

**BUSINESS PROCESS IMPROVEMENT**

**BUSINESS PROCESS IMPROVEMENT PLAN IN A  
MANUFACTURING COMPANY**



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**AN INDEPENDENT STUDY SUBMITTED IN PARTIAL FULFILLMENT  
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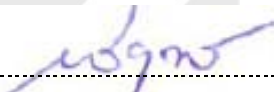
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## Abstract

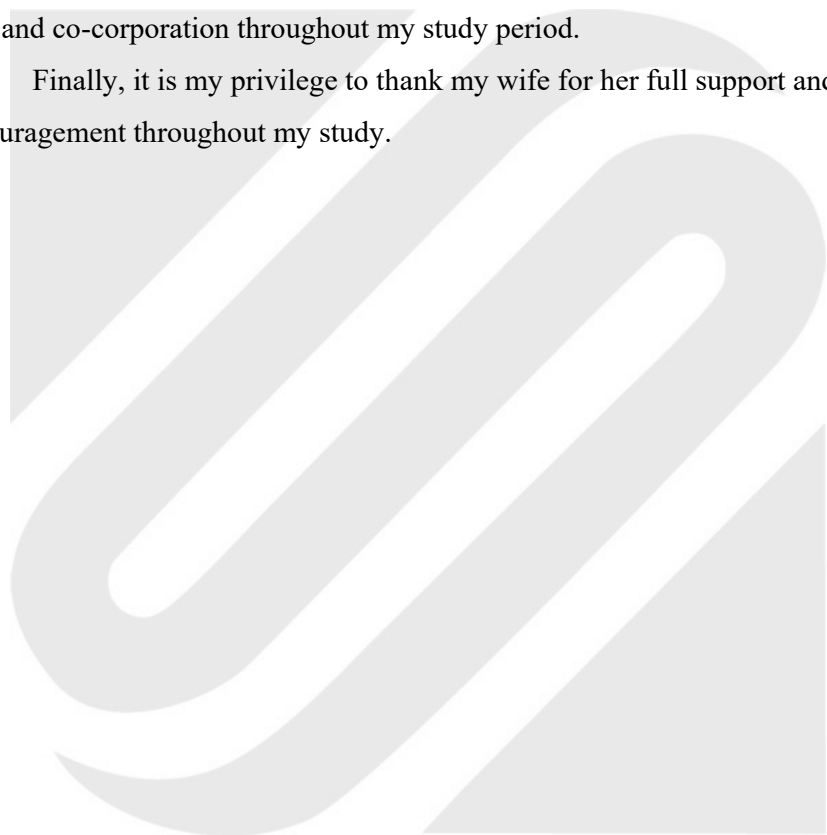
The purpose of this study is to establish a systematic approach to business process improvement in ABC Company Ltd. ABC Company is a Thailand based manufacturing company established in 2013, mainly focused upon the production of sheet metal, turned metal parts and plastic injection molded custom parts. The main objectives of this study were to identify the quality and productivity problems and to develop a business process improvement plan by using a Lean PDCA, Plan-Do-Check-Act approach. In order to analyze the data, some Statistical Process Control (SPC) tools such as bar graph, Pareto chart, cause and effect diagram were used. The production defective rate data were gathered from the company database for the analysis. Through the PDCA approach, the stage that contributes the majority of the defect was identified and the main defects were analyzed to determine the root causes. After the causes of defects were identified the solutions for improvement were suggested. Besides that, an implementation and control plan for the improvements also developed.

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## LIST OF ABBREVIATIONS

BPI	Business Process Improvement
CNC	Computer Numerical Control
DMAIC	Define Measure Analyze Improve Control
DPMO	Defect Per Million Opportunities
KPIs	Key Performance Indicators
PDCA	Plan Do Check Act
SOP	Standard Operating Procedures
SPC	Statistical Process Control
TQM	Total Quality Management
QA	Quality Assurance



# Chapter 1

## INTRODUCTION

### 1.1 Background

Manufacturing industries have a critical role in creating the international economy and development. Formation of the global economy is impossible without manufacturing products (Bryson, Clark, & Vanchan, 2015). There are many processes involved in a manufacturing industry to transform inputs into outputs, and the company's profitability is highly depending on its processes. Improvement in the process can lead to increase quality, customer satisfaction, productivity and reduction in lead time, and cost (Lientz & Rea, 2001). Business process improvement (BPI) helps the organization to optimize its processes to achieve more efficient results and thereby enhancing the business. The processes should be managed in an effective way and should be executed effectively and efficiently (Rummler, Ramias, & Rummler, 2010). BPI is an important part of a business and its implementation should be in a systematic approach in order to achieve the success. Business process improvement includes major tasks, prioritizing process that should be improved and to select the suitable methodology (Bandara, Guillemain, & Coogans, 2015).

Company ABC established in 2013 as a subsidiary, completely owned by the parent company founded in 1991 and located in Thailand. The name of the company is changed to ABC company Ltd because of confidentiality issues. The parent company is one of the leading manufacturers of professional audio loudspeakers. Currently, more than 400 employees working in this company. Company ABC is a fabrication company mainly focus on precision production of close tolerance sheet metal, turned metal parts and plastic injection molded custom parts.

Company ABC's core business is offering metal fabrication and plastic molding solutions to reach customer demands around the world. The core production activity is based on customers in the speaker manufacturing industries around the world. They have made major investments in the advanced fabrication technologies and machines from Europe and Japan. The nature of the process is manual, semi-automated and fully automated using high technology and equipment, and the assembly lines are fully human dependent.

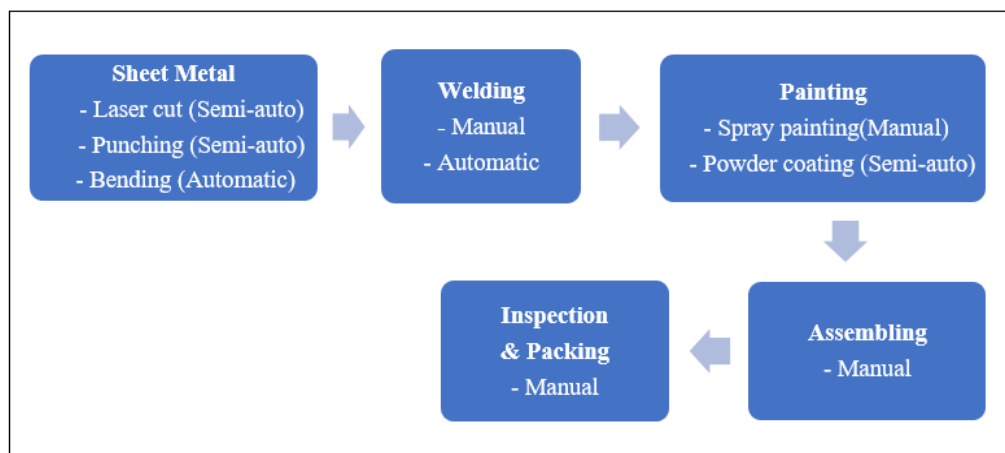
Company ABC business has been dramatically increased over recent years and manufacturing a large variety of products. There are a variety of processes involved, starts from the raw material machining, followed by Fabrication, Finishing, and Assembly.

## 1.2 Process involved

There are many stages in which the part is being followed and processed to the final product. The manufacturing has been processed as a batch and the batch size depends on customer order quantity. Different processes involved in metal fabrications are illustrated in Figure 1.

*Sheet metal:* The metal fabrication starts with this process. This includes processing of raw material, mainly sheet metal through punching, laser cut and bending operations to make as per the customer drawings. Sheet metal process equipped with a variety of advanced machines, including fully automatic and semi-automatic. The laser cut, and punching machines are semi-automatic CNC machines and the bending operation is done with a fully automatic machine with the help of robots.

*Welding:* In this the precision welding process where the parts after sheet metal operations are welded and ground. Both manual and robotic equipment involved in welding operation depending upon the size and complexity.



**Figure 1** Company ABC Process Map

*Painting:* The metal parts are gone through the painting process according to the customer requirements. A chemical treatment also attached to this process and normally done prior to painting to make sure that the attachment to the surface is good. There are

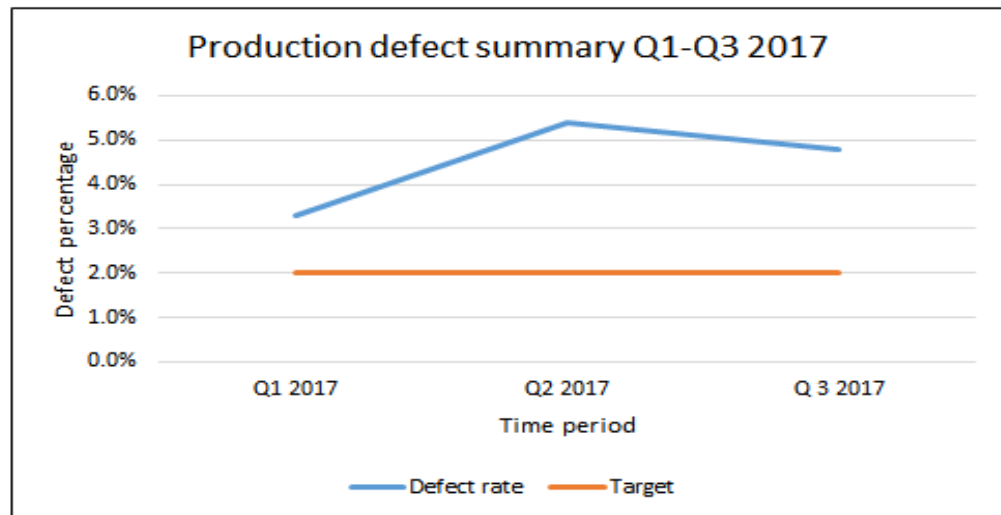
two types of painting processes carried out according to the customer requirements, spray painting and powder coating. The spray painting is a 100% manual operation, whereas the powder coating operation is done in a semi-automated line.

*Assembling:* Assembling standard parts specified by the customer is completed in this process.

*Inspection and packing:* The parts are being inspected by the final QA operators followed by packing and ship to the customer.

### 1.3 Statement of the problem

Recently Company ABC QA department has reviewed overall production and reported there are problems in the productivity and the quality-related issues in their metal fabrication process because of high defective parts. This results in high process waste, delay in production and increased customer quality complaints. The production defect summary report of company ABC, as displayed in Figure 2 says that the average defect rate in 2017 is 4.4 %,and the target set to 2% per month after reviewing with the management team.



**Figure 2** Company ABC defect percentage by quarter

### 1.4 Purpose of the Study

The purpose of this study is to make a process improvement plan for ABC Company to improve the production performance and the quality by reducing the process wastes and defects to 2% per month.

### **1.5 Study Objectives**

The objectives of this study are to explain how the process improvement plan can be implemented by Identifying the various processes involved by analyzing and identifying each process where improvement needs to be focused.

1. To identify and understand the process that contributes high defects in production.
2. To identify and analyze problems in the process that contributes high defects.
3. To create possible solutions and suggestions for the process improvement plan.
4. To develop a plan and implement the proposed solutions.
5. To develop controls such that the improvements stay in place.

### **1.6 Research Questions**

RQ1: What is the root cause of the increased number of product defects?

RQ2: How can this root cause be mitigated or eliminated?

RQ3: How can the improvement be implemented and sustained?

### **1.7 Research Objectives**

RO1.1 Develop a process map for the involved processes

RO1.2 Identify the steps in which the majority of defects is occurring

RO1.3 Identify the root causes of the defects

RO2.0 Develop possible solutions for improvements

RO3.1 Develop an implementation plan for improvements

RO3.2 Develop an evaluation and control plan to sustain the improvements

### **1.8 Summary**

This chapter gives an introduction to the study, including background, processes, and problems of ABC Company. It also described the purpose of the study, research questions, and objectives. The problem found is that the production defect rate is high and Business Process Improvement method is preferred to solve this problem. The evaluation and selection of plan and analysis tools for Business Process Improvement to accomplish objectives are explained in Chapter 2.

## **CHAPTER 2**

### **EVALUATION AND SELECTION OF PLAN AND ANALYSIS TOOLS**

#### **2.1 Introduction**

This chapter will describe topics that related to Business Process Improvement plans, methodologies, analysis tools, data collection, and planning. Moreover, this chapter will discuss the selection criteria of BPI methodology.

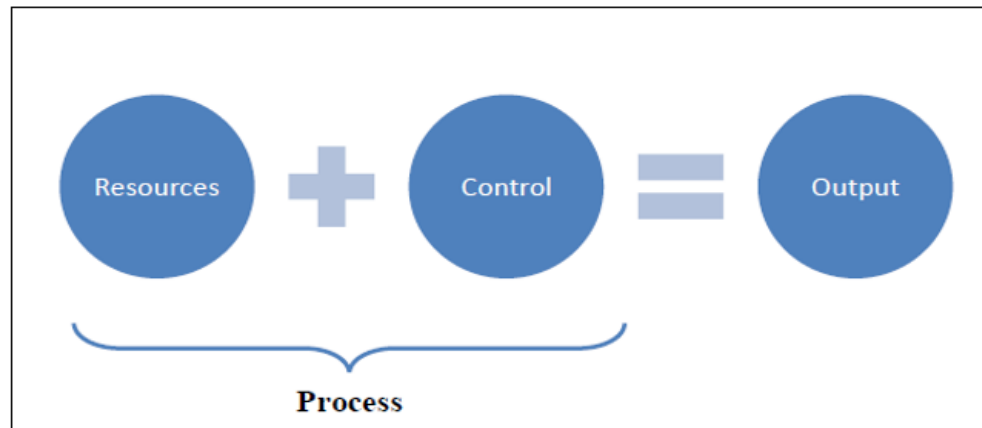
#### **2.2 Business process improvement (BPI)**

The concept of BPI was described by Harrington as “a systematic methodology developed to help an organization make significant advances in the way its business processes operate” (Harrington, 1991). Business process improvement is an approach to improve the business process in a way that meets customer demands and business goals effectively and efficiently. BPI methodology aims to identify the organization's operations and employee skills that can be improved to achieve efficient workflow that makes a quality product and service available to the customer.

##### **2.2.1 Business process**

A business process is a set of activities used in a system that transforms one or more input into the desired output that is valuable to the customer. Every product that company provides to the customer is the output of a number of activities performed. Business process organizes these activities and helps to understand the relationships among them. Business process activities are performed in the company by manual or by automated systems. (Mathias, 2012)

Figure 3 depicts a simple process flow that is transforming resources (materials, technology, and manpower) with control and value-added activities such as measurement and operation into a valuable output. In a process, the set of activities or tasks are connected with a level of control to achieve the desired outcome. Davenport defines the process as “a process is simply a structured and measured set of activities designed to produce a specific output for a particular customer or market”. (Davenport, 1993)



**Figure 3** Simple process flow

Source: Ashogbon. K, 2012: Online

### 2.2.2 Need for BPI

Improving business process will help the organizations to stay competitive and increase responsiveness to the customers, the productivity of the company's employees and return on investment. (Page, 2010). Business Process Improvement (BPI) can help to improve the ability to meet the customer needs, helps to reduce the errors, helps to identify the effective process opportunities, helps to improve the relationship between each department those involved, improve overall performance and productivity. Page describes that organizations normally go for the BPI plan due to any number of reasons, and scenarios may be different from each organization,

- Customers or suppliers complain about the business process.
- Organization department makes many errors and repeats the mistakes.
- To understand how each department can improve its efficiency so that the lead time can be reduced.
- To understand each process across each department within the company.
- To increase the productivity
- To understand each process and how it works

### 2.3 BPI Methodologies

Improving the quality of process and maintaining the performance quality are important factors for any organization to become successful. To analyze and improve the processes, it's required to have a method or model to identify process bottlenecks

and showing the improvement opportunities. Several methods or models are available for the Business Process improvement plan. (Gershon, 2010).

The methods and models that are commonly used in business process improvement are explained, and some selected models will be used in this research. These are **Lean production, Six Sigma, Total quality management and Business process re-engineering** and they are explained in the following sections (Grünberg, 2007; Gershon, 2010.) In this study, only the models that are still in common use in Businesses and applicable in primary and planning processes are explained.

### **2.3.1 Lean Production**

Lean process improvement in business is employed by companies to optimize the production system for a better performance in a cost-effective way. Lean manufacturing is focused on the reduction of waste to improve the customer value, quality, costs and production time.

Lean is a set of techniques that, when combined and matured, will allow to reduce and then eliminate the seven wastes (Wilson, 1990). Through this approach company's business processes will go through an analyzing and enhancing task to achieve optimization and new standards. This will be very effective to achieve successful results in product quality standards, cost, profit and overall performance. According to Sriparavastu and Gupta (1997), the main motivation for companies to implement lean manufacturing was to increase productivity, reduce cost and lead time, improve quality, etc. The lean concept is very powerful, and it can improve the manufacturing efficiency. The implementation is very important to ensure the success.

As mentioned in the problem statement company ABC has identified problems in terms of productivity and quality such as increased defects and lead time, customer quality complaints, etc. A Lean implementation might help to fix these problems as the direct benefits of Lean are reduced wastes, lead times and operating costs. Reducing wastes improve the quality of the products which benefits the customer also. Despite the benefits, there may be some challenges in implementing the changes in company ABC. Participation and inputs from the production staff are required for the implementation of lean principles to the workplace. There may be some resistance from some employees to change the current environment. However, this can overcome by

communicating the changes with the employees and with proper planning and implementation.

### **2.3.2 Total Quality Management (TQM)**

Total Quality Management (TQM) focuses on continuous improvements in all organizational processes and aims for customer satisfaction. Everyone in the organization needs to contribute by focusing all the aspects of processes for TQM. The *Total* in TQM means that everybody and everyone in the organization, *Quality* means customer satisfaction and *Management* means the process management system (Liem & Pate, 2004). TQM mainly focuses on quality by involving all the person in the organization's process to improve the quality.

TQM uses Kaizen as a tool and Kaizen is a methodology focused on small improvements in large numbers with the continued involvement of all employees, which leads to improving the relationship between managers and employee (Titu, Oprean & Grecu, 2010). In TQM, the improvement is planned first, followed by the implementation of the improvement in the second step. During the third step, observation is made of the effects, and the final step is to learn from the change imposed. After these four steps of improvement, it is time to find a new problem. (Grünberg, 2007).

The Total Quality Management is a business management methodology which recognizes that customer need and business goals are connected each other and inseparable. TQM ensure the effectiveness and efficiency of a business by utilizing the full potential of all the employees. TQM methodology is an approach that considers every interaction of the organization between different elements. The elements include all the organizational functions such as design, planning, production, distribution and field services (Ross & Perry, 1999). According to Peratec (1994), the benefit gained from TQM will vary from organization to organization and often benefits includes improved operational efficiency, organizational culture change, prevention of waste, customer satisfaction, improving product quality & safety and employees personal and creativity improvement.

The main principle of TQM is that most of the mistakes that made by the people are because of faulty systems and processes. This means most of the mistakes can be

prevented by identifying and eliminating the root causes (Hashmi, n.d.). There are different methods of preventing mistakes,

- Preventing mistakes from occurring
- Where mistakes not able to prevent, detect early to prevent them passing to the next process.
- Where the mistakes occur, stop production until the process gets fixed. This is to prevent the production of more defective parts.

According to Napierala (2012), there are five essential steps to TQM implementation,

1. *Commitment and understanding from employees:* It's important that all the employees in the organization know about TQM. If they have no idea about this, the implementation will not be successful.
2. *Quality improvement culture:* Organizational culture needs to be focused on an improvement basis to encourage their employee's idea to improve the processes.
3. *Continuous improvement in the process:* TQM is a continuous process and requires a constant improvement in all areas.
4. *Focus on customer requirements:* For the long-term survival of the organization, focusing on customer requirement is important to build a relationship.
5. *Effective control:* Continuous monitor and measure of business performance are essential for continuous improvement. All the details should be properly documented and maintained in every process, and this will give a good return of both time and resources.

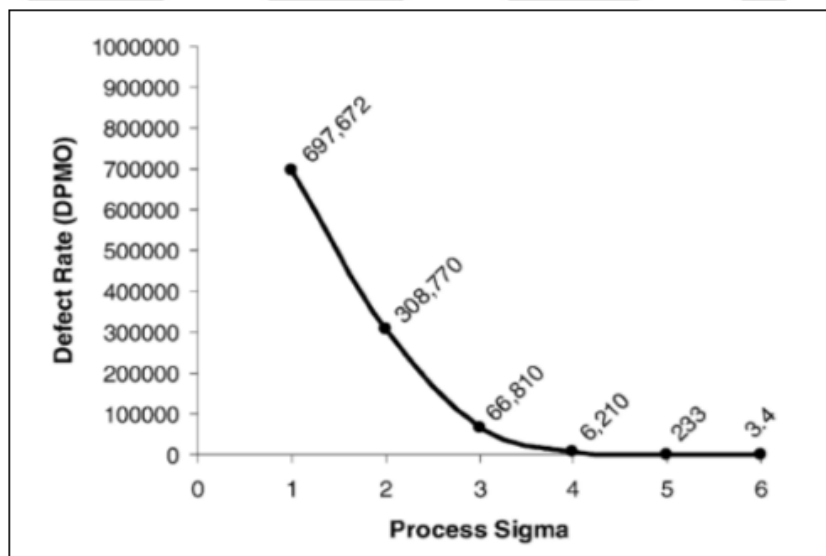
### **2.3.3 Six Sigma (6 $\sigma$ )**

Six sigma concepts came from the Motorola Company in the mid-80s. A senior engineer and scientist at Motorola named Bill Smith concluded that increased level of complexity in manufacturing result in a high number of failures and difficult to maintain quality standards. Bill Smiths idea to improve this was to set a quality goal of Six Sigma to get a satisfactory final product quality (Bertels, 2003).

Six Sigma approaches aim to decrease variation within the manufacturing process through the use of the statistical tool and supporting software. In Six sigma the term sigma ( $\sigma$ ) uses to describe the variability, in which the measurement unit is defects

per unit. The sigma indicates how often the defects are likely to occur and represents the population standard deviation. The higher sigma value indicates that the process creates fewer defects. A Six Sigma quality level is equal to 3.4 defects per million opportunities (Breyfogle, 2003). Six Sigma is a data-driven methodology and requires an accurate data collection for analyzing the process. The statistical representation of six sigma shows the performance of a process.

Figure 4 shows the defect rate versus the process Sigma level. From the figure, the sigma level can determine if the defects per million opportunities (DPMO) are known. For example, a process producing 6210 DPMO is a four sigma level process. The process sigma level is actually reflecting the process capability, higher the Sigma level higher the process capability. Once the current process performance is measured the goal is to improve the sigma level continuously towards six sigma, which is considered as world class (Breyfogle, 2003). Even though the improvement did not reach 6 sigma, the improvements from any level sigma to the next level can be considered as process improvement. For example, improvements from three sigma to four sigma can improve the process.



**Figure 4** Defect rate versus Process Sigma level

**Source:** Sá & Oliveira, 2013: Online

The main objective of six sigma is to eliminate defects and quality problems, thereby increasing the customer satisfaction. Six Sigma methodology is not only focused upon the process improvement, but also use as an effective strategy for

leadership development and cultural change within the organization. The decision-making process is based upon the facts and data collected from the process. In Six Sigma process, the members within an organization are assigned specific roles with a title. To implement six sigma successfully in an organization a highly structured format is necessary (Snee & Hoerl, 2003). Six Sigma concept uses a systematic approach using key players such as Champion, Black Belts, Master Black Belts and Green Belts. The belt names define the levels of expertise and experience of the individual who takes the responsibility for the implementation (Breyfogle, 2003).

*Champion:* Six Sigma champions are the high-level person who understands Six Sigma and is committed to its success.

*Master Black Belt:* A person who deals with the team and is responsible to answer procedure related questions and technical issues. They provide technical leadership of Six Sigma program.

*Black Belt:* A person possessing this belt has the highest skill level and with experience of working on several projects. Black Belt is responsible for execution and scheduling of six sigma project, and they are the front-line leaders.

*Green Belt:* This position also belongs to the team leader or a member of the team who is less experienced than Black Belt.

Six Sigma methodology is based on the process improvement model DMAIC. This methodology is used to improve the existing process and consist of five stages, Define, Measure, Analyze, Improve and Control (Andersen, 2007).

*Define:* This is the first step of Six Sigma methodology where the leaders define the scope, benefit, plan the target processes and select the appropriate team members.

*Measure:* This is the data collection stage and process study and also to determine the baseline capability level. Identifying the key factors that have the most influence over the process and measure them. The team measures using SPC (Statistical Process Control) or use the database information and pair them with customer criteria.

*Analyze:* In the third step analysis of collected data is done to determine variations and defects that need to improve. Here the team identifies the possible cause of the variation or defects that affect the process using the tools such as Cause and effect diagram.

*Improve:* In Improve step team provides solutions to reduce the defects by brainstorming and this should be the most effective solution. A cost-benefit analysis

should be used to identify and implement the best solution. The most preferred tool for this step is an affinity diagram, which is a brainstorming technique where a small team quickly lists the solutions when an issue is presented to them. The improvement selection should be based on the probability of success, execution time, resources and cost (Eckes, 2001).

**Control:** The final step is to verify the success of implementation and retain achieved results by monitoring. At this point, control should be put in place to give early signals when the process is going out of control. The goal of this step is to reduce variation by controlling inputs and monitoring the outputs.

Organizations that implement the Six Sigma methodology have benefits in reducing the number of defects, reducing the operating costs and increasing customer value. Six Sigma uses several unique human resources, and the personnel selection is crucial as the staffing process will directly affect the effectiveness of Six Sigma. It is important that all the team members should have a well-defined role with clear objectives. Antony (2004) has highlighted some of the limitations of Six Sigma such as the challenge of having quality data availability, selection and prioritization of projects, calculation defect rates for the non-normal situation, staff capability, the high cost of implementation, organizational culture etc.

#### **2.3.4 Business Process Re-engineering**

Business process re-engineering approach is focused on the radical changes to improve the process and this allows new ideas in the process to improve operations. (Vakola & Rezgui, 2000). The radical change helps to evolve new ideas that can help to improve the operations.

In early 1990s Hammer and Champy introduced Business process re-engineering and has a radical improvement approach, unlike other process improvement models. They explained that small changes result in small effects, and radical changes give radical improvements. By this approach, one can achieve benefits by optimizing the process that is inefficient or obsolete by redesign the whole process and gain the advantages for the organizations.

Hammer and Champy (1993) reported that many companies go for re-engineering don't succeed in it and those companies end their efforts without making any significant changes or any major performance improvements and around 50-70 %

of the organizations that undertake a re-engineering effort does not achieve the significant results. The key success factor of BPR methodology lies in knowledge, avoiding mistakes and implementation ability. According to Nepal (2017) the problem with Business Process Reengineering (BPR) is that when the organization is larger, the implementation will be more expensive and for a startup company business process re-engineering execution cost will be minimum. When the organization grows, the re-engineering process will become harder and costly. Nepal describes that the business process re-engineering steps can put into the five-stage plan.

1. Select the process for re-engineering: Select a process that causing problems and evaluate the causes
2. Define the process objectives: Specification of goals
3. Identify re-engineering enablers: Check the technological competency and the cultural readiness for a change.
4. Formulate a new design: Rewrite the process prototype and finalize.
5. Execute the new process: Training team members on the new process and new tools.

To explain more about the BPR process, Ford motors business process re-engineering is taken as an example. In the 1980s Ford, the American automobile manufacturing company was attempting to reduce the costs and decided to re-engineer the inefficient processes. They found that the accounts payable department was not as efficient and consisting of 500 people. They analyzed the current system and found that when the purchasing department writes a purchase order, they have to send a copy to accounts payable. Then the material control sends the copy of the related documents to accounts payable, and the vendor would send a receipt for the goods to accounts payable. The employee in the accounts payable has to match the three orders before issuing the payment and this took a lot of employees in this department. To eliminate this Ford re-engineered the process digitally to eliminate the invoice. In the new scenario, purchasing no need to send a copy and material control received goods based on the database matching and accept the order. By the new process, the accounts payable clerk to match the orders was completely eliminated with an almost 75% decrease in the workforce in the accounts payable department (Pearson, 2017).

#### **2.4 Selection of BPI methodology**

The purpose of this study is to make a process improvement plan for ABC Company to improve the production performance and the quality by reducing the process wastes and defects. Therefore, the methodology should focus on the reduction of wastes and defects in the production line and must guide the analysis and improvement of business processes. The above described BPI methodologies are analyzed based on these criteria.

The Lean production system focus on reducing the waste to improve quality and reduce the cost, defects and production time. This shows that the outcomes satisfy the need of the customer and help to control the cost. The lean production analysis guide which area needs to focus and what to analyze.

Total Quality Management focuses on customer satisfaction by continuous improvement. TQM will be easier to implement if the organization has a history of effective responsiveness to the environment and has been able to change the process when needed. If the company was historically not active in improving in its process, there will be a lack of skilled resources and employee skeptical attitudes. An organization should be basically ready before beginning the implementation of TQM (Tichey, 1983). For ABC Company, TQM would not be an appropriate methodology as it has no historical improvement activity record, lack of managerial skill and difficulties in coordinating and training all the employees.

Six Sigma also focuses on defects in quality just like TQM. In addition, Six Sigma tries to reduce the variation in the process. Six Sigma has proven that it can be applied in all kinds of industry and process, however, because of the structural difference between industries, the implementation may need to adjust (Bertels, 2003). A Six Sigma project would consume many resources of the company such as financial, human and time. For implementing and running the Six Sigma project organizations require competent and trained manpower (Raghunath and Jayathirtha, 2013). The DMAIC approach gives a good support for implementing the process improvement, but as Six Sigma is very specialist dependent the implementation in company ABC could be difficult as there is no Six Sigma specialist available.

Business process re-engineering aiming the radical improvement method by with a total redesign of the whole organization or process. Because of the radical characteristic, the change could lead to higher costs due to complex processes and train

the personnel. As like six sigma BPR methodology also very specialist dependent, which requires help from experts and consultants. The re-engineering implementation will be complex in company ABC due to a shortage of skilled manpower, expensive implementation, and high retraining cost.

Each BPI methods primary effect driving towards common tools and concepts, and they share some common features. Each method can solve all process related problems if properly implemented and they contribute valuable concepts and ideas to organizations. The Organization culture also has an effect on the selection of the process improvement methodology (Nave, 2002). It can be seen that the Lean production serves the most suitable criteria as it strives to improve the quality, cost by eliminating the waste. Therefore, the Lean production methodology has been chosen in this study.

## **2.5 Lean Production**

Lean production process improvement method is introduced by Toyota. As stated earlier lean method is focused on reducing waste, improvement of quality and production time and cost reduction. Waste can be considered as all the process activities that do not provide any value to the customer. Toyota categorized wastes into seven types and are represented in Figure 5.

- Overproduction - Producing more quantity than needed for the customer.
- Inventory - Holding excess inventory
- Waiting - People and machines waiting for material and information.
- Motion - Movement of people, machine, material which does not add value.
- Transportation - Excess movement of material during or after the task being conducted.
- Rework/Defective parts - Production of defective parts, which hasn't met the required standard. As a result, reworking or reproduction may need.
- Over-processing - Ineffective processes that add little or no value to the customer.

Underutilization of employee creativity and confusion also considered as a source of waste (Liker, 2004). Underutilization happens when the organization doesn't make the full use of an employee's skills, knowledge, and abilities. Examples are, a highly

trained employee's task can be performed by someone with less training or not use the creative ideas of employees when solving a problem.



**Figure 5** Seven Wastes

**Source:** Smith, 2015: Online

By implementing Lean production companies could reduce many uncertainties, and the process can run using less material, inventory, investment, people and consuming less space (Wilson, 1990). The success factor of the Lean production system is a detailed implementation plan, teamwork, and communication, management support, authority power of operational managers, proper use of available resources and continuous improvement (Keyte & Locher, 2004).

### 2.5.1 Lean Process principles

The basic approach in lean concept is the continuous repetition of the following five process improvement steps (Liem & Pate, 2004). The five core principles of lean based on the assumption that organizations made up of the process explained by Randor (2010) represented in Figure 6.

1. *Identify value:* Identifying how value is desired by the customer is the first step in the Lean process. It is useful to identify the customer and better understand their requirements and standards.

2. *Value stream mapping*: Value stream represents the entire processes and activities within the organization that transforms inputs into outputs that satisfy the need of customers. In this value stream mapping, wastes should be detected.



**Figure 6** Five principles of Lean

**Source:** Lean Enterprise Institute, Inc. 2016: Online

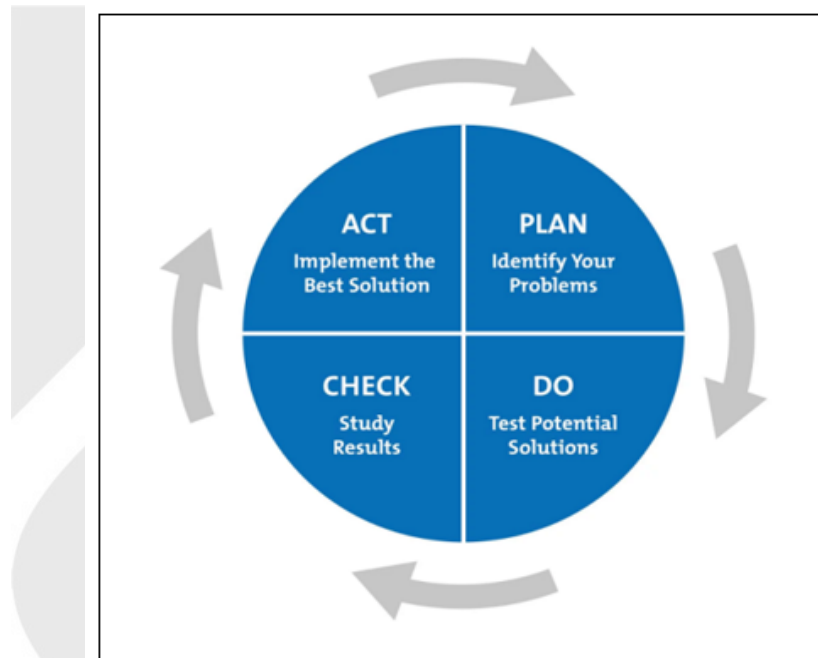
3. *Create flow*: The third step is creating a continuous flow of the product. Standardizing processes allow to run the process smoother and free up time for creativity and innovation. Processes that do not add value should be eliminated or modified.
4. *Establish a pull system*: A pull system needs to be created after the elimination of wastes and flow creation. In pull system the customer demand triggers the events in the value chain, the customers pull the products or services out of the processes. In this way the overproduction risk is decreased and also the inventory and process are linked to customer needs.
5. *Seek perfection*: The last step is seeking for perfection by doing the whole process again and continue it until perfection is reached in which perfect value is created with no waste and this may take a long time (Grünberg, 2007).

### 2.5.2 PDCA cycle (Plan-Do-Check-Act)

PDCA cycle is one of the key elements in Lean or any kind of process improvement. PDCA is a four-stage approach for continuous improvement of

processes, product or services. It also is known as Deming cycle or Shewhart Cycle. PDCA cycle is a continuous process that involves the systematic collection of data, identify problems, testing of possible solutions, assessing the results and implementing (Williams & Duray, 2013).

Figure 7 represents the plan-do-check-act cycle. PDCA is a continuous improvement cycle starts with plan step and followed by other steps in clockwise. Details of each step in a PDCA cycle explained below (Basu, 2004).



**Figure 7** Plan-Do-Check-Act Cycle

**Source:** Mindtools, n.d.: Online

**Plan:** This is the first step and is the largest part of the effort of PDCA. The planning stage includes understanding and analyzing the problem down to its root cause and identifying the solutions based on the data collected. The current situation, current problems and root causes of the problems should be identified using the data collection and analysis before seeking the solution. There are four steps involved in plan phase.

- Collecting the data
- Defining the problem
- Stating the goal
- Solving the problem

**Do:** The second step is Do or implementation stage. This involves implementation on a trial basis and this process continues until the issues of implementation are resolved.

**Check:** This stage involves the checking to determine whether the work is progressing as per the plan and the expected results are obtained. If not the PDCA cycle should continue again to find the proper solutions. (Lewis, 1999)

**Act:** In the final step, results from the check step will be initiated. If the change has been successful, the solutions are retained until the better solutions are identified. If the change not been worked, the PDCA cycle starts again with a different plan. Even though the changes are totally successful, the results are replaced with better solutions by repeating the PDCA cycle (Basu, 2004).

The PDCA cycle helps to solve the problems and implement solutions. By following these four steps the problem can be solved by accomplishing the objectives and better results can be achieved. The PDCA continuous improvement approach can help for this study to solve the problem in the Company ABC production process. Therefore, a PDCA problem-solving cycle will be suitable for this BPI process.

## **2.6 Lean tools and techniques**

Lean production approach consists of several tools and techniques to analyze and improve processes. The application of these tools and techniques assist in the improvement process, increasing the awareness of quality and change of employee's improvement attitudes. The Lean tools and techniques are important when implementing lean into a process or service. The tools give a guideline for the organization for the lean implementation. The tools and techniques that are to be used in this BPI plan are explained in below paragraphs.

### **2.6.1 Project charter**

The project charter is the first document that exists in a project, and it briefly describes the project. When a BPI plan starts, it is necessary to define what needs to be accomplished, and the project charter role is to set what exactly the project will achieve. Project charter authorizes the work and provides an authority for a project manager to begin work. There is no formal creation of a project unless a project charter is created. A project charter starts with the name of the project and often includes the following sections such as purpose, project and product overview, description, problem statements, objectives, duration

and participants (Harrin, 2017). Finally, the project charter needs to be approved by a project sponsor, an individual with overall accountability of the project.

A project charter provides the overall view of a project by describing preliminary frameworks and help to set the project on the right track and to continue in the proper direction. Therefore, a project charter will be created in this study for the planning stage in coordination within the project team. This is one of the processes that need to be completed in the initial stage, and it helps to understand how well the project is aligned with the company strategies.

### **2.6.2 Bar graph**

A bar graph, also known as the bar chart is a visual tool that uses bars to compare data among categories. The graphs can be plotted in vertically or horizontally, however, the vertical presentation is used mostly. The length or height of Each bar represents the values and the longer or higher the bar, the greater its value. The height of the bars used to show the relative size of the quantity measured (Andale, 2013).

A bar chart is useful for making comparisons between different categories by looking into the data from the graph. They can be used to give a visual representation of data, compare different types of data and compare data collected in different time periods. The bar chart also can represent categories with stacked or grouped bar charts. Bar graphs are very effective when items to be compared items between different categories or groups. There are several different styles of bar graphs to consider when presenting data visually (Beddoe, n.d.).

*Vertical bar graph:* Common type bar graph where two or more independent variables have to compare and the bars in each category drawn vertically.

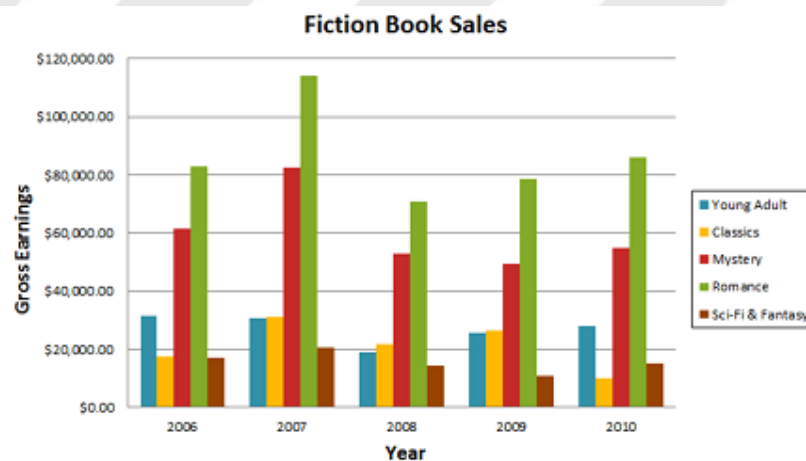
*Horizontal bar graph:* In Horizontal bar chart the bars are drawn horizontally. This is an effective way of presenting when different categories have long titles or there are a large number of categories and less space to fit all.

*Grouped bar graph:* This shows information about the sub-groups of main categories. Each subgroup represented by a separate bar. The sub-group usually color coded for easy viewing.

*Stacked bar graph:* Stacked bar graphs are similar to grouped bar charts, but the subgroups displayed on the same bar and each bar show a total of sub-groups in each category.

A bar graph uses either horizontal or vertical bars to show comparisons between two or more categories. The graph consists of two axes, one axis shows the categories or groups being compared, and the other axis represents a given quantity or value. On a vertical bar graph, the x-axis (or horizontal) shows the data categories, and the y-axis (or vertical axis) is the scale (Andale, 2013).

The example provided in Figure 8 represents a bar graph. The grouped graph depicts the gross earning of fiction books, categorizing them into five different genres (Young adults, Classics, Mystery, Romance and Sci-Fi and Fantasy) between the years 2006 to 2010. The X-axis represents the different categories of books in a different year, and the Y-axis represents the gross earnings in USD. Based on the chart, it is clear that the height of the green bar, which represents romance books is higher in every year when compared with other categories. This states that romance books earned the most income during each year between 2006 and 2010. On the other hand, sci-fi and fantasy created the lowest income out of five.



**Figure 8** An example of Vertical Bar graph

**Source:** Gwendolyn, 2016: Online

A bar graph is chosen as one of the analysis tools for this study as it is an effective visual presentation and allows the reader to understand the trends and compares the data easier than looking in a table of numerical data. They are used to compare things and track changes over time between the groups. Displayed data can be related to things like amounts, quantity, time, frequency, etc. (Russell, 2016).

Company ABC is involved in many different processes, so a grouped bar graph can help to understand which process contributes more defective parts in volume among all the manufacturing processes over a period of time. The process that creates the higher defective percentage is chosen for the improvement, hence the process improvements can be focused on that process first. To present the bar graph, the data from production and quality control departments can be used.

The first objective of this project 'To understand the process that causes high defects in production', can be accomplished by using the bar graph that presents the total defective parts in company ABC over a period of time (8-12 months). The data from the company ABC quality department can be used to create a bar graph to identify and choose the process that creates the higher percentage of defects.

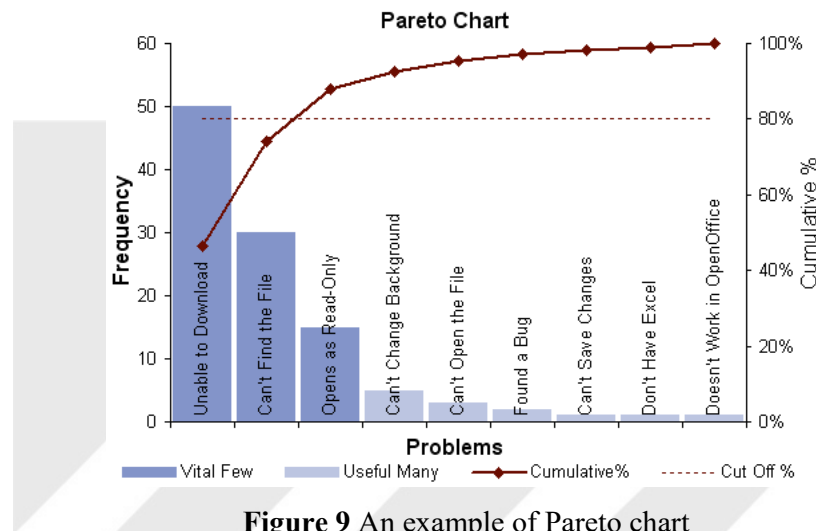
### **2.6.3 Pareto Analysis**

Pareto analysis is used to identify the major problems or causes in a process that accounts for largest frequency (Borror, 2009). It uses the concept based on the 80 / 20 rule to identify roughly 80% of problems created by 20% of factors, thus the users can identify and focus on factors or problems that should be solved first. The 20 % factors are critical, and this produces the 80 % of the results (Haughey, n.d.). The numbers don't have to be exactly 80% and 20 %; the purpose is to identify the categories that account for most of the problems followed by a cause and effect analysis to understand the causes of these problems.

The basic Pareto analysis can be based on the frequency of occurrences, and it can be based on time, cost or production output factors also. (Jackson & Frigon, 1996). This tool can be used to determine which of the identified bottlenecks should be solved in a high level of attention (Slack et al., 2007). In most processes only a few activities account for most of the process's problems, so improving only those activities can save a lot of time, while ensuring a process improvement. The Pareto chart shows where the process improvements should begin, those problem areas with a high number of frequencies.

In a Pareto chart, the list of problems or causes is collected and displayed as histograms rank ordered from the highest frequency at the left to the lowest frequency at the right. A secondary y-axis with a percentage of 0-100 % is created, and a graph is plotted using the cumulative counts of each category above the data columns. A line is

drawn on the y-axis at 80% of cumulative value parallel to x-axis creating a point of intersection on the curve plotted. This point on the x-axis separates the important causes (vital few) on the left and the less important causes (useful many) on the right (Wittwer, 2009).



**Figure 9** An example of Pareto chart

**Source:** Wittwer, 2009: Online

A Pareto chart is graphically represented as a histogram which is sorted from highest frequency to the lowest as shown in Figure 9. In this case, the different categories of problems (x-axis) are placed in order of frequency (y-axis) and used the second y-axis on the right-hand side with values from 0-100% to show the cumulative percentage of problems. The categories in the left to the point where the line graph crosses 80 % are the most significant factors and those on the right are less significant factors, in this case the first two factors, 'unable to download' and 'can't find the file' cover almost 80% of the total defects where efforts should be focused to achieve the best improvement results.

In company ABC situation, the process that creates the most defective part can be identified using a bar graph as explained earlier. Once the process is selected for the improvement, it is important to understand what are the main problems that cause the defects in that process. Pareto analysis can help to narrow down the problems in company ABC and used to determine on which area the efforts and resources need to

focus to achieve maximum efficiency. It can answer the below questions so that the process improvement can be focused on the vital few categories first.

- What are the largest issues facing in the selected process in company ABC?
- What 20 percentages are causing 80 percent of the problems in that process?
- Where should focus and put efforts to achieve the greatest improvement?

#### **2.6.4 Cause and effect diagram**

The Cause and Effect Diagram is a visual tool for organizing the possible causes of a problem or effect. It is also called Ishikawa Diagram or Fishbone Diagram. This tool helps to identify root causes of a problem or effect by ensuring a common understanding of them (Slack, Chambers, & Johnston, 2007). It's a structured team process that helps to identify the factors or causes of a problem, effect or an event. By understanding the contributing causes or factors the problem or failure can be corrected or improved.

The main stem of the cause and effect diagram leads to the defined problem and the branches leading to the main stem represents the major areas of concern, such as people, material, equipment, measurement, environment, or methods. The cause and effect diagram is constructed by conducting a brainstorming of team members who have personal knowledge of the process and systems that involved in the problem to be solved (Lighter & Fair, 2000).

The different causes are generally categorized into five groups, called 5Ms. They are man, machine, method, material and mother nature (Environment). Due to the limits of the 5 Ms, the causes can go up to 8 Ms by adding factors such as measurement, management, and maintenance (Saeger, 2015). The categories can be modified according to the situation and the type of process. In manufacturing 5 M categories is often used. When each category is explored by the team, it is not necessary that to identify causes in every category.

**Creating a cause and effect diagram:** The cause and effect analysis are conducted using a Fishbone chart (named because as it looks like a fish skeleton) to visually present the findings of a cause and effect analysis. When this diagram is completed after a brainstorming session, it is possible to analyze the problem and determine the most important factors involved to solve the problem. Following are the four steps to

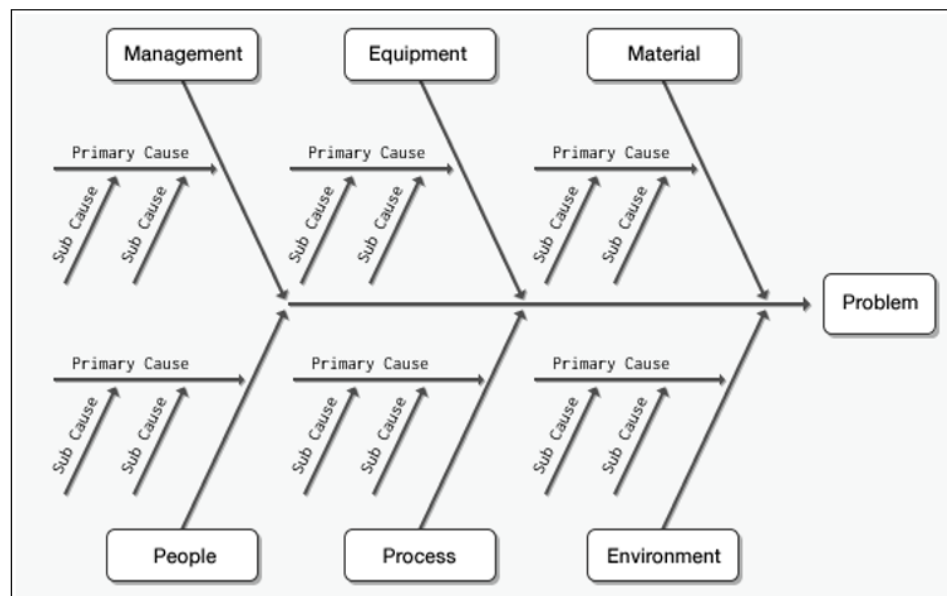
construct a cause-and-effect diagram (Rudy, 2014). Figure 10 is an example of a Fishbone diagram template.

*Step 1- Identify the problem or effect:* The first step is to determine the problem or effect, then it will be written at the head of the fish.

*Step 2-Brainstorm:* The different categories of causes (5 Ms, 8 Ms as explained above) become the primary bones of the fish. The number and type of categories are depending on type problem, situation or organization. All the cause and sub cause then added in the diagram through the brainstorming process.

*Step 3- Chart analysis:* The team will gather the data and information to verify the causes by prioritizing them.

*Step 4-Develop an action plan:* Based on the analysis according to priorities, the actual cause of the problem can be determined. Then the solution will be developed and implemented.



**Figure 10** A Fishbone diagram template.

**Source:** Rudy, 2014: Online

Cause and effect diagram offers many advantages. This process improvement tool helps to understand the significant factors involved in a process. It classifies and identifies all the causes related to a problem and provides elements for developing a suitable solution. Moreover, the brainstorming section can encourage the team members to participate in the process improvements (Saeger, 2015).

In company ABC scenario, the cause and effect diagram will be used to identify the possible causes behind the problems that identified using the Pareto analysis tool. The cause and effect diagram also will help to achieve the objective of the study ‘to identify and analyze problems in production processes’.

### **2.6.5 Brainstorming**

Brainstorming is a technique that brings a group of people to join together and discuss a common issue and find a solution. The aim of brainstorming is to find a solution for an issue that can be more productive than when each person tries to come up with their own solutions (Wilson, 2013). Brainstorming technique is often used in cause and effect diagram as a team approach to solving the problem. Brainstorming is particularly useful for situations in which less quantitative data are available for analysis and where a team input is necessary to develop the best solution. According to Wilson (2013), the basic steps that describe the brainstorming process are

- Selecting a group of participants (normally 3-10) with different backgrounds or with a background or knowledge that is needed in the study
- Presenting the problem that needs to be solved
- Conducting a brainstorming meeting to generate solutions
- Identify the objectives of possible solutions

Brainstorming in the BPI is often used in root cause analysis to generate potential causes and solutions. For this study, the brainstorming tool will be used to create the cause and effect diagram and to develop possible solutions for the root causes. A brainstorming can be extremely productive if the team members have identified the objectives properly and try to come up with individual solutions before the group session. Beyond the root cause analysis, brainstorming can be used in other areas such as product development, problem-solving, etc. (Bloom, 2012).

### **2.6.6 Process mapping**

Process mapping is a tool that used to visualize the detail of steps that takes to complete a process. A process map shows the relationship between the steps to produce an end product or service. Process mapping can be used to document a current process or a new process to gain a detailed understanding about the process, inputs, and outputs. Process map provides a visual way to understand, analyze and improve a current

method of working. Process maps are a useful tool to help to understand the process well and identify the improvement opportunities. Data gathering is an integral part of understanding and preparing a process map and created by an individual or a group of people at the workplace Graham (n.d.). There are mainly four steps involved in process mapping (Hunt, 1996), including

1. Identify the process that needs to document and define what is being mapped
2. Data gathering: The reviewer must gather information from the process participants via observations and interview from an individual who is an expert and have experience. The key part of this phase is to record information obtained and this can be like informal notes, diagram or sketches.
3. Map documentation: Document all the details collected, including inputs, outputs, and activities.
4. Analyze and evaluate: Review the process map

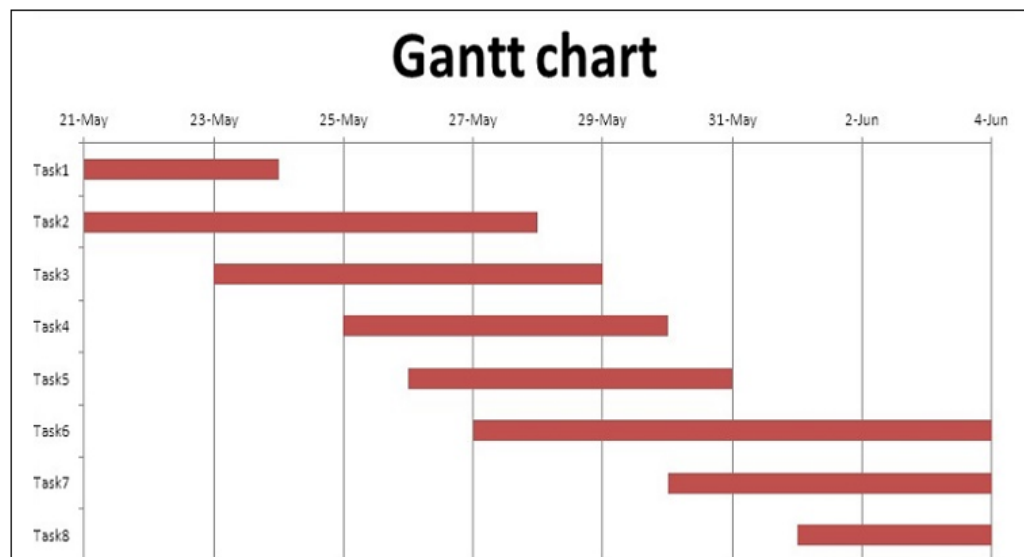
For this study, process mapping will be used for process improvement. It will be easy to understand and analyze the process once it is documented. There are many types of process maps, basic, top-down, deployment and opportunity process maps. A basic process map is the outline of the major steps in a process, which is sufficient to give an overview and is selected in this study. The top-down process map shows the major steps and the next level substeps. The deployment process map shows both flow of steps, and the people involved in each step. The opportunities are highlighted for the improvement in opportunity process maps by showing the value and non-value-added steps (Scholtes, Joiner & Streibel, 2003).

### **2.6.7 Gantt chart**

The Gantt chart is a graphical tool that uses in the project management field ranging from small to large projects. This chart is used to show the sequence of activities according to the time and useful in preparing and implementing a project plan. The Gantt chart is a bar graph consists of a time period on the x-axis, and the activities are marked parallel to this axis as bars. The bar length represents the duration of the activity and starts stop points of the bar shows the activity start-stop date. Usually, Gantt chart has two bars for each activity, one for the plan and another for actual. The Gantt chart is used when the activities have to be displayed against time, to compare the plan vs actual and plan the resources according to time (Sehgal, 2015). Figure 11 shows an example of the Gantt chart

Steps involved in plotting a Gantt chart as follows,

- Plot the time in x-axis, including the start and end dates of the project.
- Plot each activity bar in parallel to the x-axis, following the start end dates.
- Plot the actual time for the activities if needed or available



**Figure 11** Example of Gantt chart

**Source:** Sehgal, 2015: Online

For this study, the Gantt chart will be used for the implementation phase, and this can help the team to visualize the implementation plan by showing each task, time to complete each task and people responsible for each task. Also, this will help to chart the actual work against the planned to track the implementation plans.

### 2.6.8 Standard Operating Procedure (SOP)

Standard operating procedures are the documents that a company has in place to make sure that the process is carried out consistently every time. SOPs are written method of controlling a practice to obtain the desired outcome. SOPs are step by step procedures that explain how to do something, which is critical to quality or productivity or safety. The staff members in the workplace can use this document to follow the work to ensure the expected results. The Standard Operating Procedures should be the base for the everyday activities of employees in the workplace, and this has to be often updated to according to the conditions of the working practices. An example of SOP in manufacturing workplace is the step by step instructions used to make products or train the employee (Hawks, n.d.).

SOPs of a step or processes are prepared by an individual within the organization who is an expert on those activities. A team approach also can be followed for multi-tasked processes where experience from a number of people is required. It should be written with much information and details so that employees with less trained or knowledge can successfully complete the activity without supervision.

Standard Operating Procedures in a control plan will help for this process improvement study to ensure the process is carried out consistently. Therefore, SOPs should be used for this study to control and sustain the improvements. This will be helpful for the new employee training within the company, and they might need to get the job done correctly and can be used as on job reminder in the workplace that is easily accessible and understands.

### **2.6.9 Key Performance Indicators (KPIs)**

KPIs are the measures that determine how well a process is performing to enable a particular goal. They are the critical factors that define an organization's progress by tracking and analyzing. KPIs are focused on aspects of the organization that need to be maintained at a specific level to ensure the success of an improvement. KPIs is always measurable and differ from organization to organization based upon the priorities. KPIs is critical to the project team, to ensure the performance data that need to sustain the implemented improvements and help to evaluate the success of the improvements (Batulis, n.d.). Key Performance Indicators can be based on process, activity or outcome and selection of appropriate KPIs depend on the organization's ability to measure them. The creation of KPIs involves a brainstorming of the project team and the development indicators should be meaningful, measurable and manageable.

It is important to identify and develop KPIs for this process improvement plan. In this study, the KPIs are developed to analyze and monitor the implemented improvements in the manufacturing process and to control the process.

### **2.6.10 Observation**

Observation is a tool or method used for getting information or collecting data about people, process, and cultures and act as a fundamental and basic method of getting information. Observation involves carefully watching the things and trying to understand and get information about it. The observation used to increase the validity for the study, and it help the researcher to have a better understanding (Kawulich, 2005).

In this study, the researcher performs observations to know and understand the current process and the flow of each activity at Company ABC metal fabrication department. The details collected through observations with the help of the process engineer and the leaders in each department will be useful in creating the process mapping.

### **2.7 Summary**

As a conclusion to this chapter, it gives a brief explanation about the BPI process, different types of methodologies that commonly used such as Lean, Six Sigma, TQM, Business process re-engineering, etc. A Lean methodology using a PDCA cycle is selected for this study, and the reason for selection is described. Besides that, different analysis tools and other tools employed in this study, data requirements and the analysis of the data were explained. The next chapter describes the proposed research methodologies used in this study.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 Introduction**

The purpose of this study is to make a process improvement plan for ABC Company to improve the production performance and the quality by reducing the process wastes and defects. The objectives of this study are to explain how the process improvement plan can be implemented by identifying and understanding the process in which high defects occurring, identifying root causes for the defects, developing possible solutions and implementation and control plans. This chapter describes the research methodology and procedures that used to achieve the objectives of this study.

#### **3.2 Research method**

There are different types of research methods: qualitative, quantitative and mixed methods. In the qualitative method, the researcher describes the kinds of characteristics of people or events without comparing in terms of numbers or amounts. On the other hand, the quantitative method focuses on the measurements and numbers of characteristics of people or events. The quantitative research method is designed to solve a problem through determining variables, statistical interpretation of data and analysis. The qualitative research method is suitable to address how and why questions of a research question by conducting a study using the empirical material such as case studies, interviews, observation, history, observations etc. (Thomas, 2003). In the mixed method, the researcher combines the elements of both qualitative and quantitative research approaches and is used for broad and deep understanding (Watkins & Gioia, 2015). A mixed method is adopted for this study that uses a combination of both quantitative and qualitative data, as one method alone is not enough to accomplish the research objectives.

#### **3.3 Research design**

The research design for this study was adopted by using a PDCA- cycle framework. PDCA is described in chapter 2.5.2 and stands for Plan, Do, Check and Act. Figure 12 represents the research design, including the activities and tools used in each phase.

Phase	Action	Tools,documents,inputs
Plan	Define the project	Project charter
	Baseline data collection	Process mapping, Defect report
	Analyze the current condition	Bar graph,Process mapping
	Understand the major problems	Pareto analysis
	Root cause analysis	Cause and effect analysis
	Create possible solutions	Brainstorming
	Develop implementation plans	
Do	Implement improvement plan	Gantt chart
Check	Evaluate the results	Check lists, KPIs
Act	Standardization and documentation	SOP
	Control and future plans	Documentation,KPIs

**Figure 12** Research design

**Plan phase:** The purpose of the plan stage is to define the project, understand and identify the problems, analyze data, find root causes of problems and solve the problem. The first action of the plan phase was to define the project by creating a project charter in coordination of the team members. Once the project charter is approved a basic process mapping was done to understand the major steps involved in the metal fabrication process. An overall production defective data of company ABC are then collected and tabulated using a Bar graph to identify the step that needs to be focused on the initial improvement. After the step that need improvement selected the list of activities involved in that step were listed for better understanding. A Pareto diagram, then created using the defect rate data of that process to identify the factors that causing the main problems. A team was formed to brainstorm and do a cause and effect analyses to identify the major causes behind the problems and to create possible solutions.

**Do phase:** In do stage, the ideas or changes from the plan phase will be implemented on a trial basis, and the goal is to realize that the desired output has been achieved as expected in the plan phase. The results will be observed and recorded. The solutions that are going to implement in the process are to be consulted with the

organization management team, and then a team will be formed, including line supervisor, leader, operators, production and QA engineers, etc. The implementation is to be coordinated by the line supervisor according to the plan, as the supervisor is the key person in that step. The goal of this phase is to put the new practices at the selected implementation workplace.

**Check phase:** During this phase, the new practices that are implemented in place will be evaluated to see the implemented plans have reached the results as per expectations. The collected data from the do step is to be analyzed and compared with the current performance to understand whether the changes had the intended effect. The analysis will be done using the bar graph to determine the total defect rate. If there is no improvement, this process will be continued until all the issues of implementation is resolved with a modified plan.

**Act phase:** If the problems cannot be solved, the PDCA cycle should start again to find the suitable solutions with different plans. If it is successful and achieved the result, total defect rates less than 2% the solutions would be implemented in the whole process, and the changes will be documented and standardized. The success of the PDCA process is measured by comparing the defect data before and after the changes in the process. In this phase, the team will update the documents such as process maps, standard operating procedures, checklists, etc. to sustain the improvements implemented.

### **3.4 Data collection**

For the first objective, “Develop a process map for the involved processes” the researcher collected the empirical data through observation from the workplace with process engineer and leader in each department. Through the observation, each activity within the process can be understood. A process map is created using the information from the direct observations at Company ABC shop floor. The observations are performed in two times, one time for the identification of the metal fabrication process and another time to see the detailed flow of activities of the step that most of the defects occur. The observations were carried out during working days and spent one day to understand the overall process and half day to understand the detailed flow of activities in the selected stage for improvement.

For the objective, "Identify the steps in which the majority of defects are occurring" the production defect rate report data of Company ABC will be used. This data will be retrieved from the company database which includes the total produced quantities, number of defects, type of defects, etc. The data used is from the 100 % inspection results done by the Quality Assurance (QA) department in the production line each day. The data gained after the analysis is used in the Pareto analysis to identify the major problems in that process that is to be solved. The production and quality data between December 2016 and September 2017 have been used as a baseline to analyze the problems and there are no clear data available in company ABC documents prior to December 2016. So, this study is based mainly on these data collected during those 10 months from the company ABC database.

For the objectives, "Identify the root causes of the defects" and "Develop possible solutions for improvements" empirical data will be gathered through brainstorming with employees of company ABC. These data are used for the analysis of root causes and to find possible solutions. The employees chosen for the brainstorming session are engineers from production and QA, supervisor, leader and operator who work in that process. The questions for the brainstorming will be about the causes and solutions of the problems identified in Pareto analysis.

To develop an implementation plan for improving the output of root cause analysis will be used. The defect rate and checklist data are reordered and collected during trial basis implementation to develop a control plan that is the final objective of this study.

### **3.5 Data analysis**

For the first objective, "Develop a process map for the involved processes," the data collected will be then analyzed. In this analysis, the process is identified and documented all the details collected, including inputs, outputs, and activities and will review the process map with the process engineer and adjusted if needed.

The analysis of the objective, "Identify the steps in which the majority of defects are occurring" which will lead to the identification of the step in which the majority of the defects are occurring. The researcher will use a bar graph for the analysis using the defect data of last 10 months. The number of defective parts shown in the vertical axis (y-axis) and the different process in each month on the horizontal axis (x-axis). The

highest bars in each month represent the stage that contributes higher defective parts in the respective month. The process that is to be improved will be selected by analyzing the maximum number of higher bars over 10 months. Once the process is selected for improvement, the analysis will be conducted using a Pareto diagram to identify the major problems or defects in that process. The quality department set up different categories of problems that occur in each process and record the number of defects in each category daily. By using these data, a Pareto diagram is created for the selected process. In Pareto diagram, the number of defective parts in each category of problems that occurs within the process selected are plotted. The quantity of different problems is represented in descending order by bars. The leftmost bars in the diagram, the factors causing roughly 80 % of the problems are the highest and those need to solve first.

A cause-and-effect diagram is selected, for the objective” Identify the root causes of the defects”. The output from the Pareto analysis, which are the factors causing the majority of problems will be analyzed to identify the root causes. The causes of the selected defects are identified through a brainstorming session with team members and present in the cause and effect diagram. Finally, possible solutions for the causes also will be developed, that is the analysis for “Develop possible solutions for improvements.” The output of cause and effect analysis lead to the identification of root causes of the major defects and their suitable solutions. These solutions are used to develop the implementation plan.

To develop an implementation plan for improving the output of root cause analysis will be used. The data collected during the trial basis implementation are analyzed to see the desired output has been achieved as per expectation or not. The analysis will be done using the bar graph to see the defect percentage.

### **3.6 Summary**

In this chapter, the methodology of this study is identified by describing the research design, data collection, and analysis. This methodology is used as a guide to developing the BPI plan for Company ABC in the next section.

# **BUSINESS PROCESS IMPROVEMENT PLAN**

## **Section 1: Company Information**

Company ABC is a Thailand based manufacturing organization mainly focused on the precision production of close tolerance sheet metal, turned metal parts and plastic injection molded custom parts. Name of the company is changed to ABC Company Ltd because of confidentiality issues. Company ABC established in 2013 as a subsidiary, completely owned by the parent company founded in 1991 in Thailand. Currently, more than 400 employees working for this company.

Company ABC's core business is offering metal fabrication and plastic molding solutions to reach customer demands around the world. The core production activity is based on customers in the speaker manufacturing industries around the world. They have made major investments in the advanced fabrication technologies and machines from Europe and Japan. Company ABC business has been dramatically increased over recent years and manufacturing a large variety of products.

### **Problem Description**

Recently Company ABC QA department has reviewed overall production and reported there are problems in the productivity and the quality related issues in their metal fabrication process because of high defective parts, which result in high process waste, delay in production and increased customer quality complaints. According to the defect rate report, the number of defective parts found to be high and was reordered an average of 4.4 % per month in 2017 where the target set was 2%.

## **Section 2: Project Charter**

A project charter is created with the help of production and quality departments to formally communicate the existence of the project. Table 1 defines the project charter and is used as the basis to create the project plan in the initial phase.

**Table 1** Project charter

<b>Project title</b>	Business Process Improvement plan in a manufacturing company
<b>Business case</b>	Company ABC reported there are problems in the productivity and the quality related issues in their metal fabrication process because of high defective parts which result in high process waste, delay in production and increased customer quality complaints. By decreasing the defective rate, the overall productivity and quality would be improved.
<b>Goal</b>	Defective rate to be reduced to 2%
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• Develop a process map for the involved processes</li> <li>• Identify the steps in which the majority of defects is occurring</li> <li>• Identify the root causes of the defects</li> <li>• Develop possible solutions for improvements</li> <li>• Develop an implementation plan for improvements</li> <li>• Develop an evaluation and control plan to sustain the improvements</li> </ul>
<b>Phases of project</b>	Plan, Do, Check, Act
<b>Deliverables</b>	Process map, summary of problem, root causes, implementation plans, control plans
<b>Team members</b>	Engineering manager, QA manager, Production and Process Engineers, Production Supervisor

### Section 3: Process map

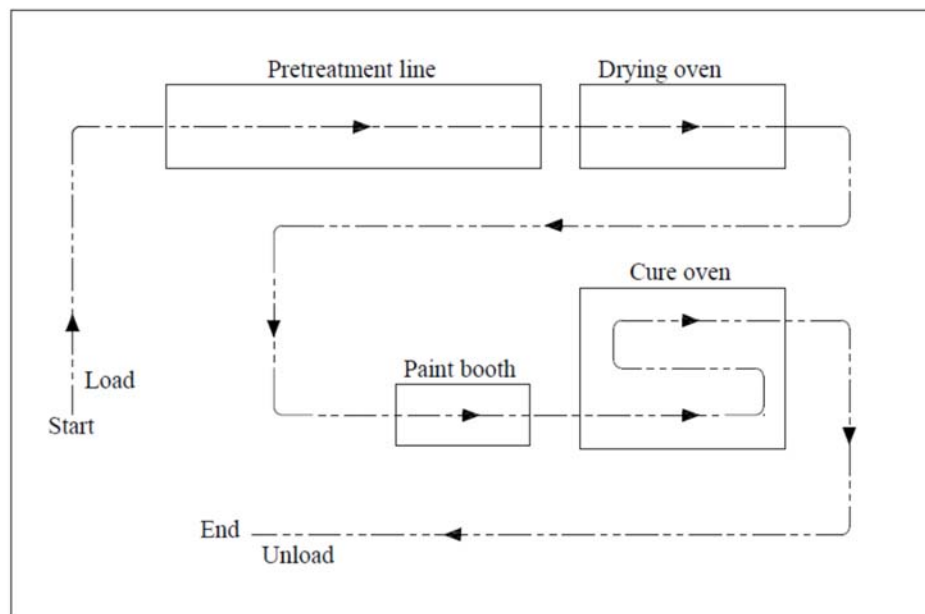
#### Process involved

There are various steps involved within Company ABC manufacturing process. The metal fabrication process includes the stages such as sheet metal, welding, painting, assembling, inspection, and packing. The process starts at Sheetmetal where the raw material undergoes several different processes followed by welding, painting, and assembling. Finally, the assembled product will be inspected and packed at the final step. All these steps ensure that the product meets the design specifications and

contributes to create the final product. Details of each step are described in chapter 1.2 and Figure 1 in the first chapter shows the process map of each step. This was prepared by visually studying the process and helped to visualize the different activities in each step.

The painting process is identified as the stage that contributes major defects, according to the production defect rate bar graph which is explained in section 4 PLAN stage. Figure 13 describes the stages involved in the company ABC painting (powder coating) process. This is a continuous process in which the parts are hanged and moved to each stage through an overhead conveyor. The process starts with manual loading the part followed by an automated chemical pretreatment, drying oven, powder booth, cure oven and unloading.

In pretreatment stage, the parts are cleaned by using chemical sprays to remove any contaminations on parts such as oil, grease, dirt, etc. Drying oven removes any moisture from the pretreatment, and the powder is sprayed in powder booth manually using a spray gun. The coated powder on the part surfaces, then cured in the cure oven at a temperature of 200°C and then parts are unloaded manually from the conveyor.



**Figure 13** Company ABC painting process

#### **Section 4: Stages of Business Improvement Process**

The methodology adopted for this study is by applying the PDCA approach, that is the Plan-Do-Check-Act process. This section includes the different stages of process improvement, tools employed, analysis and interpretation of the data that have been gathered from Company ABC to conduct the research study. The various results were presented with corresponding discussions and explanations.

### **PDCA - PLAN stage**

In plan stage, the process and the major problems are identified by analyzing the data followed by root cause analysis to find the solutions for improvement. The first four research objectives of the study will be accomplished as a result of plan stage.

### **Bar Graph**

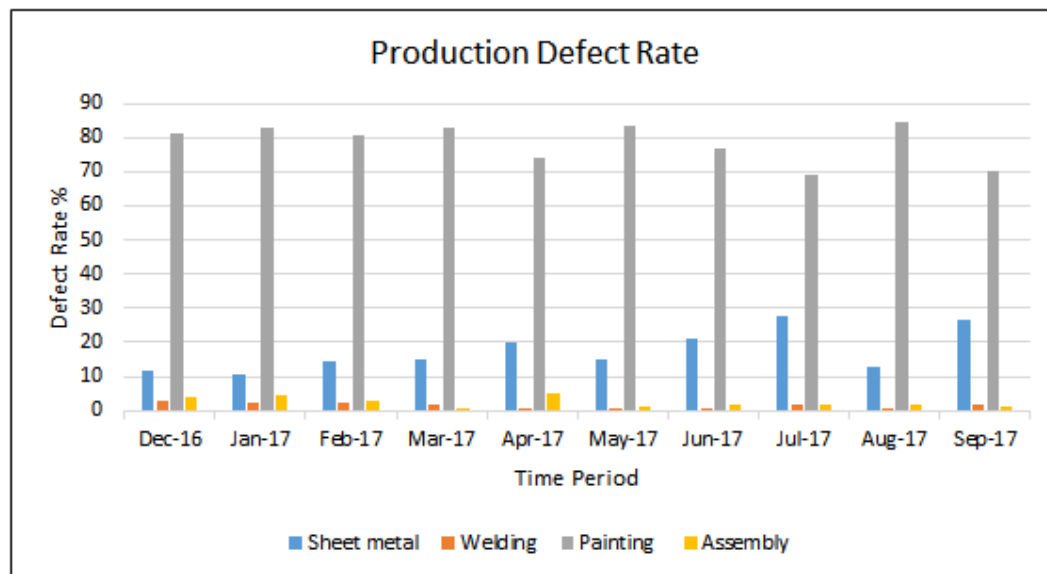
*ROI.2 Identify the steps in which the majority of defects is occurring.*

The company has identified problems in production and quality in the metal fabrication process which resulted in high process waste, delay in production and increased customer quality complaints. Table 2 shows the company ABC production defect data in the different process reported per month for 10 months from Dec 2016 to Sep 2017. This data shows the number of defects identified in each process in production.

A bar graph was plotted as displayed in Figure 14, by gathering the data from Table 2 to understand the defect rate in each process per month. Figure 14 shows the production defect percentage in each process for last 10 months. From this graph, it is clear that the painting process has high defective rate and contributes nearly 80 % of overall defects in each month. The majority of the defects, 3.4 out of 4.4 % are coming from this stage the Painting process is selected for the improvement, and study will be focused on this first.

**Table 2** Production Defect Reported per Month

Month	Sheet metal	Welding	Painting	Assembly	Total Quantity	Defect Quantity	Total Produced
Dec-16	148	34	1009	52	1243	44	1199
Jan-17	194	38	1528	80	1840	52	1788
Feb-17	127	20	714	26	887	26	861
Mar-17	227	26	1274	12	1539	26	1513
Apr-17	187	8	689	48	932	16	916
May-17	356	18	1981	27	2382	27	2355
Jun-17	513	18	1887	47	2465	47	2418
Jul-17	955	63	2385	55	3458	63	3395
Aug-17	327	23	2157	42	2549	42	2507
Sep-17	359	22	941	17	1339	17	1322
Average	339	27	1457	41	1863	41	1822
% Defect	0.8	0.1	3.4	0.1	4.4		

**Figure 14** Production defect rate**Pareto analysis**

The quality department of company ABC categorized 8 kinds of defects often occurs in the painting process and they are recorded. They are dust, rust, hanger marks, uneven paint thickness, gloss issue, stain, line issue and others. Table 3, summarizes the different categories of defects occurs in the painting process.

**Table 3** Painting Process Defect Reported per Month

Month	Dust	Rust	Hanger	Thickness	Gloss	Stain	Line	Others	Total
Dec-16	155	322	2	470	23	24	11	2	1009
Jan-17	470	194	5	781	21	33	24	0	1528
Feb-17	159	78	118	300	33	4	17	5	714
Mar-17	366	275	59	517	20	0	8	3	1248
Apr-17	193	40	38	348	13	5	12	7	656
May-17	607	236	74	994	12	38	7	13	1981
Jun-17	987	192	23	630	4	20	11	0	1867
Jul-17	592	920	63	662	104	25	9	0	2375
Aug-17	382	713	58	459	15	288	200	42	2157
Sep-17	263	140	51	167	7	269	21	7	925
Total	4174	3110	491	5328	252	706	320	79	14460

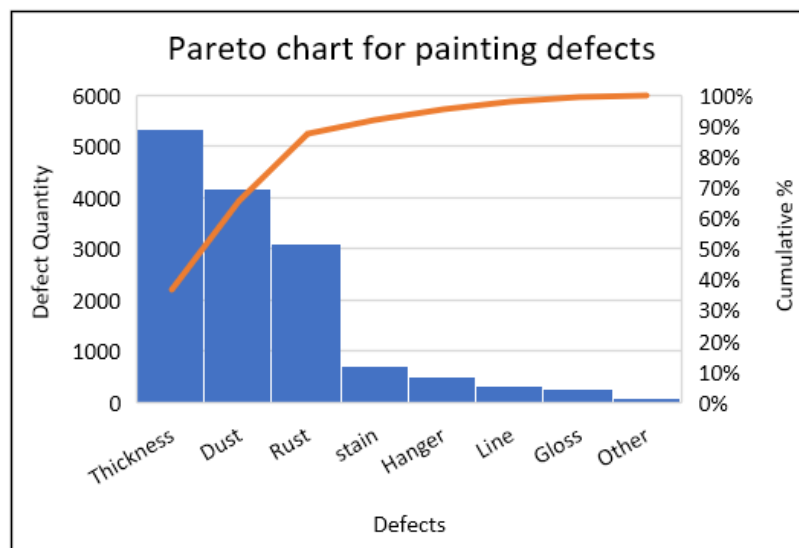
**Figure 15** Pareto chart of painting defects

Figure 15 illustrates the Pareto chart of the painting defects. The chart was constructed based on the total painting defective quantity for 10 months as shown in Table 3. The chart shows the number and percentage of defects that occur in the painting process. The majority of the defects is due to paint film thickness issue, followed by dust and rust defects. Figure 15 illustrates that the thickness and dust defects are the major contributor to the painting defects, almost 66% of the total defects. Therefore,

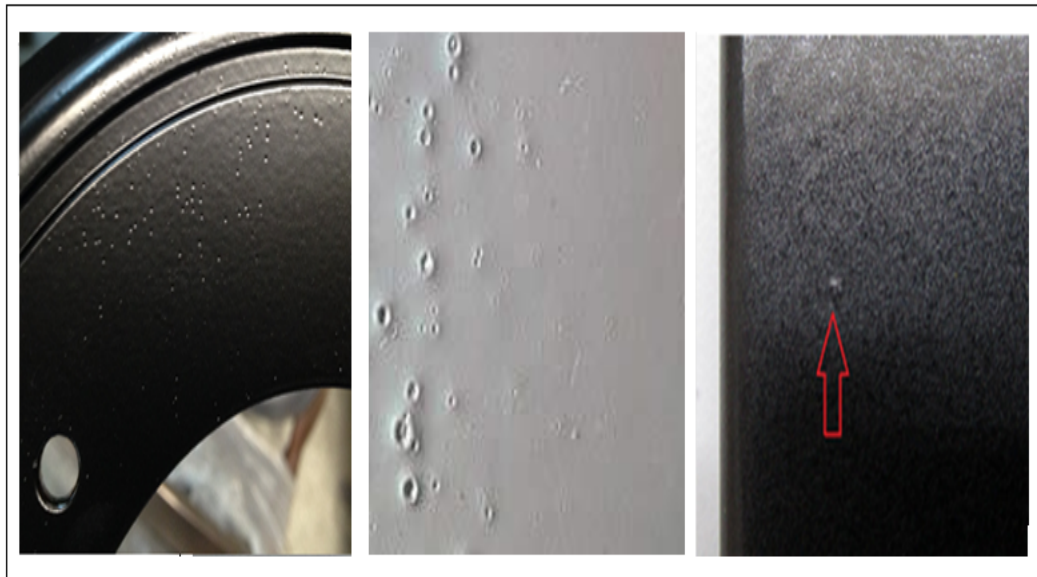
these two types of defects should be solved first for the initial process improvement. Thickness defect has the highest number of defect quantity, therefore, is given the highest priority for the improvement followed by dust defect.

**Thickness defect:** Thickness defects in powder coating are the uneven powder film coating on the part surface which can be too high or too low and causes because of the uneven powder delivery. When the thickness is high surface issues such as orange peel, color difference, and pinholes appear after powder curing on coated layer. The too low film thickness leads to the substrates shows through and insufficient coverage of a powder. The photos in Figure 16 shows the thickness defect found in ABC Company painting line.



**Figure 16** Photos of film thickness defect

**Dust defect:** Dust defect includes all the defects due to dust and dirt contamination on the part surface after painting. These defects happen when the dust contaminations stick on the powder layer during or before curing and it appears clearly on the part surface. Figure 17 shows the photos of the defective parts due to dust defects.



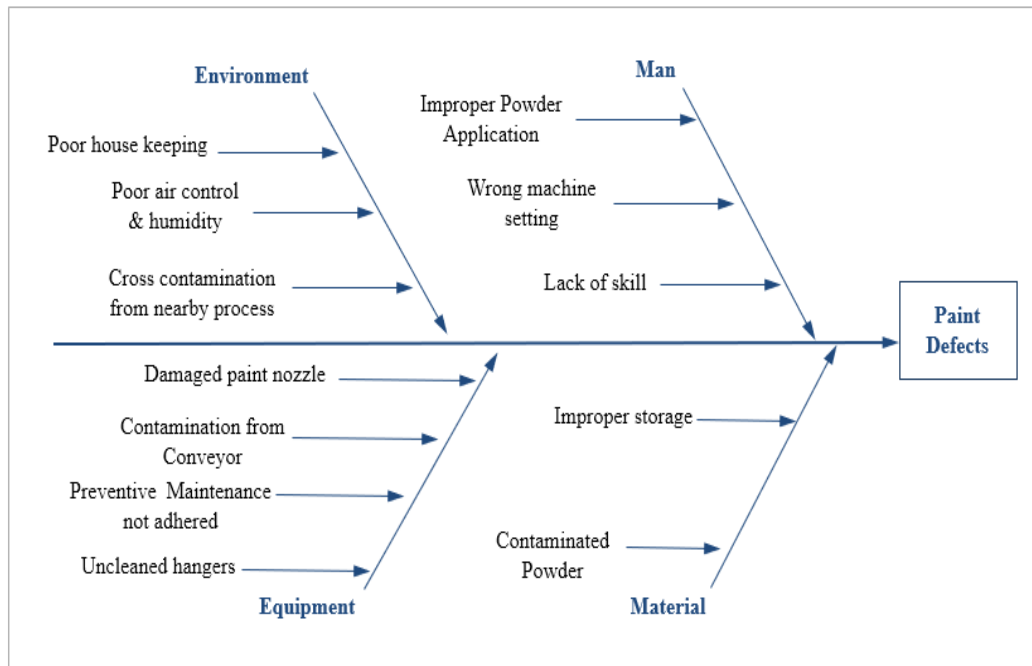
**Figure 17** Photos of dust defect

### **Root cause analysis - Cause and effect diagram**

#### *RO1.3 Identify the root causes of the defects*

A brainstorming session was carried out with the quality, production engineers and operators in the painting process to determine the most likely causes of major defects. After brainstorming, all the possible causes, including major and minor causes of both defects are summarized in a cause and effect diagram as shown in Figure 18. The major causes of these two defects are categorized in four, such as man(operator), machine or equipment, material (powder paint) and environment (shop floor area). After considering the four categories, the key cause of the painting defect is because of lack of operator skill. The following paragraphs will discuss the root causes of these defects.

*Operators* are one of the factors that must be given consideration. Thickness defects might occur when the powder application, spray even and steady strokes are not done properly and wrong settings of the spray guns. Observed that the operator did not know how to set the equipment parameters properly and this leads to the thickness defect. The poor cleaning of the paint booth and the paint gun causes the dust defects on parts. Besides that, defects could happen when the untrained operator or a new operator is assigned to do the spraying job.



**Figure 18** Cause and effect diagram for the painting process defects

Working *Environment* is another factor that causing the paint defects. The painting quality is highly depending upon the quality of its environment. The painting shop dirt and fibers, the cross contamination from the nearby water painting process, and the poor condition of the spray powder booth cause the dust defects.

*Equipment* defects occur mostly when the preventive maintenance of the painting equipment is not done properly. It was observed that the overhead conveyor movement was not smooth and when it jerks the dust and powder fall on the part surface causing the dust defect. Moreover, a damaged or defective nozzle of a powder spraying gun also contributes the possibilities of thickness defect.

*The material* is another important medium in the painting process that contributes to the thickness problems. The powder material that stored for a long time they may become lumpy and restrict the smooth flow of powder to deliver uniformly on parts. The uneven delivery of powder causes the thickness variations on products. Also, observed that the powder stored near the oven, where the temperature is much higher than the recommended storage temperature by the powder supplier. This could result in premature melting of powder paint and create defects.

### Suggested solutions

*RO2.0 Develop possible solutions for improvements.*

After collecting and analyzing the data, identified that paint thickness and dusts are the major defects in the painting process. Table 4 shows the major causes in different categories according to the priority to be solved and the suggested solutions for each to reduce these defects.

**Table 4** Suggested solutions for the major causes

Category	Priority	Causes	Suggested solutions
Operators	1	Improper methods and inadequate training	Technical training for operators
Environment	2	Airborne contamination, Contamination from nearby process	Housekeeping, Move the process to another location
Equipment	3	Poor conditions of conveyor, Damaged paint gun parts	Repair the conveyor, replace the damaged parts, preventive maintenance plan
Material	4	Poor material storage	Store powder material in storage room

**Operators:** Most of the problems from the operators caused as they followed improper methods and wrong settings of the equipment. The operator who works in the powder coating process must have knowledge about the powder material and the setup and operation of powder coating equipment. A training program will help to solve this issue, and more training for the operators can help to prevent the defects in the process, reduce the waste and save time. Moreover, training will help to increase their skills to perform this operation properly and to follow the standard settings of the equipment. This training will be suitable for the painting production leader and the operators who do the powder coating. The training should include, powder coating process introduction, powder material basics, operation and set up of equipment, application procedure, common powder coating defects and their causes, solutions of each cause and training to solve the problems. Training should be coordinated by the project manager in the

implementation phase and should be monitored by the production supervisor and follow the SOPs.

**Environment:** In order to reduce the dust defect and to ensure the quality of the product the painting shop housekeeping is very important. An effective regular housekeeping program should be implemented to eliminate the airborne contaminations on the paint shop floor and the spray booth. A weekly cleaning schedule of the paint shop and spray booth must be followed to ensure the quality. Moreover, the nearby water painting process should be moved to another location to avoid the cross-contamination to the powder coated parts. The project manager will be the responsible person for this, and the housekeeping should be monitored and controlled by using the checklists.

**Equipment:** The conditions of the equipment such as conveyors and painting gun need to be checked and fix the issues to run it smoothly. The responsible person for this will be the facility engineer. For long-term, a preventive maintenance program would be implemented and maintained as recommended by the supplier.

**Material:** The solution to reducing the material related problems is to improve the powder storage. A storage room should be arranged, where the temperature  $< 30^{\circ}\text{C}$  and humidity 50 -60 % are controlled as per recommended by the powder supplier. Also, the powder should keep away from direct sunlight and move the powder in the storage room immediately upon arrival at the factory. The project manager will coordinate this change, and this will be documented and followed by the coordination of the production supervisor.

## **Section 5: Implementation Plan**

In this section, the implementation plan for the solutions to improve the process are described. It is important that all the tasks described in the implementation plan are initiated, completed and documented to reduce the defective parts. The changes are implemented in the Do phase of PDCA cycle. The objective RO3.1 “*Develop an implementation plan for improvements*” will be accomplished by developing the implementation plan which is explained in below sections.

### **PDCA - DO stage**

In Do phase, the solution implementation plan is developed for the process improvement. The goal of this phase is to put the new practices at the implementation

worksite on a trial basis. The solutions that are going to implement in the workplace are to be consulted with the organization management team for approval, and project manager will be responsible for the overall implementation. Once the implementation plans are approved, a meeting will be conducted with the painting line employees to inform them about the new improvement changes that are going to implement in the workplace. The details of the proposed changes in different categories, including the expected outcome are shown in Table 5 and explained in below paragraphs.

**Table 5** Details of proposed changes for improvement

Categories	Priority	Changes	Expected outcome
Operator training	1	Training in powder painting	Improved operator skill
Housekeeping	2	Clean the workplace and facilities and implement a regular cleaning schedule.	Less dust and contaminations in workplace
Equipment	3	Repair equipment and do preventive maintenance.	Fewer defects due to equipment damage
Material	4	Keep the material away from heat sources and Make new storage room.	Fewer defects related to the material

**Operator training:** Operator training program is designed to address the major problem in the painting line, such as paint thickness related issues. So, training is considered as the key solution for the improvement. The training will be coordinated by the project manager with the help of production supervisor and process engineer. The training program will be started when the implementation plan is approved by the management team and details of the training are shown in Table 6.

The training will be conducted by a technical specialist from Company ABC current powder supplier. The training program will include powder coating process introduction, powder material basics, operation and set up of equipment, application procedure, common powder coating defects and their causes, solutions of each cause and training to solve the problems. The training includes both theory and hands-on

sessions conducted at the workplace and a certificate will be issued by the trainer after assessment to make sure that the operator meets a certain level of skills to perform the job. If the operator does not pass the assessment retraining will be provided to meet the minimum skill level. The operator should have a minimum certification of training to do the painting job, and this will be documented and standardized by production supervisor.

**Table 6** Operator training details

Operator training	
<b>Objective</b>	To increase the knowledge about proper and efficient manual powder application techniques, as well as troubleshooting and maintenance skills
<b>Trainer</b>	Technical Specialist from Company ABC powder supplier.
<b>Trainees</b>	The operators performing the powder coating process.
<b>Training Location</b>	ABC Company training room and painting line
<b>Highlights</b>	<ul style="list-style-type: none"> <li>• Powder coating process and material introduction</li> <li>• Operation and setting up of equipment</li> <li>• Powder Application procedures</li> <li>• Common defects in powder coating and causes</li> <li>• Solutions and troubleshooting</li> </ul>
<b>Benefits and outputs</b>	<ul style="list-style-type: none"> <li>• Better understanding of powder coating process, spraying techniques and troubleshooting</li> <li>• Reduced paint thickness related defects</li> </ul>
<b>Coordinated by</b>	Project manager, Production supervisor, Process engineer

Following are the details that need to be included in the training program

1. General overview and the introduction to powder coating process.
2. The components of powder coating equipment and its functions.

3. Guidance and procedures for starting up and operating the application equipment.
4. Troubleshooting of application equipment.
5. Powder material characteristics.
6. Proper method of applying the powder and spraying techniques
7. Common defects in the powder coating and their causes.
8. Solutions for each cause of defects and the procedure to solve.

The training at the worksite will give advantages for the operators as the equipment, environment and conditions are familiar to them. The output of this training expected are, the operators will have a better understanding of the powder coating, spraying techniques, equipment and in troubleshooting. This will help to reduce the major defect those related to paint film thickness.

**Housekeeping:** In order to reduce the dust defect and to ensure the quality of the product the painting shop housekeeping is very important. An effective regular housekeeping program should be made to eliminate the airborne contaminations on the paint shop floor and the spray booth. A thorough cleaning of the workplace, conveyors, hangers and spray booth must be done on a weekly basis to reduce the defect and to ensure the quality of parts. To follow and monitor this change a cleaning schedule will be created by the process engineer. Moreover, the nearby water painting process will be moved to another location to avoid the cross-contamination to the powder coated parts. Production supervisor is the responsible person for this implementation. When these changes are implemented, the dust related defects can be reduced or eliminated.

**Equipment maintenance:** The equipment maintenance implementation will be coordinated by the project manager with the help of a facility engineer. For the short term, the problems related to the equipment conditions should be repaired with the help of an outside supplier. As a long-term plan, a preventive maintenance practice will be implemented, which includes routine cleaning, adjustment and replacement of parts at scheduled intervals as per manufactures recommendation. Following these will ensure that the equipment performs at maximum efficiency and reduced defects. Also, a checklist will be created to maintain the equipment, including the routine maintenance plans. The facility engineer has to check all the equipment monthly and should fix if something goes wrong.

**Material storage:** A new material storage room with controlled temperature and humidity has to be made to store the powders. Construction of the new storage room is expected to complete within one month, and project manager will be the responsible person to implement this by outsourcing the job. As a first step, the material stored near the heat sources will be moved to another area in shop floor where the temperature is relatively low.

A Gantt chart is created by the team for planning, scheduling and monitoring the implementations. The Gantt chart presented in Figure 19 shows the activity, responsible person, estimated the cost in THB for each activity as well as the start and finish time week for each task. The Project manager will be the responsible person to coordinate all the activities and schedules with the team.

Activites	Responsibility	Estimated cost in THB	Week															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Implementation planning	Team	0	■															
Management approval	Project Manager	0		■														
Meeting with staff	Team	0			■													
Training in powder painting	Project Manager	25,000				■	■											
Overall cleaning and house keeping	Production Supervisor	5,000				■												
Regular cleaning schedule preparation	Process Engineer	0					■											
Move the water painting process	Production Supervisor	5,000				■	■	■										
Equipment repair	Facility Engineer	50,000						■	■									
Maintenance schedule and check list preparation	Facility Engineer	0						■										
Material storage	Project Manager	100,000				■	■	■	■									
Evaluation	QC manager	0									■	■	■	■	■	■	■	■

**Figure 19** Implementation plan Gantt Chart

## Section 6: Evaluation and Control Plan

The evaluation and control plans include the activities to evaluate the implemented changes in the workplace and sustain the successful changes. Evaluation means looking over the data and examines whether the company achieved its goal and objectives in the implementation phase or not. The changes are recommended to be implemented on a permanent basis if the implementations are successful and a control plan will analyze the measurements to ensure that performance does not vary from expectations. When the process performance found to be deficient after the evaluation,

corrective actions will be developed and implemented. The Check and Act phase of PDCA cycle describes the evaluation and control plans for the process improvement of Company ABC. The objective RO3.2 “*Develop an evaluation and control plan to sustain the improvements*” will be accomplished through Check and Act cycles of PDCA.

### **PDCA - CHECK stage**

During this phase, the new practices that are implemented in place will be evaluated to see the implemented plans have reached the results as per expectations. The collected data from the do step is to be analyzed and compared with the current performance to understand whether the changes had the intended effect. The analysis will be done using the bar graph to determine the total defect rate. If there is no improvement, this process will be continued until all the issues of implementation is resolved with a modified plan.

It is important to allocate responsible persons to monitor each implementation for the success of the implementations. The first improvement that is the training of operators, monitoring responsibly will be given to the production supervisor. A training certificate issued by the trainer verifies that the operator met the specific skill sets to perform the painting job well. Also, the training program should be arranged for any new employee come to work in painting section, and he/she should get the certificate to perform the painting operation.

Housekeeping improvement will be monitored by using the cleaning schedule and checklist. Production supervisor and leader are the responsible people to monitor this and they can be easily managed this by following as per schedule and using a checklist. The improvement related to equipment is monitored by the facility engineer by following the preventive maintenance schedule as per manufactures spec and equipment checklist. The final improvement related to the material storage area does not require any measurement system to monitor separately as it is easily observable. Once the new room for material storage is ready the production supervisor and leader have to make sure that all the powder material is stored inside.

**Key Performance Indicators (KPIs):** The overall performance should be monitored even though it is important to follow the performance of all the improvements individually. The reduction of defective parts in production by 2% is the primary goal

of this project that set in the beginning. The improvements that plan to implement will increase the productivity and quality by reducing the defect rate in the process. The changes should be monitored for two months after all the changes are completed to determine how the defective rate shape up after implementation. The output of this measurement will be a good indicator of the process improvement.

The Key Performance Indicator for this process improvement is found to be the production defect rate. This can be calculated by the number of defective units divided by the total number of units produced in a time frame will give the defective rate. The lower can get this number, is the better and indicates the performance has been improved. Monitoring the defect rate of production is important to evaluate whether the improvement implementations are effective and successful in relation to the goals and objectives of this study. Normally in Company ABC, the quality control department measures the production defect rate KPI, thus on the responsibility of QA manager. The KPI, defective rate will be monitored for two months and then evaluated to see whether the implemented changes are successful in meeting the goal.

The KPI for the individual improvements in the categories such as the operator training and the material is the thickness defect data and for the category related to the equipment and the environment is the dust defect data in the painting section. These data will be updated in the QA database on a daily basis and lower the number the better the performance. The production supervisor will be the responsible person to monitor this individual performance.

#### **PDCA - ACT stage**

The improvement changes will be implemented on a permanent basis when the goals and objectives are accomplished as planned in the beginning. If the defect rate goes down by 2%, the process improvement can be considered as successful. In this phase, it is important to create an awareness among the employees and concerned people about the new successful practices.

The improved performance and the improvement process will be documented by the team, including all the details and changes. This will provide a roadmap for replicating successful improvements in the process. Updating of process documents also should be done with the new standard of performance. The new practices such as checklists for the regular cleaning, equipment maintenance will be implemented on a

permanent long-term basis to standardize the process. The KPI, defective rate should be monitored by the production and quality managers on a monthly basis to make sure that the process is within the control. At the same time, the preventive measures such as cleaning checklist, maintenance schedule should be monitored by the responsible persons. Things to be monitored and controlled by the responsible persons to keep the process stable are,

*Production Defect rate KPI:* To monitor overall defect rate

*Painting thickness defect data:* To monitor improvements in operator and material categories

*Painting dust defect data:* To monitor improvements in equipment and environment categories

*Checklist:* To ensure the cleaning and housekeeping activities are followed as per planned.

*Preventive maintenance schedule:* To make sure that the preventive maintenance of the equipment is done properly

*SOP:* This is the document that clearly describes the procedure of each operation. Working in accordance with the well defines SOPs will help to reduce the defective parts and increase the quality and productivity.

### **Corrective Action Plan**

If the implementation results are not satisfactory to solve the problems, the team will decide whether to make more changes in the previous solutions or discard them and start new. Once implemented changes not resulted in reducing the defect rate the PDCA cycle has to be repeated for the improvements with necessary modifications and also by using the knowledge gained from the initial improvement plan. If the modifications did not work, the solutions are abandoned and a new PDCA cycle is repeated with a different plan.

## Summary

The purpose of this study was to develop a business process improvement plan for Company ABC to improve the productivity and quality by reducing the defect rate in production. The main objectives of this study, to identify the quality and productivity problems and to develop a business process improvement plan by using a Lean PDCA was met. The higher number of defects was from painting stage. Based on the Pareto analysis the main defects found in painting were thickness and dust issue. The major root causes of these defects were identified using the cause and effect diagram and solutions to improve the process was suggested through brainstorming. The implantation and control plans have been proposed and need approval from company management for successful implementation.

In conclusion, the implementation of the proposed solution will help to reduce the defective parts of production and thereby reduce the productivity and quality related issues. The defective rate reduction will improve the production efficiency of Company ABC by reducing process waste, delay in production and customer complaints. This study provided the solutions based on the PDCA cycle to solve the two main types of defects in painting. The BPI process should be continued to determine a solution for the remaining types of defects to minimize the defective rate. The implementation of the proposed solutions determines the success of the company by enhancing its competitive advantage.

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