AN APPLICATION OF DMAIC METHOD TO REDUCE DEFECTS: A CASE STUDY OF BUCKLE MANUFACTURING

SATHAPORN RUNGRUENG

A Proposal of the Six-Credit Course
SCM 7203 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

April 2015

AN APPLICATION OF DMAIC METHOD TO REDUCE DEFECTS: A CASE STUDY OF BUCKLE MANUFACTURING

By

SATHAPORN RUNGRUENG

A Proposal of the Six-Credit Course
SCM 7203 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

April 2015

DMAIC CONCEPT FOR DEFECT REDUCTION: A CASE STUDY OF BUCKLE MANUFACTURING

By

SATHAPORN RUNGRUENG

Submitted in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Supply Chain Management
Assumption University

Examination Committee:

1. Dr. Ismail Ali Siad (Chair) .....
2. Dr. Piyawan Puttibarncharoensri (Member) .....
3. A. Thanapat Panthanapratez (Advisor) .....

Approved for Graduation on: April 22, 2015

Martin de Tours School of Management and Economics
Assumption University
Bangkok, Thailand

April 2015

Assumption University
Martin de Tours School of Management and Economics
Master of Science in Supply Chain Management

Declaration of Authorship Form

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

AN APPLICATION OF DMAIC METHOD TO REDUCE DEFECTS: A CASE STUDY OF BUCKLE MANUFACTURING

I confirm that:

1. This work was done wholly or mainly while in candidature for the M.Sc. degree at this University;

2. Where any part of this dissertation has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;

3. Where I have consulted the published work of others, this is always clearly attributed;

4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this dissertation is entirely my own work;

5. I have acknowledged all main sources of help;

6. Where the thesis/project is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;

7. Either none of this work has been published before submission, or parts of this work have been published as: [please list references in separate page]:

Signed _____

Date _____

Assumption University
Martin de Tours School of Management and Economics
Master of Science Program in Supply Chain Management

Student Name Sathaporn Rungrueng
ID: 561-9108

ADVISOR'S STATEMENT

I confirm that this thesis/project has been carried out under my supervision and it represents the original work of the candidate.

Signed: _____
(A. Thanapat Panthanapratez)

Date _____

ACKNOWLEDGEMENT

First of all I would like to thank my advisor, A. Thanapat Panthanapratez who always supported me kindly. His advice was kept in my mind forever and it has been a great opportunity for me to be his student all along.

I would like to thank all staff of BB Company for useful information, especially the production manager, Khun Boy. This project would not have succeeded without his support and good suggestions.

Last, my deepest gratitude is to my parents and my family for their love and encouragement all the time.

Sathaporn Rungrueng
Assumption University
April 2015

ABSTRACT

This case study is about a buckle manufacturer who produces the product inefficiently which led to defect occurrences in the production process. These defect occurrences negatively affected profit, revenue and sale opportunity of the company. With the use of the DMAIC model, a solution could be developed to reduce the problem substantially.

BB Company has defect occurrences causing in the production process. As the analysis of the defect value data from January to December 2014 of BB Company showed that the highest defect value came from the plating process that totaled THB 456,830 or 85% of the total defects in production process based on Pareto analysis. There are two major defect types occurring from the plating. These are peeled off and burnt buckles. The total value of these two defect types is THB 412,715 or 92% of the total defect value in plating process. Thus this study focused on solving the problem of the defects types of peeled off and burnt buckles which is the top value of defect occurrences in the plating process. After root causes was revealed, the improvements are developed to reduce and prevent defect occurrences in order to increase working efficiency. The work instructions, regulation and check sheet report were also provided as the solution. Moreover as a group discussion with relevant workers in order to ask the questions about the proposed improvements both of peeled off and burnt buckles whether they are appropriate for the current problems, the results of discussion show that solutions are effective and can be applied in the company to solve the problem of defect occurrences sustainably.

This study applied the DMAIC model to substantially reduce defect occurrences in the company. In addition, DMAIC can help the company gain better understanding of actual root causes by analyzing in depth and help to propose an effective improvement based on data and facts.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Assumption University
Martin de Tours School of Management and Economics
Master of Science in Supply Chain Management

Form signed by Proofreader of the Thesis/Project

I, Dr. Scott Roach, have proofread this thesis/project entitled DMAIC CONCEPT FOR DEFECT REDUCTION: A CASE STUDY OF BUCKLE MANUFACTURING

Mr. Sathaporn Rungrueng

and hereby certify that the verbiage, spelling and format is commensurate with the quality of internationally acceptable writing standards for a master degree in supply chain management.

Signed _____

(Dr. Scott Roach)

Contact Number / Email address bobbyroaches@hotmail.com

Date: April 16, 2015

CHAPTER I

GENERALITIES OF THE STUDY

Due to high competition among businesses, customers can access different sources of products with lower costs than ever. People can buy products from across of the world easily. Although in the past it was hard for people to buy products from overseas by themselves because of limitations of communication and barriers of business, now the world has changed and people can freely communicate and do business. The competition of business is not only in one area but there is also competition among businesses around the world. Companies which are willing to engage in global business need to develop themselves to gain lower costs and better quality over their competitors. To achieve this goal, supply chain management is a critical point that everyone needs to focus and improve for sustainable growth and development.

According to Mangan, Lalwani, Butcher, and Javadpour (2012), supply chain management is the management, across and within a network of upstream and downstream which are related to facilitate the flow of materials information and resources. The goals of supply chain management are to create value and enhance value in order to satisfy customers.

Problems in supply chain can directly affect a company in terms of revenue and profit. Companies have to increase quality and reduce costs in order to satisfy customers. But this is not enough for competition of businesses. The company should solve the problems that affect revenue, profit, long lead times and low quality. To improve low quality, the production process is one critical factor which requires focus since there may be many gaps that cause problems of product quality such as defects in production process. Defects in production can directly impact the supply chain because the company will need to rework or scrap the product as waste which negatively affects cost, profit and resources. Defects create uncertainty in the process.

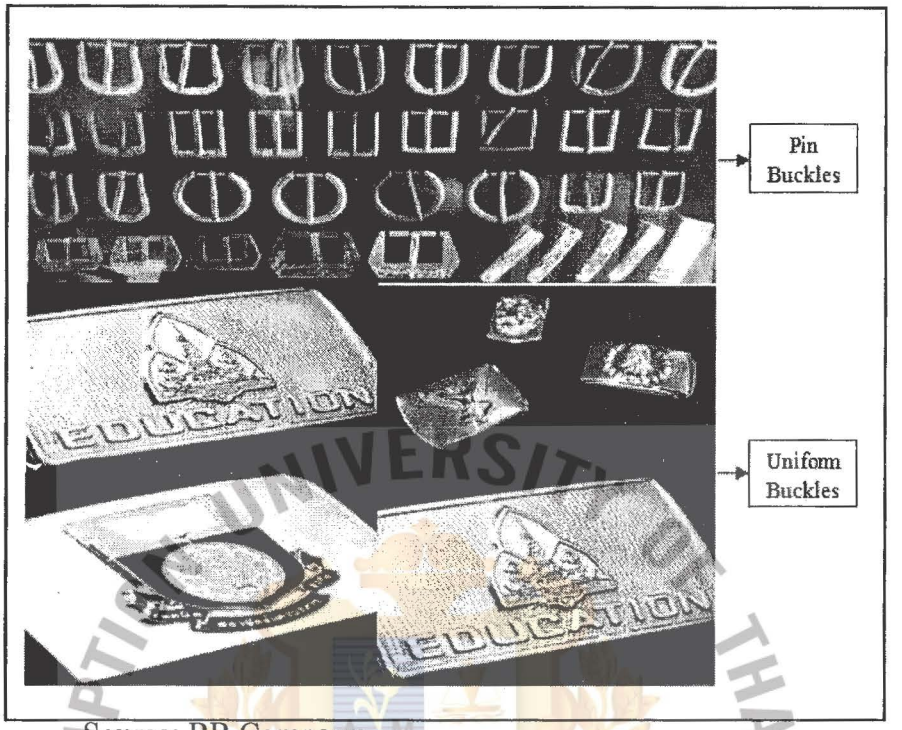
In addition defects also reduce production capacity and customers' satisfaction by creating products or services that require rework or must be scrapped (Bozarth & Handfield, 2008). Process quality means doing something right the first time with minimum reworking, scraping and waste in order to save cost, time and resources (Gill, 2008).

Gygi, Decarlo, and Williams (2008) stated that Six Sigma is a methodology for minimizing mistakes and maximizing value. Mistake require companies to do certain tasks over again and do a part that has to be replaced that costs time, material waste, efficiency lost and productivity reduced. When company has to do the work again, they also use additional resources to correct a problem before it is delivered to the customer. Six Sigma methodologies take effort to change and transform into improved performance. This current research study is based on the Six Sigma methodology and applies Define-Measure-Analyze-Improve-Control (DMAIC) to identify the current root cause and solve the problem.

1.1 Background of the Research

BB Company was established in 1970 as a small family business. The main products of the company are belt buckles which are produced from zinc, bronze, steel, aluminum and metals depending on the specifications given by the customers. In the beginning, the company produced fashionable and uniform buckle models. The main orders came from local customers who wanted to buy their products. Over the years the company gained more experience, reputation, reliability. Due to increasing of customer demand, both of local and overseas, the company has begun to use higher quality automatic machines and skilled workers in their production. This has allowed them to produce large lots and to increase production capacity efficiently with high levels of customer satisfaction. In addition, the company can provide made-to-order products which are perfectly fit for the specific needs of customers.

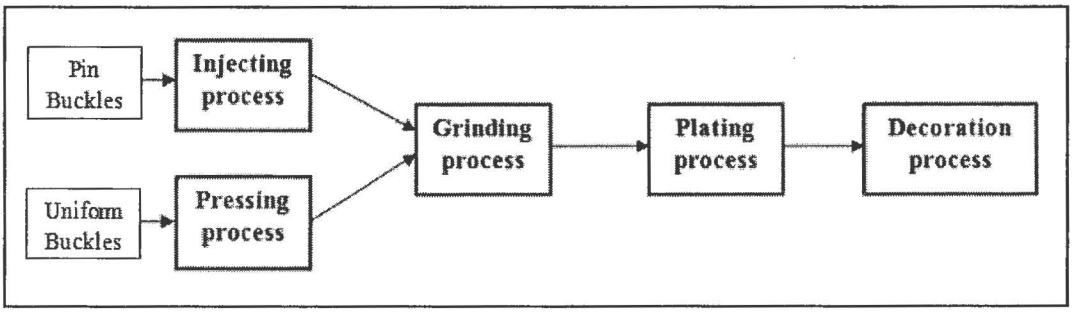
Figure 1.1: Product Overview



Source: BB Company

The BB Company produces two types of buckles: pin buckles and uniform buckles. The beginning stage is different for the two types of buckles. Pin buckles require an injection machine to melt the raw materials (Zinc). This machine injects the raw material into the shape that customers need. In contrast, uniform buckles require a pressing machine to make the buckle into a flat shaped pattern.

Figure 1.2: Process of Buckle Production



Source: BB Company

Figure 1.2 shows the production process of the two types of buckle. The first step (injecting or pressing) is the start of the process to make the material into a given shape and design. Some designs will require the injecting process and some designs will require the pressing process. The second step is a grinding process which helps to make the buckle's surface to become polished and smooth. The third step is a plating process that is used to plate the buckle with its final colors using chromium nickel and gold color depending on the customers' request. The last step is decoration to provide additional details for specific requirements.

1.2 Statement of the Problem

BB Company has found defect occurrences in the production process which can cause the company to lose revenue and resources due to reworking and scrapping the defective buckles. Additionally, the company also loses the opportunity to get more profit. So the company wants to eliminate the root causes that are main factors causing inefficient production because of employee lack of knowledge regarding work instructions and regulations. There are many processes in the production of buckles but the main factors which are reducing efficiency and effectiveness of the company are occurring in the processes of injecting, pressing, grinding and plating.

Table 1.1: Value of Defect Occurrences in Production Year 2014

Process	Defect value in Thai Baht (THB)	Percentage (%)	Cumulative (%)
Plating process	456,830	85.21%	85.21%
Pressing process	34,500	6.44%	91.64%
Grinding process	24,600	4.59%	96.23%
Injecting process	20,200	3.77%	100.00%
Total	536,130	100.00%	

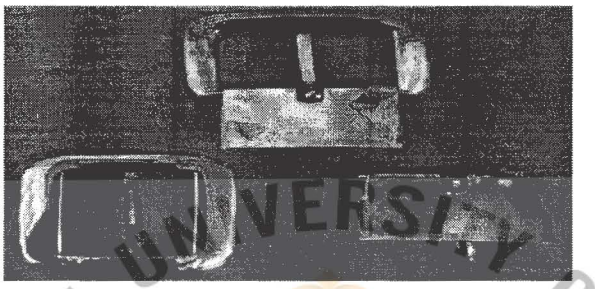
Source: BB Company

Table 1.1 shows the value of defects occurring in the production process caused in four processes which directly impact the company through loss in value. The total defect value is THB 536,130. The first is plating process which cost THB 456,830. Second is the pressing process which cost THB 34,500. The third is the grinding process which costs THB 24,600. The fourth is the injecting process which costs THB 20,200. This research will focus on solving the root cause resulting in the highest defect value in production process. By applying Pareto analysis (which states that 80 percent of a problem can result from 20 percent of potential causes), it can be seen that the plating process is responsible for the largest amount of the defects.

The defect data in plating process identified as three types of defect:

a. Peeled off
b. Burnt
c. Rough and matt

Figure 1.3: Defect Types from the Plating Process

Defect Type From the Plating Process	Examples	Description
Peel Off		The plated surface will peel off like a flake.
Burnt		Some plated areas are dark
Rough and Matt		Plated surface is not polished and smooth

Source: BB Company

Figure 1.3 shows sample pictures of defect types. For the "peel off" type of defect, the plated surface of the buckle peels off like a flake. For the "burnt" buckles, the plated surface is dark. Normally the good buckles will be a silver color. The "rough and matt" type buckles have a plated surface which is not polished and smooth.

Table 1.2: Value of Defect Occurrences in Plating Process Year 2014

Defect Types in Plating Process	Value in Thai Baht (THB)	Percentage (%)	Cumulative (%)
Peeled Off	287,185	62.86%	62.86%
Burnt	135,530	29.67%	92.53%
Rough and Matt	34,115	7.47%	100.00%
Total	456,830	100.00%	

Source: BB Company

Table 1.2 shows the value of defect occurring in the plating process collected during the twelve months of 2014. Peeled off, burnt and rough & matt are the types of buckle defects that are caused in the plating process. Based on Pareto analysis, this research will concentrate on the peeled off and burnt types of defects to solve the problem in plating process. This study aims to answer the research question: "How can BB Company reduce defect occurrences in the production process?"

1.3 Research Objectives

The objectives of this research are:

1.3.1 To identify the cause of defects occurring in the production process and propose a solution to eliminate these defects based on data and fact.

1.3.2 To apply the Define-Measure-Analyze-Improve-Control (DMAIC) model in order to improve the operations of the production process.

1.4 Scope of the Research

This research aims to reduce and prevent defect occurrences in the production process by focusing on the top of 80% of defects (in terms of value) in plating process. Historical data is collected for the twelve months of 2014. Interviewing was conducted with relevant people (including one production manager and three workers in plating process) in order to understand the current process and the root cause of the

defects. Finally, an improvement plan is recommended for an improved process in order to prevent defect recurrences.

This study is based on the Define-Measure-Analyze-Improve-Control (DMAIC) tools used to reduce and prevent defect occurrences in production. A literature review supporting this study provides evidence that this tool and the data and facts which it can provide will assist in the understanding of root causes and can eliminate defects in the plating process.

1.5 Limitation of the Research

This research has two limitations as detailed below:

1.5.1 This research will focus on the prevention of defect occurrences in plating process in order to identify their root cause and develop a solution plan. Thus the defect occurrences of other processes are not included in this study.

1.5.2 This research will focus on solving the problems causing of 80% of defect value that occurs in the plating process. The remaining 20% of the defect value in plating process will not be addressed.

1.5.3. The problem solving methodology used in this study may not be suitable for other companies since differences likely exist in different business's operating processes.

1.6 Significance of the Research

The significance of this research is the application of the DMAIC approach to identify the root cause and propose solution plan to prevent defect occurrences in the plating process. In addition, this research can help the company to gain a better understanding from the analysis of the current process that leads to the current problem and develop a solution in order to prevent defect occurrences from recurring.

1.7 Definition of Terms

Cause and Effect Diagram: It is Ishikawa diagram which is the tool used for root cause analysis and to explore and to show the source of problems occurring in the process. This tool can be used to identify the key factors that should be solved using categories and ideas. The diagram helps to determine the root causes of problems through the use of a structured approach (Ilie & Ciocoiu, 2010).

DMAIC: It is a problem solving method which consists of five steps which are Define, Measure, Analyze, Improve and Control. DMAIC can help to identify current root causes and develop solutions based on data and fact systematically in order to prevent problem recurrence (Summers, 2007).

Pareto analysis: This principle can identify the most effects (often 80%) that result from a small number (often only 20% of causes. It also helps to specify the major problems that occur from only a few causes (Fagerhaug & Andersen, 2000).

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter discusses the selected literature that is related to this study. The research aims to eliminate and prevent defect occurrences in a plating process. The related literature and concepts are as follows:

1. Six Sigma Methodology
2. DMAIC
3. Cause and Effect Diagram
4. Pareto Analysis

2.1 Six Sigma Methodology

Six Sigma is a set of problem-solving methodologies for business process and performance improvement. Six Sigma methodologies are designed to create quality improvement which aims to minimize waste and maximize value. When work or outcomes are flawed from incorrect actions, the company needs to scrap its products or redo the work. This means that the company has to use extra resources in some way in order to correct a problem before the product is delivered to the customer (Gygi et al., 2008).

Summers (2007) stated that companies using the Six Sigma methodology see an enhanced ability to provide value to meet customers' requirements. They have a better understanding of key business processes and the process flow of improvements. The purposes of improved process flow are to reduce cycle time, increase capacity, improve productivity rates and eliminate defects in order to reduce costs and waste while increasing product and service reliability.

Six Sigma methodologies are used by management to understand and reduce problems by applying process control tools. One such tool is the Define-Measure-Analyze-Improve-Control, or step by step approach. This tool can help to identify and

eliminate variation in processes that is root cause of problems and also propose effective solution plans (Goldsby & Martichenko, 2005).

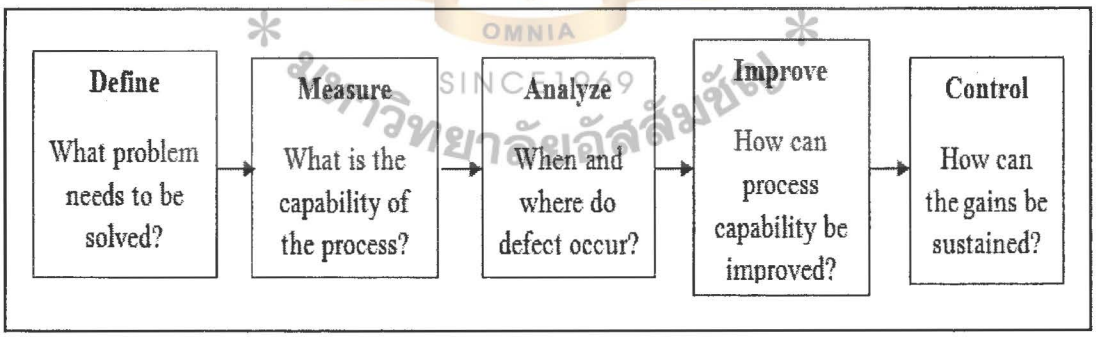
.

2.2 DMAIC (Define-Measure-Analyze-Improve-Control)

The DMAIC approach is a way to improve processes that aims to raise quality and reduce negative outcomes effectively. This tool can create better results by developing effective solutions. Furthermore the DMAIC approach can be employed to optimize current processes using data and facts in order to achieve sustainable and measurable results in a systematic manner (Alexander, Renata, Olin, & Christian, 2008).

DMAIC is like a roadmap for Six Sigma It is the backbone methodology which is applied in Six Sigma improvement efforts. The vision of DMAIC is recognized as problem-solving tool that can help businesses develop and provide opportunities for improvement. Moreover DMAIC focuses on quality achieved through variation reduction which is the principle of this strategy (Goldsby & Martichenko, 2005).

Figure 2.1: Five steps of DMAIC



Source: Goldsby and Martichenko, (2005)

Figure 2.1 shows the five steps of DMAIC approach which are: Define-Measure-Analyze-Improve-Control.

2.2.1 Define

The Define step of DMAIC focuses on identifying the problem by selecting the scope of the project. First the problem must be defined clearly and precisely. The define step shows what problem needs to be highlighted and solved. Voice of the customer or customers' requirements and voice of company are used to identify the defect or waste and provide an order for improvement prioritization (Goldsby & Martichenko, 2005).

According to Gygi et al. (2005), the Define stage of breakthrough strategy of DMAIC helps to delineate the certain areas of the problem to be improved. The Define stage creates a clear direction for solving problematic areas. First it is important to clarify the current situation by analyzing the level of the problem, where it is occurring and financial impact of problem. Once problem is stated clearly, the relevant people will understand what scope of the problem is and can better concentrate on how to resolve the matter.

2.2.2 Measure

After the Define stage has been clearly scoped, it is time for the Measure stage to assess the current problems. Measurement should be prioritized in order to allow relevant people to know which measurements are the most important. Basically the measurement areas consist of cost, time and quality (Goldsby & Martichenko, 2005).

Measurement is a critical part of DMAIC. It is the basic area of improvement. If measurement goes the right way and gets the correct answer of exact problem, improvements will be very effective. Measurement is the starting point before going in-depth for solution (Gygi et al., 2005).

2.2.3 Analyze

Goldsby and Martichenko (2005) mentioned that the DMAIC process will proceed with the Analyze step which is a scientific method used to find the actual root cause of the problem that is causing non-value added activities, unnecessary costs, lost profit or the dissatisfaction of customers. The Analyze stage uses experiment to understand the relationship of cause and effect between two or more factors and provides improved results such as gaining more customer satisfaction, reducing costs, increasing profits and developing better operations in the future.

2.2.4 Improve

Although the root cause has been identified and recognized there still needs to be an improvement in order to get a better outcome. This is concern of the Improve stage of DMAIC. Another way of looking at this stage is that it is the opportunity to deal with the problem solving by applying the most effective method to achieve the solution. However, making effective change is not an easy thing for the business because it requires good ideas and implementations to generate possible solutions to the problem (Goldsby & Martichenko, 2005). The goal of the Improve stage consists of generating solutions based on the root cause, selecting the best solutions and implementation of the measures required to solve the problem (Alexander et al., 2008).

2.2.5 Control

Goldsby and Martichenko (2005) explained that even though the solution has been proposed and selected in the Improve stage of DMAIC, what can prove more challenging is sustaining the effort. The final stage is Control of DMAIC process. This stage focuses on how to sustain the corrective action and promptly react to unexpected challenges that might occur.

According to Summers (2007), the Control stage ensures that the new controls and work instructions stay in place. It is easy to believe that new and better methods

should be utilized without failure but there is a tendency to return to old methods. This stage can help to ensure that after the successful implementation of new methods, the problem does not reoccur.

Table: 2.1 DMAIC Process Sequence

Stages	Goals	Tools
Define	Describe the specific problem. Identify the project's goal.	Financial Analysis, Project Charter, Process Improvement, Pareto Analysis.
Measure	Collect data with a view to the specifications needed. Use graphs, charts and statistics to analyze the key output measurements and identify their specific characteristics.	Measurement Matrix, Data Collection, Pareto Analysis, Observation, Data Source Analysis, Histogram
Analyze	Collect and verify the suspected causes. Identify the relationships between input and output of processes. Summarize the root causes for the problem at hand.	Cause-and-Effect Diagram, Process Flow Chart, Value Analysis, Observation, Data Collection
Improve	Generate solutions based on the root causes. Select the best solutions for achieving the goal.	Brainstorming, Poka Yoke, Should-Be Process Map, Pilot Program
Control	Secure the sustainable solution and long-term success	Process Documentation, Control Chart, Check Sheet

Source: Alexander et al. (2008)

Table 2.1 shows the goals and tools of DMAIC in each step. The *Define stage* will specify the scope of problem and its goal is to find which problem needs to be the focus of the improvement efforts based on data and fact. The *Measure stage* is used to collect data in depth in order to identify which key areas and key items are needed to

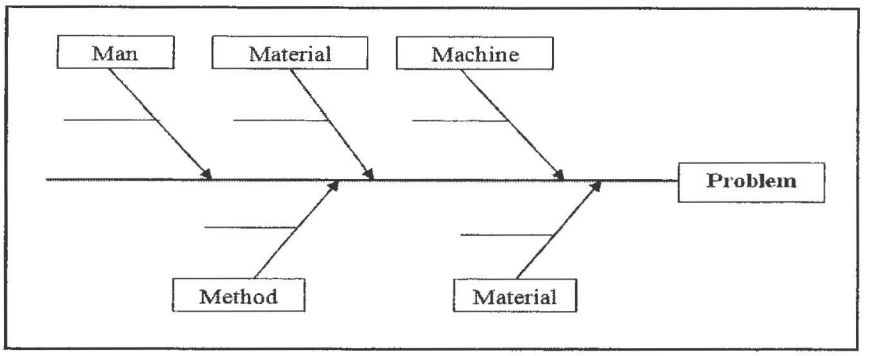
focus and analyze for major problems. Since it is hard to focus on all problems, tools such as Pareto analysis are applied in the *Define stage* and *Measure stage* to find the top defect items in order to reduce the scope of the problem.

In the *Analyze stage*, the data will be examined and the suspected causes will be investigated in order to dig down to the root causes. In this stage the researcher identifies the relationships between inputs and outputs in the process that lead to the problems. Often this stage uses the cause and effect diagram to reveal major root causes by categories. In the *Improvement stage*, solutions will be proposed and developed in order to get the best solution for the identified root causes. The *Control stage* mainly focuses on ways to secure the improvement and provide long-term success sustainably (Alexander et al., 2008).

2.3 Cause and Effect Diagram

An effective tool used as part of a problem solving process is the cause and effect diagram, also known as an Ishikawa diagram or fishbone diagram. This tool can create list of process input variables that could affect key process output variables. Furthermore this technique can provide an opportunity for improvement efforts. The main purpose of this technique is to create the interview process that can close in on the root cause of the focal problem. Common categories aimed at possible sources of root causes include: people, processes, technology, equipment, materials and the environment (Breyfogle, 2003)

Figure 2.2: Sample of Cause and Effect Diagram



Source: Doshi, Kamdar, Jani, and Chaudhary, (2012)

This Figure 2.2 shows a sample of cause and effect diagram. The purpose of this diagram is to provide the potential root causes based on the current problem that needs to be resolved.

According to Summers (2007), the steps in using Cause and Effect Diagram are explained as follows:

- Identify clearly the effect or the problem. The stated effect or problem statement is written in a box at the end of line.
- Identify the causes. Interviewing begins concerning the potential causes of the problem. General topic areas are usually methods, materials, machines, people and the environment. Under each major area, sub causes related to the major cause should be identified.
- Build the diagram. Organize the causes and sub causes in diagram format.
- Analyze the diagram. At this point, solutions will need to be identified and examined for feasibility.

This study applied a cause and effect diagram by analyzing the problem in the Analyze stage in order to identify the root cause of the defect occurrences. The diagram was used to classify the topics of root causes into categories consisting of people, equipment, management and environment. Then the sub-causes were defined in each category to show more detail about root causes related to the topics. This study identified root causes by categories via the cause and effect diagram which made it easier to understand and develop the solutions later on.

2.4 Pareto Analysis

Gotzamani (2011) stated that Pareto analysis is a quality control tool that ranks data from the highest frequency of occurrences to the lowest frequency of occurrences. This is done because 80 percent of problems tend to result from only 20 percent of potential causes. The values of the Pareto tool is that it emphasizes the need to focus first on the 20 percent of causes that need to be solved by ignoring the remaining 80 percent.

According to Cervone (2009), the Pareto analysis is commonly used for decision methods. It is a simple tool used to determine which task has the most impact and it also can help to identify the most important problem in an area where there are a number of problems to be solved. This method is based on a statistical principle created by the Italian economist Vilfredo Pareto. Pareto analysis is also known as the 80-20 rule, which states that 80 percent of results come from 20 percent of activities which is where the first priority should be focused.

According to Summers (2007), a Pareto Analysis is conducted by using as following steps:

- Select the subject for analysis. This can be a particular product line exhibiting a problem or a department or a process.
- Determine what data needs to be collected. Determine what needs to be tracked. For example: numbers, percentages, costs or defects.
- Collect data related to the quality problem. Ensure that the time period during which data will be gathered is established.
- Use a check sheet to collect the data. Record the total numbers in each category. Categories will be the types of defects or imperfect conditions.
- Determine the total number of defects and calculate the percent of total in each category.
- Determine the costs associated with the defect.
- Construct a Pareto chart or table by arranging the data from the largest to the smallest category.

- Analyze the chart or table. The largest percent shows the vital few causes (often 20%) that result in 80% of the problems.

This study applied Pareto analysis to indicate the top 80% of defect value occurrences that need to be the focus in both the Define stage and the Measure stage. The data were used to determine defect value by category in the production process (in Define stage) and value by defect type in the plating process (in Measure stage). Then the researcher determined the total defect value and calculated the percent of the overall total attributable to each category. Pareto tables were then constructed by arranging the data from the largest to the smallest category and accumulating the percentage for all of the categories. In the last step the table showed the largest percent of defects that was attributable to just a few causes (often 20% that result 80% of main problems).

2.5 Summary of the Selected Literature

This study applied the DMAIC approach to understand root causes and solve the problem for the organization. The selected literature is summarized in Table 2.2.

Table 2.2: Summary of Selected Literature

Study	Objective	Originality	Result/Finding
Franchetti (2012). "The Six Sigma Approach to Solid Waste Management and Minimization: Moving towards Zero Landfill Facilities"	The goals are to apply the five steps of Six Sigma DMAIC process to reduce the amount of solid waste by 5%, increase the recycling rate for paper and metal by 10% in order to gain a 10% cost benefit in expenditures and revenues in the solid waste removal and recycling efforts.	To demonstrate that the Six Sigma concept can be applied in the solid waste management field to improve quality, reduce waste and increase company profitability.	The organization achieved a 38% cost savings by adopting Six Sigma DMAIC tools. Moreover the company also improved its image and sustained results through statistical monitoring and evaluation.
Bhargava and Bhardwaj (2012). "Six Sigma Methodology Utilization in Telecom Sector for Quality Improvement- A DMAIC Process"	To apply the tools of Six Sigma in the Telecom industry to achieve operational improvement and sustainable business benefits.	The DMAIC model is implemented in the study in order to meet the objective set for a quality improvement project in service function to gain more customer satisfaction.	Quality in service function and customer satisfaction have been improved and increased by applying DMAIC tools in order to identify a root cause and purpose a solution plan.
Kumar and Sosnoski (2008). "Using DMAIC Six Sigma to systematically improve shop floor production quality and costs"	How a leading manufacturer of tools succeed in continuous improvement by adopting the DMAIC Six Sigma process to realize cost savings and improve shop floor quality.	Using DMAIC Six Sigma approach to identify a root cause and solve the problem of product and quality process that improved profitability by reducing unnecessary costs.	The problems have been improved. This tool helps to achieve annual cost saving of $12,500. Furthermore the scrapped parts were reduced to about 8 defective parts per month or equal to 1,646 per year.

Study	Objective	Originality	Result/Finding
Jacobsen (2010). "Quality Revolution Reduces Defects, Drives Sales Growth at 3M"	The improvement team started to focus the Six Sigma approach in order to find the root cause and develop continuous improvement. The targets were to reduce defective parts by 25% per year and trim total complaints by 15% per year as well.	Lean Six Sigma DMAIC tools were used to identify possible factors which are causing defect occurrences in the production of 3M. After root causes were revealed, Lean Six Sigma DMAIC tools were used to propose and develop a solution plan.	3M can succeeded in defect reduction from 12,000 parts per million to 475 and customer complaints fell by 90%. Moreover sale growth increased by 54%.
Jirasukprasert (2012). "A Case Study of Defects Reduction in a Rubber Gloves Manufacturing Process"	To investigate root causes of defects and provide a solution to eliminate defective gloves in production by using the DMAIC Six Sigma methodologies.	The DMAIC Six Sigma methodology was used to reveal root causes of defects in production and help to provide effective improvement sustainably.	This study shows the improvement of defects per million were reduced from 195,095 to 83,750 and solved its Six Sigma level from 2.5 to 2.9.
Prashar (2014). "Adoption of Six Sigma DMAIC to reduce cost of poor quality"	How to apply Six Sigma DMAIC approach for root cause identification and cost of poor quality reduction.	To demonstrate that the success of Six Sigma DMAIC model in improving the process of repairing, maintenance and reduced cost of failure.	Because of DMAIC application, the company reduced the cost of poor quality in the repairing division and the rejection rate was decreased from 9% to almost 0%.

Source: Author

Franchetti (2012) explained the steps involved in solid waste analysis and a minimization process that is based on a Six Sigma approach to solve the problem. Six Sigma can employ a holistic view of the process to determine what needs to be done to minimize or eliminate defects for waste disposal activities at a landfill. This study

provided the framework to ensure that the goals are successful. The five steps of the DMAIC Six Sigma model will be applied. After the project was done, the organization improved quality, reduced waste and gained more profitability which came from a 38% cost saving.

According to Bhargava, Bhardwaj, and Rathore (2012), DMAIC tools of Six Sigma can achieve improvements in service functions. DMAIC tools help to define and measure the major problems in service that, in this case was a service delivery defect. This tool also brings additional benefits to telecom industries and helps organizations to adopt best practices in their service delivery process in order to increase customer satisfaction levels and provide continuous improvement.

Kumar and Sosnoski (2008) stated that the DMAIC Six Sigma process can be applied to identify main problems and gain continuous improvement. After the root cause was identified the defect of warped parts was determined as the main factor causing the loss of company profitability. As a result from the DMAIC model that was adopted the company increased revenue and profit by eliminating the occurrence of the defect of warped parts.

Jacobsen (2010) explained that the 3M Company was facing a high volume of product defects that led to customer complaints for seven years. 3M applied Six Sigma methodology by using the DMAIC approach as a problem solving method. The Cause and Effect diagram and Pareto analysis were used to pinpoint the root cause as well. After the root cause was revealed DMAIC was used to propose improvement actions. With this, 3M reduced defect occurrences from 12,000 parts per million to 475 parts per million and customer complaints reduced by 90% while sales growth also increased by 54%.

Jirasukprasert, Garza Reyes, Kumar, and Lim (2012) stated that their case study of defect reduction in a rubble gloves manufacturing process success was achieved by adopting Six Sigma principles and DMAIC tools. After DMAIC was implemented, the study revealed that the root cause of defective gloves was related to an optimum

oven temperature and the speed of the conveyor. When the results of the DMAIC process were applied, the organization improved its process and reduced the defect of leaking gloves from 195,095 defects per million to 83,750 defects per million which its Six Sigma level increased from 2.4 to 2.9.

Prashar (2014) explained that this case study shows how to use Six Sigma DMAIC methodology to reduce the cost of poor quality in a repairing function used by a company engaged in overhauling critical components of transport helicopters. The repairing function was facing a problem with high costs of poor quality. The major problem was a high rejection rate due to cooling assembly failures. The root causes of the problem came from cross-fitment of bearings and extreme tolerances. After applying the DMAIC process, solutions were proposed that the design of bearing should be matched with software to solve the problem of cross-fitment and a new hydraulic jig be purchased with an electronic jig instead of manual jig. The result from this approach was that the failure rate was reduced from nine percent to two percent.

2.6 Summary

The literature review describes a number of previous studies that used the DMAIC approach help to gain a better understanding of root causes and reduce defect occurrences in production.

The DMAIC problem solving method, which consists of five steps, can help companies to develop improved production processes by applying Cause and Effect Diagrams, Pareto Analysis and Six Sigma methodology in order to identify root causes and propose solutions. The DMAIC approach will be used in the next chapter to show the current problems that are causing defects in production and determine how to eliminate the root causes and then sustain the improvement.

CHAPTER III

RESEARCH METHODOLOGY

The framework concept of this research is to identify root causes by analyzing company processes which cause defect occurrences. In this chapter the researcher applied the DMAIC method and other appropriate tools to reveal root causes and to propose efficient improvement methods to reduce or eliminate defect occurrences in the production process. The analysis was based on the defect data for the 12 month period from January to December of 2014.

3.1 Data Collection

The researcher collected the production department defect occurrence data from the 12 month period from January to December of 2014. This was done to find out the major problem which was causing defects in the production processes. This data was complete and was provided in a spread sheet format showing of the value of defects occurring in each step of the production processes.

The initial data used consisted of the defect occurring in the injecting process, pressing process, grinding process and plating process. The value of the defect occurrences was examined to give a better understanding of all problems occurring in production process. After the initial data was analyzed to find out the main problem, the plating process was selected and studied to gain more in-depth detail. In addition the interview sessions were conducted with the production manager and workers from the plating process to gain more data about the plating process. These interviews were held in order to understand the current process and possible root causes for the defects. The researcher also conducted observations within the company to ensure that the data from interviewing session was correct and to find more potential root causes.

3.1.1 Defect Occurrences Data Report in Year 2014

The defect occurrences data reports of the production process were collected for the 12 months of 2014. They provided the defect value from the injecting process, pressing process, grinding process and plating process. An overview of defect occurrences data was shown in Table 3.1.

3.1.2 Defect Data Report of Plating Process In-Depth in Year 2014

The company's defect data report of the plating process revealed the details of the defect types along with their value. Information from plating process defect report for the12 months of 2014 showed three types of defects: peeled off, burnt and rough & matt buckles. An overview of defect types occurring in the production process is shown in Table 3.2.

3.1.3 Interview Sessions Data:

The interview sessions were held in two rounds. In the first round, the researcher interviewed the production managers. The second round was interview session with three employees who work in the plating process and have over five years of experience with plating. These interviews were conducted in order to gain a better understanding of the current actions and reasons that lead to defect occurrences in the plating process.

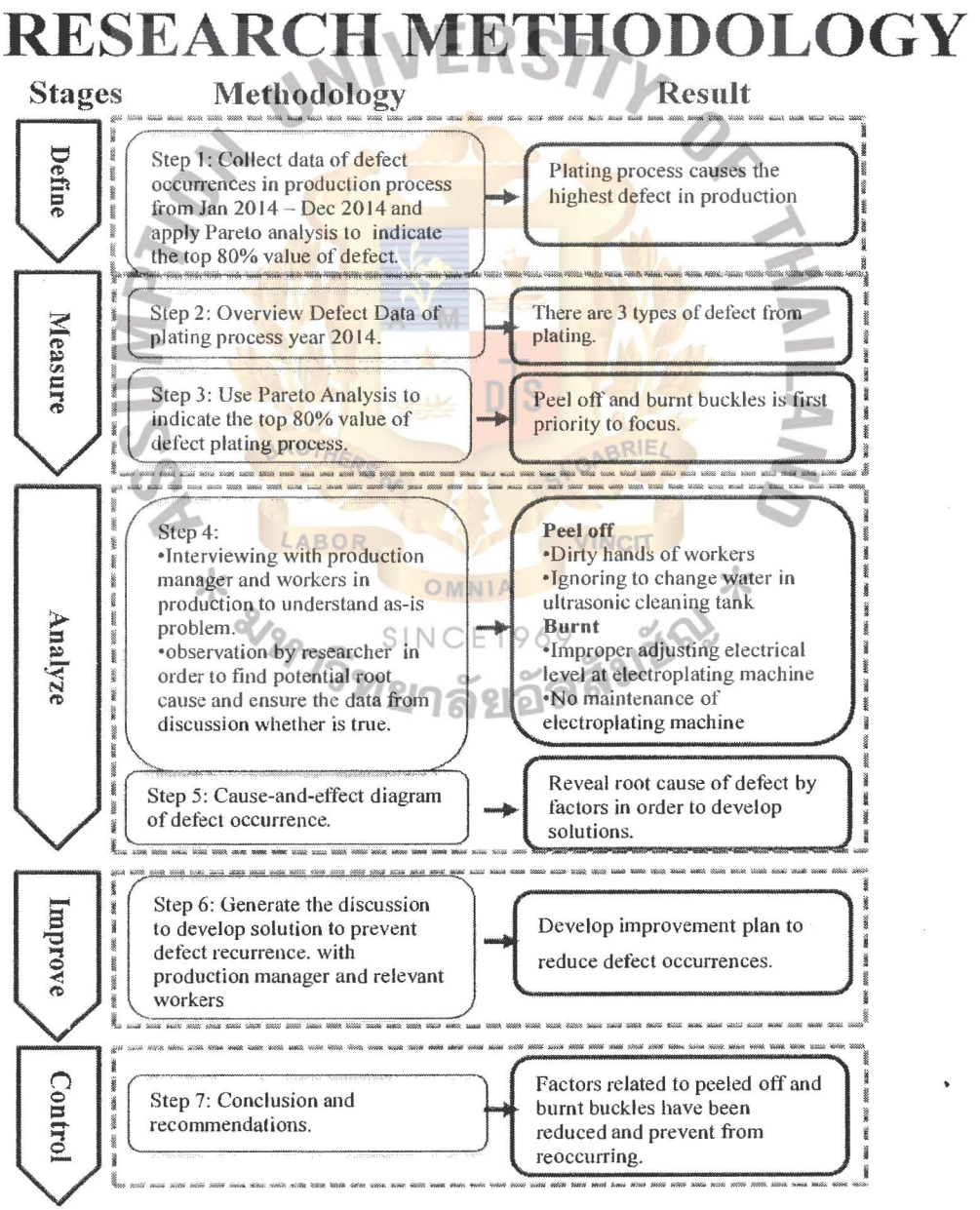
3.1.4 Observation Data:

The researcher observed the workers at the company to ensure that the data from the interview session was valuable and correct. Additionally, the researcher wanted to find the potential root causes of the defect occurrences and observe the working methods used in the plating process.

3.2 Data Analysis

The DMAIC methodologies were applied for data analysis in order to identify the root causes and eliminate the problem of defect occurrences in the plating process. The research methodology framework is shown in the five-stage DMAIC approach depicted in Figure 3.1.

Figure 3.1: Research Methodology Framework



Source: Author:

Figure 3.1 shows the research methodology framework in order to give holistic view of the research and results that were applied using DMAIC in each stage. DMAIC Model consists of the five stages of DMAIC analysis. In the first stage Define is based on the data from the production department for the year 2014 regarding the defect value of occurrences taking place in the production process. By applying Pareto analysis to find the main part of the process where defects occurred, it was identified that the top 80% of defect value took place in the plating process. The plating process then became the focus in the next stage. In Measure stage, the researcher collected additional data regarding defects occurring in the plating process in 2014. Here it was found that there are three main defect types that occurred in this process. Pareto analysis was once again applied in the Measure stage in order to reduce the scope of the problem by identifying the top 80% of defect value occurring within plating process. The result from Pareto analysis revealed that the top defect value comes from two defect types: peeled off and burnt buckles. These defect types needed to be improved first.

In the Analyze stage is used to find the root cause of defect occurrences in the plating process. The data used in the analysis came from interviewing plating process workers and performing observation at the BB Company. This was done in order to thoroughly understand the current process and be able to identify the root causes for improvement. For the Improve stage, in order to find solutions, the researcher worked with the production manager and workers to find and develop the proper solutions. In the Control stage plans were developed to provide a sustainable improvement to prevent defect recurrences.

DMAIC (Define-Measure-Analyze-Improve-Control)

According to Alexander et al. (2008), the DMAIC approach is employed to optimize existing processes forms the basis for a systematic and fact-based process improvement that achieves sustainable and measurable results. The aim of DMAIC is to raise quality by reducing rework and scrap. The DMAIC methodology helps to effectively reduce or even eliminate poor quality.

3.2.1 Define Stage

The Define stage in this research focuses efforts to find the main problems in production processes that negatively affect profit and revenue of the company by using production defect data for the year 2014 collected from BB Company. There are four main processes of production that are causing defect occurrences. After reviewing the data on the amount of defect value being caused in each production process Pareto analysis was applied define which production processes caused the highest defect value. That focused efforts on those factors causing 80% of total defect value. The remaining 20% of defect value occurrences from other production processes are not included in this study. That is because this study aimed to reduce the defects that were the major causes of negative effects on profit and revenue of the company.

The historical data of defect value occurrences in the production department was collected for the time period from January to December 2014. The researcher reviewed this data and found that defective items occur from four separate processes of the production. Those are defects from injecting process, the pressing process, the grinding process and the plating process.

To evaluate the data of defect occurrences in production processes, the researcher categorized the defect occurrences by value to show the loss to BB Company and then applied Pareto analysis in order to point the area of problem in the production process that is causing the highest defect value. The defect value data from the injecting process, the pressing process, the grinding process and the plating process for the year 2014 are provided in Table 3.1.

Table 3.1: Defect Value by Production Process for the Year 2014

Process	Defect Value in Thai Baht (THB)	Percentage (%)	Cumulative (%)
Plating Process	456,830	85.21%	85.21%
Pressing Process	34,500	6.44%	91.64%
Grinding Process	24,600	4.59%	96.23%
Injecting Process	20,200	3.77%	100.00%
Total	536,130	100.00%	

Source: BB Company

Table 3.1 shows defect value by production process. According to the data provided and using Pareto analysis, the plating process has the highest defect value which is 85.21% of total defect value in production and its cost is THB 456,830. Therefore based upon Pareto analysis, the plating process is the first priority upon which further analysis needs to be focused. Therefore, in the Measure stage, this research then turned to identifying the buckle defect types occurring from the plating process that negatively impacts to cost of BB Company.

3.2.2 Measure Stage

From the Define stage, this research showed that the plating process causes the highest defect value in production process. In the Measure stage, the data regarding defects in plating process was collected from production department for the period from January to December 2014 in order to identify the defect types arising from plating process. There are three main defect types. Pareto analysis was once again used, this time in Measure stage to specify the top defect type value. It is appropriate to use this technique in this stage because this study aims to focus on the highest value of defect types caused in the plating process. This would be the main problem. Therefore the researcher applied Pareto analysis in both the Define stage and the

Measure stage in order to find out which key problem area is the first priority to be improved.

In the Measure stage Pareto Analysis (or the 80-20 rule) was applied in order to the find the top 80% of defect types value in plating process As stated before, result of small number of causes (20%) can be responsible for a large number of the total defect value (80%) in plating process.

Table 3.2: Pareto Analysis of Defect Types in the Plating Process for the Year 2014

Defect Types in the Plating process	Value in Thai Baht (THB)	Percentage (%)	Cumulative (%)
Peeled Off	287,185	62.86%	62.86%
Burnt	135,530	29.67%	92.53%
Rough and Matt	34,115	7.47%	100.00%
Total	456,830	100.00%	

Source: BB Company

Table 3.2 shows the Pareto analysis results of buckle defect types in value. This Pareto Analysis suggests that research should focus on the top 80% of defect types which cause the highest value in terms of cumulative percentage. According to results shown in this table, the total defect value in the plating process is THB 456,830. The researcher found that the top 80% of defect types in plating process are "peeled off" and "burnt" with a combined cumulative percentages of 92.53% or THB 422,715 out of the total defect type value. Therefore the key defect types in the plating process that research focused to improve were the defect types of peeled off and burnt. The next step is to identify the root cause of peeled off and burnt in Analyze stage.

3.2.3 Analyze Stage

This stage is used to analyze and find out the root cause of defect occurrences in the plating process. The following steps were used to identify the root cause.

a. The researcher collected information about the root cause from one production manager and three workers who work in the plating process, and have over five years of experience with the plating process. The interviews were conducted in order to clearly understand the current process and the reasons that lead to defect occurrences. The production manager of BB Company recommended that the researcher to choose three specific workers from the ten workers employed in the plating process because those particular workers had over five years of experience in the plating process. These three workers have worked in and understand all operational steps used in the plating process such as tying buckles on copper wire, cleaning with the ultrasonic tank and plating the buckles.

b. The researcher observed the working methods of workers who work in the plating process including workers who were interviewed by researcher. This was done in order to make sure that the data obtained from the interviews was correct. The observation was also done to try and find potential root causes of the defect occurrences.

c. The researcher identified the main reasons which are causing the defects in the plating process by applying fishbone analysis (or the cause-and-effect diagram) in order to identify the root cause. The root causes identified then form the basis for the improvement plan.

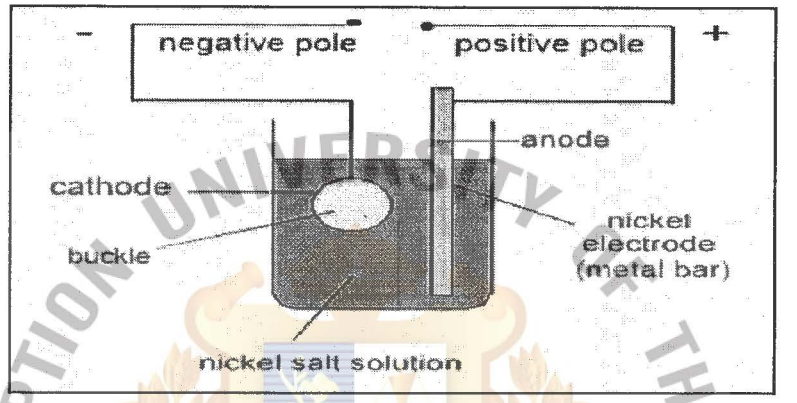
The interviews and observations performed by the researcher provided much information about the plating process and the behavior of the workers involved in that process. The following section discusses these findings.

3.2.3.1 Root Cause of Peeled Off Buckles

3.2.3.1.1Interview results

a. In the interview with the production manager, he explained how electroplating machine works:

Figure 3.2: Sample of Electroplating



Source: BB Company

As shown in Figure 3.2, the object to be coated is connected to the negative electrical pole and becomes the cathode. The metal bar, which is nickel or chromium, is connected to positive pole and becomes the anode. When the electroplating machine (see photo in Appendix A) is working, the object acting as cathode will attract from the anode the salt of the metal from the metal bar to coat on object's surface which gives it its color. But if buckles are dirty from fat on the buckle's surface, that buckle will not be a proper conductor. Therefore buckles acting as objects to be coated will be coated imperfectly and the plated color will peel off like a flake. The dirt or fat on the buckles' surface comes from the step of workers using their hands to tie buckles on to the copper wire as a part of the plating preparation. Most of workers are not aware that they need to keep their hands clean while working and the company does not have clear work instructions and regulations to manage this work process.

Another reason for the peeled off buckle defect comes from dirty water used in cleaning with the ultrasonic tank (see photo in Appendix B) which is not changed for clean, new water on a regular basis. Before buckles are plated, they need to be cleaned

with water in the ultrasonic tank. The ultrasonic cleaning tank converts electricity into vibration that move through the water in the tank. The vibration is around 70%-80% effective at cleaning the dirt and fat on the buckle's surface. However, as buckles are cleaned in this process they leave dirt and fat in the tank. These wastes continue to accumulate as buckles are washed throughout the day. Therefore if the water in tank is too dirty the ultrasonic tank cannot clean the buckles as well as they should be cleaned. Currently no measuring equipment is employed to tell workers when to change the water in ultrasonic tank. Instead, workers measure by approximating the quantity of buckles which were cleaned in this cleaning step. The company has no work instructions that set a standard to control the frequency of changing the water. Normally the water in ultrasonic tank should be changed every 300 kilograms of buckles. The standard of changing water every 300 kilograms was provided by the company that sold the ultrasonic cleaning tank to BB Company. Buckle weighing instructions are needed because in the cleaning step with ultrasonic tank the workers may take different models of buckles (with varying weights) to clean all at one time as a group. Therefore, there will be the different models all being cleaned at the same time and weighing results may vary. Workers need to weigh buckles every time for the cleaning step due to the different models and quantities being cleaned. Then workers can document how many kilograms of buckles were cleaned in each time. Once the accumulating kilograms reach 300 kg then it is time to change the water.

Based upon the interview with the production manager the root causes of the peeled off buckles can be summarized as arising from two factors. These factors are the dirty hands of workers and failing to change the water in ultrasonic cleaning tank as often as necessary because the company does not have clear work instructions and regulations to manage working methods. Additionally, workers also are unaware of the effects of these factors.

b. In the interview session with three workers from plating process the researcher learned about that process. The workers explained the steps in the plating process and stated that after the buckles have been grinded, the final process is the plating which gives the buckles their final colors. The plating process involves these steps:

1. Tie the buckles with copper wire
2. Clean the buckles with water in the ultrasonic tank for 20 minutes
3. Plate the buckles with copper as the first plated layer (around 2-3 minutes)
4. Plate the buckles with nickel or chromium or gold for their final layer (around 30-40 minutes, for gold around 5-15 seconds).

According to the interviews with the workers, the peeled off buckles are caused from the dirty hands of worker touching the buckles' surface during the step of where the workers use their hands to tie the buckles with the copper wire. This is the part of plating preparation that leads to buckles with coatings that peeled off in the final plating process.

The interviews also revealed several reasons for the workers having dirty hands: First, before working time workers do not wash their hands. Second, workers usually eat food or snack during working hours because management has no rule against doing so. Third the company does not provide enough washing places for workers. Currently there are only two sinks (each with one faucet) for fifty workers (see in Figure 3.4). The workers also reported that they usually do not change the water in ultrasonic cleaning tanks since they do not know when they should change the water. They also stated that the company does not provide work instruction to the workers.

After interviewing the workers, the researcher can summarize the root causes of peeled off buckles. This product defect comes from the dirty hands of workers touching the buckles. This occurs because company lacks of regulations and work instructions to design to prevent this. Additionally, there are not enough washing places for workers in the working area.

3.2.3.1.2 Observation results

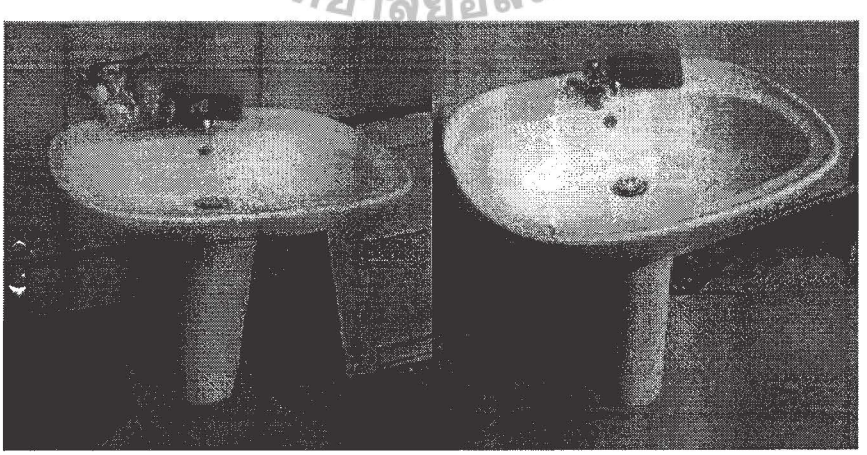
The researcher visited BB Company and found that most of the workers did not realize the need to wash their hands before they start working in the morning and after lunch hours. Additionally, workers usually eat food and snack while working.

Figure 3.3: Working Methods Observation

Source: Author

Figure 3.3 shows a picture of workers who were eating food during working hours and a picture of the workers tying the buckles with copper wire.

Figure 3.4: Two Sinks Provided by the Company



Source: Author

Figure 3.4 shows two sinks with one faucet at each which are located in the toilet area of the company.

The researcher walked around the work area and found that the company has provided too few washing places for fifty workers. Additionally there is no short break time to let workers eat food, clean hands and relax. From observation at cleaning stage using the ultrasonic tank it was found that there is no weighing machine to measure how many kilograms of buckles were cleaned in this process. Therefore the workers change the water by roughly estimating by sight, the weight of the buckles that have been washed. After reviewing company documents looking for work instructions and regulations of the company the researcher did not find these documents for workers in the company.

The researcher performed observation at BB Company which included walking around and observing and reviewing documents to ensure that the data obtained from the interview with the production manager and workers matched with what actually took place in the plating section. This provided a greater assurance that the data obtained could be used to develop an effective solution in the Improvement stage.

3.2.3.1.3 Summary of Interview and Observation Results for Peeled Off Buckles

Interview and observation results were analyzed by the researcher. The factors that are the root cause of the peeled off buckles are shown in Table 3.3.

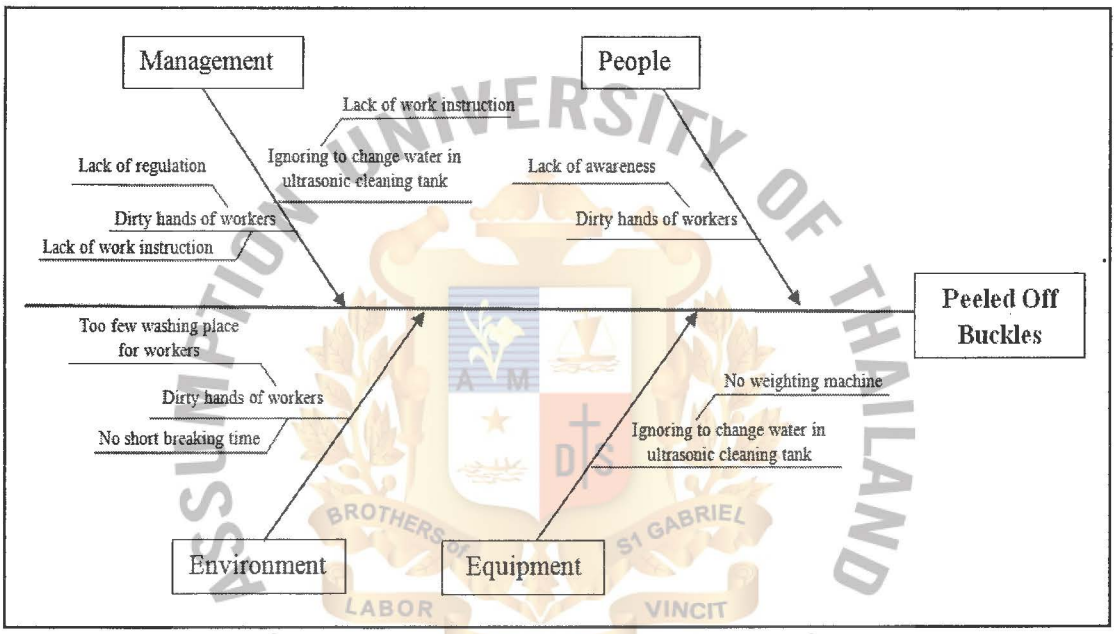
Table 3.3: Root Cause of Peeled Off Buckles

Root Causes of Peeled Off Buckles	Interview with Manager	Interview with Workers	Observation
Dirty hands of workers	√	√	√
Ignoring to change water in ultrasonic cleaning tank	√	√	√

Source: Author

Table 3.3 shows the root causes of peeled off buckles which developed from interviews with the production manager, three workers and observations conducted by the researcher. The root causes that led to peeled off buckles are dirty hands of workers and ignoring to change water in ultrasonic cleaning tank. The root causes of the peeled off buckles were identified in cause and effect diagram.

Figure 3.5: Cause and Effect Diagram of Peeled Off Buckles



Source: Author

Figure 3.5 shows the cause and effect diagram for the effect of peeled off buckles. The main root causes come from people, management, environment and equipment. People can lead to this problem because people are unaware of the need to keep their hands clean and they usually eat snacks or food during working time. In the environment, the company does not provide enough washing places for fifty workers to clean their hands conveniently and there is no short break time for workers so they can relax and clean their hands frequently. For the Company there is the lack of a weighing machine to measure the weight of the buckles going through ultrasonic cleaning step. This means that the workers have to estimate when to change the water instead of having a way to measure it. In addition, company has not provided work instructions and regulations to control the workers and their working methods.

3.2.3.2 Root Cause of Burnt Buckles

3.2.3.2.1 Interview results

a: From the interview with the production manager it was found that buckles are burnt because workers lack work instructions and training on how to properly set the electrical level for the final color plating with nickel and chromium in the electroplating step. Different colors and models of buckles require different levels of electricity and different amounts of time. If workers set the electrical levels too high just using their experience some of the buckles will be burnt due to inappropriate settings.

b: From the interview with the three workers it was learned that workers who are responsible for the plating process have never been trained. Nor have they had work instructions from the company about how to properly set the electrical level in order to guide them in how to use machine correctly. Workers always set the electrical level based on their experience and this sometimes results in the plating process burning some of the buckles.

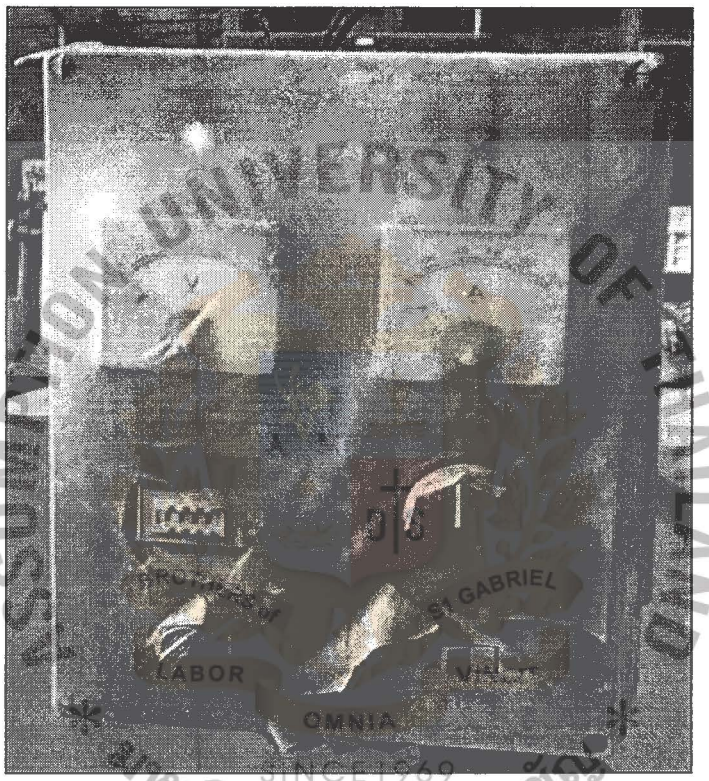
The results of the interviews with the production manager and workers indicates that workers relying on their experience to set the electrical levels is sometimes resulting in improper electrical level setting which can cause burnt buckles in the final plating process. This is occurring because the company has not provided training and work instructions to help the workers understand how to adjust the electroplating device to the right electrical levels.

3.2.3.2.2 Observation results

The researcher monitored work in the plating process area and found that workers have no work instructions to guide them on how to set proper electrical levels on the electroplating machine. Before plating, workers always roughly check the size, model and quantity of the buckles that are about to be electroplated and then they adjust the

electrical level using their experience. This sometimes results in improper electrical level adjustments which can lead to burnt buckle defects. The researcher did not see any evidence of work instructions or training being conducted in order to educate workers in the proper use of the electroplating equipment.

Figure 3.6: Control Panel of Electroplating Machine



Source: Author

Figure 3.6 shows the control panel of electroplating machine. The researcher views this as a potential cause of burnt buckle defects. In the yellow area of control panel there is a knob that is to be rotated to set the electrical level. However, the numbers on control panel of the electroplating machine are illegible due to lack of maintenance. Additionally, the electroplating machine is not periodically calibrated in order to make sure that it is working properly.

The purpose of the observations made by the researcher is to check the data collected from interviews with production manager and the workers to ensure that this data is

true. Burnt buckles are caused from improper adjustments of the electrical level at electroplating machine by workers because electrical level required will vary based upon the final plated colors being used and number of buckles being plated at any one time. The plating time period will affect the thickness of the coating color on the buckles' surface. In addition, the researcher found some other possible factors that may be resulting in burnt buckles. The numbers for the settings on control panel of the electroplating tank are illegible due to lack of maintenance and the machine does not receive periodic calibration.

3.2.3.2.3 Summary of Interviews and Observation Results for the Burnt Buckles

Analysis of the interviews and observations has provided several factors that appear to be the root causes of burnt buckles. These root causes are shown in Table 3.4.

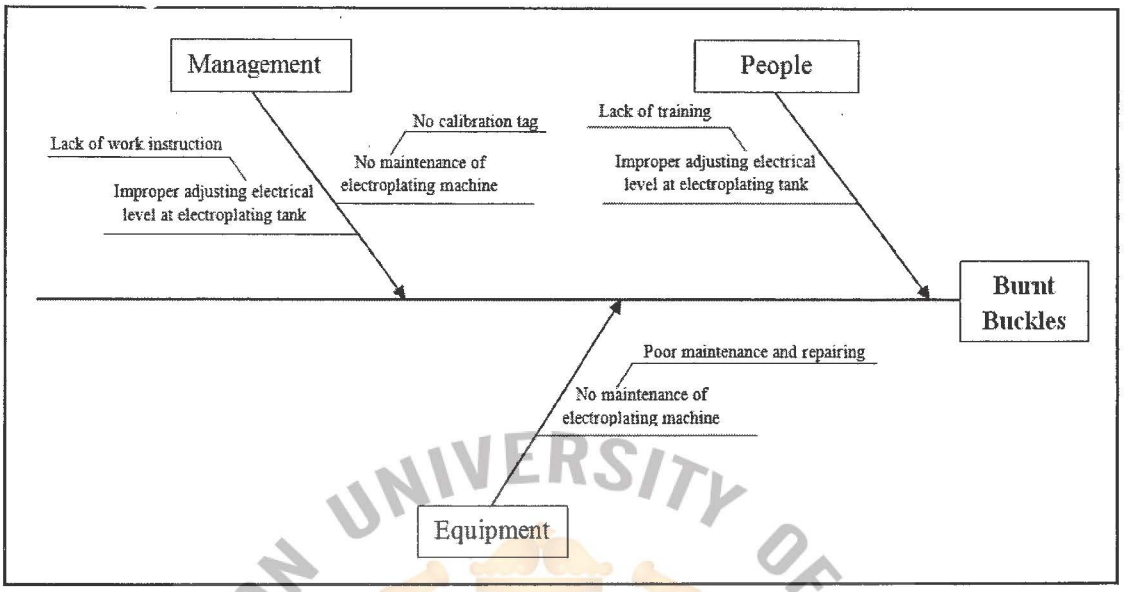
Table 3.4: Root Causes of Burnt Buckles

Root Cause of Burnt Buckles	Interview with Manager	Interview with Workers	Observation
Improper adjustment of the electrical levels at the electroplating machine	√	√	√
No maintenance of electroplating machine			√

Source: Author

Table 3.4: shows the root causes of burnt buckles which were determined by analysis of the interviews with the production manager and plating process workers and from observations made by the researcher. The root causes that lead to burnt buckles consist of improper adjustments made to the electrical level at the electroplating machine and lack of maintenance of the electroplating machine. The root causes of burnt buckles were identified in cause and effect diagram.

Figure 3.7: Cause and Effect Diagram for Burnt Buckles



Source: Author

Figure 3.7 shows cause and effect diagram for burnt buckles. Root causes come from people, management and equipment. Workers lack training regarding how to adjust the proper electrical level to prevent defect occurrences of burnt buckles. The company does not provide work instructions in order to guide workers on how to operate the equipment using the right methods. Also the company does not perform calibration to check to see if the electroplating machine is functioning properly. Moreover the electroplating machine is poorly maintained by the company.

3.2.4 Improve Stage

After the root causes were identified in the Analyze stage, the researcher created solutions along with the help of the production manager and the plating process workers. The goal was to develop effective improvements by providing such needed improvement as work instructions, worker regulations and training to create awareness in workers to prevent defect recurrences in the plating process. These solutions will be recommended to the management of BB Company.

3.2.5 Control Stage

In order to sustain the solutions designed to prevent defect recurrences, a number of recommendations will be as a part of this research. Defects in the plating process may be reduced or prevented by providing training, worker regulations and work instructions for plating process workers to create awareness and help them understand how to achieve continuous improvement. New work instructions and regulations will be documented and controlled closely by the supervisor and production manager in order to promptly solve problem recurrence.

3.3 Summary

This chapter provides an explanation of the research methodology. The data was analyzed and the actual root causes were identified by applying the DMAIC approach. The focus of this research was to reduce defect occurrences in the plating process which is the key factor in the problems occurring in the buckle production processes. Furthermore, the DMAIC approach also helps in finding ways to improve and sustainable methods to prevent defect recurrences.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

This chapter presents the Improve and the Control stages of the DMAIC model. The three stages of Define, Measure and Analyze were completed in the previous chapter. In order to solve the problem of defect occurrences, the results of Define stage helped to identify which production process was experiencing the highest defect value. The Measure stage helped to pinpoint the key defect types which represented the highest defect value in the plating process. Pareto analysis was applied in both the Define and Measure stages to make these determinations. In Analyze stage, the root causes of the defects were revealed by observing at the company and through interviews held with the production manager and plating process workers. These actions allowed the researcher to gain a better understanding of the current process. In addition, a cause and effect diagram was used in this stage to identify root causes by category (e.g. management, people, equipment, etc.)

4.1 Define: The researcher collected the data on defect values from BB Company in order to reduce the scope down to the main problem that was negatively affecting profit and revenue of the company through the use of Pareto analysis. This analysis technique indicated the process responsible for the top 80% of defect value in buckle production process. As the result, plating process was identified as causing the highest defect value which became the focus of the remaining stages of this research.

4.2 Measure: The researcher collected more data regarding defect value occurring in plating process and found that there are three defect types which are caused in plating process. Pareto analysis was applied once again in this stage to find out the key defect types which resulted in the highest value of defects. The result of this analysis showed there are two defect types that account for over 80% of the defect value in plating process. These types of defects are peeled off and burnt buckles. Thus the root causes of these two defect types were examined in the Analyze stage.

4.3 Analyze: The researcher interviewed the production manager and workers in the plating process section in order to understand the current process and how it might be leading to the problem. In addition, observation at the company was conducted by the researcher to ensure that the data from the interviews was credible. The observations were also conducted in order to identify potential root causes by viewing the working methods and reviewing company documents.

The results from the interviews and observations were used to construct the cause and effect diagrams. It was found that the root causes of peeled off buckles comes from two factors: the dirty hands of workers touching the buckles and transferring dirt and fat to the surface prior to plating, and ignoring to change water in ultrasonic cleaning tank on a regular basis. People, management, environment and equipment are the main categories of root causes for the peeled off buckles. People can lead to this problem because people are unaware of the need to keep their hands clean. In the environment, the company does not provide enough washing places for the fifty workers to clean their hands conveniently and there is no short break time for workers which would allow them to relax and clean their hands frequently. The Company does not have equipment to measure the cumulative weight of buckles passing through the ultrasonic cleaning tank operation. Furthermore, the company does not provide work instructions and worker regulations to control workers and their working methods.

For the burnt buckles the root causes are from the categories of people, management and equipment. Workers lack training regarding how to adjust the electroplating device to the proper electrical level. Furthermore, the company does not provide work instructions that tell workers operating the electroplating device the right methods making adjustments to the device based upon the type of plating to be done, and the quantity of buckles involved. The company also does not periodically check the calibration of the electroplating machine. Moreover the electroplating machine is poorly maintained by the company and its workers.

4.4 Improve: After the root causes were revealed in Analyze stage, the researcher developed a solution plan with assistance from the production manager and three workers from plating process who had taken part in the interviews. From this, a plan for effective improvement was proposed. The plan suggested that the company could reduce or eliminate the major defects in the plating process by providing proper work instructions, developing employee regulations and conducting training to create awareness for workers to help prevent defect occurrences of peeled off and burnt buckles in the plating process. Relevant workers also can get involved with brainstorming which can motivate the workers to conform to the newly developed solutions. Furthermore, the solutions will be recommended to the management of BB Company.

Table 4.1: Summary of Root Causes and Improvement Plan & Actions for Peeled Off Buckles

Root Cause	Description	Improvement Plan and Actions
People	Factor of dirty hands of workers 1) Workers lack awareness of the need to keep their hand clean while working with the buckles	- Provide training sessions for workers who work in the plating process to create awareness and make them understand what they should do to increase working efficiency.
Management	Factor of dirty hands of workers 1) Lack of regulation to prohibit workers eating food during working time. 2) Lack of work instructions to control working methods of workers. Factor of ignoring to change water in ultrasonic cleaning tank 1) Lack of work instruction to control working method for workers.	- Establish regulations to control and prohibit workers eating food during working hours. - Provide work instructions to manage the working methods of workers to solve the problem of dirty hands of workers and changing water in ultrasonic cleaning tank when required.
Equipment	Factor of ignoring to change water in ultrasonic cleaning tank 1) No weighing machine to measure the cumulative weight of buckles which were cleaned.	- Provide weighing machine for measuring cumulative weight of buckles which were cleaned in the ultrasonic cleaning tank.
Environment	Factor of dirty hand of workers touching the buckles 1) There are too few washing places for workers. 2) No short break time to let workers clean their hands	- Provide three more sinks for workers to clean their hand conveniently. - Set two rounds of short break times for ten minutes in company regulation (break time: 10.00-10.10, 15.00-15.10)

Source: Author

Table 4.1 shows the summary of root causes of the defect occurrences for the peeled off buckles which were classified as dirty hands of workers and ignoring to change water in ultrasonic cleaning tank. Main root causes come from the fishbone generated

categories of people, management, equipment and environment. Improvement plans to reduce or eliminate the peeled off buckles were created by brainstorming with the production manager and relevant workers.

Table 4.2: Summary of Root Causes and Improvement Plan & Actions for Burnt Buckles

Root Causes	Description	Improvement Plan and Actions
People	Factor of improper adjusting electrical level of the electroplating machine 1) Workers lack training on how to use the machine correctly.	- Arrange training sessions for workers to increase their knowledge on how to adjust the electrical level of the electroplating machine.
Management	Factor of improper adjusting electrical level of the electroplating machine 1) Company does not provide work instructions to workers about how to properly use the electroplating machine. Factor of poor maintenance of electroplating machine 1) There is no periodic calibration of the electroplating machine to ensure its proper function.	- Provide work instructions for workers how to properly use the electroplating machine for plating buckles correctly. - Outsource with a certified company to check and calibrate the machine quarterly.
Equipment	Factor of poor maintenance of electroplating machines 1) company does not have maintenance and repair for the electroplating machines.	- Provide maintenance and repair for the electroplating machines every two months in order to maintain these machines in good condition.

Source: Author

Table 4.2 shows root causes of defect occurrences for burnt buckles. There are two factors leading to the defects. These are improper adjusting electrical level of the plating machine and poor maintenance of electroplating machine. Main root causes come from the fishbone generated categories of people, management and equipment. Brainstorming with the production manager and relevant workers was conducted to propose the solutions and provide effective prevention from defect occurrences.

4.4.1 Improvement Plan and Actions for Peeled off Buckles

4.4.1.1 Training: BB Company will arrange training sessions for the workers who work in plating process in order to build awareness for defect reduction of peeled off buckles. The training will be designed to help them understand what they should do to prevent defect occurrences due to dirty hands. A training session sheet for defect reduction by keeping workers' hands clean (See in Appendix C) was developed for the company in order to explain the recommended content for this training session.

4.4.1.2 Regulations: Company regulations regarding eating food during working time in the production area (See in Appendix D) were created for the company's workers. This was done in order to solve the problem of workers eating food while working which gets transferred to the surface of the buckles from the workers dirty hands causing the plating to peel off in the final plating process. Thus the goal of the regulation is to prohibit workers from eating food during working time in the production area and to inform workers that they are allowed to have food only in the dining room of the company. The regulation will be launched via company announcement.

4.4.1.3 Work Instructions: Work instructions are developed to manage the working methods of employees and to solve the problems of peeled off buckles and prevent its recurrence. These work instructions were developed by brainstorming with the production manager and relevant workers in plating process. The work instructions will also build an understanding of the right process for workers that will help the company gain sustainable efficiency and effectiveness. In addition, the work instructions will become a part of the SOP (Standard Operating Procedure) of the company.

The work instructions were provided for preventing defect occurrences of peeled off buckles as follows:

a. Work instruction of keeping workers' hands clean during the plating process
b. Work instruction for changing the water in the ultrasonic cleaning tank

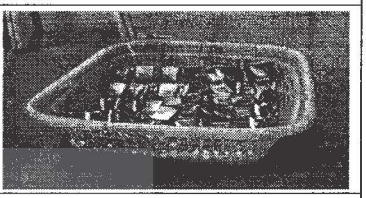
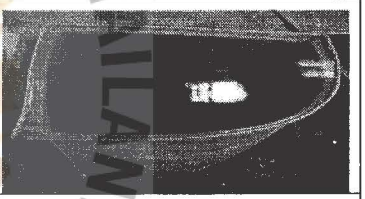
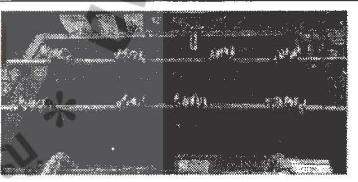
Table 4.3: Work Instruction of Keeping Workers' Hand Clean During the Plating Process

BB Company Document Number: xxx-xxx	**Work Instruction** Keeping Hands Clean of Workers During the Plating Process	**Production Department** Prepare Date: Effective Date
Operator: Workers in the plating process		
Step	**Working Description**	**Remark**
1	Before starting working and touching the buckles in the morning and after lunch break, workers, who work in the plating process, must clean their hands with soap at the provided washing places.	
2	In periods of short break time, workers must clean their hands with soap at the provided washing places.	
3	In the process of tying buckles on to copper wires for plating preparation, workers who work in this task must wear rubber gloves.	
Prepared by Supervisor		Approved by: Production Manager

Source: Author

Table 4.3 shows the work instruction for keeping workers' hands clean during the plating process that aims to prevent defect occurrences that arise from dirty hands of workers touching the buckles. Washing hands before starting working and during working hours is a very necessary method. Additionally, workers need to wear rubber gloves during the step of tying buckles on to copper wires in order to make sure that hands of workers do not cause the buckles to get dirty. This work instruction will be closely monitored by the supervisor.

Table 4.4: Work Instruction for Changing Water in the Ultrasonic Cleaning Tank

BB Company Document Number: xxx-xxx	**Work Instruction** Changing Water in the Ultrasonic Cleaning Tank	**Production Department** Prepare Date: Effective Date
Operator: Workers in plating process		
Step	**Working Description**	**Remark**
1	Put the buckles that need to be cleaned in the basket.	
2	Measure the quantity of buckles with weighing machine in kilograms in each bucket and note the weight on the provided sheet to show how many kilograms of buckles were cleaned in the ultrasonic tank.	Mark sheet for buckles quantity cleaned in ultrasonic cleaning tank step (See in Appendix E)
3	If the quantity of cleaned buckles reaches 300 kilograms, workers must change the water in ultrasonic cleaning tank immediately.	
4	Clean the buckles with ultrasonic cleaning tank for 20 minutes.	
Prepared by: Supervisor		Approved by: Production Manager

Source: Author

Table 4.4 shows the work instruction for changing water in the ultrasonic cleaning tank. The purpose of this work instruction is to manage working methods regarding when the water in the ultrasonic cleaning tank should be changed out for new water. A Weighing machine will be provided for workers to measure the cumulative weight of buckles which were cleaned in this cleaning step. Moreover, workers need to note the weight of buckles cleaned in the ultrasonic tank on the mark sheet for the quantity of buckles cleaned in ultrasonic cleaning tank step (see in Appendix E) by kilogram.

If the cumulative total of cleaned buckles reaches 300 kilograms, then workers need to change new water immediately. This will be monitored by the supervisor.

4.4.1.4 Weighing Machine: Since the company lacks a weighing machine to measure the weight of the buckles which were cleaned in ultrasonic cleaning tank. This factor leads to workers failing to change the water in the ultrasonic cleaning tank. The new water needs to be changed if the cumulative weight of buckles cleaned in ultrasonic tank reaches to 300 kilograms. Thus the company will provide a weighing machine for workers to measure the cumulative weight of buckles such as the weighing device shown in Figure 4.1.

Figure 4.1 Weighing Machine Model

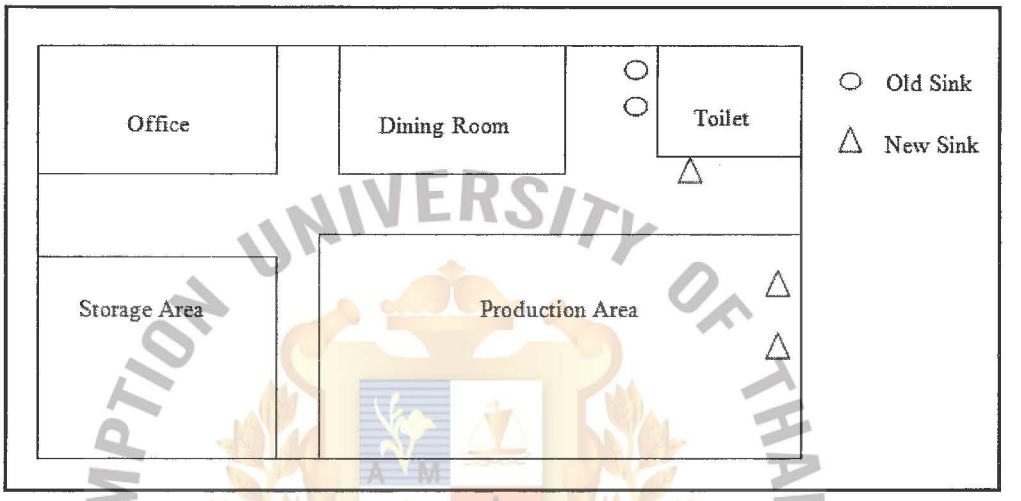
Source: BB Company

Figure 4.1 shows the model of weighing machine which was recommended by the production managers because this weighing machine model can measure the weight of buckles up to 100 kilograms at a time. It also can be moved anywhere in the work area conveniently. This model is the same model which company had used three years ago. The production manager will assign the purchasing department the task of buying this weighing machine model as recommended by the production manager.

4.4.1.5 Washing Places: Currently the company does not provide enough washing places for workers. There are only two sinks for fifty workers. After discussion with

production manager and relevant workers, the company will provide three more sinks, each with a single faucet. This is the same as the old sinks which are used now. The location of new sinks is provided in the diagram shown in Figure 4.2.

Figure 4.2: Layout of BB Company Showing Sink Locations



Source: BB Company

Figure 4.2 shows the layout of BB Company. The old sinks were located only in the toilet areas and the current quantity of the sinks is not enough for all workers to clean their hands. Therefore the company will provide three more sinks (one sink for the toilet area and two sinks for the production area) in locations that are easy to set up with the required plumbing. In these new locations all workers can reach the sinks and clean their hands easily. The production manager will responsible for providing the new sinks.

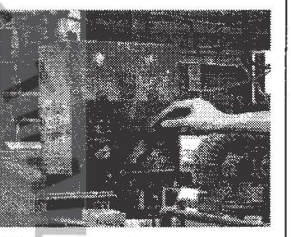
4.4.1.6 Short Break Time: Since the company has no short breaking time to let workers clean hands and relax some will be added. The company will provide regulations regarding short break times (see in Appendix F) which will be launched via company announcement. The purpose of the short break time regulations is to assist in solving the problem of the peeled off buckles that is occurring due to the dirty hands of workers. This new regulation will let workers clean their hand more frequently. The short break time was set up for 10 minutes in the morning and 10 minutes in the afternoon.

4.4.2 Improvement Plan and Actions for Burnt Buckles

4.4.2.1 Training: BB Company will provide training sessions for the workers who are responsible for the electroplating machine in order to help them gain more knowledge and understanding about how to use the electroplating machine correctly and thereby reduce defect of burnt buckles. A training session sheet for defect reduction by adjusting electrical level appropriately (See in Appendix G) was developed for the company in order to recommend the content of this training session.

4.4.2.2 Work Instructions: Work instructions for adjusting the electrical level of the electroplating machine properly were provided to define the steps required to use the electroplating machine correctly. Creation of the work instructions should help to solve this problem and prevent the occurrences of burnt buckles. The work instructions were developed by brainstorming with the production manager and relevant workers in plating process. The work instruction of adjusting electrical level of electroplating machine will be also become a part of the SOP (Standard Operating Procedure) of the company.

Table 4.5: Work Instruction for Properly Adjusting Electrical Level of Electroplating Machine

BB Company Document Number: xxx-xxx	**Work Instruction** **Properly** adjusting the Electrical Level of the Electroplating Machine	**Production Department** Prepare Date: Effective Date
Operator: Workers who respond for electroplating machine		
Step	**Working Description**	**Remark**
1	Check the model, specific color and quantity of buckles which are going to be plated with guideline of company regarding how to correctly plate buckles with the electroplating machine.	Guideline of how to properly adjust electrical level of electroplating machine (See in Appendix H)
2	Adjust electrical level as recommended by the company guidelines.	
3	After finishing electroplating step, workers need to check the quality of plated buckles. If there are defective buckles from plating, workers need to put detail in check sheet report of the defect occurrences and submit this to the production manager.	Check sheet report of defect occurrences (See in table 4.6)
Prepare by: Supervisor		Approved by: Production Manager

Source: Author

Table 4.5 shows the work instructions for properly adjusting the electrical level of the electroplating machine. Currently workers adjust electrical level of the electroplating machine using only their experience which causes defect occurrences from burnt buckles. The work instructions and attached guidelines provide information for how to properly adjust the electrical level and time of the electroplating machine (see in Appendix H for each model and color of belt buckle. The guideline provides statistic

data about buckle plating which was developed by the production manager. Supervisor will monitor the working methods of workers to ensure that they are aligned with the work instructions.

4.4.2.3 Calibration of Electroplating Machines: The Company currently is in lack of calibration for the electroplating machines in order to make sure that the machines are still working properly. Therefore the production manager will outsource the task of calibrating the electroplating machines to a certified company to perform quarterly in order to ensure their proper functioning.

4.4.2.4 Maintenance and Repair for the Electroplating Machines: The Company will provide preventive maintenance schedule for the electroplating machines (see in Appendix I). The purpose of this schedule is to confirm that maintenance and repair has been conducted. The maintenance and repair for the electroplating machines is required to be checked every two months to ensure that the machines are in good condition and ready to use. The supervisor will be in charge of maintenance and repair for electroplating machines and tracking in the schedule.

4.5 Control: The Control stage is designed to sustain the improvement plans developed in the Improve stage. In addition, this Control stage is to ensure that the new controls of regulations, work instructions and others solutions stay in place so that the plating process does not return to their old methods. Improvements are monitored and documented continuously by the supervisor and the production manager. A check sheet report for detailing defect occurrences was provided in this stage in order to promptly react and investigate defects reoccurring in the plating process. The researcher developed a control plan with assistance from the production manager and relevant workers that provides controls for regulations and work instructions. This was done because once the improvement has been conducted, it is necessary to ensure that the workers continue to conform to the new regulations and work instructions.

4.5.1 Control for Regulations: The Production manager and supervisor will monitor daily whether workers eat food during working time in the production area. If there are some workers breaking the company regulations such as eating food in the production area, the supervisor will give a warning card to those workers and reduce their performance score which will directly affect their year-end bonus.

4.5.2 Control for Work Instructions: The work instructions, which are established by the company, will be monitored daily by the production manager and supervisor to ensure that workers conform to the new working methods designed help to prevent defect occurrences. If there are some workers working method that do not conform to the work instructions, the production manager and supervisor will investigate the reason of doing the non-conformances and remind that workers to conform to the work instructions. In addition, supervisor will give a warning card to worker and reduce their performance scores which directly affect their year-end bonus.

4.5.3 Check Sheet Report: Based upon the brainstorming of the researcher with the production manager and relevant workers, the company will provide check sheet report as shown in Table 4.6.

Table 4.6: Check Sheet Report of Defect Occurrence

Check Sheet Report of Defect Occurrences					
Date: dd/mm/yy	Defect Type		Recorded by:	Investigated by:	Remark
	Peeled off	Burnt			

Source: Author

Table 4.6 shows the check sheet report for defect occurrences by defect type for peeled off and burnt buckles. The purpose of check sheet report is to monitor the defects occurring from the plating process. This information will be recorded by workers who perform the task of operating the electroplating machine. If there are

defect occurrences from the plating process, the production manager and supervisor will promptly investigate the problem in order to find the root cause and prevent defect recurrence.

4.6 Summary

This chapter summarized the root causes of defect occurrences from peeled off and burnt buckles in plating process. The improvement plans such as training sessions, regulations and work instructions were also proposed and developed to solve the problem. Furthermore, a control plan was established in order to sustain the improvements and prevent defect recurrences in the future.

The researcher conducted a group discussion in order to ask the questions about what they think the solutions provided whether it is effective as shown in Appendix J and K. The results from group discussion with relevant workers can be concluded that the solutions of peeled off and burnt buckles are all effective for the company which can help the defect reduction in plating process. In addition, training, work instructions and other qualified improvements are very necessary to improve the working methods of workers and make them understand how to work correctly in order to increase working efficiency and reduce defect in production process.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This research is focused on solving the problem of defect occurrences in the belt buckle production process for BB Company. The DMAIC model was used in this study in order to find root causes and develop effective solutions. Therefore this chapter presents the discussion of findings, summary, conclusions, theoretical implications, managerial implications, limitations and recommendations for future research.

5.1 Summary of the Findings

The purpose of this study was to solve the problem of defect occurrences in belt buckle production process in an efficient manner. This problem directly affects profit and revenue of the BB Company. As result of reviewing related literature, the researcher found that the DMAIC model is suitable tool for solving and preventing defect occurrences in the production process employed in this study.

BB Company had a problem with defect occurrences in production process which had an overall value of THB 536,130 in defect costs and caused the company to lose revenue and profit as well. An analysis of the defect value data from January to December 2014 indicated that the highest defect value came from the plating process which was THB 456,830 or 85% of the total costs of defects based on Pareto analysis of the data. There are two major defect types caused from plating which are peeled off and burnt buckles. The total value of these two defect types was THB 412,715 or 92% of total defect value in plating process. Therefore this study focused on solving the problem of the two defect types of peeled off and burnt buckles which were the top value of defects occurring in the plating process. In order to solve these problems this study sought to answer the research question of whether the Define-Measure-

Analyze-Improve-Control (DMAIC) model could be used to reduce defect occurrences in the belt buckle plating production process.

Working with the researcher, improvement plans were proposed by the production manager and relevant workers in order to provide regulations, equipment and work instructions to reduce or eliminate defect occurrences and increase working efficiency. In addition, control sheet reports were developed as a part of the control plan in order to sustain the improvements.

5.2 Conclusions

This study applied the Define-Measure-Analyze-Improve-Control (DMAIC) model to reduce defect occurrences from a production process. The root causes were identified and analyzed systematically using the DMAIC method in order to reduce defects caused in the production.

DMAIC can help the company gain a better understanding of the actual root causes by analyzing in-depth to propose improvements based on data and facts. The company could implement this model in order to achieve sustainable defect reductions. This study applied the DMAIC model to substantially reduce defect occurrences in the company. The root causes were identify and analyzed systematically in order to reduce defects caused in the production process. Moreover as a group discussion with relevant workers in order to ask the questions about the proposed improvements both of peeled off and burnt buckles whether they are appropriate and useful for the company, the results show that solutions are effective and can be applied in the company to solve the problem of defect occurrences efficiently.

The new solutions that were launched by the company, there will be resistance to change in the organization. Change would be uncomfortable for the employees to change the new way of thinking and doing because the employees will be familiar with old method rather than new method. Change creates anxiousness and uncertainty for the employees since they will feel they lose the security and tend to prefer the

current actions that they are doing even though change will make their organization better. When change is introduced, the reaction of employees cannot be unpredictable. As the result of change introduced, the resistance to change will occur in the organization.

The resistance to change will happen since company is lack of communication, misunderstanding about the need for the change, poor communication, returning to old method and employee does not feel the benefit of making the change for the company. In order to succeed with managing resistance to change, the following steps were taken.

a. Company needs to educate and communicate to the relevant employees in order to help them understand how these changes will affect them personally. Communication the reason for the change in such way can educate them for the need and the purpose of changes in the company.

b. Relevant employees need to participate and get involved with developing the new solution since they are more likely to conform rather than resist the new method of new solution. This way of employees' participation would motivate them to support the changes in the company.

c. Production manager and supervisor need to support and facilitate employees during the difficult time of the changes. Managerial support from the company can help employees reduce fear and concern during transition period.

d. Production manager and supervisor will lead employees to accepting the changes by making clearly discussion that the resisting change can lead to losing job, firing or not promoting employees.

In time of change, manager and supervisor are close to the employees who need to adopt change in the company for the solution in production process. In many cases, mostly the role of manager and supervisor will be impacted by the change. Thus

manager and supervisor will be in charge in order to support employees for change adopting. The important role of manager and supervisor were taken by following steps.

a. Communicate: Manager and supervisor need to directly communicate the change for employees because they want to hear change messages about how their work or their team will be affected by the change.

b. Advocate: Manager and supervisor need to demonstrate their support actively for the change because manager and supervisor must be firstly on board to engage with the change before they can support their employees and employees

c. Coach: Manager and supervisor must get involved to support employees through the process of change by coaching them to educate how to change and reduce resistance in the company such as goal, action plans and time lines furthermore manager and supervisor will provided ongoing guidance to employee as they complete the action plan.

d. Manage resistance: In terms of managing resistance in the company, manager and supervisor are in the best position to identify what the root cause of resistance occurs among employees. After Manager and supervisor understand the reason of resistance, they can come up with such as training in order to solve the problem which is suitable with resistance occurrence.

5.3 Theoretical Implications

The Define-Measure-Analyze-Improve-Control (DMAIC) model was used in this study to analyze and reduce problems in the operating process that were causing defect occurrences. As the result of reviewing previous studies applied DMAIC, the researcher found that DMAIC is tool for problem solving method and root cause analysis which effectively solved the problem and proposed the sustainable

improvement plan in the organization. So this study aimed to apply DMAIC to solve the problem in buckles manufacturing.

The purpose of this research was to apply the DMAIC model to illustrate sustainable solutions for the problems in the production process that were suitable for BB Company. The root causes were showed current actions which led to defect occurrences. The root causes were analyzed and solutions were proposed to prevent defect recurrences in the future.

5.4 Managerial Implications

This study will help BB company find root causes of their production problems and solve those problems using the DMAIC process. This study also involved developing improvement plans for defect reduction in the plating process. Tools such as Pareto analysis and the cause and effect diagram were used to indicate the main area of the problem and root causes for those problems based on data and fact. BB Company will benefit from the use of the DMAIC model and through its use increase profit, revenue and the efficiency of its production process.

5.5 Limitations and Recommendations for Future Research

This study focused on the prevention of defect occurrences in the plating process in order to identify root causes and develop a solution plan using the DMAIC model. Thus the defect occurrences in other processes are not included in this study. In addition, this study only sought to solve the problems leading to the top value of defect types occurring in the plating process. The problem solving methodology used in this study may not be suitable for other companies because there are differences across businesses and operational processes.

For future research, DMAIC is a useful problem solving method which can be applied in other businesses and research projects in order to find and analyze root causes and

generate solutions. Data collection is a very critical step since DMAIC model can only be effective and efficient if the data being analyzed is correct and accurate.

BIBLIOGRAPHY

Bhargava, M., Bhardwaj , A., & Rathore A.P.S. (2010). Six Sigma methodology utilization in telecom sector for quality improvement-a DMAIC process. *International Journal of Engineering Science and Technology*, 2(12), 7653-7659.

Bozarth, C.C., & Handfield, R.B. (2008). *Introduction to Operations and Supply Chain Management.* New Jersey: Pearson Prentice Hall.

Breyfogle, F.W. (2003). Implementing Six Sigma. New Jersey: John Wiley &Son.

Doshi, J.A., Kamdar, J.D., Jani, S.Y., & Chaudhary S.J. (2012). Root Cause Analysis using Ishikawa diagram for reducing radiator rejection. *International Journal of Engineering Research and Applications,* 2(6), 684-689.

Fagerhaug, T., & Andersen, B. (2000). *Root Cause Analysis: Simplified Tools and Techniques.* Wisconsin: Quality Press.

Franchetti, M. (2012). The Six Sigma approach to solid waste management and minimization: Moving towards zero landfill facilities. *Journal of Environmental Science and Engineering,* 1, 299-311.

Gill, A. (2008), An effect-cause-effect analysis of project objectives and trade-off assumptions. *International Journal of Managing Projects in Business,* 1(4), 535-551.

Goldsby, T., & Martichenko, R. (2005). *Lean Six Sigma Logistics : Stretegic Development to Operational Success.* Florida: J.Ross Publishing.

Gotzamani, K. (2011). Critical factors for effective implementation of the HACCP system: a Pareto analysis. *British Food Journal,* 13(5), 578-597.

Gygi, C., DeCarlo, N., & Williams, B. (2008). *Six Sigma for Dummies.* New Jersey: Willey Publishing.

Cervone, H. (2009). Applied digital library project management. *OCLC System & Service: International Digital Library Perspectives, 25(2),* 76-81.

Ilie, G,. & Ciocoiu, C.N. (2010). Application of fishbone diagram to determine the risk of an event with multiple causes. *Management Research and Practice,* 2(1), 1-20.

Jacobsen, J. (2010) Quality Revolution Reduces Defects, *Drives Sales Growth at 3M.* Retrieved February 22, 2014 from American Society for Quality (ASQ): http://asq.org/public/manufacturing/why-quality/case-studies.html.

Jirasukprasert, P., Garza Reyes, J.A., Kumar, V., & Lim, M.K. (2012). A Six Sigma and DMAIC application for the reduction of defects in a rubber gloves manufacturing process. *International Journal of Lean Six Sigma,* 5(1), 2-21.

Alexander, J., Renata, M., Olin, R., & Christian, S. (2008). *Six Sigma+Lean Toolset - Executing Improvement Projects Successfully*. Heidelberg: Springer-Verlag.

Kumar, S., & Sosnoski, M. (2009). Using DMAIC Six Sigma to systematically improve shopfloor production quality and cost. *International Journal of Productivity and Performance Management, 58*(3), 254-273.

Mangan, J., Lalwani, C., Butcher, T., & Javadpour, R. (2012). *Global Logistics & Supply Chain Management.* West Sussex: John Wiley &Son.

Prashar, A. (2013). Adoption of Six Sigma DMAIC to reduce cost of poor quality. *International Journal of Productivity and Performance Management,* 63(1), 103-126.

Summers, D.C.S. (2006). *Six Sigma: Basic Tools and Techniques.* New Jersey: Pearson Prentice Hall.

APPENDICES

APPENDIX A: Electroplating Tank

APPENDIX B: Ultrasonic Cleaning Tank

APPENDIX C: Training Session Sheet for Defect Reduction by Keeping Workers' Hands Clean

Training Session Sheet			
Topic: Defect reduction by keeping workers' hands clean			
Objective: - To educate workers about why the dirty hands of workers can cause the peeling off of buckle coatings. - To build awareness in workers in order to prevent and reduce peeled off buckles by keeping the hands of the workers clean			
Participant: Workers who work in the plating process			
Location: Company meeting room			
Date: dd/mm/yy **Time: hh:mm**			
Period	**Content**	**Trainer**	**Methodology**
15 Minutes	Introduce the objectives of this training session and the importance of the plating process	Production manager	Presentation
25 Minutes	Describe how the electroplating machine works	Supervisor	
15 minutes	Explain the reasons why dirty hands of workers can cause the defect of peeled off buckles	Production manager	
30 Minutes	Educate workers on how to keep their hands clean correctly and prevent the defect of peeled off buckles.	Supervisor	Presentation and video
10 minutes	Question and Answer	Production manager and Supervisor	
Prepare by: Supervisor		Approved by: Production Manager	

APPENDIX D: Company Regulations Regarding Eating Food during Working Time in the Production Area

(LETTERHEAD)

ANNOUNCEMENT

Date: DD/MM/YY

BB Company announces a new regulation regarding eating food. This applies to all employees:

- Workers are not allowed to eat food during working time at production area.
- All workers can eat foot at only dining room of the company.

Effective date: DD/MM/YY

Best Regards,

(.....)

Managing Director

APPENDIX E: Mark Sheet for Buckles Quantity in Ultrasonic Cleaning Tank Step

Date (DD/MM/YYYY)	Quantity (Kilogram)	Cumulative (Kilogram)	Recorded by:
5/1/2015	78	78	Mr.A
7/1/2015	130	208	Mr.A
8/1/2015	54	262	Mr.A
9/1/2015	38	**300**	Mr.A
***************Change Water***************			
10/1/2015	90	90	Mr.A
11/1/2015	82	172	Mr.A
12/1/2015	128	**300**	Mr.A
***************Change Water***************			

APPENDIX F: Company Regulation Regarding Short Break Time

(LETTERHEAD)

ANNOUNCEMENT

Date: DD/MM/YY

BB Company announces new regulation regarding short break time. Workers are allowed to take two rounds of short break time for 10 minutes in the morning and afternoon. This applies to all employees:

- Morning break 10:00-10:10
- Afternoon break 15:00-15.10

Company will remind workers for break times by alarm sound every time.

Effective date: DD/MM/YY

Best Regards,

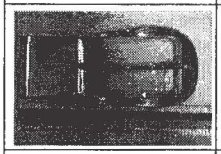
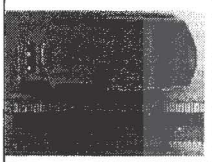
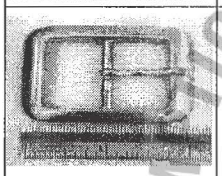
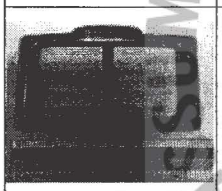
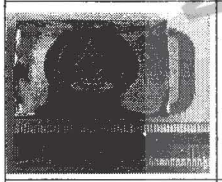
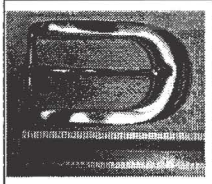
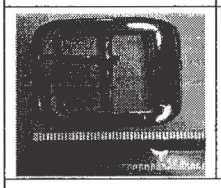
(.....)

Managing Director

APPENDIX G: Training Session Sheet for Defect Reduction by Appropriately Adjusting the Electrical Level

Training Session Sheet			
Topic: Defect reduction by appropriately adjusting the electrical level			
Objective: - To provide knowledge and understanding how to correctly use the electroplating machine to prevent defect of burnt buckles.			
Participant: Workers who are responsible for the electroplating machine			
Location: Company meeting room			
Date: dd/mm/yy **Time: hh:mm**			
Period	**Content**	**Trainer**	**Methodology**
15 Minutes	Introduce the objectives of this training session and the importance of correctly adjusting electrical level of electroplating machine	Production manager	Presentation
45	Illustrate how to correctly use the electroplating machine to prevent the defect of burnt buckles with guidelines from the company.	Supervisor	Presentation and video
10 minutes	Question and Answer	Production manager and Supervisor	
Prepare by: Supervisor		Approved by: Production Manager	

APPENDIX H: Guideline of How to Properly Adjust Electrical Level of Electroplating Machine

Model	Plating Time and Electrical Level by Color						Unit
	Nickel		Chromium		Gold		
	Time (Min)	Electrical Level	Time (Min)	Electrical Level	Time (Sec)	Electrical Level	
	40	5V 3A	8	7.5V 3A	15	3V 3A	240
	30	5V 3A	5	7.5V 3A	10	3V 3A	240
	30	5V 3A	5	7.5V 3A	10	3V 3A	240
	35	5V 3A	5	7.5V 3A	10	3V 3A	240
	30	5V 3A	5	7.5V 3A	10	3V 3A	240
	30	5V 3A	5	7.5V 3A	10	3V 3A	240
	25	5V 3A	3	7.5V 3A	5	3V 3A	240
V= Volt A= Ampere							

APPENDIX I: Preventive Maintenance Schedule for the Electroplating Machines

Preventive Maintenance Schedule for Electroplating Machines																																																
Year: 2015	Month																																															
Name of Machine	January				February				March				April				May				June				July				August				September				October				November				December			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Electroplating Machine 01																																																
Electroplating Machine 02																																																
Electroplating Machine 03																																																
Electroplating Machine 04																																																
Electroplating Machine 05																																																

Maintained by

Supervisor

APPENDIX J: Questions and Answers of Solutions of Peeled Off Buckles

Peeled Off Buckles			
Problem	**Solution**	**Question**	**Answer**
Factor of dirty hands of workers 1) Workers lack awareness of the need to keep their hand clean while working with the buckles	Provide Training	What do you think about training sessions provided for solving the problem of peeled off buckles whether it is effective? Please give us the explanation?	The training session is suitable for the improvement because the workers will be educated how to reduce defect and also built awareness of defect reduction of peeled off buckles by keeping their hands clean.
Factor of dirty hands of workers 1) Lack of regulation to prohibit workers eating food during working time.	Provide regulation	What do you think about regulation provided for solving the problem of peeled off buckles whether it is effective? Please give us the explanation?	This regulation about prohibiting workers eating food during working time is effective because currently workers usually eat food in working area without the control from the company. So after the company announces this regulation which will force the workers, they will not break the company regulation and they will not return to old habit. In addition, it is good because production manager and supervisor will be in charge to monitor workers' behavior.
Factor of dirty hands of workers 1) Lack of work instructions to control working methods of workers. Factor of ignoring to change water in ultrasonic cleaning tank 1) Lack of work instruction to control working method for workers.	Provide work instructions	What do you think about work instruction provided for solving the problem of peeled off buckles whether it is effective? Please give us the explanation?	The work instructions are a good way to guide workers to work accordingly with the right working methods. The step of work instruction of cleaning hand and changing water in ultrasonic tank can directly solve the problem form peeled off buckles since now the company has never launched any work instruction for workers so this is the reason why workers do the wrong things in working methods. After work instructions are established workers will know how to do the right steps in plating process.

Peeled Off Buckles			
Problem	**Solution**	**Question**	**Answer**
Factor of ignoring to change water in ultrasonic cleaning tank. 1) No weighing machine to measure the cumulative weight of buckles which were cleaned	Provide Weighing machine	What do you think about new weighing machine provided for solving the problem of peeled off buckles whether it is effective? Please give us the explanation?	The weighing machine which is provided for plating preparation step is the need for the workers to measure the quantity of buckles passing ultrasonic cleaning tank. Currently the company has no weighing machine so once the company provides it, workers can weigh the quantity of buckles and know when the water in ultrasonic tank should be changed exactly.
Factor of dirty hand of workers touching the buckles 1) There are too few washing places for workers.	Provide more washing places	What do you think about new washing places provided for solving the problem of peeled off buckles whether it is effective? Please give us the explanation?	Currently the washing places are not enough for 50 workers to clean their hand conveniently so if the there are more washing places, it will be good for the workers. Three new additional washing places which will be provided, workers can clean their hands easily as much as they want.
Factor of dirty hand of workers touching the buckles 1) No short break time to let workers clean their hands	Establish regulation via company announcement	What do you think about company announcement regarding short break time provided for solving the problem of peeled off buckles whether it is effective? Please give us the explanation?	The short break time should be in the company because workers can relax and have the time to clean their hands during short break time. Ten minutes for break time is enough for workers.

APPENDIX K: Questions and Answer of Solutions of Burnt Buckles

Burnt Buckles			
Problem	**Solution**	**Question**	**Answer**
Factor of improper adjusting electrical level of the electroplating machine 1) Workers lack training on how to use the machine correctly.	Provide training	What do you think about training sessions provided for solving the problem of burnt buckles whether it is effective? Please give us the explanation?	This training session can help workers understand how to use the electroplating machine correctly in order to prevent defect occurrences from burnt buckles because the contents of this training session is related directly to the reason of burnt buckles and step of how to use machine properly.
Factor of improper adjusting electrical level of the electroplating machine 1) Company does not provide work instructions to workers about how to properly use the electroplating machine.	Provide work instruction	What do you think about work instruction provided for solving the problem of burnt buckles whether it is effective? Please give us the explanation?	This work instruction can be the direction of workers to do right step for electroplating machine using. If they do not have this work instruction about electroplating machine using, they will not understand how to use machine correctly step by step.
Factor of poor maintenance of electroplating machine 1) There is no periodic calibration of the electroplating machine to ensure its proper function.	Outsource with a certified company to check and calibrate the machine quarterly	What do you think about outsourcing certified company to check and calibrate the machine quarterly for solving the problem of burnt buckles whether it is effective? Please give us the explanation?	The electroplating machines which are using in the production, they are never calibrated to ensure its proper function. The company has no knowledge and equipment to check the machine. Thus outsourcing certified company to calibrate machines is good idea because the certified company is reliable to measure and check the right result. If the machine is not functioning, the certified company can fix the machine immediately.

Burnt Buckles			
Problem	**Solution**	**Question**	**Answer**
Factor of poor maintenance of electroplating machines 1) company does not have maintenance and repair for the electroplating machines.	Provide maintenance and repair for the electroplating machines every two months	What do you think about policy of maintenance and repair for solving the problem of burnt buckles whether it is effective? Please give us the explanation.	Maintenance and repair is very necessary for the company because electroplating machines need to be ready to use. If something is broken during the production, the production line may be interrupted. So according to maintenance and repair policy which will be monitored by supervisor every two months, it is effective plan to prevent machine broken during production.