Project Dissertation Report on

PROCESS IMPROVEMENT IN SOFTWARE COMPANIES USING SIX SIGMA

Submitted By :
Abhishek Dhiman
(2K19/EMBA/501)

Under the Guidance of:

Mr. Yashdeep Singh

(Assistant Professor)

DELHI SCHOOL OF MANAGEMENT

Delhi Technological University

Bawana Road, Delhi - 110042

Jan - May 2021

CERTIFICATE

This is to certify that the dissertation report titled **PROCESS IMPROVEMENT IN SOFTWARE COMPANIES USING SIX SIGMA** is a bonafide work carried out by of Abhishek Dhiman **EMBA 2019-21** and submitted to Delhi School of Management, Delhi Technological University, Bawana Road, Delhi-42 in partial fulfillment of the requirement for the award of the Degree of Masters of Business Administration.

Signature of Guide
(DSM)

Signature of Head

Seal of Head

Place : NEW DELHI
Date : 20TH MAY 2021

DECLARATION

I, **Abhishek Dhiman**, student of **EMBA 2019-21** of Delhi School of Management, Delhi Technological University, Bawana Road, Delhi – 42, hereby declare that the dissertation report **PROCESS IMPROVEMENT IN SOFTWARE COMPANIES USING SIX SIGMA** submitted in partial fulfillment of Degree of Masters of Business Administration is the original work conducted by me.

The information and data given in the report is authentic to the best of my knowledge.

This report is not being submitted to any other University, for award of any other Degree , Diploma or Fellowship.

Place : New Delhi **Abhishek Dhiman**

Date : 20th May 2021

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Abhishek Dhiman
(2K19/EMBA/501)

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CHAPTER1

INTRODUCTION

This chapter mainly discusses why we have chosen Six Sigma for their master thesis and what will be done in this field. The description is divided into four parts – Motivation, Aims and Objectives, Research Questions, and Research Methodology. And also, the outline of the entire paper is presented by the end of this chapter.

1.1 Motivation

In recent years, the companies and organizations around the world are showing great interests in quality. Six Sigma approach is a structured quantitative method which is invented by Motorola in 1986 for improving the product quality. Its aim is to enhance organization's performance by using statistical analytic techniques. After two decades of successful implementation in manufacturing, Six Sigma is approved as an effective methodology for improving quality.

Nowadays, some researchers believe that Six Sigma can bring large benefits for software companies. Furthermore, software companies have already started to implement Six Sigma approach, like Ericsson, Tata Consultancy Service, etc . However, there are still some problems and misconceptions existed about the applicability of Six Sigma in software companies.

Our work can help to debunk the misconceptions about the applicability of Six Sigma in software companies. And provide steps for software companies to implement Six Sigma. The scope of this paper is demonstrated in Figure 1.1 which shows the relationship between Quality and Six Sigma.

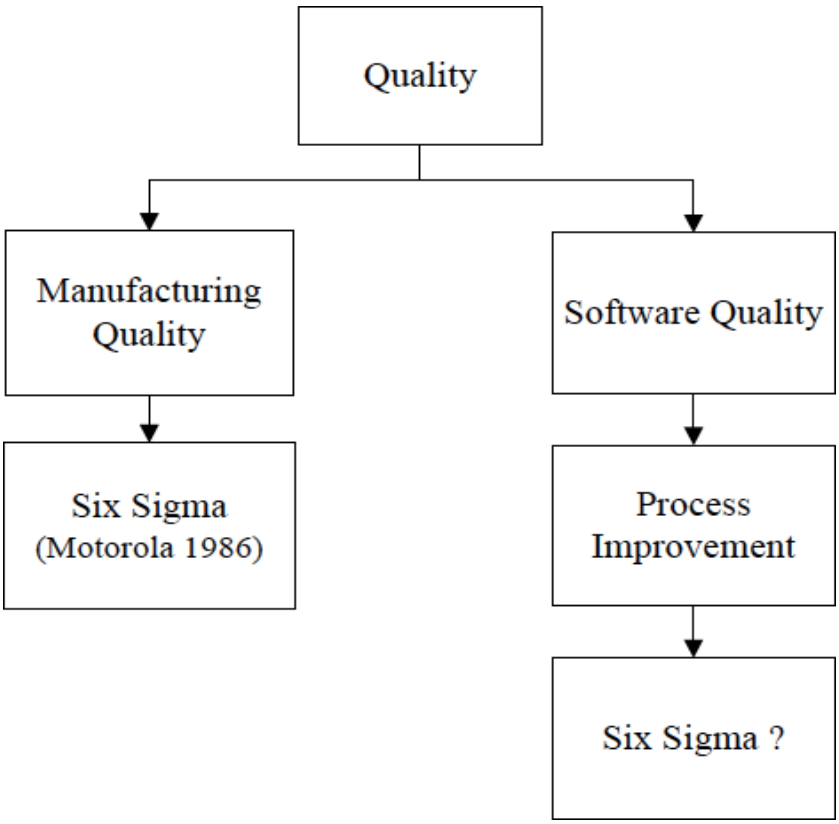

Figure 1.1 Relationships between Six Sigma and Quality

1.2 Aims and Objective

The main aim of this paper is to provide Steps for software companies who want to implement Six Sigma for process improvement. To achieve that, following objectives shall be reached

- Identify the differences of Six Sigma in manufacturing and software companies.
- Discuss the acceptance of Six Sigma in software companies.
- Compare the academic research results with the reality of software companies.
- Identify the state-of-art of Six Sigma in software.
- Screen out the suitable Six Sigma tools and techniques for software companies.
- Discuss the future work for Six Sigma in software companies.

1.3 Research Questions

- What are the definitions of Six Sigma?
- What is the condition of Six Sigma in manufacturing?
- Are there any hurdles when we implement it to software companies?
- Why software companies choose Six Sigma?
- What kind of tools and techniques are used in Six Sigma?
- Which of them are suitable for process improvement in software companies?
- "What is the state-of-art for the implementation of Six Sigma in software?
- What are the steps to implement Six Sigma in software companies for process improvement?
- What is the further work for Six Sigma in software?

1.4 Research Methodology

A mixed methodology will be used which include both qualitative and quantitative research has been used for research.

In the qualitative research methodology part, a detailed and comprehensive literature study have been carried out. The literature study consists of articles, books, web materials, discussion forms and others. The literature study is used to find out the characteristics of Six Sigma, the tools and techniques used in Six Sigma, and to analyze the suitability of these tools and techniques for process improvement in software companies. A list of tools and techniques have been provided, which are helpful for Six Sigma implementation. With the help of the literature study, the condition of Six Sigma in manufacturing has been identified. After completely understanding the usage of Six Sigma in manufacturing, the research moved to follow research questions – applicability of Six Sigma in software and why software companies choose Six Sigma for process improvement. In order to answer these research questions, different views which provided by software specialists have been discussed. Then authors

analyzed the difference between manufacturing process and software process. Once the differences are clear, we can easily find out the applicability of Six Sigma for software.

In the quantitative research methodology part a case study are reviewed. Before interview, we have made enough preparations which include company background investigation, question list preparation, and some interview skill learning. To have a best communication, a quite environment and one backup phone have been prepared.

Regarding question list, it was generated after Six Sigma approach studying and company background learning. The motivation behind the interview was firstly to understand how Six Sigma is implemented in a manufacturing company. Secondly how Six Sigma improves a particular manufacturing process. The case study shows how a particular manufacturing process is improved using Six Sigma. Secondly, to understand how Six Sigma is implemented in Software Company & how it improves particular software processes.

CHAPTER 2

INTRODUCTION TO QUALITY AND SIX SIGMA

In recent decades, the companies and organizations around the world are showing great interests in quality. Especially in 1970s and 1980s, the success of Japanese industry stimulates the whole world to focus on quality issues. The experience from them proved that the requirements and expectations of customers are the key factors which decide the quality.

2.1 Definition

The word "quality" comes from the Latin "qualitas", and Cicero (a roman orator and politician, 106-43 B.C.) is believed to be the first person who used the word . Until the a few decades before, the concept of quality has been significantly extended as we know it today. There were many popular definitions for quality concept. Table 2.1 lists some of them.

Year	Definer	Definition of quality concept
1931	Walter Shewhart	*"...there are two common aspects of quality. One of these has to do with the consideration of the quality of a thing as an objective reality independent of the existence of man. The other has to do with what we think, feel or sense as a result of the objective reality. In other words, there is a subjective side of quality".*
1951	Joseph Juran	*"Fitness for use".*
1979	Philip Crosby	*"Conformance to requirements".*
1979	Genichi Taguchi	*"The losses a product imparts to the society from the time the product is shipped".*
1985	Edwards Deming	*"Quality should be aimed at the needs of the customer, present and future".*

1990	Myron Tribus	*"Quality is what makes it possible for a customer to have a love affair with your product or service."*
2000	ISO 9000: 2000	*"The degree to which a set of inherent characteristics fulfills the requirements, i.e. needs or expectations that are stated, generally implied or obligatory".*
2004	Bengt Klefsjöand Bo Bergman	*"The quality of a product is its ability to satisfy, and preferably exceed, the needs and expectations of the customers".*

Table 2.1 Definitions of quality concept.

From the definitions above, we can find some interesting common points. Firstly, almost all factors are conducted around customers. In another word, it can be said as *customers decide the quality* (e.g. Juran in 1951, Deming in 1985, and Tribus in 1990). Secondly, according to customer, two things are commonly considered as which shall be fulfilled – customer requirements and customer expectations. The requirements are what customers request and demand. These are the basics of the quality. The expectations are what the customers expect and look forward to. Sometimes, the customers do not know what they really need. So that demands developers to have a good understanding about the customer minds.

Although the definitions in Table 2.1 are similar, they also have distinctions which make them different. For example, "*fitness to use*" (Joseph Juran, 1951) is defined from end user's view. In contrast, Philip Crosby (1979) defined the quality as "*Conformance to requirements*" from producer's view. The reason is their backgrounds are different.

Gavin conducted a further identification of these differences in 1984. Five approaches to the quality concept are claimed which include transcendent-based, product-based, user- based, manufacturing-based, and value-based, see Figure 2.1. From transcendent-based view, the quality can be identified by

experience. Mostly is very successful. But from this point of view, the quality is not defined very clearly. This problem can be solved by product- based approach. The quality can be exactly defined and measured. However, the cost for quality cannot be judged by customer. User-based approach's opinion is that the quality is decided by customer. Customer's satisfaction is the only scale which reflects product quality. Manufacturing-based perspective relates to accomplish the requirement specification. Reducing defects is the main task of quality improvement. According to value-based approach, the quality relates to cost and price. Generally price is decided by cost. A high quality product means that the customers are willing to pay for it. In Gavin's view, an organization cannot have just one approach for the quality concept, but that different parts of organization need different approaches.

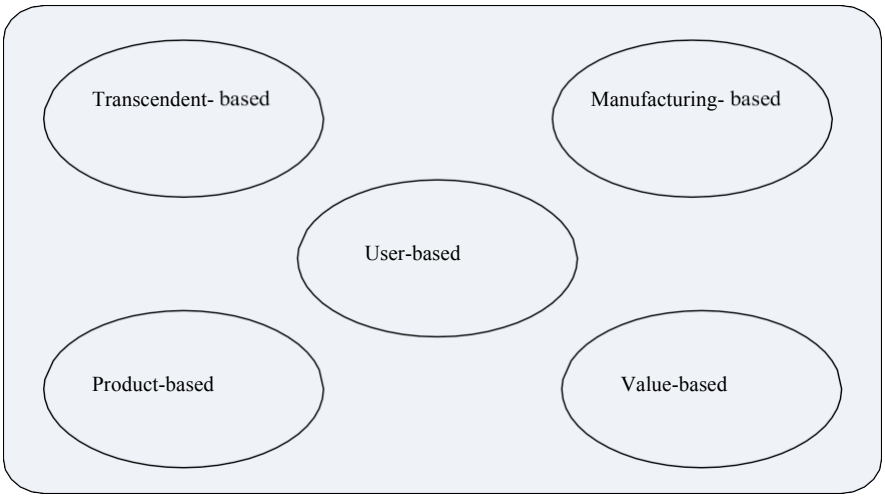

Figure 2.1 Five approaches of quality concept from Gavin (1984)

In quality issues, customer plays one of most important roles. A high quality product shall fulfill customers' requirements, and satisfy their expectations. Due to Gavin's theory, there are several approaches for quality concept. An organization cannot have just one approach, but it uses different approaches in different parts.

2.2 Why Quality Improvement

"Quality is free. It is not a gift, but it is free. What costs money are in-quality things - all the actions that involve not doing jobs right the first time." – Philip Crosby.

Many companies pay a lot in correction, i.e. 80% of the cost in a Software Engineering (SE) project is commonly related to after-delivery corrections. And we also found

- Unsatisfied customers tell in average 10 persons about their bad experiences. 12% tells up to 20 other persons.
- Satisfied customers tell in average 5 persons about their positive experiences.
- It costs 5 times as much to gain new customers than keeping existing ones.
- Up to 90% of the unsatisfied customers will not make business with you again, and they will not tell you.
- 95% of the unsatisfied customers will remain loyal if their complaints are handled fast and well.

All above motivate us to improve quality. Improved quality can affect the success in many different ways:

- More satisfied and loyal customers
- Lower employee turnover and sick leave rates
- A stronger market position
- Shorter lead times
- Opportunities for capital release
- Reduced costs due to waster and rework
- Higher productivity

Figure 2.2 demonstrates the importance of quality which expressed by Deming in 1986. In this figure, Deming connects improved quality with company prosperity.

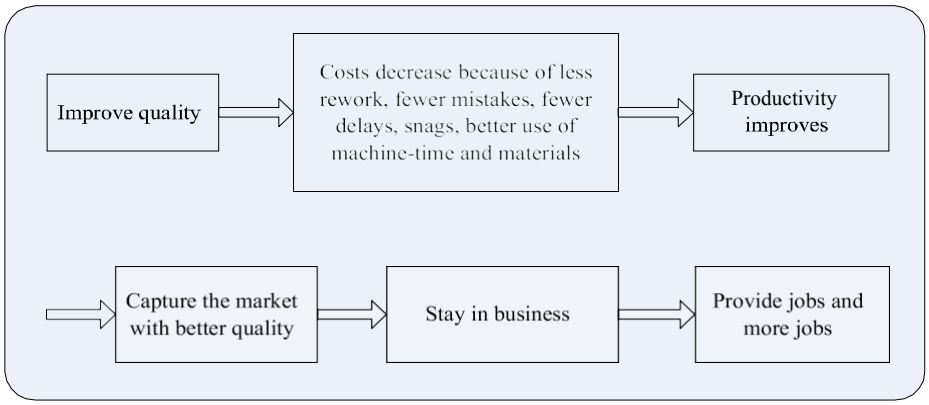

Figure 2.2 The importance of quality from Deming

As we seen, improving quality does not mean losing money in business. Proper improvement will bring organizations much more benefits.

2.3 Software Quality

Modern society is highly dependent on software products, i.e. bank system, telephone network, supermarket system, etc. As said by the general public usually blamed the computer", making no distinction between hardware and software. However, millions facts of software failures alert us to focus on software quality in everyday lives. Today, software customers are demanding higher quality and are willing to pay a higher price for it. Improving quality has become the common goal of each software development phase.

Similar with general quality concept mentioned in Section 2.1, high quality software shall have following factors :

- Developing in the right way
- Matching the requirement specification
- Good performance meeting customers expectations
- Fitness for use

Combining with Gavin's five approach of quality concept , Kitchenham and Pfleeger describe software quality in another way:

- *Transcendental view* – Software quality is thought as an ideal, but may never implement completely.
- *User view* – High quality software shall meet the users needs, and have a good reliability, performance and usability.
- *Manufacturing view* – This view focuses on product quality during production and after delivery to avoid rework. Adopted by IS0 9001 and the Capability Maturity Model, the manufacturing approach advocates conformance to process rather than to specification. Hence, to enhance product quality, improving your process is very much essential.
- *Product view* – Be different with above views, product view assesses quality by measuring internal product properties. Software metrics tools are frequently used.
- *Value-based view* – High quality product always means a high cost. Different product purchasers always have the different value view. So that this approach puts much more efforts on considering the trade-offs between cost and quality.

Different views can be held by different groups involved in software development, i.e. customers or marketing groups have a user view, researchers have a product view, and the production department has a manufacturing view. It is not enough that only one view is identified explicitly. All views influence each other. Measuring each view clearly is one of assurances for high quality.

2.4 Software Process Improvement

Based on five approach of quality concept, process improvement aims to have a better control in software development. Managers or organizations generally divide the whole project into smaller phases, such as requirement analysis, planning, coding, testing, releasing, etc. These phases are known as the Software Project Life Cycle (SPLC). Within each project phase, we use iterative processes to achieve phases deliverables. Figure 2.3 shows a typical iterative of project processes. Project processes are distributed into five groups – initiating process group, planning process group, executing process group, monitoring and controlling process group, and closing process group.

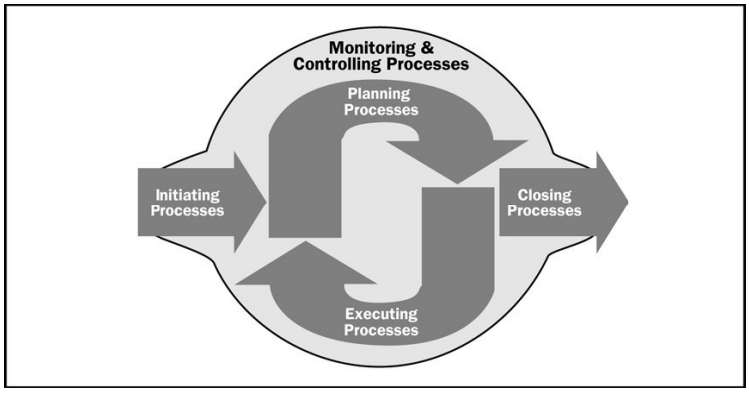

Figure 2.3 A typical project processes cycle

Quality in a software product can be improved by process improvement, because there is a correlation between processes and outcomes. As defined by IEEE, process

is a sequence of steps performed for a given purpose. It provides project members a regular method of using the same way to do the same work. Process improvement focuses on defining and continually improving process. Defects found in previous efforts are fixed in the next efforts. There are many models and techniques for process improvement, such as CMMI, ISO9000 series, SPICE, Six Sigma, etc.

CHAPTER 3

Six Sigma

History

In 1980s, Bob Galvin the CEO of Motorola was trying to improve the manufacturing process. The Senior Sales Vice President Art Sundry at Motorola found that their quality is extremely bad. They both decided to improve the quality. Quality Engineer Bill Smith at Motorola in 1986 invented Six Sigma. It was applied to all business processes. In 1988 Motorola Won the Malcolm Baldrige Quality Award, as a result other organizations were also interested to learn Six Sigma. Motorola leaders started teaching Six Sigma to other organizations. Initially Six Sigma was invented to improve the product quality by reducing the defects, but later Motorola reinvented it. The new Six Sigma is beyond defects, it focuses on strategy execution. It became a management system to run the business. It was invented for an improvement in manufacturing industry but now it is applied in almost every industry i.e. Financial Services, Health care and Hospitality. Originally Six Sigma was introduced in United States but now it is in applied in many countries around the world.

3.1 Definition

Six Sigma is a structured quantitative method which is originally invented for reducing defects in manufacturing by Motorola in 1986. Its aim is using statistical analytic techniques to enhancing organizations performances, and to improving quality. Since Six Sigma has evolved over the last two decades, its definition is extended to three levels

- Metric
- Methodology

- Management System

Six Sigma approach satisfies all the three levels at the same time. Those levels are discussed in the following sections.

3.2 As a Metric

"Sigma" is the Latin symbol "σ". Here we use it to symbolize how much deviation exists in a set of data, and that is what we called *standard normal distribution*, or the *bell curve*. The normal distribution, also called the *Gaussian distribution*, is used for continuous probability distributions, see curves in Figure 2.4. The probability density function is shown as below – "μ" is the mean and "σ^2" is the variance.

$$\frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

The standard normal distribution is the normal distribution with a mean of zero and a variance of one (the green curve in Figure 2.4). From the figure, we can see that in a standard normal distribution, 50% of the values are under the mean and 50% of the values are above the mean.

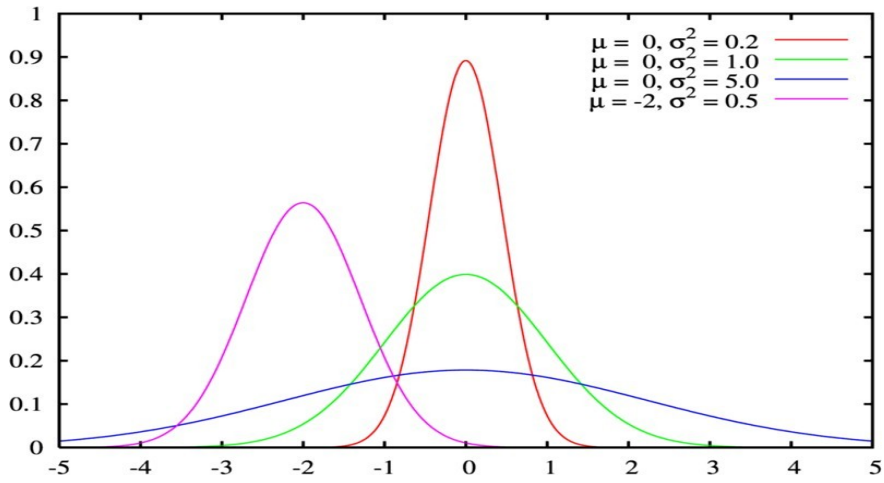

Figure 2.4 Normal distributions [32].

"In Six Sigma approach, Sigma is used as a scale for levels of process capability or quality. According to that, Six Sigma equates to 3.4 Defects Per Million Opportunities (DPMO). Therefore, as a metrics, Six Sigma focuses on reducing defects.

Figure 2.5 demonstrates how Six Sigma measures quality. In the figure, if we achieve 68% of aims, then we are at the 1 Sigma level. If we achieve 99.9997% of aims, then we are at the 6σ level which equates to 3.4 DPMO. From this point of view, Sigma level is to show how well the product is performing. It seems this level can never be achieved. However, the Sigma level is not our purpose, the real purpose is to improve quality continually. The higher Sigma level we have reach, the higher quality we get.

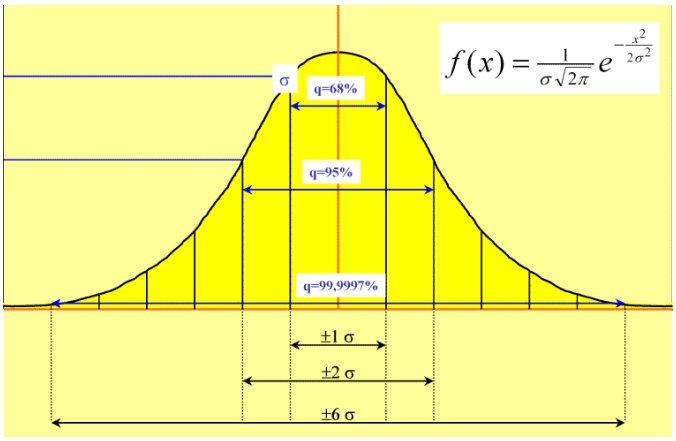

Figure 2.5 How Six Sigma measures quality

3.2. Sigma Level Calculation

The calculation of Sigma level is based on the number of defects per million opportunities (DPMO). The formula is

$$DPMO = 10^6 * D/ (N*O)$$

Where D means the number of defects, N means number of units produced, and O is the number of opportunities per unit. For example, a software company wants to measure their software product's Sigma level. In their product, there are 200,000 lines of code (LOC). For each LOC, the company performs one check to test the quality. During the testing, 191 defects are detected. Then we have DPMO = 10^6*191 / (200,000*1) = 955.

DPMO	Sigma Level
1,144	4.55
986	4.60
816	4.65

Table 2.2 A part of DPMO to sigma conversion table

3.3 As a Methodology

Six Sigma approach is not just counting defects in a process or product, but it is a methodology to improve processes. The Six Sigma methodology focuses on

- Managing the customer requirements
- Aligning the processes to achieve those requirements
- Analyzing the data to minimize the variations in those processes
- Rapid and sustainable improvement to those processes

When we look at Six Sigma as a methodology, there are many models available for process improvement like DMADV, DMAIC, Breakthrough strategy, Roadmap,

New Six Sigma, Eckes method, Six Sigma Roadmap, IDOV, and DMEDI. The most widely used models are DMAIC and DMADV. The DMAIC model is used when a process or product is in existence but is not meeting the customer requirements. And the DMADV model is used when a process or product is not in existence or is needed to be developed.

❖ DMAIC Model

Motorola implemented the first Six Sigma model called as MAIC (Measure, Analyze, Improve and Control). It was developed by Dr. Miakel Harry. This model was used to solve the already known quality problems. GE, unlike Motorola was unaware of their quality problem. They needed a model that can firstly map the real quality problems and then to solve them. Dr. Miakel Harry took advantage of his experience at Motorola and developed a new model DMAIC (Define, Measure, Analyze, Improve and Control) see Figure 2.6. Nowadays this model is mostly in Six Sigma implementation. The phases of DMAIC model are explained as follows:

- Define phase is to define the customers requirements and their expectations for product or services. To align the project goals with business goals. To define the project scope, the start and stop of the process.
- Measure phase is to develop a data collection plan for the current process. To collect data for the current process and to develop a measurement system. The measurement system is used to calculate the current performance of the process.
- Analyze phase is to find out the gap between the current performance and the goal performance. To analyze the collected data of current process and to determine the main factors of the poor performance. To find out the source of variation in the current process.
- Improve phase is to identify and select the right design solutions to fix the

problems. The set of solutions to improve the sigma performance are selected on the basis of root causes identified in Analyze phase.

- Control phase is to finally implement the solutions. To provide the maintenance of the improved process so that the improved Six Sigma process can run for a long time.

Figure 2.6 Phases of DMAIC model.

❖ DMADV Model

DMADV (Define, Measure, Analyze, Design and Verify) model was developed by Thomas Pyzdekis. This model is applied to the development of new processes or products. The phases of DMADV are described below.

- Define phase is to find out the customer needs and expectations and to define the project scope.
- Measure phase is to identify the CTQs (critical to qualities), process capability and risk assessment.

- Analyze phase is to develop the high level design concepts and design alternatives To select the best design.
- Design phase is to develop plans for test verification, this may require simulations.
- Verify phase is to implement the process in operational scale.

3.4 As a Management System

Through experience, Motorola has found that using Six Sigma as a metric and as a methodology are not enough to drive the breakthrough improvements in an organization. Motorola ensures that Six Sigma metrics and methodology are adopted to improve opportunities which are directly linked to the business strategy. Now Six Sigma is also applied as a management system for executing the business strategy.

Six Sigma approach provides a top-down solution to help the organization. It put the improvement efforts according to the strategy. It prepares the teams to work on the highly important projects. It drives clarity around the business strategy.

3.5 Summary

Nowadays, the quality property of product is becoming much more important than it before. To examine the quality, we should consider different approaches which include customer, transcendent-based, product, manufacturing, and product value. Not all approaches shall be used in one product, but we use different ones in different parts.

Improving quality is not free. It costs a lot of money, time and resources. However, the benefits are also attractive. Not only increasing profits, but also can obtain

loyalty, stronger market position and lead time, reduced costs, higher productivity, and more job opportunities. Proper quality improvement does not mean losing money in business, it means future investment.

Software demands high quality. Five approaches should also be considered. Based on those approaches, process improvement is generated to fulfill them. It provides project members a regular method of using the same way to do the same work. Defects found in previous efforts are fixed in the next efforts. One brilliant method is Six Sigma.

Six Sigma approach have been invented for more than two decades. It is successfully and continually used in manufacturing. Now it was spread to many other fields all over the world. Six Sigma approach focuses on process improvement. After it was invented, Six Sigma definition has reached three levels – as a metric, as a methodology, and as a management system. As a metric, it aims to reducing defects. The highest level 6σ equates to 3.4 defects per million opportunities. As a methodology, it focuses on improving process. DMAIC and DMADV models are the most common used. As a management system, it combines the metric and methodologies for executing the business strategy, and aims to continuous improving product quality.

CHAPTER 4

TOOLS AND TECHNIQUES IN SIX SIGMA

This chapter mainly describes the tools and techniques which are used in Six Sigma process improvement projects. By using those tools and techniques, Six Sigma projects become easier and effective.

4.1 Introduction

Since the Six Sigma approach is invented, many old quality tools are adopted in Six Sigma process improvement project. At the same time, some new specific tools and techniques are introduced. In the chapter, those tools and techniques are distributed in two parts.

The first part is related to the most popular 7 Quality Control (QC) tools. They are Cause- effect Diagram, Pareto Chart, Flow Chart, Histogram, Check Sheet, Control Chart, and Scatter Plot. Those tools are original gathered by Kaoru Ishikawa in 1960s. After these yearsevolution and their easy-to-use property, 7 QC tools are applied in every quality improvement projects in various fields. In Six Sigma, they are extensively used in all phases of the improvement methodology (see Figure 3.1). The functionality of them is described in Section 3.2 in detail.

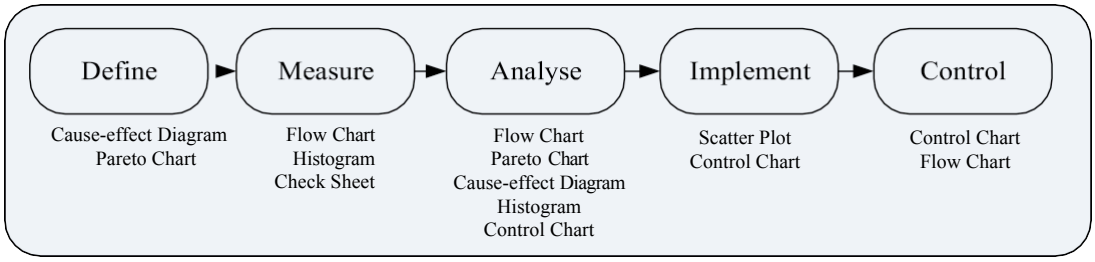

Figure 3.1 The distribution of 7 QC tools in Six Sigma

Another part is a collection of special tools which are frequently used in Six Sigma projects. We also associate them with the five phases of DMAIC methodology (see Figure 3.2).

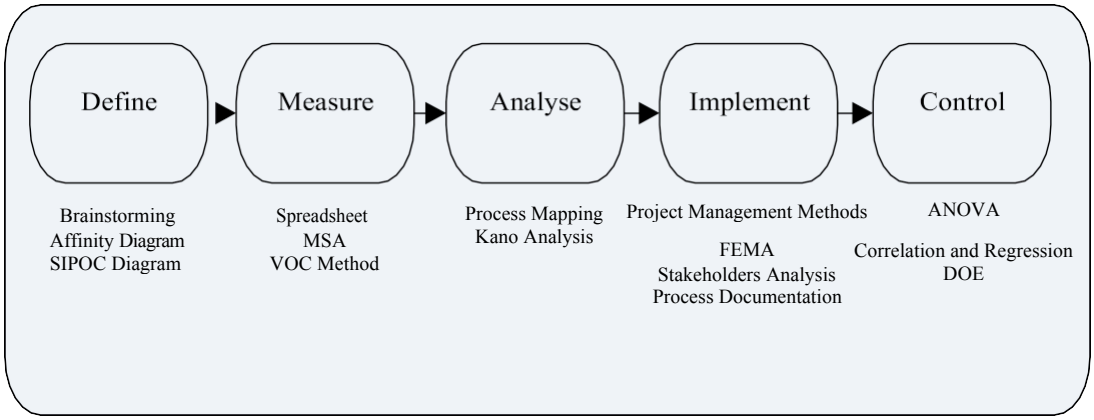

Figure 3.2 The distribution of other special tools in Six Sigma.

4.2 Seven Quality Control Tools

Seven quality control tools frequently used in Six Sigma projects are introduced in the following sections.

4.2.1 Check sheet

The check sheet is used to collect data of the desired characteristics of a process that should be improved. If the collected data is incorrect, most efficient methods will result in a failure. In Six Sigma methodology it is used in the measure phase. The check sheet is represented in a tabular form. The check sheet should be simple and aligned with the characteristics that are to be measured.

4.2.2 Histogram

Histogram is used in Six Sigma in the analyze phase. It is used to learn about the distribution of the data collected in the measure phase. Often we have huge data and each observation cannot be represented in figure. With the help of histogram the collected data is divided into different classes or intervals. The area of each rectangle in the histogram is proportional to the number of observations within each interval or class. So if we sum the areas of all rectangles it is equal to total number of observations.

When applying a histogram there should be at least 50 readings to get a good understandable shape of distribution. The number of intervals or classes should be between 6 and 12. To get the intervals it's good to take the difference of highest and lowest value in the data. If there are too many or too less data values or intervals then the histogram will be of a flat or peaked shape.

4.2.3 Pareto Chart

The Pareto chart was introduced by Joseph M. Juran in 1940s. Juran named it after the Italian statistician and economist Vilfredo Pareto (1848-1923). There are several quality problems to be addressed in a project. Often the problems are solved one by one. The Pareto chart helps in deciding the order of problems in which they should be solved. Pareto chart is related to the 80/20 rule found in business economics. The 80% of problems are because of 20% of causes.

In the Six Sigma methodology Pareto chart has two main functions. Firstly in the define phase it helps in the selection of the appropriate problem. Secondly in analyzes phase it helps in identifying the few causes that lead to many problems.

4.2.4 Cause and Effect Diagram

The cause and effect diagram is also known as fishbone diagram or an Ishikawa diagram. It was introduced by Dr Kaoru Ishikawa in 1943, while working in a quality program at Kawasaki Steel Works in Japan. Once we have a quality problem its causes must be found. Cause and effect Diagram helps to find out all the possible causes of an effect (problem). It is the first step in solving a quality problem, by listing all the possible causes. In Six Sigma it is used in the define phase and analyze phase.

The reason that Cause and Effect Diagram is also called Fishbone Diagram is that it looks like a skeleton of a fish. The main problem is the head of the fish, the main causes are Ribs and the detailed causes are the small bones.

4.2.5 Stratification

Stratification is used to divide the collected data into subgroups. These subgroups help in finding the special cause of variation in the data. It provides an easy way to analyze the data from different sources in a process. It is used very less as compare to other quality tools but it is beneficial. In the Six Sigma methodology it is used in the improve phase. The collected data is usually stratified in the following groups: machines, material, suppliers, shifts, age and so on. Usually stratification is done in two areas but if the data is large than further stratification is also possible.

4.2.6 Scatter Plot

Scatter plot is used to define the relationship between two factors. Its main function is to identify the correlation pattern. The correlation pattern helps in understanding the relationship between two factors. In Six Sigma methodology it is used in the improve phase. Once you know the relationship between the factors then the input factor values are set in a way so that the process in improved.

While constructing the Scatter plot the input variable is placed on the x-axis and

the output variable is placed on the y-axis. Now the values of the variables are plotted and the scattered points appear on the figure. These points provide the understanding of the variables and the process can be improved. Often there are many variables affecting the process, in this situation a series of scatter plots should be drawn.

4.2.7 Control chart

The Control chart was introduced by Walter A. Shewhart in 1924. Industry is using Control chart since the Second World War. It is also known as Statistical Process Control (SPC). In Six Sigma methodology it is used in analysis, improve and control phase. In analyze phase Control chart is helpful to identify that the process is predictable or not. In improve phase it identifies the special cause of variation. And in control phase it verifies that the process performance is improved.

It shows graphically the outputs from the process in different time intervals.

There are two main purposes of Control chart. First is the creation of a process with a stable variation. The second is to detect the change in the process i.e. alteration in mean value or dispersion.

4.3 Special Tools

Any technique which can improve process quality can be a Six Sigma tool. As said in above section, only seven QC tools are not enough for the whole Six Sigma projects. By investigating, we found many other tools which can also significantly help to improve process. Some of they are listed below

4.3.1 Brainstorming

As defined by Alex Osborn Brainstorming is a conference technique by which a group attempts to find a solution for a specific problem by amassing all the

ideas spontaneously by its members. It is designed to obtain ideas related to a specific problem as many as possible. It motivates people to generate new ideas based on themselves judgments. If the environment is comfortable and participants feel free to announce their minds, it will produce more creative ideas. To organize an effective and successful brainstorming, you shall follow steps below

- Define the problem which you want to solve. Only well defined problem could generate the best ideas. In contrast, an unclear defined problem will mislead participants.
- Set down a time limit and an idea limit. Generally the meeting is around 30 minutes to generate 50 to 100 ideas. It depends on the size of groups and the type of problem.
- There should be absolutely no criticism for any ideas. Everyone's ideas need to be written down even they are such impossible or silly. Try to keep everyone involved to develop ideas, including the quietest members.
- Once upon the limited time is over, select the best five ideas which everyone involved in the brainstorming agreed.
- Write down five criteria for judging which idea is the best one for the defined problem.
- Give each idea a score of 0 to 5 points which depends on how well the idea meets each criterion. Add up the scores when all ideas have been evaluated.
- The idea which gets the highest score is the best solution for the problem. At the same time, the other ideas shall be recorded as the alternatives in case the best one is not workable.
- Brainstorming is a great way to generate ideas. During the brainstorming process there is no criticism of ideas which is to motivate peoples creativity. Individual brainstorming can generate many ideas, but it is less effective for each ones development.

4.3.2 Affinity Diagram

The affinity diagram is developed by Kawakita Jiro, so it is also called KJ method. It is used to organize large number of data into logical categories. Generally, we use affinity diagram to refine the ideas generated in brainstorming which is uncertain or need to be clarified. To create an affinity diagram, we need to sort the ideas and move them from the brainstorm into affinity sets, and creating groups of related ideas. Below issues should be followed.

- Group ideas according to their common ground. The reason can be ignored.
- Using questions to clarify those ideas.
- If an idea has several characteristics, we should copy it into more than one affinity set.
- Combine the similar small affinity sets into one, and break down the complex sets.

The final result of affinity diagram shows the relationship between the ideas and the category, which can help brainstorming to evaluate ideas. And it is also considered the best method for the ideas without speaking.

4.3.3 High-Level Process Map (SIPOC Diagram)

SIPOC diagram is a Six Sigma tool which is used to identify all process related elements before we start to work. Predefine those factors can avoid we forget something which may influence the process improvement, especially in complex projects.

SIPOC is the logograms for “Suppliers, Inputs, Processes, Outputs, and Customers . All your works are to

- Identify suppliers and customers who will influence the projects.
- Obtain the inputs for processes from suppliers.
- Add value through processes.

- Provide outputs to meet customers requirements.

4.3.4 Measurement System Analysis (MSA)

Measurement System Analysis (MSA), or called Measurement Capability Analysis (MCA), is used to assess the capability of process measurement systems by using experimental and mathematical methods. The purpose is to improve your measurement system, to ensure the system provides the unbiased results with little variations.

Because every project has the different background, so that needs we modify our measurement system to meet customers needs. For example in tolerance measurement, it can be measured in millimeter, centimeter, decimeter and meter. MSA's job is to analyze customers needs, and select the appropriate measurement scale. Other factors which influence the measurement system are

- Cycle time
- Cost
- Stability
- Bias
- Linearity
- Response-to-Control (RtC) Variable Correlation and Autocorrelation
- Gage R&R (Repeatability and Reproducibility)

4.3.5 Voice of the Customer (VOC) Method

Voice of the customer method is a process to identify customers requirements for high quality product. The customers come from different fields. External customers usually are common customers, suppliers, product users, partners, etc. And internal customers include employees from market department, product development department, and so on.

There are several ways to capture the voice of the customer – individual or group interviews, surveys, observations, customer specifications, complaint logs, etc. Through these methods, we can get the stated or unstated needs from the customer. By assessing and prioritizing those collected requirements, it provides ongoing feedbacks to the organization.

4.3.6 Kano Analysis

Kano analysis is developed by Dr. Noritaki Kano, it is a quality tool which help to prioritize customer requirements based on their satisfaction. That is because all identified requirements are not equally importance. The result can help us to rank the requirements and identify the few critical ones which have the highest impact. Furthermore, it can help us to make the decision.

In Kano analysis model, there are three types of customer needs (see Figure 3.3).

- *Must-Be*. Must-be needs are the requirements that have to be met. The customers believe must-be needs are very basic which even do not have any necessary to discuss. For example, in a bank system, the deposit function and draw-out function are must-be needs.
- *Delighters*. Delighters are the needs which the customers do not expect. When those needs are met, the customers will be very happy. When user login the bank system, there are some bright music played in the background. However, he will still be angry when he cannot find any function related to the deposit. The delighters can only have the effects if and only if the must-be needs are met.
- *One Dimensional*. One-dimensional needs are the ones which need to be discussed and negotiated, such as the price. The customers will be more satisfied when the price falls. But on the other hand, the development company will be much unhappier.

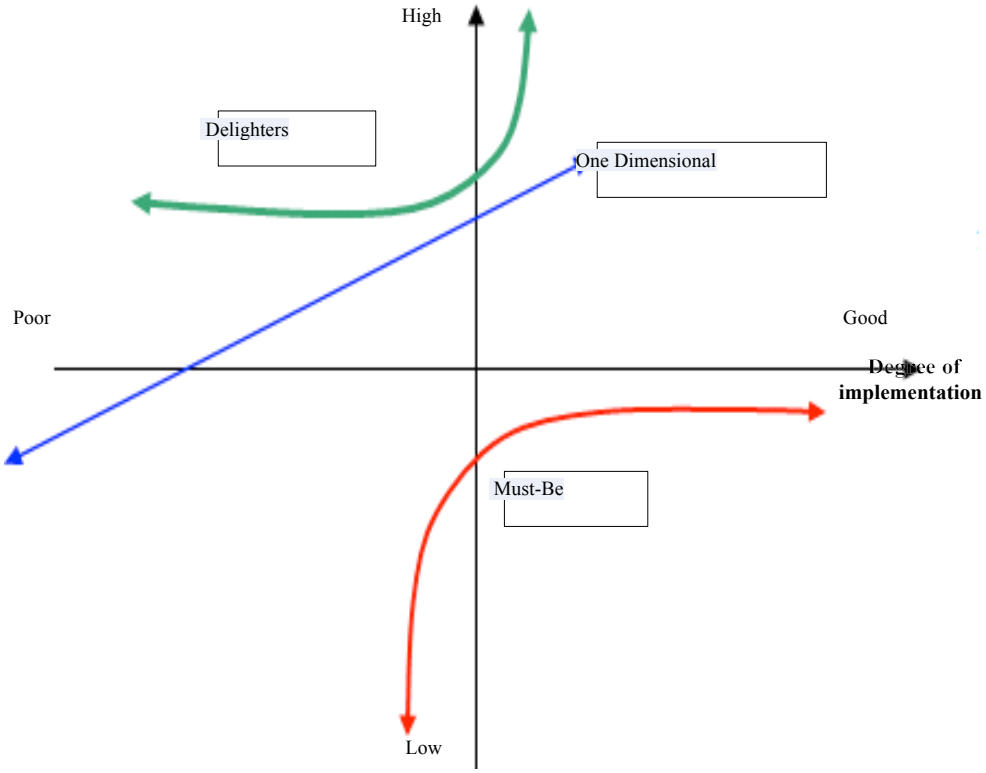

Figure 3.3 The Kano Analysis Model with three customer needs

Using Kano Analysis in Six Sigma project to understand customers' needs can help you to create more value for customers and make them satisfy with your produces and services. Furthermore, priorities of requirements are assessed. This can help the company to figure out what are the customers most concerned which close the relationship with customers.

4.3.7 The Others

The other methods are seldom used, but still very helpful. They are

- *Project Management Methods* – The project management skills can significantly help the Six Sigma improvement projects, such as project

planning, project charter, scheduling, communication, HR management, and project management tools.

- *Failure, Effect and Mode Analysis (FEMA)* – The main work of FEMA is to assess risks and put efforts on controlling and minimizing risks. Before you work with those risks and identify their causes and effects, using flow chart to prioritize them in the timely sequence is a nice choice.
- *Stakeholders Analysis* – Identifying the people who have a stake on the Six Sigma process improvement project. Those people will directly or indirectly influence the projects or results. The ones who are not satisfied will insist to changes.
- *Process Documentation* – Effective, clear, comprehensive process documentation is very helpful for the Six Sigma projects, such as process maps, task instructions, measures, etc.
- *Analysis of Variance (ANOVA)* – It is a collection of statistical models which analyzes the variations presented in the project. It is used to assess the differences between groups of data.
- *Correlation and Regression* – These tools assess the relationships (presence, strength and nature) among variables in process.
- *Design of Experiments (DOE)* – It is used to assess the performance of a process. Generally, it tests two or more characteristics under the different conditions. By comparing, the causes of a problem will be identified. It also can be used to optimize results.

4.4 Summary

There is no a specific tool or technique for one specific phase in Six Sigma. Any tool that is helpful for the process improvement can be applied in Six Sigma project. As mentioned above, seven quality tools are most widely used in all kinds of quality improvement. They are Cause-effect Diagram, Pareto Chart, Flow Chart,

Histogram, Check Sheet, Control Chart, and Scatter Plot. The other special tools are gathered from successful Six Sigma cases which include Brainstorming, Affinity Diagramming, SIPOC Diagram, MSA, VOC Method, Kano Analysis, and so on.

Tools are tools. Using the proper one in the right place is the key factor which influences success. How to control such great power demands the understanding and familiarity of tools and techniques. That is why we need the help from specialists. The detail of how to control Six Sigma is presented in the next chapter.

CHAPTER 5

SIX SIGMA IN MANUFACTURING

This chapter firstly analyzes the corporate framework of Six Sigma in manufacturing from academic view. After that, successful experiences from Company 1 and ABB are described. The aim is to identify what is the condition of Six Sigma in manufacturing. And it will help us to implement Six Sigma in software.

5.1 Manufacturing Corporate Framework

The corporate framework of Six Sigma has been launched by Motorola for many years. Lots of companies like GE, ABB, and AlliedSignal have enlarged during the implementation. Nowadays Six Sigma approach has become more pragmatic.

In, Magnusson and his copartners have make a comprehensive and deep analysis with this corporate framework. Figure 4.1 shows that there are four factors and one methodology (DMAIC) within the framework. Four factors are top management commitment, stakeholder involvement, training scheme, measurement system. Among them, top management commitment and stakeholder involvement is the base of the framework. Without them, the other factors and methodology are meaningless. All four factors support the core methodology which is used in every improvement projects.

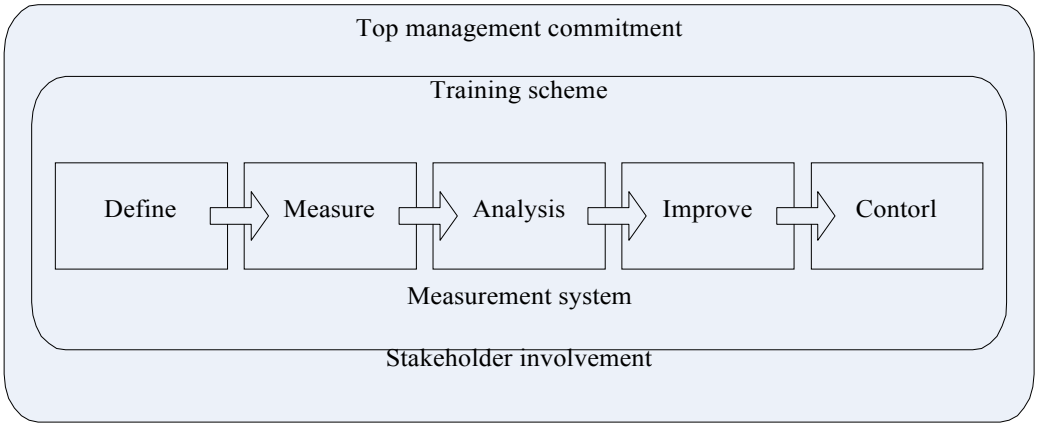

Figure 4.1 The corporate framework for Six Sigma

5.1.1 Top Management Commitment

Top management commitment can be break down into three parts – top management, personal belief and commitment, and set a tough goal. Below we will discuss them separately.

- *Top management* – For a company, implementing Six Sigma is a strategic decision which aim to save cost and increase revenue. It needs to be taken by top management. Actually in many companies, Six Sigma is given the top priority. The members of top management generally are the company owners, project sponsors and advocates. Those people shall be open-mind and hear the Six Sigma report frequently.
- *Commitment* – Top management needs a high degree of personal belief and commitment. When launching Six Sigma, any confusion or doubts about the top management will slow down the progress. Just like John F. Welch (CEO of GE) have said in his speech at the GE 1996 Annual Meeting in Charlottesville, … we have selected, trained and put in place the key people to lead this Six Sigma effort, … we have the balance sheet that will permit us to spend whatever is requirement to get to our goal and … the return on this investment will be enormous.
- *Set a tough goal* – It is the responsibility of top management. A clear goal

can motivate people and lead them to success. At the same time, the tough goal should be achievable. Some companies set their goal for process performance to 3.4 DPMO (equals to 6σ). That is not impossible, but we can set it more intelligently. For example, we set the goal to reduce DPMO by 50% for each year. In reality this number is even higher. ABB have set the goal to be 68% for a yearly reduction, while GE's goal is 80%.

From all above, we can say top management commitment is to select the right person to lead the Six Sigma effort, trust them and support their decisions, and set a smart tough goal which improves process performance continuously.

5.1.2 Stakeholder Involvement

Only top management commitment is not enough to reach the goal which is set for improving process performance. The companies also need stakeholders' help. Stakeholders are people or organizations who will be affected by the product and who have a direct or indirect influence on the product. Stakeholder involvement is to show the improvement methodology and tools of Six Sigma to stakeholders and get their support. The stakeholders can be employees, suppliers, customers, etc.

Stakeholder involvement can shorten the distance of companies with their suppliers and customers. They could give many precious opinions from their view, and those opinions can help to improve process performance or modify our Six Sigma activities. Supplier involvement is essential. That is because the variation in their products will be transferred to the company processes. Sharing the Six Sigma information and process performance data can help them to improve their product quality, which indirectly improves the company process. The Six Sigma can only become the success when tied with customers. They shall be allowed to join the process improvement, share the responsibility. Later on, they will be happy and proud since they are involved.

However, training for stakeholders is necessary. Some courses can help them to

understand process improvement and Six Sigma comprehensively. And that can also help to improve their processes.

5.1.3 Training Scheme

Training in Six Sigma includes the knowledge of process performance, methodology, statistical tools, deployment, frameworks, etc. The experience from Motorola, GE, Dow Chemical, etc has proved the training can extremely be cost saving. In Motorola, the reported return on investment ratio was 29:1. In GE, the investment on Six Sigma increased from US$ 250 million in 1996 to US$ 450 million in 1998. They believe the high investment in Six Sigma training is towards to a rapid revenue growth and cost reductions.

Figure 4.2 demonstrates the Six Sigma training scheme. From the figure, we can see that there are five roles in Six Sigma – White Belts, Green Belts, Black Belts, Master Black Belts and Champions. According to the roles, Six Sigma training courses are divided into three levels – Basic level for White Belts, Medium level for Green Belts and Comprehensive level for Black Belts. In some companies, they have Yellow Belts between White Belts and Green Belts.

- *The Basic level course for White Belt* – provides a basic introduction of Six Sigma including some basic experiments, variations introduction, cost of poor quality, etc. Generally, it only spends one day and is offered to front-line employees.
- *The Medium level course for Green Belt* – is the advanced version of Basic level. The participants are selected to learn some Six Sigma tools, measurement, process management, and how to use improvement methodology in the real projects.
- Comprehensive level course for Black Belt – is more comprehensive and aims to create full-time improvement experts. In the course, the participants are required to perform an improvement project to save a specific cost.
- Two additional course – Six Sigma engineering and Six Sigma

management focus on process design and interaction management separately.

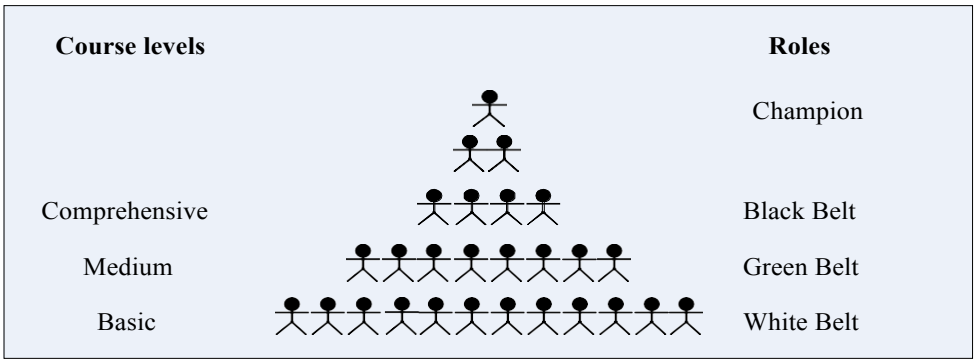

Figure 4.2 The Six Sigma training scheme with course levels and roles.

Two other roles are Master Black Belts and Champions. Master Black Belts are selected from the people who have Black Belt qualifications. Their job is to teach Six Sigma courses within Six Sigma training scheme. Champions who are on the top of organizations drive the whole process. Those people have extra experienced knowledge of Six Sigma, take part in selections of improvement projects, and make decisions.

The number of people play different roles depends on the size of company. For example, in a 2,000 employees company, it should have one Master Black Belt at least. There should be 20 Black Belts for every Master Black Belt and 20 Green Belts for every Black Belts.

5.1.4 Measurement System

Measuring process performance can help us to identify problems from poor process performance, which is good at solving problems in the early stage. A simply metric – DPMO (Defects Per Million Opportunities) – is used to evaluate the variation in critical-to-customer characteristics of processes and products.

There are two types of characteristics that can be included in the measurement system – continuous characteristics and discrete characteristics. Discrete characteristics are number- related, which provides attribute data. Generally, most of observations are applied for it. Measuring continuous characteristics can provide continuous data which could assist all observations. Although two types of characteristics are measured and analyzed differently, the results shall be combined into one number (the average of all individual characteristic results) for the whole company process performance. This combined DPMO value is simple and easy, and it can make the attention of whole company on the process performance.

5.2 IMPROVEMENT METHODOLOGY

After the foundation is settled, a specific Six Sigma project can be started. Six Sigma approach provides a formalized improvement methodology – DMAIC model which we have briefly introduced. This model starts with a define phase, and other four specific phases are followed – measure, analysis, improve, and control.

5.2.1 Define

This phase is to select the proper improvement projects and identify process to be improved. One of most valuable source is Six Sigma measurement system. The DPMO value has indicated the poor performance process. Other valuable sources are customer complaints, competitor analysis, employee suggestions, etc. In general, only poor performance processes or characteristics need improvement. Otherwise, the whole product shall be improved.

Among a number of potential improvement projects, the Pareto chart and the cause-effect diagram can be used for prioritization. The criteria are.

- Benefits for customers.
- Benefits for company.
- The complexity of the process.
- Cost saving potential.

With the help of above criteria and statistical tools, a characteristic or process will be identified for improvement. At the same time, a team shall be organized for the improvement project. In this team, a project sponsor from top management shall be appointed, which is to ensure that the project gets top managements focus. Other members like Black Belts who is responsible for management and making decision, Green Belts and White Belts who assist Black Belts' work. It is obviously that all the team members shall have a great understanding with Six Sigma. Several Six Sigma training courses are essential.

5.2.2 Measure

There are mainly two jobs in measure phase. The first one is to assist define phase for improvement project selection. Before the improvement project is defined, several characteristics or processes shall be measured. Most of Six Sigma companies apply the mental model (i.e. Y is a function of X). Y is selected from variation results through Six Sigma measurement system, while X factors which influence Y need to be identified for each Ys. The relationship is demonstrated in Figure 4.3.

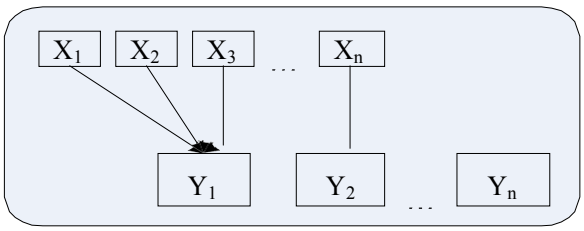

Figure 4.3 Relationships between Ys and Xs

The other job of the measure phase is to collect the data for the selected Ys and Xs. Before the selection decision is made, related data such as types, sizes, measurement intervals, and how to record the data are needed. Be different with the measurement of process performance, measurement of Ys and Xs are more detailed and project related.

5.2.3 Analyze

Analyze phase assesses the data which is collected for Ys and Xs. By assessment, the performance of Ys can be calculated in terms of DPMO values or sigma values. After comparing those values, similar processes can be discerned. Based on those analyses, a goal for improvement can be set.

5.2.4 Improve

All of activities within improve phase starts from deciding if the selected Y or Ys need to be improved. Then we need to identify and measure Xs which associate with the decided Y or Ys. A group of statistical tools and experiments are applied to find out the improvement opportunities. We can also identify the special causes for variations among the Xs. If the result is that those variations can be improved, then they should be removed or their impacts reduced. On the other hand, if there are no special causes which are identified or those variations cannot be improved, we shall reapply statistical tools and redesign experiments. If the results do not change after several iterative, we shall consider that might be the design problems of process or product. Then, the process or product is designed with the aim of improvement.

5.2.5 Control

There are also two activities in control phase. After improvement phase has been carried out, the planned improvements shall be verified. Improper or incorrect improvements will be discovered and corrected in the next improvement project. Control Chart and DPMO Track Chart are highly

recommended to verify the long-term effects of improvements.

Another important activity in this phase is to formalize the results. The results which only match a single process or product will be reorganized and reanalyzed to match the whole company. Both successful and failed cases shall be formalized, reported and stored. The companies should gain experience from those cases for further improvements. Based on that, a guideline shall be established. And that will be very helpful for the future Six Sigma projects. Every company shall create their own Six Sigma project guideline.

CHAPTER 6

THE ACCEPTANCE AND MOTIVATION OF SIX SIGMA IN SOFTWARE COMPANIES

This chapter discusses the different views on applying Six Sigma in Software companies and the differences between manufacturing and software processes. Furthermore two questions are addressed. First one is the acceptance of Six Sigma in software companies. Second one is why software companies should adopt Six Sigma approach.

6.1 Different Views on Applying Six Sigma in Software Companies”

Since Six Sigma approach was successfully applied to manufacturing industry for more than two decades, it is considered as a new star in the world of quality. There is a common misconception that Six Sigma is only applicable for manufacturing industry. The application of Six Sigma in software companies has faced many controversies. There are many different views on applying Six Sigma in software companies.

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6.1.1 Binder's View

Binder has pointed out three main difficulties. Based on the three difficulties, Binder claimed that Six Sigma is not applicable in software companies. The three difficulties are.

- *Processes* - Software processes are fuzzy as compare to the manufacturing processes. So the application of Six Sigma is easily established and documented in manufacturing, not in software.
- *Characteristics* - There are difficulties in meaningful measurements of software characteristics. Software cannot be measured as weight, distance, width, etc. Total number of faults cannot be measured in software.
- *Uniqueness* - Manufacturing products are generally mass produced but software products are one-off.

Binder's view is doubtable because only on the basis of three differences, he denied the applicability of Six Sigma in software. In order to identify the real situation, we need a comprehensive understanding about the differences between manufacturing and software.

6.1.2 Two Misconceptions Debunked by Tayntor

Managers cannot deny the importance of reducing defects, increasing customer satisfaction and operating more efficiently. Many software companies are now adopting Six Sigma. Claimed by Tayntor, there are two misconceptions associated with Six Sigma in software companies. The first is that, Six Sigma is a statistical analysis, so it is applicable for manufacturing and engineering processes and it has very little or no relevance to software. The second is that Six Sigma cannot be adopted in just a few areas of the company. It should be applied to the entire company. Both these misconceptions should be debunked.

6.1.2.1 Six Sigma Has No Relevance in Software

There is some misconception that Six Sigma applies to manufacturing processes but not to software. The truth is that the tools and techniques of Six Sigma can help software companies by ensuring that the "three rights" are in place.

- *The right people are involved* – Many software projects fail because of poor requirements. Poor requirements are caused because all stakeholders are not represented or they participate very late in defining the requirements. Six Sigma approach solves this problem by focusing on teamwork and clearly identifying the customer requirements."
- *The right problem is solved* – Six Sigma tools not just clearly identify the customers requirements but also impact on the proposed solution. Proper use of Six Sigma tools helps in focusing on the high value system components.
- *The right method is employed* – Six Sigma tools helps the software companies by evaluation the processes and finding the variation in them, finding the causes of defects and ways to prevent them. Example if a project is over budget Six Sigma techniques finds out the main causes and the ways to correct them.

6.1.2.2 Six Sigma Is Applied in Whole Company

The second misconception is that the Six Sigma is only helpful if the whole software company has adopted it. This is a fact that it is easier for a software company to implement Six Sigma if the whole company adopts its philosophy. But there are benefits of adopting Six Sigma tools and incorporating the processes into software development, even if the whole company is not using Six Sigma.

So Six Sigma has applicability to software companies. The reasons for adopting Six Sigma are clear – fewer defects, faster delivery and increased customer satisfaction.

6.1.3 Cost Misunderstanding

There is a misconception that designing a system to Six Sigma is very expensive. Since Six Sigma focuses on the quality from the beginning of a project so it has minimal cost to improve quality. On the other hand if we wait up to the testing phase in finding the defects then the cost to fix the defects is very high. A cost and benefit analysis should be done in the Six Sigma program to determine the actual gains.

6.2 Software versus Manufacturing

Six Sigma approach has brought large number of profit to manufacturing by improving product quality. However, the differences between software and manufacturing make it hard to apply Six Sigma directly to software. Identifying these differences can help us to solve this problem.

6.2.1 The Differences between Software and Manufacturing

There are many differences between software and manufacturing. Table 5.1 shows the differences between software and manufacturing products, while the Table 5.2 shows the differences of processes.

Software Product	Manufacturing Product
"It has logical components."	"It has physical components."
"It has no material existence and has no physical properties."	"It has physical properties i.e. color, mass etc."
"It do not have any link with the physical laws i.e. Newton's laws."	"It obeys physical laws."

Table 5.1 Differences between software and manufacturing products

Software Process	Manufacturing Process
"Input is customer requirements, skills, tools etc."	"Input is raw material. Raw materials do not have much variation in quality."
"It is not visible. It is made visible through documentation, i.e. Data flow diagrams, flowcharts, entity relationship diagrams, decision trees, decision tables, use case diagrams, object oriented models etc."	"It is visible."
"All software characteristics cannot be measured on continuous scale. the output is either correct or wrong. Software has fault tolerance to increase reliability. It is usually done by putting redundant modules."	"It has design tolerance. Design tolerance means the maximum range of variation in which the In most cases manufactured part can work."
"It is difficult to predict the behavior of a software process, due to changes in requirements and technology changes."	"It is easy to predict the behavior of a manufacturing process."
"In software productivity the most important factor is human intelligence."	"The manufacturing productivity is most of the times machine intensive."
"The external factors that may affect a software process are programming skills, level of expertise, knowledge of developer and customer, tool and technologies that are used."	"The external factors that may affect a manufacturing process are temperature, humidity, machine performance etc."

"The process variation in a software process is due to differences of skills and experience of one developer to another."	"The process variation in a manufacturing process is due to difference between components."
"Technology in software processes changes very fast."	"Technology in a manufacturing process changes very slow."

Table 5.2 Differences between software and manufacturing process

The differences are demonstrated in following points:

- *Non repetitiveness* - Once software is developed, it can be reproduced into millions of identical copies. This is the reason why software developers focus on the development process unlike manufacturing process where the focus is on the reproduction of the identical copies.
- *Input and output* - Unlike manufacturing process the inputs and outputs are different in each software process. Each software process deals with different set of user requirements.
- *Cognition* - In software development the transformation of user requirements to a module is cognitive intensive. On the other hand manufacturing activities are targeted to minimize cognition.
- *Visualization* - Software development is an intellectual process, before the implementation of Six Sigma it needs to be visualized. This visualization is done by documentation. To find the data relationships, tools are used i.e. data flow diagrams, entity relationship diagrams and object models.
- *External Factors* - The external factors in a manufacturing process are temperature, relative humidity, human interaction, machine performance. None of these factors affect software development processes. In software development processes the external factors are programming kills, level of expertise, knowledge, etc.

- These differences do not mean that Six Sigma is only applicable to manufacturing. If we know these differences very clearly and be careful about them when applying Six Sigma in software, then those differences are not difficulties. Actually Six Sigma is applicable to software companies. For example Motorola is using Six Sigma in his software department for many years and Tata consultancy Services has gain lots of profits after applying Six Sigma.

6.3 Why Software Companies Choose Six Sigma Approach?

After the above discussion there is a question that does Six Sigma make sense in software companies. The answer is yes, Six Sigma is good for software companies especially for the following situations.

- *Legal Responsibility* – Six Sigma approach helps to fulfill the legal responsibility. Now-a-days if something goes wrong people go to the lawyers according to Human Rights Act. Up to now disasters are not blamed on software's but software's can cause huge disasters. Software has many identical copies. These copies are installed in different companies. If there is some defect in the software then all the companies are at great risk of failure. Even the most powerful companies like Microsoft are fearful to such failures.
- *Mission Critical Systems* – Now a days softwares are developing for mission critical systems. The failure of a mission critical results in a great loss to society. Here comes Six Sigma which means 3.4 defects per million opportunities, it can prevent the software from failing. In 1988, American Airlines lost 59 million dollars in ticket sales. The problem was the discount ticket was mistakenly blocked in the ticket reservation system. As a result travelers moved to their competitors. These weaknesses can be removed by Applying Six Sigma which provides near defect free performance.

- *Complex Systems* – The application of Six Sigma is very effective in case of complex systems. For example there a complex system with like 1000 modules if all the parts are designed according to Six Sigma than there is a higher probability of getting a defect free system.
- *Software Company* – Software companies have a bad reputation of buggy and late. Today software size is very large like more than thousands of lines. It has more probability of having many defects. In this situation Six Sigma can help us to get a near defect free product.

According to a survey conducted in software companies by, the following results are found. Most software companies have completed five to ten Six Sigma projects and their bottom-line saving per project is over £100k on average. In most companies the Six Sigma level varies from 2.54 to 4 Sigma. The following criteria were used by most companies in survey to find the success of Six Sigma.

- Impact on bottom-line
- Reduction of defect rate.
- Reduction in cost of poor quality.
- Improvement in a process.
- Reduction in customer complaints.

CHAPTER 7

Case Study Review

Introduction

This case is referred from [6]. Customer Relationship Management (CRM) was started in 1990‟s in United States. It is also known as Customer Service System or Call Center. It is a modern way of marketing. Computer telephone integrated technology and internet technology are used. Some world-class companies, like Microsoft and Oracle, have already adopted the CRM. By the use of the technology, companies gain more customer satisfaction and faster revenue growth. The motivation behind the case study review in CRM is that it belongs to the service industry same as software's. So later it would be helpful in proposing the steps for the implementation of Six Sigma in softwares.

The success rate of CRM can be improved by improving the CRM implementation processes. Figure 6.6 indicates a Human Resource (HR) company using Six Sigma approach to improve its CRM implementation processes.

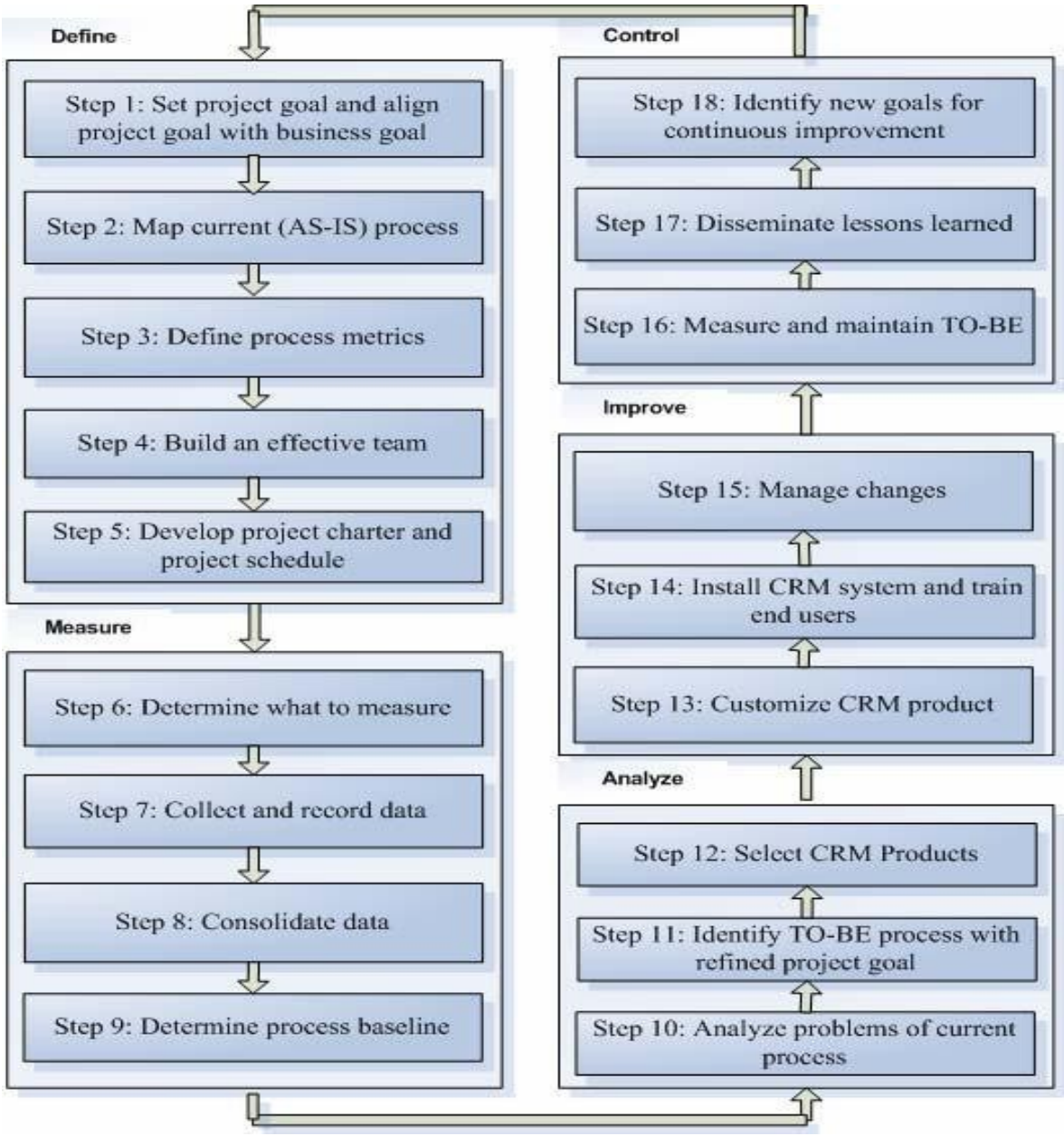

Figure 6.6 Using Six Sigma approach to improve CRM implementation processes

7.1 DMAIC Method

DMAIC method is main tool for Six Sigma process improvement project. In following sections, main activities are summarized according to different phases.

7.1.1 Define phase

- Set project goals. The main goal in this case is to improve sale and service process. More specifically, to reduce 20% loss of opportunity and 50% reduction in customer complaints.
- Create As-Is process. It describes the process in a relative logical way, shown in Figure 6.7.

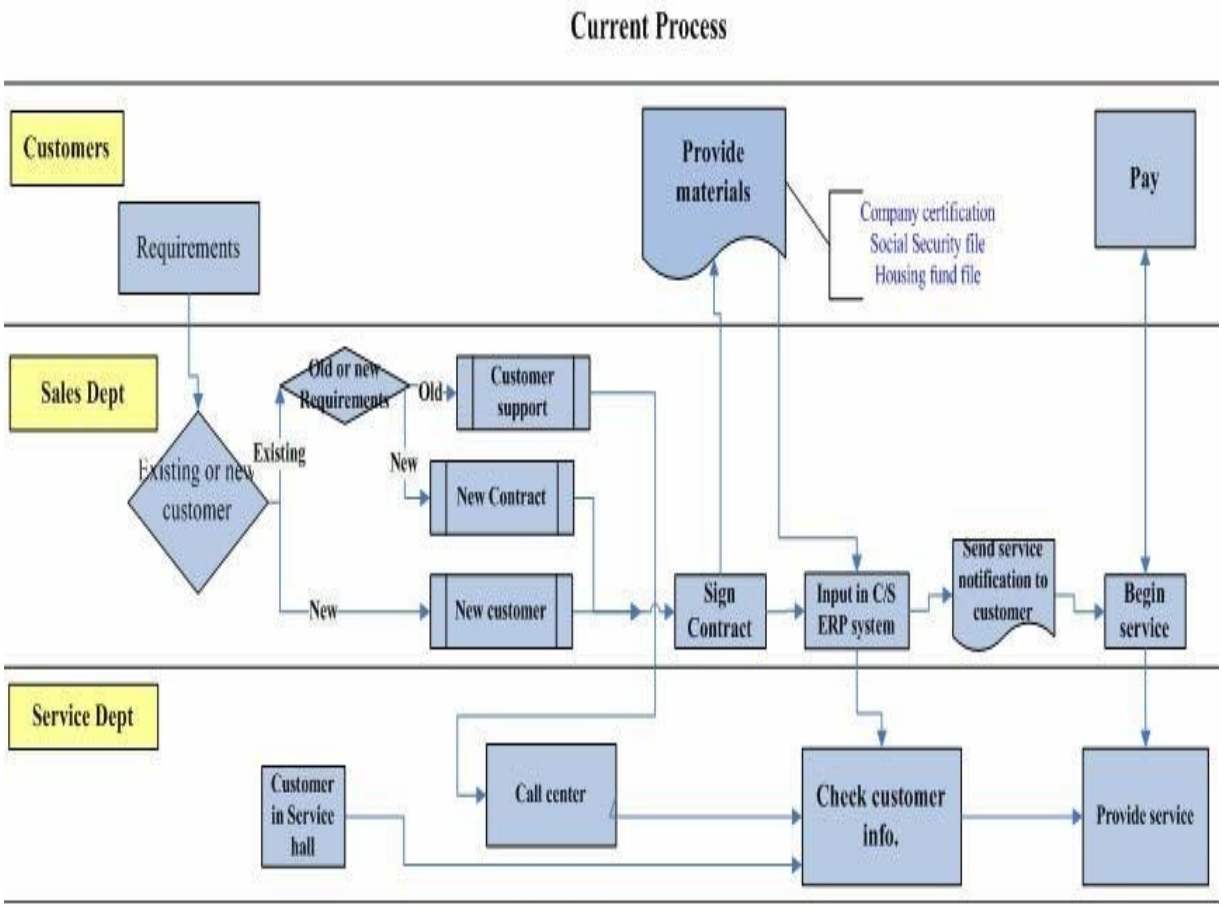

Figure 6.7 As-Is process in CRM implementation project.

- Define process metrics. Two process metrics were defined for service and sales quality in this case (see Table 6.1). The loss opportunity metric

was to count the total number of opportunities that were lost. The customer complaint metric was to count the total number of complaints from customer.

Process Metrics	Description	Data to Measure
"Loss of Opportunities"	"Measure how many opportunities are lost among all the opportunities."	"Potential customer info, opportunity product, loss or not, competitors info".
"Customer Complaints"	"Measure the number of the complaints received among all the possible complaints"	"Customer info, complaints problem, solved or not."

Table 6.1 Process metrics for sales and service quality

- Organize a team for project. Team members are made up by IT specialists, project managers, CRM experts, and the CEO.

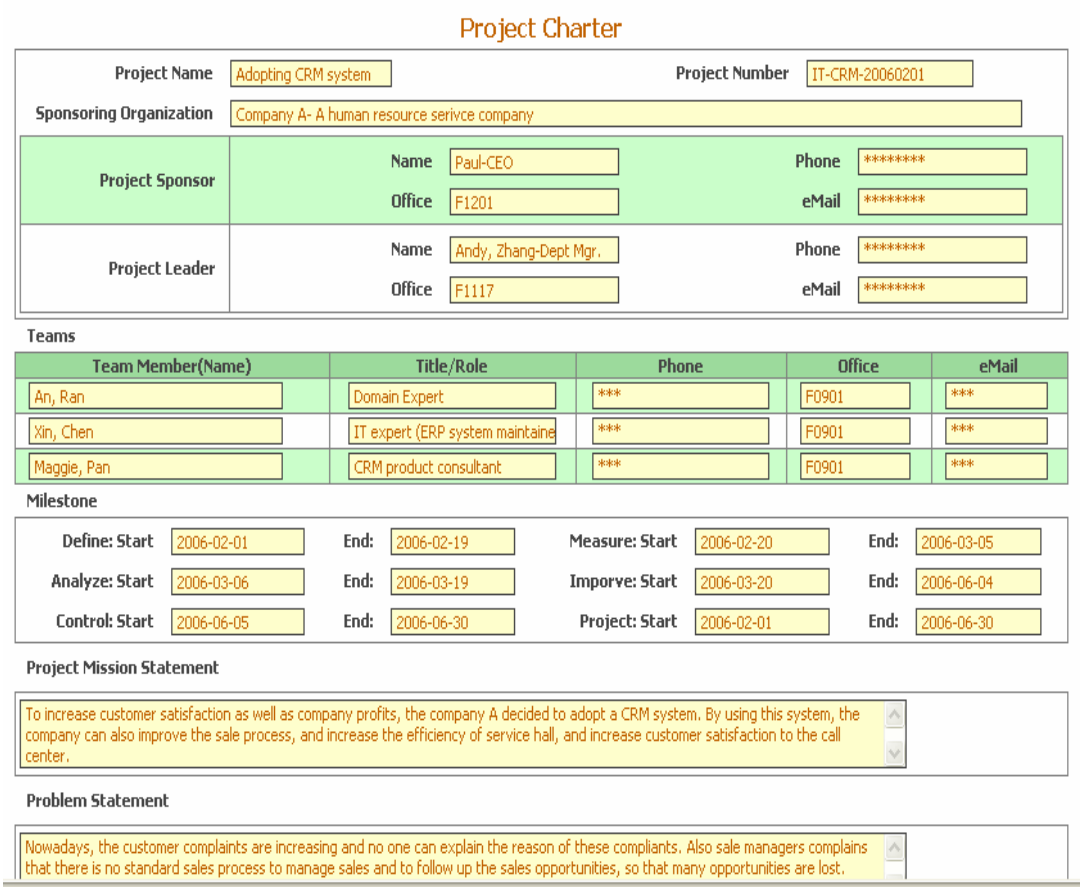

Figure 6.8 Project charter for CRM implementation project

The project goals indicate when to terminate the project. As-Is process and process metrics help to analysis processes, furthermore to decide which process should be improved. At last, project team and project charter are conducted.

7.1.2 Measure phase

- Measurement. Measure the data for the loss of opportunity which includes following elements: name, address, telephone number, interesting services, opportunity loss or win, etc. And measure the data for customer complaints which contains customer information, complaint problem, and problem solved or not, and so on.

- Collection. Collect information from salespersons for the loss of opportunity, and conduct a survey from customers for customer complaints.
- Checking errors.
- Determine the process baseline For loss of opportunity, the sigma level is 0.22. And for customer complaints, the sigma level is 2.98.

7.1.3 Analyze phase

- Identify the sources for problems. With the help of cause and effect diagram, the problems in the current process were analyzed (see Figure 6.9). Three main sources are identified in the current process. Firstly for the sales, no standard process was followed. Secondly in call centre information, no call information is saved. Thirdly salespersons cannot connect to ERP system.
- Refine the processes according to project goal.
- External solutions are considered. In this case, the project team decides to use MSCRM product for the call centre because of its standard sales process and friendly user interface.

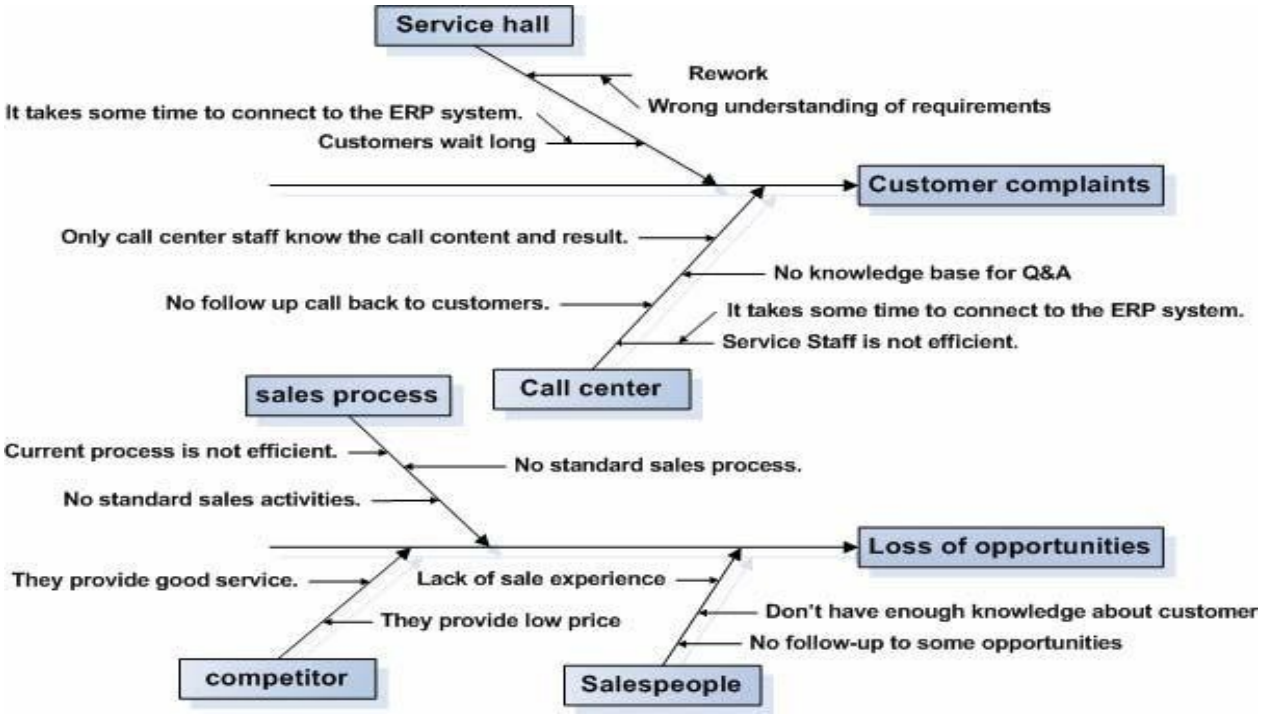

Figure 6.9 Cause and effect diagram for CRM implementation project

7.1.4 Improve phase

- Apply new system. In this case, a new MSCRM system is installed. Related training is conducted at the same time. There are three levels of trainings: administrator training, manager training, and end user training.
- Modify current process according to the result of analyze phase.

7.1.4 Control phase

- The performance of the new system was measure after three months. The Sigma level for the loss of opportunity was 1.25. And the Sigma level for customer complaints was 3.83. This shows the success of Six Sigma implementation for the CRM.
- New goals were identified for further improvements.

7.2 Case Summary

In this case, Six Sigma approach is integrated with business method CRM. The final result shows that the DMIAC model can not only be used in single situation, but also works in complex integration projects. As Figure 6.6 shows, five DMAIC phases are divided into several steps. Each step has a clear defined input and output. The output of previous step mostly is the input of the next step. And finally, the project result is managed by control phase to keep a long-term performance.

From this case, we can find single CRM implementation process generates a low level success rate . However with the help of Six Sigma approach, the results are significant improved. That means Six Sigma approach can not only

improve process by itself, but also can integrate with other improvement method.

In this paper, authors have conducted a literature review for Six Sigma approach, a comparison between Six Sigma approach's applicable fields, and an acceptance and motivation discussion for using Six Sigma in software, a real manufacturing interview, finally a method for applying Six Sigma in software companies. The main outcome of research is lessons learned from literature view, interview and case studies. And those lessons are integrated with the final method. This method can be used as a guideline for software companies to implement Six Sigma for quality improvement purpose. And this method can also be used by researchers in area of quality for further research.

While investigated the concept of Six Sigma approach, we found that Six Sigma approach had three forms for quality improvement. The first form is as a metric which equals to 3.4 defects per million opportunities. This is a requirement for the highest quality level. The final aim of Six Sigma is to reach this defect degree. The second form of Six Sigma approach is as a methodology. It basically provides two models for process improvement. DMAIC model is used for existed process improvement, while DMADV model can be used in new process development. The last form is as a management system, which is binding with company business strategy.

Several quality tools have been investigated and introduced after Six Sigmas definition. Some of them have been successfully used for many years, while some were just invented. Using proper tools can accelerate our progress.

The field difference is the main hurdle for introducing Six Sigma approach to software. The investigation of manufacturings Six Sigma framework provided us a deep study in Six Sigma approach. And that also answered the question – what baffle Six Sigmas implementation in software.

After the investigation of manufacturing framework, a comparison between

manufacturing and software and an acceptance discussion for Six Sigma approach in software have been presented by us . By using powerful and reasonable evidences against last century wrong assumptions, authors believe that applying Six Sigma approach in software is possible at this moment. At the same time, authors testified that there is a need for software to use Six Sigma approach for quality improvement.

The final research result is mixed into a method for applying Six Sigma approach in software companies. And this is conducted by integrating all authors‟ previous works. It can be used by software companies for implementing Six Sigma on their own development processes. It also can be used by researchers for further research. Two main parts are involved – environment establishment and the enhanced methodology. The first part provides software companies and researcher a top-down introduction for Six Sigma framework. By learning that, software companies and researchers can build their own framework. The other part is an enhanced methodology. Authors have integrated lessons learned from the research with the DMAIC model, which makes the model contain software characteristic. This method is believed can handle all general cases.

At last but not at least, Six Sigma approach is a good tool for quality improvement. Through the research, authors found it is possible to apply Six Sigma approach in software companies. The final research result will help software companies and researchers step by step to achieve their quality goals.

7.3 The Cost of Six Sigma

When we do investigation on the application of Six Sigma approach in reality, one interesting thing catches our attentions. That is the cost of Six Sigma which including pre- cost, project cost, maintenance fee, recruitment spending, etc. Meanwhile, all companies which we have done interview or case study review are world-class ones in their specific field, which are able to afford the cost during quality improvement. All these information tell us the cost of Six Sigma is not cheap.

We have separately discussed that the cost spending on quality improvement is not cheap but worthy. However, all evidences in our research have pointed out that the cost of Six Sigma is not an easy burden for small size companies. To have a long-term improvement or to keep a long-term high performance, the support from abundant funds is very much essential.

On the other hand, currently the implementation of Six Sigma approach is on its initial phase, especially for software. During the growth of understanding, self-improvement and the integration between quality approaches, we believe the cost of Six Sigma can be reduced on a reasonable and acceptable level.

CHAPTER 8 – Conclusion

Research Questions Revisited

- What are the definitions of Six Sigma?

A detailed literature study is carried out to find out the definitions of Six Sigma. The literature study consist of articles, web materials books. The Six Sigma has definitions at three levels i.e. matrix, methodology and strategy. At matrix level Six Sigma is 3.4 defects per million opportunities which means 99.9997% defect free product. Six Sigma approach at methodology level is not just counting defects in a process or product, but it is used to improve processes. When we look at Six Sigma as a methodology, there are many models available for process improvement like DMADV, DMAIC etc. At strategy level, through experience, Motorola has found that using Six Sigma as a metric and as a methodology are not enough to drive the breakthrough improvements in an organization. Motorola ensures that Six Sigma metrics and methodology are adopted to improve opportunities which are directly linked to the business strategy. Now Six Sigma is also applied as a management system for executing the business strategy.

- What is the condition of Six Sigma in manufacturing?

Six Sigma approach has been successfully applied in manufacturing for two decades. From the successful experiences, a successful Six Sigma project must base on at least four foundational activities. They ensure the progress of projects from top management to human resources. They are

- Top management
- Stakeholder involvement
- Training scheme
- Measurement system

When the foundation is well settled, a specific Six Sigma project can be started. From the successful cases, some models can be borrowed to help us to run the project. DMAIC model is a formalized improvement methodology which is the most popular one from successful cases. It contains five phases – define, measure, analyze, improve, control. Each

phase has a clear defined aim and an outcome. It is not very hard to follow this sequence and achieve the project goal.

- The applicability of Six Sigma in software's and why software companies choose Six Sigma?

Six Sigma approach can be applied in software companies if we involve the right people, solving the right problem, and using the right method. At the same time, although using Six Sigma approach for process improvement costs a lot, it worth. Few defects, faster delivery and increased customer satisfaction will generate more potential profits than you think. The differences between software and manufacturing are obvious and unavoidable. The main distinct factors of software are non-repetitiveness, unique input and output, cognition, visualization, and some external factors such as employee skill and knowledge. These differences are reflected on the software product and software process. Still applying Six Sigma approach in software companies is beneficial. Firstly, all deny opinions and misconceptions are built on the misunderstanding of Six Sigma approach and unfamiliar with the software. Secondly, we never say applying Six Sigma approach in software is just the copy of manufacturing method. The differences do exist. According to them, we need to modify the Six Sigma approach, as the same time with the software process. Change them to fit for software processes. And that demands further research and more experiments. It can help software companies to reduce defects, improve quality, increase customer satisfaction, and enhance market-share. That is also the answer of why software companies choose Six Sigma, especially for complex systems, mission critical systems, and legal responsibility.

- What kind of tools and techniques are used in Six Sigma? Which of them are suitable for process improvement in software companies?

There is no a specific tool or technique for one specific phase in Six Sigma. Any tool that is helpful for the process improvement can be applied in Six Sigma project. However seven quality tools are most widely used in all kinds of quality improvement. They are Cause-effect Diagram, Pareto Chart, Flow Chart, Histogram, Check Sheet, Control Chart, and Scatter Plot. The other special tools are gathered from successful Six Sigma cases which include Brainstorming, Affinity Diagramming, SIPOC Diagram,

MSA, VOC Method, Kano Analysis, and so on. Using the proper tool in the right place is the key factor which influences success.

- What is the state-of-art for the implementation of Six Sigma in software?

In the Case Six Sigma project starts from defining the project goal and the problem which needs to be solved, then project team. The team members are selected from all levels inside or outside of company, for instance, CEO who comes from the top of company, Team Leaders who lead the project, customers involved from outside of company, and other members come from different departments within the company. DMAIC model divides Six Sigma project into five phases. In each phase, there is a clearly define input and output. The output of the previous phase normally is the input of the next phase. In each phase, there are several steps to achieve phase goal. Numbers of quality tools are introduced to each step. There is only one criterion for quality tool selection – fitness for use. When the Six Sigma project is terminated, gained experiences will be documented and applied in other Six Sigma projects. Sometimes the project goal cannot be achieve by only one Six Sigma project. Then more Six Sigma projects can be organized according to situation. The spirit of Six Sigma approach is towards a long-term improvement.

- Steps towards applying Six Sigma in software companies for process improvement?

We have provided a method for the implementation of Six Sigma in software companies. The Six Sigma environment is the basis for all Six Sigma improvement projects. It provides fully support and guarantee (financial, strategy, human resources, top management, etc.) to keep project towards success. Environment establishment step contains three activities. The first one is to reform organizations superstructure. In some place, it was called top management. The main purpose is to gain top managements trust and commitment. If a Six Sigma project loses top's focus, it won't last to the end. Meanwhile, the principle of Six Sigma approach is continuous quality improvement. It needs continuous support from the superstructure. The second important activity is to establish Six Sigma education system. Long-term improvements need numbers of quality specialists. This system is built for this aim. Finally, company needs to establish some necessary standards or rules to keep continuous improvement. DMAIC has been selected as the main model for organizing Six

Sigma project. Research findings and software properties have been integrated with the selected model. Its functionality has been enhanced to meet software company requirements. Activities and quality tools were blended with each step in each model phase. By the purpose of practicability and authenticity, most of them came from interviews and case study reviews. Authors anchor their hopes on using this method to help software companies for quality improvement, and also supporting quality researcher's further research.

Recommendations

Six Sigma is successfully used in manufacturing industry for two decades. The challenge was to employ Six Sigma in software development. In this thesis research we have concluded that Six Sigma is applicable in softwares. There are differences between software and manufacturing process, but if we take care of them Six Sigma Works well in software. It can bring large benefits to software companies. There are software domains where Six Sigma is highly beneficial i.e. complex systems, mission critical systems etc. Six Sigma tools are very useful for software process improvement.

The main challenges of Six Sigma in software are to identify the CTQs (critical to quality) and to establish cost efficient project Ys that can be used to indentify root cause, and measure improvements. Another challenge is that the processes used have quite long life span (a development project can take 2-3 years) and the processes are furthermore not to be classified as stable and repeatable.

We have proposed steps for the implementation of Six Sigma in software. The steps are proposed after interviews and case study reviews. We believe that the steps are reliable. The final research result will help software companies and researchers step by step to achieve their quality goals.

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