	Percent reject As-Is	To be
False reject	30.0%	14%
-Tester false short circuit	26.4%	14%
-Operator skill	3.3%	0%
-Contamination at flex cable	0.4%	0%
Missing part	24.0%	1%
- Area 1	8.0%	1%
- Area 2	8.0%	0%
- Area 3	8.0%	0%
Bridging solder	22.0%	5%
- Area 1	7.3%	1.7%
- Area 2	7.3%	1.7%
- Area 3	7.3%	1.7%
Connector misalignment	14.1%	6%
Others	10.0%	73%
Total	100%	100%

Source: ABC Company

Figure 4.16: Production Yield on May- Jun 2013



Source: ABC Company

According to Figure 4.16, the result of production yield has been increased from 90% to 97% and this achieves the company's targets. The significant reject criteria have been changed from a false reject to "other" due to the fact that in ww.23 a customer try to change some components which effect the products. The reject criteria can be defined as a tolerant issue regarding raw materials and a marginal limit from a new design.

4.6.Summary

The test station is technically a time-consuming process of which the output process itself largely depends on process time as well as capability of a test machine which is consigned and under the control of a sole customer. In order to improve the first yield, this chapter has explored based on the root cause analysis as well as found out corrective action to be implemented at the test and production processes. If the improvement can be done with an accepted agreement from customers, there will be a significant breakthrough of the improvement seen at the production yield. Referring to the analysis of the root cause and implementation, the result shows positive outcomes. The production yield can be increased from 90% to 97% based on the target. It means that DMAIC and tooling can be implemented effectively.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes findings, conclusions and recommendations of the case study focusing on the ABC Company and also addresses managerial implications, limitations and possible recommendations for future research.

5.1 Summary of the Findings

This case study is aimed to increase production yield by applying DMAIC as a guideline for the step-by-step analysis. According to low production yield, caused by false reject, missing parts, bridging solder and connector misalignment can be detected by a test machine. In addition, the analysis of finding the root causes and solutions can be done by using the tool which can declare that most of the root causes are from man and machine and the problem was found at a manual process. Based on the problem found, the company needs to adjust the machine in order to make it reliable together with an appropriate training program for employees.

5.2 Conclusions

Referring to the objective of this study focusing on increasing production yield from 90% to 95%, there are sets of theories, concepts and tools that are implemented in the project. DMAIC is the process step towards actual practices. In each phase of DMAIC, it also requires a cross-functional team to brainstorm and perform the problem analysis and helps to find the corrective action in each area concerned. Thus, the subsequent phase is to implement and control in order to maintain new practices and to solve problems in a long-term basis. Based on the result given, it can be said that ABC company achieves the target of yield at 95%. This helps the company to achieve cost saving as well as to boost up customers' satisfaction.

5.3 Theoretical Implications

Using DMAIC in ABC company helps to find the root cause and to fix the problem. In each phase of DMAIC, there are tools that can help the team to analyze the problem such as Pareto chart, FMEA, Fish bone diagram and so on. From the study, it apprears that the important tool lies on team's brainstorming and C-E analysis because when the problem occurs, all the team member who directly responds to the product need to know in depth and find out the solution in order to fix the root cause as a teamwork. There are many potential causes that may affect the product. C-E analysis is the tool that needs to be materialized and implemented along the shop floor in order to determine in-process actual issues at each process step. Team brainstorming can help to reduce bias and assumption which are not derived from proper fact findings before concluding that the cause is not from this and that process without appropriate back-up.

5.4 Managerial Implications

This project can be carried out based on participative involvement and driving force of the management team. In order to implement the new process or new work instruction, employees need to be well trained and maintain up-to-date work instruction. Normally, operators will be familiar with the old work instruction. An implementation of the new instruction is required to have some lead time in order to adjust the practice and that effects with the positive result. The management is helpful for driving the whole team and follow up the result in order to check the actual implementation in a production line. In addition to this, the turnover rate of the operator is considerably high resulting in the training program to be re-arranged and that could give a significant impact on production yield.

5.5 Limitations and Recommendations for Future Research

This case study aims to improve production yield of ABC company only. Tools and concepts can be largely dependent on work instructions, cultures and products. Based on the business of ABC company which is on a high-mix-low-volume basis, it takes long time to record data and follow up the result. However, this project can be implemented with other products in ABC company in the future but also needs to adjust methodology and consider an appropriate set of tooling to be applied as well.

BIBLIOGRAPHY

Antony, J., Bhuller, A. S., Kumar, M., Mendibil, K., & Montgomery, D. C. (2012). Application of Six Sigma DMAIC methodology in a transactional environment. *International Journal of Quality & Reliability Management, 29(1),* 31-53.

Arumugam, V., Antony, J., & Douglas, A. (2012). A lean tool for improving the effectiveness of Lean Six Sigma. *The TQM Journal, 4(3),* 275-287.

Besterfield, D. (1998). *Quality Control* (5 ed.). (S. Helba, Ed.) Ohio: Pretice-Hall, Inc.

Cervone, H. (2009). Applied digital library project management: Using Pareto analysis to determine task importance rankings. *OCLC System & Services, 25(2),* 77.

Estorilio, C., & Posso, R. (2010). The reduction of irregularities in the use of "process FMEA". *International Journal of Quality & Reliability Management, 27(6),* 721-733.

Ghosh, S. K. (2013). Root cause analysis, Lean Six Sigma and test of hypothesis. *The TQM Journal, 25(2),* 170-185.

Gupta, V., Acharya, P., & Patwardhan, M. (2012). Perfective partice: Monitoring quality goals through lean Six-Sigma insures competitiveness. *International Journal of Productivity and Performance Management,* 61(2), 194-203.

Hammershoj, R. (1986, September). The Justification of 100% Conductor Testing for Improved Yields. *Microelectronics International, 3(3),* 24-26.

Hutchins, D. (1980). QC Circles. *Industrial and Commercial Training, 12(1),* 8-15.

Islam, S., & Ahmed, M. (2012). Business process improvement of credit card department: case study of multinational bank. *Business Process Management Journal, 18(2),* 284-303.

Ismyrlis, V., & Moschidis, 0. (2013). Six sigma's critical success factors and toolbox. *International Journal of Lean Six Sigma,* 4(2), 108-117.

Kumar , S., & Sosnoski, M. (2009). Reflective practice; Using DMAIC SixSigma to systematically improve shopfloor production quality and costs. *International Journal of Productivity and Performance Management, 58(3)*, 254-273.

Leon, H. C., Perez, M. T., Farris, J., & Beruvides, M. (2012). Integrating Six Sigma tool using team-learing processes. *International Journal of Lean Six Sigma*, 3(2), 133-156.

Nooramin, A. S., Ahouei, V. R., & Sayareh, J. (2011). A Six Sigma framework for marine container terminals. *International Journal of Lean Six Sigma, 2(3),* 241-253.

Subburaman, K., Sawhney, R., Sonntag, C., Venkateswara Rao, P., & Capizzi, C. (2010). A modified FMEA approach to enhance reliability of lean system. *International Journal of Quality and Reliability Management, 27(7),* 832-855.

Summers, D. (2007). *Six Sigma: Basic tools and techniques.* New Jersey: Peason Prentice Hall.

Villarreal, M., & Kleiner, B. (1997). Analytical tools for facilitatin task group performance. *Journal of Workplace Learning,* 9(3), 94-97.

Webber, J. (1990). FMEA: Quality Assurance Methodology. *Industrial Management & Data Systems , 90(7),* 21-23.

APPENDICES

APPENDIX A

Questionnaire for cause and effect matrix

Questionnaire for cause and effect matrix

Please mark "circle" on the number that effect production yield based on rating 0-3 as detail below.

0 = Not effect with production yield

1 = small effect with production yield

2 = Middle effect with production yield

3 = High effect with production yield

No.	Define mode	Factor	Rating: No effect → High effect			
1	Machine	No jig and fixture	0	1	2	3
2	Machine	Contamination at flex cable	0	1	2	3
3	Machine	Short circuit in flex cable itself	0	1	2	3
4	Machine	Use wrong test software	0	1	2	3
5	Machine	Poor size of Solder tip	0	1	2	3
6	Machine	Poor of set up parameter	0	1	2	3
7	Machine	Pick and place machine is not accuracy	0	1	2	3
8	Machine	Temperature	0	1	2	3
9	Machine	Solder volume control at screen print	0	1	2	3
10	Man	Operator skill	0	1	2	3
11	Man	Operator discipline	0	1	2	3
12	Method	Work instruction	0	1	2	3
13	Method	Handling during process	0	1	2	3
14	Material	Size of component	0	1	2	3
15	Material	Component itself missing from pocket	0	1	2	3
16	Material	Flex pad misalignment	0	1	2	3