INTEGRATION OF DMAIC METHODOLOGY AND CAPA CONCEPT FOR QUALITY IMPROVEMENT IN SEMICONDUCTOR INDUSTRY

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UNIVERSITI SAINS MALAYSIA

2017

INTEGRATION OF DMAIC METHODOLOGY AND CAPA CONCEPT FOR QUALITY IMPROVEMENT IN SEMICONDUCTOR INDUSTRY

by

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Thesis submitted in fulfilment of the requirements

for the degree of

Master of Science

June 2017

ACKNOWLEDGEMENT

In the name of Allah Most Gracious, Most Merciful,

Alhamdulillah. Praise to Allah SWT, whom with His willing and guidance in giving me the opportunity to complete my master research.

I owe my deepest gratitude to my supervisor, Dr. Elmi Abu Bakar for his continuous support of my master research, for his patience, motivation, and immense knowledge. His guidance helped me throughout the research and writing process.

I wish to express my warm thanks and appreciation to my husband, my mother and family for their endless love, pray and continuous support from the beginning until the end. Without their understanding with my work it would have been impossible for me to finish this research.

I am thankful to the QDOS Flexcircuits Sdn. Bhd. Staffs, especially Mdm. Satariah Bt Yet and Miss Puah Lai Guat for giving me lots of opportunities to learn and to do research upon my thesis. Not forgetting my friend and colleagues from Innovative System and Instrumentation (ISI) research team for continuous support and helped in feeding me new knowledge and make this research enjoyable and sometimes unforgettable experience.

Last but not least, to all the lecturers, technicians, staff and financial support from Ministry of Higher Education (MOHE), Knowledge Transfer Program (KTP) Division of Industry and Community Network (BJIM) and Universiti Sains Malaysia, (USM) are gratefully acknowledged.

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LIST OF ABBREVIATIONS

CA	Corrective Action
CAPA	Corrective and Preventive Action
CN	Change Notice
DMAIC	Define, Measure, Analyze, Improve, Control
DFSS	Design for Six Sigma
DOE	Design of Experiment
ET	Electrical Test Department
FPC	Flexible Printed Circuit
FPCA	Flexible Printed Circuit Assembly
FR4	Fire Resistance Type 4 (support material)
ICA	Interim Containment Action
ISO	International Organization for Standardization
OQA	Outgoing Quality Assurance (basically for data purpose)
OQC	Outgoing Quality Control Department
PA	Preventive Action
PCB	Printed Circuit Board
PDCA	Plan-do-check-act
QER	Quality Enhancement Rating
QC	Quality Control
QFD	Quality Function Deployment
QI	Quality Improvement

QP	Quality Planning
QT	Quality Tools
RCA	Root Cause Analysis
SMT	Surface-Mount Technology
TP	Target Punch Department
TQM	Total Quality Management

INTEGRASI METODOLOGI DMAIC DAN KONSEP CAPA BAGI PENAMBAHBAIKAN KUALITI DALAM INDUSTRI SEMIKONDUKTOR

ABSTRAK

Terma kualiti di dalam industri menjadi faktor utama bagi mengukur kebolehsaingan suatu firma. Konsep, kaedah dan alat telah digunakan secara meluas dalam menambahbaik serta mengawal kualiti produk. Dengan itu, industri berusaha bagi menghasilkan produk yang baik. Bagi memastikan tindakan kualiti lebih teratur, laporan kualiti yang tersusun adalah sangat penting. Tujuan kajian ini adalah untuk menghasilkan rangka kerja penyelesaian masalah yang baru di mana metodologi DMAIC (*Define-Measure-Analyze-Improve-Control*) menjadi pendekatan utama untuk gabungan konsep CAPA (*Corrective and Preventive Action*). Metodologi DMAIC sering diterangkan sebagai suatu pendekatan dalam penyelesaian masalah dan suatu strategi kualiti berasaskan data kerana ia adalah sebahagian daripada inisiatif kualiti Six Sigma. Manakala konsep CAPA merupakan siasatan sistematik pada punca masalah yang dihadapi. Dalam kajian ini, dua pendekatan tersebut digabungkan dalam penghasilan Laporan *Quality Enhancement Action* (QEA), di mana laporan ini bertujuan untuk membawa pengurusan industri ke arah tindakan yang lebih jitu berkenaan isu kualiti dalam sektor elektronik. Laporan ini telah disahkan melalui kajian kes dan kajian soal selidik. Hasilnya telah menunjukkan laporan dan juga rangka kerja baru tersebut adalah praktikal. Selain itu, laporan kualiti ini bukan sahaja focus kepada penyelesaian masalah, malah boleh memecahkan jurang sesebuah organisasi. Menerusi penambahbaikan proses and kualiti, industri dapat lebih berdaya saing bagi menghasilkan produk yang lebih baik di masa hadapan.

INTEGRATION OF DMAIC METHODOLOGY AND CAPA CONCEPT FOR QUALITY IMPROVEMENT IN SEMICONDUCTOR INDUSTRY

ABSTRACT

The term quality in industry has been a key factor in measuring a firm competitiveness. Tools, methods, and concepts have been massively applied in improving and controlling product quality. Thus, industries urge themselves to cope with the needs of complete goods. In order to get a structured quality action, an organized framework is highly reliable. The purpose of this research is to develop a new problem solving framework where DMAIC (Define-Measure-Analyze-Improve-Control) is the main approach, with infusion of CAPA (Corrective and Preventive Action) concept. The DMAIC method is often described as an approach to problem-solving and a data-driven quality strategy as it is an integral part of the Six Sigma quality initiatives. Meanwhile, the CAPA concept is the systematic investigation of the root cause of identified risks or problems, widely implemented in industries. In this research, these two approaches are merged in designing a new quality reporting document named as the Quality Enhancement Action (QEA) report. The report presents the structured quality action in a more efficient way conducted in the electronics sector. The report has been validated through case studies and a survey through questionnaire. The outcomes confirmed the application and the practicality of the report as well as the new framework to improve quality issues. On the other hand, the quality report is not only focus on problem solving and decision making, but can break down organizational barriers. Through process and quality improvement, industries will have the capability in producing better goods in future.

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CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter consists of five sections, beginning with the research background. This section briefly discusses on the research field and scope. Next, the second section discussed on problem statement. While the following sections are research objectives and scope of research. Lastly, this chapter ends with thesis layout.

1.2 Research Background

Over a decade there has been a significant increase in high quality awareness among manufacturing industries. Evolution of technologies is expected to bring more effectiveness to mass production along with better product quality. This evolution also comes along with high expectations from customer. Thus, industry improves themselves to cope with customer needs. Various actions, quality tools, quality improvement are adapted into the process. Malaysia is also not lagging behind. Our industries are facing the same challenges too. Thus, we need to learn and cope with other global company to build a dynamic and strong stake to elongate good manufacturing practices.

An organization with strong and continuous improvement system tend to withstand barriers and can rapidly grow. The improvement can be said as a crucial thing to do. Lots of questions have to be asked to industry “Why the profit is down?” or “What is the problem?” The answer will bring many potential causes. Most of the barriers lie in their manufacturing process. Necessary guidance or solution are

needed to solve the problem. Here, production issues are mostly cause by quality problem. So now, industry needs a guide for effective problem solving. Here, quality is the major stake while the improvement action definitely will support the objectives. So, proper guide is essential to gain the desired quality results.

In order to survive in this growing industries, companies have to compete to promote high-end products. Competitive environment will lead to continuous process improvement. How do we want employees to embark in a successful process improvement program? Would they get through the problems? Or just making the problem unsolved and get even worse? One of the possible cause of this situation is understanding. So now, "How to make employees understand and able to carry process improvement?" The answer lies in finding the correct medium which assist the implementer in an effective way through the project completion.

Now, the suitable medium to ignite the understanding is the adaptation of quality tools incorporate with necessary methodology and guidance. Implementer now is to lead their process improvements through detailed description of problem solving techniques. The framework of all the methods or techniques is to monitor the implementer to be in a right path towards best quality improvement actions. The guidance must be a systematic, focus, controlled and timely manner.

1.3 Problem Statements

Process improvement needs a proper guide to possibly eliminate defects. Thus, there must be a focused method to achieve the goal. But somehow, industries are stranded with lots of methods or tools and the methods sometime being misused. The solutions become lengthy when they try to cope with the methods and end up mixing the tools but then there is no correct root causes are found. Practitioners must

be clear on what tools they want to adapt to, unless there are systematic guidance to successfully do the process improvement. Here, DMAIC methodology is introduced to manage the problem solving issues with the aid of CAPA concept. Later on in Chapter 2 and 3, this two methods will be further discussed where DMAIC and CAPA are merged to develop a new framework.

Next, the crucial problem would be implementers have lack of understanding and skills. Sometimes, mistakes are made from the very beginning since they do not even know how to cope problems with the problem solving tools. "What the next step is and fail to find the answer (Rohleder and Silver, 1997). When this happen, later on the problem is not going to find the best solution. They tend to solve the problem based on their past experience (Lee and Chuah, 2001).

The third problem is the most common issues in industry. It is the experience based issues. Actually this problem does correlate with the above problem when implementers do not have thorough understanding on the methods used, then they rely on their seniors on what they are experience before. This can bring about a bigger problem once it becomes a "culture". Let say a major defect is reported then practitioners do the process improvements by all means, but at the end the defect still occur. The company will rely on the most independent senior to solve the issues once again instead of seniors guiding to a proper problem solving.

In addition, another problem is poor documentation for problem solving analysis. Data is scattered, not focused, incorrect method and many more. We do have plenty of problem solving documentation or so called "quality report" and we can simply use it. But, is the report can really match to our situation? Would that be effective enough to reach best solution? So now, this research will design a new

quality report accordingly to the new methodology to cope with all this improper documentation and guide practitioner to successful analysis. Later on the new quality report will be discussed in upcoming chapters.

1.4 Research Objectives

The objectives of this research are explained below:

1. To develop a structured framework for quality improvement. Through a combination of process improvement framework to cover various aspects of problem solving procedures;

2. To improve the current quality report. A proper reporting document for solving quality issues will be generated.

3. To validate effective problem solving analyses and promote wide industrial applications for the proposed new framework together with the new designed quality reporting document.

1.5 Scope of Research

This research is test directly in industries where two case studies are done practically. Thus, the scope of this research is to develop a new framework. Then later on, a new quality report will be designed as a contribution to the industry and some tests will be done through the two case studies. Each case study took about a month to be monitored and each of them is solving different quality issue. New practitioners will be included as implementer in the case study validations since one the mission of the new report is to guide everyone including new practitioners to the process improvement. Therefore, through the tests, the effectiveness of the report can be validated.

1.6 Layout of Thesis

This thesis consists of six chapters. Chapter 1 briefly provides an overview of the whole research. Beginning with the current quality issues, some explanation is included to discover the issues of quality in manufacturing industries. Then comes the problem statements to strengthen the needs of this project and we will go through the scope of research and objectives of the research are discussed as well.

While Chapter 2 covers the literature review related to this research. Then the chapter also focus on DMAIC methodology, how the framework is and the history of it. Then, the literature review of CAPA concept is discussed. The last part being the most important of this research where literature findings for both quality tools is discussed.

Next, Chapter 3 bring us to the closer look on how the DMAIC and CAPA correlate in building the QEA report. Here the framework of DMAIC methodology and CAPA concept will be merged and a new framework will be developed. Lastly, the new framework will then converted into a document, namely QEA report specifically to guide process improvement.

Chapter 4 includes presentation, analysis and discussion of the case studies done in real industry. Results for the case studies are documented and discussed for the reliability and effectiveness of the QEA report. The result of the pilot run is then discussed in the next chapter to validate the effectiveness of the report.

Chapter 5 will further validate the report through a survey of questionnaire. Here, the result from the questionnaire will reflect the practicality and the effectiveness of the report to solve quality issues.

Lastly, Chapter 6 will conclude important findings and recommendations for further developments of the QEA report. All results and findings are concluded in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter analyzes and summarizes literature related to this research by providing the basis for quality and process improvement to perform this thesis. This chapter is divided into five sections. The first two sections will review the basic knowledge of quality and improvement plus the related current issues. While the third section, introduces the quality improvement framework to develop the quality reporting documentation. Next, the fourth section will discuss previous studies on related framework as the foundation prior to the new proposed quality framework in Chapter Three. Findings from the literature review will then be discussed at the end of this chapter.

2.2 Quality and Process Improvement Overview

What is quality? If 10 people were asked to define quality, there would probably be 10 different perspectives given as the answers. Most of the answers will be absolute (Arnold and Holler, 1996). One thing these people would agree is that everyone is expecting the best on quality. In addition Juran and Godfrey (1999) and Pyzdek and Keller (2013) defined quality improvement as a target to reach the level of remarkable performance – a significant level that is better than any past or the current level. In other words, "improvement" can be represented as a "breakthrough" action in lifting a company to be more efficient. Different authors have different definitions towards this term but share the same understanding. On the other hand, quality improvement is also closely related to the process improvement where

actions taken towards the improvement mostly involve the process improvement. There are many terms used to present process improvement such as the continuous improvement (Jorgensen et al., 2003), business process re-engineering (Abdolvand et al., 2008) and business process redesign (Davenport and Short, 1990; Mansar and Reijers, 2005). These concepts are related to a range of activities from the process of implementing improvement to the complete restructuring of organizations. The term and definition of process improvement are different but the approach and aim are similar. Other references can be observed in the various definitions and methods of process improvement as discussed in the literature:

…as to improve product quality by reducing particular manufacturing defect through the utilization of software tool to support the high value-added product (Huertas-Quintero et al., 2011).

…as to apply the lean six sigma method in improving the process capability; continuous improvement program will lead to manufacturing quality target (Indrawati and Ridwansyah, 2015).

…quality improvement of processes and products need series of data collection and analyses are required to solve quality problems (Köksal et al., 2011).

…as a process is planned and organized, continuous incremental improvement and innovation practices are in order to satisfy customer requirements, competitiveness and effectiveness of the whole organization (Jorgensen et al., 2003).

…continuous process improvement can be done through defining, measuring and analyzing the failures of production process (Jevgeni et al., 2015).

From discussions stated above, process improvement can be defined as an action taken to improve process capability through various methods and tools.

Moreover, the action must be well-planned to gain positive impact for the innovation.

Through a survey by Industry Week (IW) and Manufacturing Performance Institute (MPI), 100 questions were included and 967 responses received. The results showed that more than 95% of plants closest to the world-class have an established methodology improvement. Table 2.1 shows the summary of the world-class progress (Taninecz, 2004).

Table 2.1: World class progress

	No. of plants	***Plants (%)***
No progress	236	25.9
Some progress	448	49.2
Significant progress	207	22.7
Fully achieved	19	2.1

There are several reasons why companies need to perform process improvement. The main reason is that when improvement efforts succeed, the company can have a significant economic gain. The process improvement benefits the company by increasing profit margin through eliminating or reducing the non-value-added activities.

2.3 Issues related to quality improvement

Quality improvement and control are vital in industries. Efforts done to produce good products exceeding customer requirement seem to be the lifestyle of the manufacturing process. Moreover, most of the industries state that poor quality products, mistakes, and delays are no longer tolerable (Redmond et al., 2008).

Industries nowadays are prone to drive the manufacturing systems in producing high-end products with less or even no rework phase.

As discussed earlier, process improvement helps many companies to improve competitiveness and increase profits. These success stories can be found in many cases. Although there were many successful implementations of quality improvement, failures still happened. These failures may be caused by several factors. According to Muthiah and Huang (2006), more than 75% of companies had no progress towards the world-class report and quality certification. On the other hand, at least one certification was obtained among the 72.9% of plants closest to the world-class. This survey somehow showed that most of the plants or companies did not take quality achievements seriously. With so many improvement efforts ending with failure, one may wonder why companies ever make any efforts to gain success.

There are different reasons for the uprising issues in conducting quality improvement. Some relevant explanations on the barriers to quality improvements by several quality gurus as cited by Arnold and Holler (1996) are:

- No specific methodology. A new method, philosophy or tools need to be adopted to cope with the current needs of the new economic age and avoid from being blended with the common mistakes, delays, defects or any other lapses (W. Edward Deming, 1980s).
- Organization does not have the vision to attain quality. Managing quality makes extensive use of three such managerial processes; Quality planning, control and improvement (Joseph M. Juran, 1979).
- No proper process investigation. The concept of Zero-defects emphasizes the achievement of zero defects in good engineering practices and process investigation. Moreover, the defect is supposed to be corrected at the point of

source for immediate feedback rather than at a later stage (Shigeo Shingo, 1980s).

- No management commitment and quality improvement team. For a successful project, commitment from the high-level managers is crucial. Actions must be more than the voice order and specific quality team must be formed (Philip B. Crosby, 1960s).
- No customer-based improvement program. As in the Total Quality Control (TQC), a dissatisfied customer is a sign of a lack of quality. Thus, the company must meet customers' requirement rather than just focusing only on production (Armand V. Feigenbaum, 1990s).

Kaynak and Hartley (2005) reviewed some issues relating the quality and process improvement and found that complexity which stems from rapid changes in product design, demand, competitors and high technology evolution often become the distinctive competency for today's industry. To retain success in this environment, the company must possess capable managers, effective teamwork and create a learning and innovative culture. Sharing and adopting knowledge in a critical view will develop successful competition among the global industries. Meanwhile, Su et al. (2014) found that many industries have achieved quality performance at a high-level stage but only to be lost later on. These organizations no longer have to compete with product quality and services and thus need to have dynamics capabilities in configuring conditions and situations in the companies and sustain the competitive benefits.

2.4 Common problem solving and improvement methodology

2.4.1 8 Disciplines of problem solving (8D)

The 8D methodology involves teams working together in order to solve problems, using a structured 8 step approach to help focus on facts, instead of opinions (Riesenberger & Sousa, 2010). The 8D steps are:

- D1-team formation;
- D2-problem analysis;
- D3-containment actions;
- D4-root cause analysis;
- D5-corrective actions;
- D6-verification of the effectiveness of the corrective actions;
- D7-preventive actions;
- D8-congratulate the team.

The 8D methodology is effective in developing proper actions in order to eliminate root causes and in implementing the permanent corrective actions to eliminate them. It also contributes to explore the system of control that allowed the escape of the problem. There are reports of the successful use of this methodology to deal with chronic recurring problems, mainly defects or warranty issues. As a whole, this methodology was never intended to replace a systemic quality system. The 8Ds' objective is to face the problems and discover the weaknesses in the management systems that permitted the problem to occur in the first place. Please refer Appendix A for a sample of 8D report.

2.4.2 4 Quadrants (4Q) Methodology

4Q is data driven problem solving process for continuous improvement also called 4Q improvement methodology that was developed and applied in ABB company in 2009 to stop fights between Lean, Six Sigma DMAIC, PDCA, 8D and other promoters arguing superiority of one approach against the other (Jevgeni & Eduard, 2014). 4Q stands for the 4 quadrants: Measure, Analyze, Improve and Sustain.

Q1 - MEASURE	Q2 - ANALYZE
Define opportunity. Investigate to understand the current state in detail.	Identify and confirm root causes if the problem.
Q4 – SUSTAIN	**Q3 - IMPROVE**
Maintain the improvements by standardizing the work methods or processes.	Develop, pilot and implement solutions that eliminate root causes.

Figure 2.1: 4Q methodology

The 4Q process is a problem solving method similar to Six Sigma DMAIC. In 4Q the Define step is a part of Q1 Measure and also part of the trigger that starts a 4Q project. Table 2.2 presents the basic description of 4Q steps.

Table 2.2: 4Q steps

Pre 4Q	Q1 MEASURE	Q2 ANALYZE	Q3 IMPROVE	Q4 SUSTAIN
• Develop, draft problem statement • Take immediate action • Identify initial project scope • Create business	• Form a team • SIPOC process map • Capture VOC & translate to CTQ • Stakeholder map	• Analyze variation • Analyze waste • Identify root cause • Document root causes on Cause & Effect	• Brainstorm solution • Select optimum solutions • Conduct pilot study (or Risk Analysis) • Verify &	• Select control techniques (SPC) • Standardize via documentation • Develop control metrics (KPI's)

case • Determine objectives • Create project charter	• Communication & project plan • Collect data • Calculate baseline process performance • Revisit problem statement	diagram • Select top 3 root causes • Validate selected root causes as actual root cause	validate improvements • Review stakeholder map & common plan • Implementation & solution plan • Implementation actions on solution plan	• Monitor progress • Validate improvements in process performance • Share lessons learnt • Thank the team • Celebrate success • Close project

2.4.3 Toyota's A3 Problem Solving Process

The A3 report was first discovered by Toyota Motor Corporation. The report was named by the A3 sized paper (11"×17" inches) and Toyota believes that when structuring problem solving around one page of paper, then the thinking is focused and structured. To comprehend the A3 reports and the thinking behind them requires a good understanding of the Plan-Do-Check-Act (PDCA) cycle. PDCA is a high-level methodology for continuous improvement that has long been a basic element of the Total Quality Management (TQM) (Sobek & Smalley, 2008).

The A3 report is simple and consists of seven sections, which are:

- Background
- Current condition and problem statement
- Goal statement (Measurable objectives)
- Root-cause analysis
- Countermeasures
- Check/confirmation of effect
- Follow-up actions

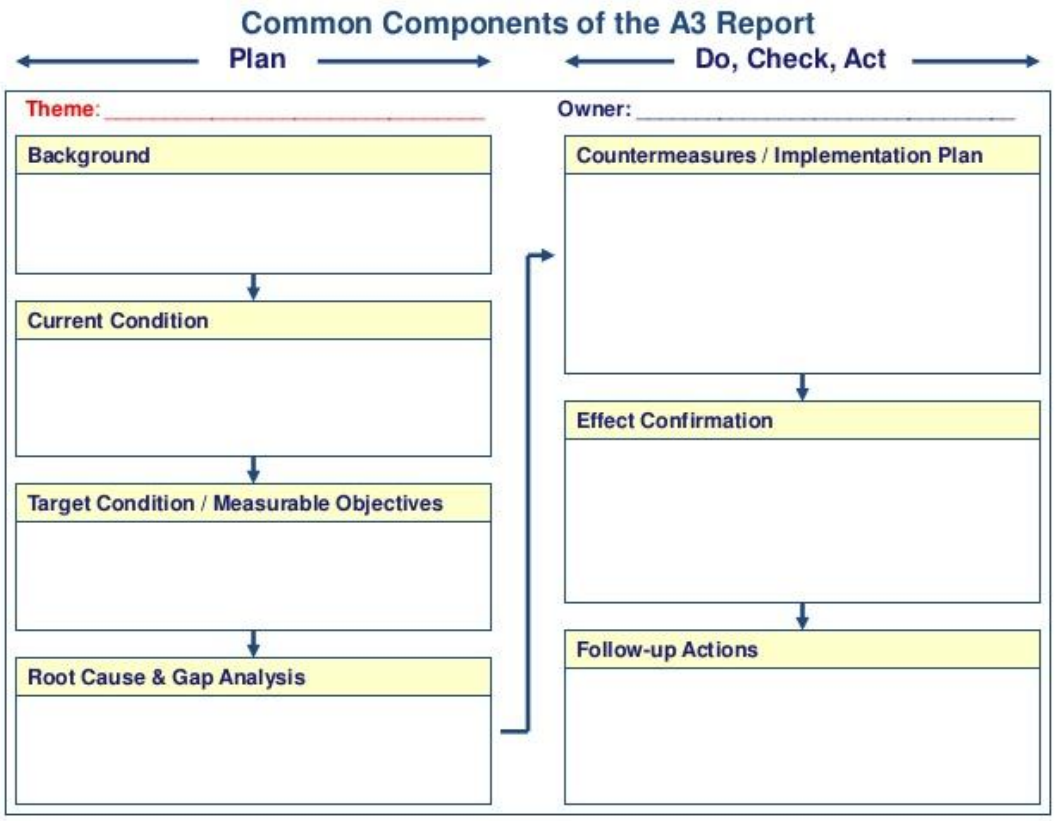

Figure 2.2: A3 problem-solving template

This report offers as mechanisms for managers to mentor others in root-cause analysis and scientific thinking. Moreover, the content ideally depicts a systems viewpoint on what it is best for the current situation.

2.5 Quality improvement framework to develop a quality report

2.5.1 Definition of framework

In general, framework presents a structure of the process, ideas, and methods to create a system or concept, usually in a simplified form. Different writers have different definitions. Some writers refer to framework as being a prescriptive set of things to do. Others describe the framework through diagrams, charts and other sorts of pictorial forms. The wide perspectives on framework make no specific definition as long as the framework implementer meets the objective to create an effective and easy to be used framework.

Thawesaengskulthai (2010) stated that a set of framework needs to integrate and combine similar activities. Frameworks can be a useful way in guiding improvement direction, clarifying the contribution and effectively managing all the initiatives to the organization vision. Secondly, organization designs the framework based on successful improvement to formulate a new system and ideas to perfection. He also stated that framework is an empirical research to justify rational improvement actions. This statement was agreed by Carpinetti et al. (2003) who said that conceptual framework is prioritizing actions to develop strategic decisions. Activities have to be connected and logically ordered with the support of value-adding chain to develop or manage quality and improvement actions.

In conclusion, the term “framework” has a functionality as mentioned by Rouse and Putterill (2003) who said that framework is a useful way to provide prescription and direction for guiding purposes as well as become a model towards the concept and system representation.

2.5.2 The importance of building a framework in developing quality report

Industries nowadays are facing competitive environments especially in expanding economic gain by finding initiatives to create improvement steps. Bunch of quality tools, standards, methodologies are available to be integrated in meeting the need of the company. In the previous point, "framework" was introduced as one of the effective initiatives to drive process improvement. Jevgeni et al. (2015) said that many issues in manufacturing companies are caused by the situation where the problem was not understood. In the end, the company is not anymore close to the customer's expectation and requirement. Thus, the authors emphasize that the use of a conceptual framework is necessary in having a systematic and effective improvement.

The concern of adapting framework in the quality or process improvement has been widely agreed by many researchers. For instance, Thawesaengskulthai (2010) presented a holistic framework in selecting Quality management (QM) and improvement actions. Companies are now pressured towards continuous improvement (CI) and have the desire to achieve high performance and organization excellence. Thus, structured improvement initiatives like a "framework" must be adopted by managers. Through the framework, the company can easily organize and brainstorm desired tools or methodologies which are suitable to deal with manufacturing problems.

In addition, the approach to process improvement framework will describe quality reporting since the approach or concept must have purposes in such a way organized in the designed framework (Koning and Mast, 2006).

Several authors were found to share the related points of the importance of developing framework closely as discussed below:

- A framework can present a theoretical development in the process improvement actions. The prioritization of improvement approach is based on measurement and analysis (Bendell, 2005).
- A framework is able to provide consistent and accurate support on selected knowledge applied in the integrated models. Not only illustrating the model, framework can also be a tool in leading process improvements in the field (Huertas-Quintero et al., 2011).
- A framework will highlight the root cause for arising problems through supportive methodology. The challenge to realize improvement can be considerately helped via a structured concept (Hicks and Matthews, 2010).
- A framework can easily control the improvement process and empower the gaining of selected knowledge. This author also agreed on the ability of framework to prioritize approach specifically in the root cause analysis (Mandal, 2012).
- Support business process re-engineering by being a consultant program in a particular idea. Moreover, framework clearly improves process focus by its structured features (Grover and Malhotra, 1997).

In short, the developed framework offers loads of advantages towards process improvement. Therefore, having a framework which is the "brain" of a successful report is a priority before creating a quality reporting documentation. The framework will structure the report accordingly to the knowledge, tools or methods applied in a more systematic manner.

2.5.3 Framework and quality reporting requirements

Firstly, this section will review the framework requirement and then later on highlight the important points of developing a quality reporting document. A framework is normally designed with the purpose of showing clear flow of required actions to achieve project goals. Rouse and Putterill (2003) said in order to support the implementation, a framework must consist not only an overview but also more detailed and clear information describing the content of each element and relationship between the elements. For instance, several reviews on the framework requirements can be concluded as follows:

1) Present a clear streamline on the proposed improvement actions (Furterer and Elshennawy, 2004);
2) Have a guided step, straight forward and easy to understand contents (Jones et al., 2010)
3) All steps or phases are well-integrated (Awwwards-team, 2016; Vootukuru, 2008)
4) The use of appropriate pictorial diagram to relate every point or step (Mishra and Sharma, 2014)
5) Represent a roadmap for implementation (Pohl, 2010).

Moreover, Yusof and Aspinwall (2000) also agreed on the above points and listed several points to design good framework such as 1) systematic and can be easily understood; 2) simple structure; 3) general enough to suit different contexts; 4) representing a roadmap and planning tools for implementation; and 5) having guided steps between the elements. In conclusion, several important points as listed above are required to generate an effective and useful framework.

Secondly, this section will review the requirements of building quality reporting documents. A report is supposed to reflect the designed framework to illustrate the framework goals into a report for better implementation and results. According to the ISO 9001:2015 standards (ISO, 2015), there are some guidance on the requirements for documented information. Below are some of the important points highlighted:

1) The document (referred here as the report) is applicable to various types of industries regardless of the size of the organizations;
2) Details of documentation is relevant to the desired results of the improvement process;
3) The report is able to cope with the organization's quality management system (QMS) while adding value to the QMS such as procedures, specifications, quality plans, strategic plans, test, and inspection plans and others.

For the report formatting, generally, the document must be understandable. Here, AHRQ (2016) has listed tips on creating appealing reporting documents which are: 1) clear on the purpose of the report through appropriate design ideas; 2) easy to read; 3) considers the use of visuals and colors to reinforce the content; 4) highlights the main points and easy to be operated; 5) formats relevant charts and diagram in a simple yet effective way.

Apart from the above points, the report must convey terms or details from previous reports (e.g., part number and reference number) so that practitioners will be able to cope and work through the report guidance as in Appendix A.

2.6 Process improvement frameworks and concept

In this section, previous studies related to the quality and process improvement frameworks and concept are reviewed. The frameworks studied were from various researches, industries and organizations but all were classified in the problem-solving methodologies. The reason for doing such reviews is to choose a better framework in forming the new framework. Later on, the review will be summarized based on the requirements of a framework.

2.6.1 Plan-Do-Check-Act (PDCA) Cycle

The PDCA, also called as the "Shewhart cycle" was created by Walter Andrew Shewhart in 1939. Later on, the cycle was made popular by the guru of modern quality control, Dr. William Edward Deming in 1950s and famous by the name of "Deming cycle" (Moen and Norman, 2009).

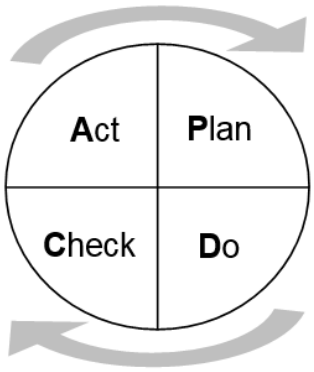

Figure 2.3: PDCA cycle (Sokovic et al., 2010)

PDCA is basically a continuous improvement framework which consists of a four-step approach, acronym for Plan, Do, Check and Act. This framework is commonly used in organization culture as a tool to improve and control process or product that involves repetitive work. PDCA has a simple approach which is potential for defining and developing a new improvement process. The framework

mainly provides a general phase outline which allows users to add appropriate steps into each phase. The advantages of the PDCA framework are: (1) straightforward and easily understood; (2) all well-integrated phases; and (3) suitable for broad application.

However, the simplicity of the PDCA cycle makes performing the process improvement difficult as the framework does not provide any supporting component information. The framework assumes users to have knowledge of the process improvement and PDCA methodologies, or in other words, the framework urges implementers to think out of the simple methodology, which surely can be gained by the experienced ones but not a new practitioner.

2.6.2 DMAIC Process Improvement Framework

The DMAIC methodology is one of the Six Sigma quality initiatives initially developed by Mikel Harry and Bill Smith from Motorola in 1987. DMAIC is the acronym for Define, Measure, Analyze, Control and Improve. After a few decades, the DMAIC methodology which is part of the Six Sigma tools has been widely applied by many companies. The achievement, successful case studies and lots of other applications have proven the effectiveness of these quality tools. By not majoring only on quality, the DMAIC methodology benefits various industrial problem-solving cases. The focus of this methodology is the strategy to resolve problems and improve processes basically driven by the data (Maleyeff and Kaminsky, 2002).

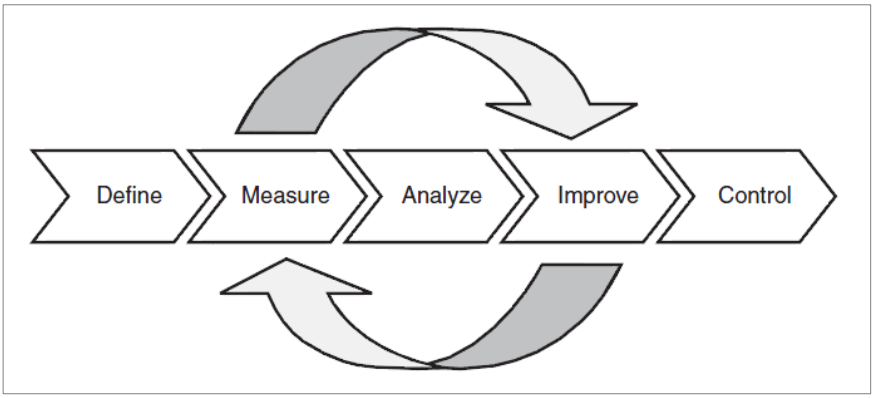

Figure 2.4: DMAIC Methodology (Hambleton, 2007)

Define: problem selection and benefit analysis
D1. Identify and map relevant processes
D2. Identify stakeholders
D3. Determine and prioritize customer needs and requirements
D4. Make a business case for the project

Measure: translation of the problem into a measurable form, and measurement of the current situation; refined definition of objectives
M1. Select one or more CTQs
M2. Determine operational definitions for CTQs and requirements
M3. Validate measurement systems of the CTQs
M4. Assess the current process capability
M5. Define objectives

Analyze: identification of influence factors and causes that determine the CTQs' behavior
A1. Identify potential influence factors
A2. Select the vital few influence factors

Improve: design and implementation of adjustments to the process to improve the performance of the CTQs
I1. Quantify relationships between Xs and CTQs
I2. Design actions to modify the process or settings of influence factors in such a way that the CTQs are optimized
I3. Conduct pilot test of improvement actions

Control: empirical verification of the project's results and adjustment of the process management and control system in order that improvements are sustainable
C1. Determine the new process capability
C2. Implement control plans

Figure 2.5: Reconstruction of DMAIC methodology (de Mast and Lokkerbol, 2012)

The strengths of the framework are 1) Simple and easily understood; (2) all well-integrated steps; (3) suitable for broad application; and (4) represent a roadmap for implementation. Besides, DMAIC also proposes a clear methodology to assist practitioners and suggest several tools towards the better implementation.

2.6.3 Raytheon Six Sigma framework

The Raytheon Six Sigma framework as shown in Figure 2.6 was established by Danial Burnham from Allied Signal in 1998 (Michael, 2004). This framework proposes six steps in guiding projects, which are visualizing, committing, prioritizing, characterizing, improving and achieving. This framework is considered new in the industries and keeps on developing its successful achievement from time to time.

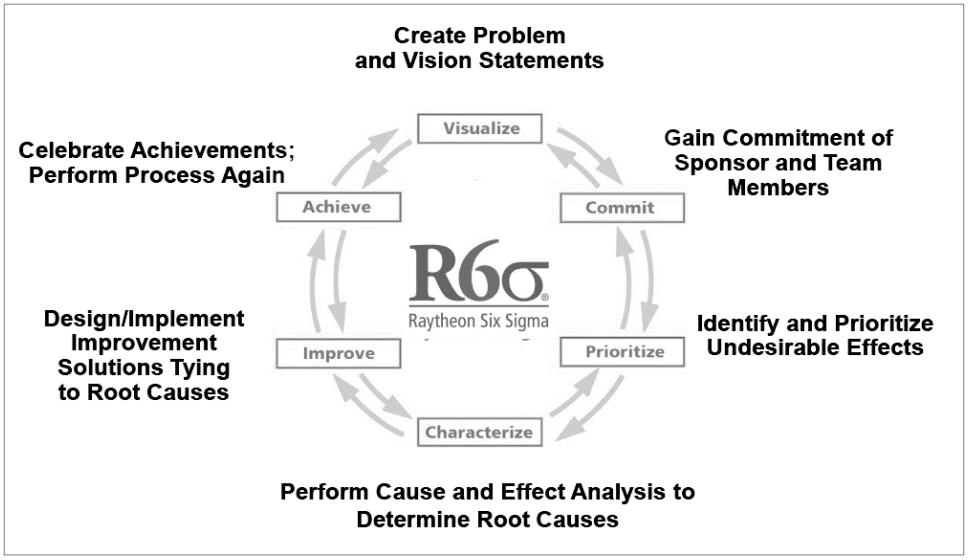

Figure 2.6: Raytheon Six Sigma Six Step Process (Raytheon, 2014)

This framework is a knowledge-based process to maximize customer value through the changes of recent culture. The vision of Raytheon Six Sigma consists of three main aspects which are building new culture, increasing productivity and growth. The focus then elaborates specifically on the main vision (i.e. build new culture) which are (1) customer focus; (2) eliminate waste; (3) knowledge-based in all levels; and (4) entrust workforce (NASA, 2002).

Figure 2.6 shows that this framework 1) has all well-integrated steps; (2) is suitable for broad application; and (3) represents a roadmap for implementation.