Improve project management by using Six Sigma tools
- An empirical study in Siemens Industrial Turbomachinery

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Abstract

Traditional project management has been implemented by most of the companies in today’s business world in order to monitor and control the projects (Tonnquist, 2008). Project management techniques have been proven for decades and its performance has been maximized (Heldman, 2011). We think that the PM techniques have gradually reached its limits. For today’s companies, it is vital to find a more effective and innovative method which can be integrated into the project management in order to maintain their competitive advantages (Pyzdek, 2003).

As a relatively new business management approach and strategy, Six Sigma seeks to improve the quality of the product and process by using some quantitative methods and tools (Michalski, 2003). Actually, Six Sigma has been broadly implemented in many companies and received a positive effect (Pande et al., 2000). However, most of the Six Sigma usage happens just in the Six Sigma projects and these projects need the great support from the top-management level and require plenty of resources for training and maintain (Pande et al., 2002).

The purpose of this thesis is to suggest an approach/methodology for how simple Six Sigma tools and methods can be combined with the traditional project management. In this case, those non-Six Sigma projects can still use some easy Six Sigma techniques to maximize the benefits. In order to achieve this purpose, the following methodologies are implemented: literature review to identify relative factors including quality, time, cost, communication and customer satisfaction, surveys and interviews to find out the current situations and problems in Siemens Industrial Turbo machinery (SIT) project management, empirical studies to develop some models and methods in which Six Sigma tools are integrated in the project management in SIT.

In this thesis, based on the empirical research of the case company of SIT, we are going to suggest some Six Sigma tools to be integrated into project management. The research questions include:

1. How can the selected Six Sigma tools improve the project management?
2. The Pros and Cons of implementing Six Sigma methods and tools in the project management.
3. What tools of Six Sigma are suitable to increase the performance of the project management in SIT

As the result of this thesis work, once it is testified it is feasible and fit in the SIT project management process, we think that there is a great chance it should be amplified and spread to many more business areas.

*Key words: Six Sigma, project management, QFD, FMEA, SIPOC*
Acknowledgement

The authors would like to thank all the people who had helped and supported us during the process of writing the master thesis.

During the summer of 2011, we had the chance to study the project management performance at Siemens Industrial Turbomachinery AB in Finspang. We would like to thanks Ivona Ljungdell, Saideh Novin Askloef and Maria Johansson, our supervisors at SIT, by providing us the guidance, meetings and resources. Maria had done a lot of coordination to facilitate the whole thesis writing process. Our interviewees - the nine project managers from Gas turbine, Steam turbine and Solution departments and black-belt specialist Greg in SIT had helped us tremendously with all the questions that we asked and information we need, we would like to give our special thanks for their time and sincerity.

From the institute of technology at Linköping University, our supervisor Peter Cronemyr and our examiner Bozena Poksinska had offered us attentive guidance, professional advices and valuable suggestions during the whole process of the thesis. And the thoughts and arguments let us to view our findings from a more practical perspective. We also would like to thank our opponents Jianqi Fu and Bing Han for their useful feedback and improvement comments.

During the study of Six Sigma tools combined with project management, we had been inspired to learn more about how to set up and implement the quantitative perspective into the project management activities.

Linkoping, Sweden, Oct. 2011

Lin Yang and Guannan Feng
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Chapter 1 Introduction

1.1 Background of Six Sigma and project management

In today’s business world, with the rapid development of the economic globalization, the international business competition has become increasingly severe (Porter, 2000). In order to seize more market share, companies set their focus of competition not only on developing the innovative technologies, but also on the quality of their products. Strengthening the quality management has been considered by most of the companies as a critical way of enhancing their competitiveness (Madu and Kuei, 1993).

Thus more and more business corporations are now implementing quality improvement methodologies such as Lean Production, total quality control and Six Sigma (Dahlgaard and Dahlgaard-Park, 2006). Among these methodologies, Six Sigma attracts more and more attention because it has evolved from a focus on achieving the quality level and process improvement using statistical tool to a comprehensive management framework for managing a business (Snee and Hoerl, 2002). Six Sigma has become the synonym for improving quality, reducing cost and increasing customer loyalty (Bertels and Strong, 2003).

The concept of Six Sigma has been introduced by Motorola in 1987 (Henderson and Evans, 2000). Six Sigma has been launched in the very first place as a pure quality management method and it was designed only for manufacturing and production processes (Brue and Howes, 2005). However, with decades of development, more and more companies discovered the advantages of Six Sigma. In 1996, GE set Six Sigma as a kind of management strategy and implemented this strategy throughout the whole company (Henderson and Evans, 2000). Three years later, with the help of Six Sigma, GE made the profit of 20 billion USD (Klefsjö and Bergquist, 2003). Since then, Six Sigma was no longer a simple management method. Many non-manufacturing companies, such as service enterprises, started to use Six Sigma to improve quality of service and increase the customer loyalty (El-Haik and Roy, 2005). It has evolved into an efficient business process optimization. It has become one of the most important strategies for those companies who are pursuing the excellence of management. Thus, more and more projects have become pure Six Sigma projects since they were integrated with the methods, techniques, and personnel of Six Sigma management (Bertels and Strong, 2003).
On the other hand, the traditional and classic project management is still playing an important role in the project-oriented organization, and a small oversight can easily affect the success of the project (Heldman, 2011). However, many project management methods have failed because business couldn't measure the effectiveness of the methodology or quantify the value added by process changes (Harrington, 1991). Six Sigma uses the data with tools and techniques which companies can use to test their performance both before and after Six Sigma projects (Bertels and Strong, 2003). Business can integrate Six Sigma into project management. The standard DMAIC process which stands for Define, Measure, Analyze, Improve and Control can be followed to reduce probability of failures, human errors and oversights (Shankar, 2009). The errors can be reduced in DMAIC by using statistical tools and techniques such as fishbone diagram, Ishikawa diagram, Design of experiments, process flow diagram and others (Pyszdek, 2003).

There is considerable literature on both of Six Sigma (Bertels and Strong, 2003; Brue and Howes, 2005; Michalski, 2003) and project management (Heldman, 2011; Schwalbe, 2008; Tonnquist, 2008), while the research on the relationship between them or how to combine them is limited and doesn’t provide enough details. Six Sigma is based on the strategic goals of continuous improvement as a tool to bring significant and lasting change in the targeted and important projects (Sandholm and Sörqvist, 2002). As the competition increasing by the minute, the need for project management by integrating Six Sigma will be more in the days to come. Based on the characteristics of the project management and methodologies of Six Sigma, it is vital to discuss how the Six Sigma can be used to improve the project management, such as optimizing the project processes, minimizing the defects and costs, and improving the customer satisfaction (Tonnquist, 2008).

1.2 The background of the company

Siemens Industrial Turbomachinery AB (SIT AB) located in Finspong Sweden belongs to the oil and gas division within energy sector of Siemens AG, and it is a leading supplier for a wide range of products, solutions and services for the power generation, transmission and distribution (SIT, 2010). Before they were called Siemens in 2003, they had several names which were STAL, STAL Laval, ASEA STAL, ABB STAL and Alstom Power. The main products they deliver are steam and gas turbines, turn-key power plants and service and
components for heat and power generation. The turbines are the power sources not only for producing electricity, steam and heat, but also for the compressors and pumps, mainly in the oil and gas industry. This facility in Finspong employs around 2700 employees and the annual turnover is 10 billion Euros (Siemens, 2009; SIT, 2010).

The quality system of the SIT AB was certificated according to ISO 9001:2000, and their guiding principles are high efficiency, low service costs and low environments impact. They regard quality as the products and services delivered in a timely manner by full filled the agreed commercial terms.

SIT is divided into 2 business units, the service unit and the unit of Industrial Power Turbines. In this paper we just focus on the unit of Industrial Power Turbines. Under this unit there are three department which are Gas turbine (GT), Steam Turbine (ST), and Solution (SOL).

The project is the main way to perform the turbine production and the project managers are responsible for the delivery of the project. Usually each project manager is responsible for 3 or 4 project at the same time. For both of the units, business excellence division is in charge of the quality management such as Six Sigma, and total quality management. As so for, Six Sigma method has gain remarkable success in the service unit; however, SIT didn't use the Six Sigma tools into the production unit project management so much. Here comes the exploration of this topic.

1.3 Purpose and research questions

We have seen that Six Sigma may have the great potential of bringing significant benefits to improve the project management and various companies all over the world are interested in applying Six Sigma tools in their project management. However, using Six Sigma tools is based on the analysis and research of the data that the company has performed. In the manufacturing process, applying Six Sigma is not hard in manufacturing environment since the process of manufacturing is fixed and the customer’s demands on the quality are clarified and easy to be measured. In the project management, project managers face many contingency problems whose resolutions are not always there. Often, project managers cannot find a
successful case to follow. The working progress is hard to be measured by accurate data. Thus the Six Sigma tools are rarely used in the field of project management.

Moreover, the projects are either pure Six Sigma projects which follow the methods, techniques of Six Sigma management and contain Six Sigma expertise, or pure traditional and classic project management which has nothing to do with Six Sigma. These two extreme managements both have some disadvantages. For Six Sigma projects, they require plenty of resources of the organizations and for traditional projects, the outcome and performance are sometimes not guaranteed. Based on this fact, we are trying to figure out a way of integrating some of the Six Sigma ideas and methods into project management in order to improve the performance of project management to some extent, and in the meanwhile, the cost and resources would not be too high as the pure Six Sigma projects require.

In this thesis, based on the empirical research of the case company of SIT, we are going to suggest some tools in Six Sigma field to be integrated into the project management. This thesis will help us to improve the awareness and understanding of implementing Six Sigma in project management.

Our research questions are as following:
- What tools of Six Sigma can be suggested to increase the performance of the project management in SIT?

We conduct some surveys and interviews to create a picture of the main problems in SIT. Then we develop some selection criteria for choosing the appropriate Six Sigma tools for the improvement of project management.

- How can the selected Six Sigma tools improve the project management?

Most importantly, once we have the right and suitable Six Sigma tools for the projects, we dig deeper to gain a clear view of how the Six Sigma tools can improve the project management performance in detail.

- The Pros and Cons of implement Six Sigma methods and tools in the project management.
We assume that the outcome of implementing Six Sigma methods in the project management is not only positive. There are some negative effects too. We find out what the Pros and Cons are so that we can gain a deeper understanding.

1.4 Limitations

The first limitation comes from the generalizability of the result. Since the research was conducted in one company, this implies the limitation of the generalizability from this case to other companies. The research questionnaire was developed by the authors and supervisors, thus the subjective bias could exist. The further study can be carried out more completely in a long term study.

The second limitation could be the methodology. Due to the time duration limitation, it was hard to avoid all the deficiencies in conducting the research. According to Marc and Miller (2008), the credibility of the research can rely on the reliability, validity and objectivity. During the interviews we have conducted with the project managers, the notes were made instead of the voice recorder due to confidentiality problems. And taking notes by hand may influence the objectivity. To minimize the bias and the impact of personal interpretations and perceptions, a supervisor from SIT and a facilitator from university were located in the interviews also. The final empirical data was integrated from notes of four persons. For ensuring the validity and reliability, the questions in the interviews were checked by the supervisor in SIT to ensure they are aligned with the purpose of the study.

1.5 Dispositions of report

The disposition of the report is as following: Chapter 1 describes the background of the topic, the purpose, research questions and limitations.

In Chapter 2, the methodology that was used to conduct the research is presented, and the methodology includes literature review, survey and interview. These approaches direct the way to solve the research questions that we propose in the last chapter.

Chapter 3 is the theoretical framework derived from the literature review. In this chapter, the academic research about the project management and Six Sigma is presented. Based the
literature review, we create a general understanding of project management and Six Sigma, and based on this understanding we suggest the solution for the proposition questions.

In Chapter 4, we introduce several Six Sigma tools which we consider can be used in the project management to improve the performance of PM. Chapter 5 presents the empirical findings we have gathered in SIT. We describe several current project management situations and problems which we have found during our thesis work in SIT. Then we make our suggestions and recommendations of implementing specific Six Sigma tools to improve the current performance of PM. We also provide some simple example for explaining how these tools can be implemented.

1.6 Glossary

SIT: Siemens Industrial Turbomachinery AB
SS: Six Sigma
GT: Gas Turbine department in SIT
SU: Steam Unit department in SIT
SOL: Solution department in SIT
VOC: Voice of Customer
QFD: Quality Function Deployment
CTQ: Critical To Quality
SIPOC: Suppliers, Inputs, Process, Outputs and Customers
FMEA: Failure Model Effect Analysis
RPN: Risk Priority Number
2 Chapter 2 Methodology

2.1 Introduction

This chapter presents the research methodology of the master thesis. We describe research approach that we have chosen and the procedure that we collected data. The limitation with the possible source of divaricators to ensure the study’s reliability and validity are also explained in this chapter.

2.2 Research design

The first step was to identify and understand the research background and the initial proposal of the possible tools of Six Sigma to improve the project performance. The problems were described and identified through the discussion with the supervisors at the university and the case company. Based on the problem description and corrected proposal of the research questions, an extensive literature was selected and discussed in the analysis process.

The empirical data was then collected through the surveys and interviews with 9 project managers (3 from Steam turbine, 3 from Gas Turbine, and 3 from Solution). Besides the 9 managers, we had a two-hour meeting with the Master Black Belt from SIT to gain deeper understanding of six sigma implementation in SIT. After the data collection, the analysis was conducted within the context of the theoretical background and aimed at answering the research questions. Then the conclusions were developed as the final part of the thesis after the suggestions and recommendations of improvement about SS tools. The outline of the reports followed the procedure of the research in subsequence. The Figure 1 reveals the structure of the thesis.
2.3 Research strategy

2.3.1 Literature study

In order to have a fully understanding of the previous work which has been done by other researchers, a literature review has been conducted. Generally, two main fields have been studied, which are Six Sigma and Project Management. In the Six Sigma field, we mainly reviewed the concept and development history of Six Sigma, the classic model of Six Sigma, and the success factors for implementing Six Sigma programs. In the project management field, we focused on the main elements which PM contains, such as: quality control, cost control, time control, risk management, and communications in PM. The search of some research papers has been conducted in different databases, such as Academic Search Premier and Google scholar. We also referred to some books and journals which were provided by the library of Linköping University and by our supervisor Peter Cronemyr.

2.3.2 Data collection and analysis

The selection of an appropriate approach to collect data ensures the quality of data. For data collection, the study intends to analyze and compare multiple projects in similar manner to find out the general and urgent problems within the project management in SIT. There were nine interviews in total. These nine interviewees were performed with project managers of Gas Turbine department, Steam Turbine department, and Solution department. They were selected with the help of the project director in SIT. Nine project managers filled out a survey
questionnaire with six aspects of project implementation, and then the results were analyzed. Based on the analysis, an interview based on each result from survey was performed with each project manager to achieve deeper understanding of the problems within the projects. The analysis strategy was primarily based on the qualitative data (Lekvall and Wahlbin, 2008) that was collected through surveys and interviews.

The data collection includes two parts, the primary and secondary data. The primary data was collected through the direct contacts with the project managers using survey and interviews. The secondary data was collected through the other data sources such as website, documentation from SIT. The detailed data collection is presented as bellow.

2.3.3 Survey

The survey questionnaire was developed based on the understanding of the relevant theory derived from the literature (Groves et al., 2009). During the process of designing the survey, the following five principles were always kept in mind to ensure the quality of the questions.

- What is the aim of the question?
- Is the scope of the question proper?
- Are there unstated or misleading assumptions?
- Can the respondents answer this question in an adequate manner or to an adequate degree?
- Are the scales clear?

The first version of the questionnaire was developed in the Six Sigma language including the key factors of successful implementation of SS, the usage of tools in SS and the result of implementing SS in project management. After the first meeting in SIT, the questionnaire was modified to the language of project management. It should be noted that the aim of the questionnaire was to study the current problems in project management and the potential tools of SS to solve these problems, thus the survey questions should cover both of the topics. The second version of the questionnaire was consistent of the background information of the respondents and six important aspects of the project implementation, which were cost, time, quality, customer satisfaction, risk and opportunity and communication. The questions for the six aspects were passed several rounds of the revision and refinements before the questionnaire was distributed. The survey questionnaire was enclosed in Appendix 1.
The samples of the respondents were determined on the basis of filling the information requirements for the research, thus nine managers (3 from GT, 3 from SU and 3 from SOL) were chosen as the samples in this survey. The questionnaires were delivered by e-mail. In order to increase the response rate, the authors’ supervisor Saideh Novin Askloef in SIT distributed the questionnaires. All the respondents replied and the response rate was 100%.

2.3.4 Interview

After we had analyzed and documented the results of the surveys, we conducted a series of interviews based on the surveys so that we could gain a deeper understanding of the current PM situations and problems in SIT. The structure of the interview is based on Gubrium and Holstein (2001).

There were nine interview guides for our nine interviewees, and each of the questionnaires contained around 15 questions. The questions were designed differently based on the results of the surveys. The reason of why we did this was that each interviewee had his own management problems, and the intention was to have a better focus on these problems. On the other hand some of the questions were the same to summarize the common management problems among these nine interviewees. By doing this, we could have a comparison among these answers. Finding out not only the pattern and common problems among the interviewees, but also the individual problems of each interviewee, helped us to understand deeply the root causes of the PM issues. This facilitated us to provide accurate Six Sigma tools to project managers in SIT.

The interviews were divided into three parts. The first part included the general and background questions about the position and some other general information of each interviewee. The second part was the main part of the interviews. The questions were related to the main aspects in PM which were cost, time, quality, and customer satisfaction. The last part of the interviews was more related to the potential Six Sigma tools which we intended to suggest. We introduced the specific tools to the interviewees, and described the working mechanism of each tool. The interviewees were supposed to express their personal opinion about whether these suggested Six Sigma tools could fit or improve their daily project management. Semi-structured interview guide was used for all the interviews. The interview guide can be found in the Appendix 2.
All nine interviews were conducted in SIT with the supervision by Maria Johansson and Ivona Ljungdell. Each interview lasted about one hour. Since we had signed the confidentiality agreements with Siemens, the whole process of the interviews was not tape-recorded; instead, we took notes of each answer. In order to prevent the misunderstanding and faulty data during the interviews, our supervisor Maria Johansson and the interviewer Ksenia also took notes of each answer. In the analysis phase, we have combined all the notes together, so that we could have the information from the interviews as accurate as possible.
3 Chapter 3 Theoretical Framework

3.1 Six Sigma

3.1.1 The concept of Six Sigma

Technically, sigma is a Greek letter which is written as $\sigma$. It is a statistical unit and used both as a symbol and a metric of process variation. Process performance equals Six Sigma when the variation in the individual process or product characteristic gives no more than 3.4 defects per million opportunities (Yang, 2003). Compared to the $3\sigma$ which has 66,807 defects per million opportunities, $6\sigma$ is a considerably high standard and goal; however, this ultimate goal is unattainable for most industries and companies. The different yield under different level of sigma is shown as below (Table 1):

<table>
<thead>
<tr>
<th>Sigma ($\sigma$)</th>
<th>DPMO</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>691,500</td>
<td>30.85</td>
</tr>
<tr>
<td>2</td>
<td>305,837</td>
<td>69.15</td>
</tr>
<tr>
<td>3</td>
<td>66,807</td>
<td>93.32</td>
</tr>
<tr>
<td>4</td>
<td>6,210</td>
<td>99.38</td>
</tr>
<tr>
<td>5</td>
<td>233</td>
<td>99.977</td>
</tr>
<tr>
<td>6</td>
<td>3.4</td>
<td>99.99967</td>
</tr>
</tbody>
</table>

Table 1: Different yield under level of sigma

Six Sigma is also considered as quality management methodology. If a manufacturing or service process is strictly controlled by Six Sigma, then this process hardly has many defects. Coming to a higher level, Six Sigma is not only a simple quality management methodology, but it also contains many concepts, thoughts, methods, and tools which are combined together to help us achieving the target of business excellence (Yang, 2003).

There is considerable literature which defines Six Sigma in many different ways. Tomkins (1997) defines Six Sigma as “a program aimed at the near-elimination of defects from every product, process and transaction.” Lowenthal (2002) considers that Six Sigma focuses on two things: the customer’s requirements and the processes meant to fulfil those requirements. Park
et.al (1999) believes that Six Sigma is a “new strategic paradigm of management innovation for company survival in this 21st century, which implies three things: statistical measurement, management strategy and quality culture.”

In one word, all these different definitions of Six Sigma reflect one basic principal: Six Sigma is a business strategy, it can satisfy the common interests of each member in the same value chain, including stakeholders, customers, employees, and suppliers. Basically, it is also a methodology of customer focus. It can increase the level of production and service quality in the companies; maximize the overall profits, and breakthrough the bottleneck of the companies’ development (Chua, 2001).

3.1.2 The history of Six Sigma development

When the concept of Six Sigma was introduced by Motorola in 1987, modern quality has already had a history of over 100 years or so (Berger, 2002). In the following section, several important developments and methodologies of Six Sigma will be elaborated.

Between 1900 and 1920, the well-known scientific management was invented by Frederick W. Taylor (Gordon, 2007). He analyzed the processes and turned them into a set of standard and repetitive tasks to make the work tangible and measurable.

In 1924, Walter A. Shewhart made first control charts which were spread as Statistical Process Control (El-Haik and Roy, 2005). Shewhart charts contributed to not only specifying the work process by using the engineering method, but also using the statistical methods to quantify the quality and variability of the processes.

During the 1950s, W. Edwards Deming, Armand Feigenbaum, and Joseph M. Juran became prominent as consultants to Japanese to improve their quality and competitiveness after the Second World War (Besterfield, et. al, 2003). They made many and complex contributions to quality management, and some of them are the origins of six sigma. Deming laid stress on the importance of management and management system should be responsible for 94 percent problems (Besterfield, et. al, 2003). He also improved the PDCA circle (plan, do check, action) which was first introduced by Shewhart. Juran emphasized the ongoing quality improvement
for a succession of projects based on the customer satisfaction and dissatisfaction, and believed the top management involvement was critical. Feigenbaum defined TQM (total quality management) as a system to ensure production and service at the most economical levels while meeting customer satisfaction (Besterfield, et al, 2003).

The first generation of six sigma appeared during late 1980s and early 1990s and it was part of continuous improvement and total quality management (Bertels & Strong, 2003). This Six Sigma process improvement included mainly four steps: measure-analyze-improve-control. But this approach didn’t succeed because of the lack of leadership support. The second generation emerged at Alliedsignal in 1994 (Bertels & Strong, 2003). The mainly difference between the first and second generation is the integration of voice of customer. In the second generation, a new step called “define” was added by GE in 1995 (Bertels & Strong, 2003). In this step, the data for customer needs and requirements is collected to identify the critical quality attributes to improve customer satisfaction. Thus the DMAIC methodology now widely used in six sigma implementations was shaped. Finally, the combination of DMAIC, process management and service design (Design for Six Sigma, DFSS) was implemented in the company not only in quality management but as a business strategy (Bertels & Strong, 2003).

3.1.3 The DMAIC process improvement methodology

The DMAIC methodology is one of the most recognized features of Six Sigma, and is one of the most widely tested and merited approaches to bottom-line focused process improvement available today (Pyzdek, 2003). Many companies all over the world apply this methodology in their manufacturing or service processes in order to minimize the defects. This methodology is consisting of five phases: Define, Measure, Analyze, Improve, and Control.

Phase 1 (Define): this phase is the starting point of the whole process. The main target of this phase which we have summarized based on the information Pyzdek (2003) provided is to figure out the issues as following:

- Select the right project.
- Who are the customers?
- What are the customer’s demands or requirements?
- Identify the customer’s Critical-To-Quality.
- Develop the project and team charter

The common tool used in this phase is called the fishbone diagram (Speegle, 2009). It is a simple x-y cause and effect model where x stands for the input factors and y stands for output variable. We need to designate at least one characteristic which we would like to improve through this process. They are marked as y in the fishbone diagram. For each y that has been identified, it is extremely important that the project group acquire a thorough understanding of the customer requirements for this characteristic (Magnusson et al, 2003). The fishbone diagram is shown as Figure 2 (Magnusson et al, 2003):

![Figure 2: The fishbone diagram](image)

Phase 2 (Measure): The first activity of the measure phase is concerned with identifying for each y a number of input factors, x, which might influence y. In reality there are two types of x, which are control factors and noise factors. Control factors can be controlled physically, as opposed to noise factors that are considered to be uncontrollable, too costly to control, or not desirable to control (Magnusson et al, 2003). The goal of this phase is to describe the opportunity for improvement and quantify the baseline performance, is to identify the deficiencies and defects in the whole process through the measurement (Gupta, 2004). The managers need to decide what kind of measurement they intend to use to get the actual data, such as sample size, the duration of the measurement. With these actual data, managers can discover those processes which have significant deviation compared to the standards, and those
which have a large space to be improved. The common tool here is also the fishbone diagram in which we can get a clear picture of causes and effects.

Phase 3 (Analyze): In this phase, managers use various tools and statistical methods to analyze the actual data which they have collected. After the analysis, they will find out all causes which affect the outputs and identify those root causes which affect the outputs significantly. According to Gupta (2004), the common tools used in this phase are Pareto Analysis, Cause-and-Effect Analysis, Multi-vary Analysis, and FMEA. Analyse phase makes the preparation and sets up the target for the next phase: Improve.

Phase 4 (Improve): This phase is related to selecting those product performance characteristics which must be improved to achieve the goals (Park, 2003). These goals could be minimize or eliminate the defects and waste during whole production process. All of these goals are identified in the “Define” phase according to the customers’ requirements and demands. The previous phases: Define; Measure, and Analyze, is the preparation for the “Improve” phase in order to find a way to maximize the profits of the enterprise. It requires the Six Sigma project teams to come up with as many feasible solutions as possible. Team members can gather around, discuss and evaluate all those solutions through the mind storm. Finally, they select one or some the most suitable solutions and set up the implement plan.

Phase 5 (Control): Once the solution has been implemented they should be monitored to make sure that the improvement targets for y have been achieved (Magnusson et. al, 2003). In this last phase of the DMAIC methodology, keeping monitoring the performance of the new improved process is vital. The goal of this phase is to promote and keep the continuous improvement meanwhile to prevent the backwards. Team members usually achieve this goal by using Statistical Process Control (SPC) methods (Park, 2003).

The most advantages of DMAIC methodology are summed up as follows:

- Expose the real problems. DMAIC is a systematic quality management approach of removing the appearance and examining the inner characteristics of the process (Pande et.al, 2002).
- Concentrate on the customers. From the beginning to the end of DMAIC, customer focus is one of the most important aspects. In this way, it is easier to reach the customers’ requirements and improve the customers’ satisfaction (George, 2003).

- Based on the facts. All the phases are implemented base on the facts and actual data. This is very important especially when it comes to the quality improvement and control of the products and services (Pande et.al, 2002).

- Continuous and sustainable improvement process. What DMAIC provides us is not a one-way process; it is more like a round improving process in which the previous knowledge and experiences are valuable for the optimizing the process continuously, in order to achieve the business excellence (Pande et.al, 2002).
The flowchart for DMAIC methodology is shown as below in Figure 3.

Figure 3: The DMAIC flowchart (Park, 2003)
3.1.4 **Success factors for implementing six sigma programs**

The success factors of Six Sigma project implementation have been identified by several authors. Schöen (2006) suggested six most important factors of Six Sigma implementation based on the literature review of Henderson and Evans (2000), Goldstein (2001), Antony and Banuelas (2002), Sandholm and Sörvist (2002) and Pande et. al. (2000). The six factors suggested by Schöen include management commitment; focus on training; project selection; strategy for implementation; linking Six Sigma to business strategy and focus on results. Snee and Hoerl (2002) also identified three successful attributes of the Six Sigma implementation by comparing the very successful and less successful projects. These three successful factors are committed leadership, use of top talent, and support infrastructure. The less successful projects didn’t have management commitment, but only the supportive leadership; they didn’t have the formal appointment of the Black Belt; and there was no formal supportive infrastructure such as “no formal project selection and process, only part time resource available and not involved in the financial system (Snee and Hoerl, 2002).”

Jones et al. (2010) stated the role of Black Belt as a success factor. He argued that the roles of Black Belt are used differently in different organizations, and it would be helpful to measure the degree of Black Belt dedicated to Six Sigma or the degree that they split their time in Six Sigma and management activities. Schroeder et al. (2008) mentioned Black Belt can help to fill the gap between the top management and Six Sigma project team.

From the literature above, the top management and the supportive system are important to implement Six Sigma successfully. Choo et al. (2007a&b) argued that the improvement of quality is affected by both the quality methods and psychology variables and they also tested these variables on the six sigma implementation. Thus the implementation from an organisational learning perspective (Wiklun et.al, 2002) is necessary to be taken into consideration. They stated that all the aspects of implementing Six Sigma such as the knowledge in behavioural science should be implemented rather than implementing DMAIC merely. The Black Belts and Master Black Belts should have the training on change management besides the usual training on statistical methods. When Black Belt and Master Black Belt master the knowledge of quality and management, this organization could reach the goal of facilitating the organizational learning.
Jones et al. (2010) proposed a conceptual framework for Six Sigma implementing with reference to both contextual elements (e.g. leadership) and methodological techniques (e.g. DMAIC). The role of executive support is facilitated by Black Belt (Jones et al., 2010), and Black Belt are champions that direct and manage Six Sigma initiatives (Schroeder et al., 2008). “While top management is not directly involved in Six Sigma implementation, it is believed that through supporting and empowering Black Belts top management can accelerate the progress of Six Sigma implementation” (Jones, et al., 2010) The model is shown in Figure 4.
3.2 Project management

3.2.1 The concept of project and project management

The definition of project varies from one company to another. In some cases, the word is used loosely to describe any task, exceptional or recurring. Thus, a “project” could mean any routine that demands time (Thomsett, 2010). Tonnquist (2008) has pointed out that the project is a temporary organization which is appropriate when there is a need for coordination between various parts of the company. It has 4 criteria:

- Specific goal: a unique assignment;
- Specific time period;
- Specific resources;
- Unique work arrangements: temporary organization

This temporary organization is created within the company and enables the company to keep the strong focus on customer value through the goal management. In the project, the project manager has the full authority and responsibility of the planning, execution, and closing of the organization (Tonnquist, 2008). Key project management responsibilities include creating clear and attainable project objectives, building the project requirements, and managing the triple constraint for projects, which is cost, time, and quality (Tonnquist, 2008).

Project management is the science of organizing the components of a project, whether the project is development of a new product, the launch of a new service, or a marketing campaign (Tonnquist, 2008). It is the discipline of planning, organizing, securing, and managing resources to achieve specific goals. No matter what type of project, project management typically follows the same pattern:

- Definition
- Planning
- Execution
- Control
- Closure
However, although the project is relatively independent from the line production within the company, a successful project management result is depended not only on the internal management but also on the cooperation between the line production and the project team. During this period, line managers create value through improving individuals’ skills and processes, while project managers create value through delivering results and changes (Tonnquist, 2008). It requires an intensive collaborative work among the company management, line manager, project manager, and the individual employees. Looking back to many fail cases of project management, two major reasons are:

- Unclear internal project control and management;
- Inefficient collaboration among the top management, line manager, project manager, and employees.

### 3.2.2 Triple constraint for project management

One major challenge of each project is making the project work and be relatively successful within the Triple Constraint (Tonnquist, 2008). The Triple Constraint (Figure 5) contains three elements which are quality (both process quality and product quality), cost (both expenditure and resources) and time (schedule). These three elements of a project are connected with each other. If one of these elements is restricted or extended, the other two elements need also then be either extended/increased in some way or restricted/reduced in some way. There needs to be a balance between these three elements that only when fully understood by the Project Manager, allows for the successful planning, resourcing and execution of a project. These are the key elements of a successful project and these are the things that will determine whether or not you have successfully managed a project.

Tonnquist (2008) explained that a project manager has to know which factor is most important in the project, and where it is possible to compromise if the project does not stick to the plan. One famous approach of prioritizing is to rank the triple constraints by sharing 100% among:

Quality____%  Time____%  Cost____%
The prioritization needs to be done in the early phase of the project and this can only be completed by communicating with the clients, both internally and externally. Project manager gathers all the team members to have a thorough discussion and ensure a full understanding of the project. If, for instance, the top priority of one specific project lies with the Time, it indicates that the delivery time (schedule) is more important than the other two in this project.

Now, we are going to look a bit more closely at the three elements which build up the Triple Constraint:

3.2.3 Quality (Process and Product)

This element includes quality planning, quality control and quality assurance. Quality planning involves identifying which quality standards are relevant to the project and preparing plans that will satisfy the requirements. Quality control is the appraisal of specific project outcomes to determine if they comply with quality requirements and taking corrective action if non-compliance is found. Quality assurance is the periodic review of actual project performance to ensure that quality plans have been implemented and that quality procedures are being followed correctly. Quality assurance also involves taking corrective action if non-compliance with established procedures is found or modifying the quality plan if quality control results show that it is inadequate. (Tonnquist, 2008)
Tonnquist (2008) stated that the quality planning, quality control and quality assurance combined together is known as Quality management plan. In this plan, project teams are required to use some tools and methods to monitor and control the process. One approach is using the trend chart to establish the quality standard the project should comply with. In many cases, this is regulated by the clients. Another method is using the Cause and Effect Diagram. Quality also refers to the scope of the project, which is a clear, specific statement of what has been agreed to be preformed/achieved in a particular project. In other words, the scope of the project lays out the functions, features, data, content, etc. which is contained in the project. You could also be said that the scope clearly expresses the desired final result of a project.

3.2.4 Cost (both expenditure and resources)

This second element of the Triple Constraint is known as either Resources or Cost. Resources always cost money so the two are interchangeable in many ways. When we talk about the cost of a project, we are talking about what needs to be applied or assigned to the project in terms of money and effort in order to make things happen. This can be resources like manpower/labour, it can be materials needed for the job, resources for risk management and assessment or any third party resources that might need to be secured. (PMI, 2008)

In order to develop an estimation of a project cost, it depends on several variables including: resources, work packages such as labour rates and mitigating or controlling influencing factors that create cost variances tools used in cost are, risk management, cost contingency), cost escalation, and indirect costs. (PMI, 2008)

Cost Process Areas:
- Cost Estimating is an approximation of the cost of all resources needed to complete activities.
- Cost budgeting aggregating the estimated costs of resources, work packages and activities to establish a cost baseline.
- Cost Control - factors that create cost fluctuation and variance can be influenced and controlled using various cost management tools.
3.2.5 Time/Schedule

Time, in project management, should be planned to its smallest detail. The amount of time required to complete each and every component of a project is analyzed. Once analysis has taken place, those components are broken down even further into the time required to do each task. Obviously from all of this we are able to estimate the duration of the project as well as what and how many/much resources need to be dedicated to that particular project. For analytical purposes, the time required to produce a deliverable is estimated using several techniques. One method is to identify tasks needed to produce the deliverables documented in a work breakdown structure or WBS. The work effort for each task is estimated and those estimates are rolled up into the final deliverable estimate.

The tasks are also prioritized, dependencies between tasks are identified, and this information is documented in a project schedule. The dependencies between the tasks can affect the length of the overall project (dependency constrained), as can the availability of resources (resource constrained). Time is different from all other resources and cost categories.


3.2.6 Risk management in project management

Risk management is a structured approach which consists of “risk identification, a qualitative way of risk analysis, a quantitative way of risk analysis and risk response plan” (Vose, 2008). Contingency response with extra time/cost buffer for unseen events can be a wise decision based on the experience from previous project execution.

Risk identification

Risk event is the event that may have a negative impact on the project. The first step is to identify the risk (Tonnquist, 2008). Usually brainstorming is an excellent way to identify and discover the potential risks. The phases of pre-study and planning of project need to be
implemented before risk planning and response planning. Consequently there are many available resources for identifying the potential risk events. And the project team members should use these resources as much as possible. The resources include “project charter, the work breakdown structure, the SWOT analysis (Strength, Weakness, Opportunity and Threat), the requirement specification, the time and resource estimates, resource and staffing planning, stakeholder analysis, the chosen solution” (Tonnquist, 2008). Among these resources, the SWOT analysis method has the priority for project risk identification during preparation. The treats and weaknesses of SWOT should be eliminated or minimized by experienced planning. Some threats and weakness may probably not be eliminated. All the identified risks should be documented and stated in the project planning.

The categorization of the risk events is also recommended. This can make the risk event more clear and facilitate the process of risk response plan. The risk categories may include: technique and execution risks, project management risks, organizational risks, external risks and etc (Zaval and Wagner, 2011).

Quantitative risk analysis

Both the probability of the risk events and the impact of the consequence will have the influence on the project (Molenaar et al., 2010). Thus the risk value of the project should be calculated based on both factors, which can be shown as "probability” multiplied “impact”. Both probability and impact are rated on the scale from one to five and one is the lowest and five is the highest (Figure 6). The project manager will make risk response plan based on the risk value. Usually a group of members need to be assigned for risk analysis with the risk mitigation plan. To analysis the risk level, the team should insert the result into the risk matrix as shown in Table 3. After calculation, the risks which are located in the upper right corner have been responded via risk response planning. Usually the mitigation should be done before project initiation if the score is above 20. And the risk with high impact values also should be migrated (Tonnquist, 2008).
The risk with the higher priority may need deeper analysis. The impact of the risk extends to the product quality, resource and project schedule influence (Kendrick, 2009). The Table 3 is the matrix of risk with these three parameters. This matrix table can illustrate which of the risk consequence has the highest influence.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Probability 1 to 5</th>
<th>Impact 1 to 5</th>
<th>Risk value ( P \times I = )</th>
<th>Risk response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>T</td>
<td>R</td>
<td>Q</td>
<td>T</td>
</tr>
</tbody>
</table>

Table 3: Risk matrix with quality, time and resource

**Risk response plan**

The risk response plan is the strategy for dealing with the potential risk to ensure the project success (Heldman, 2011). Usually the strategies for risk response are as following:

- Avoid risk
- Transfer risk
- Mitigate risk
- Accept risk
3.2.7 Communication in project management

The purpose of communication is to reach the communication goals for all the stakeholders and express clearly of what the manager want to the different stakeholder to know, feel and do (Tonnquist, 2008). And it is one of the important tasks for project managers.

Communication model

The basic communication process is shown in

Figure 7 (Tonnquist, 2008), and this model is based on the model of Lasswell, Shannon and Weaver (1949). Communication is a two-way flow while the information can be transferred in one direction (Narula, 2006). When sender and receiver have information transmission between each other, communication happens. To achieve an effect in this communication model, the senders send the information of the current situation of the project and obtain the response from the receivers (Tonnquist, 2008). All of these information transmission and feedback exchange need be based on one purpose; otherwise the communication would be meaningless. Right and precise encoding and decoding in this model can be a vital process to avoid the misunderstanding. Thus it is important the senders and receiver speak the “same language” and the message can be interpreted as the way it was meant to be. A communication way which is comprehended by both sides can facilitate the communication process.

Feedback from the receiver can be a good signal of the success of the communication (Stewart et al., 2007). Based on the feedback from information receiver, the senders can evaluate the effect of this communication and also can improve the process continuously. The interference sometimes can interrupt the communication both in transmission and feedback. This can obstruct the communication result from the wanted purpose.
Communication plan

It is importance to establish a regular communication system in project. This can facilitate the process of sending the information to the target groups in an appropriate manner (Heldman, 2011). By planning with the information flows, the risk of making mistakes and the misunderstanding between the members can be minimized. The communication plan can make sure the information that the project managers want to distribute correctly.

Table 4 is an example of the communication plan in the project (Tonnquist, 2008). Six parts should be included which are who-receiver, why, what, how, when and who-sender. In the example, there are suggested situations in each column, and the whole plan should contain the practical situation for each project. Four methods/systems can be important to implement the project communications which are reports system, meetings system, project office and project portal.

<table>
<thead>
<tr>
<th>Who-receiver</th>
<th>Why</th>
<th>What</th>
<th>How</th>
<th>When</th>
<th>Who-responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>All project members</td>
<td>Establish the project with the important</td>
<td>Pre study Requirements</td>
<td>Project meetings Reports</td>
<td>Pre-planed</td>
<td>Project manager Sponsor</td>
</tr>
</tbody>
</table>
A vital part of project communication is about progress and performance reporting (Schwalbe, 2008). The project manager needs to obtain the information from the team members about what they have accomplished and how much time they have used. This information is important for the right decisions of the project managers. Failing of the performance reporting, a risk may happen, such as the wrong perception from the steering committee and sponsors about the project progress (Schwalbe, 2008). The report from team members to project manager should include resource or activity level, result and time reporting (Tonnquist, 2008). The report from project manager to sponsor or steering committee can be a little different, which should include the overall project activity, result and time and cost reporting.

There are different kinds of meetings to be scheduled in the project planning phase. Project meeting should be held regularly, at least once a week. Steering committee meeting should also be held regularly, especially during the tollgates and unforeseen events (Tonnquist, 2008).

Project office is the locations that can keep the group members work together (Block and Frame, 2001). Usually the wall of the office is used for the changes and results continuously updated on daily bases. This generates an image for the group members about the task and the prioritization. Project portal is a virtual office for project team. It is the administrative platform where the project documentation stored and shared (Srikantaiah et al., 2010). The convenient web service

<table>
<thead>
<tr>
<th>Clients</th>
<th>Reference group</th>
<th>Line organization</th>
<th>stakeholders</th>
<th>Budget and calculation</th>
<th>Online project</th>
<th>When needed</th>
<th>Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deliver decision documentation</td>
<td>Distribute the finical reports</td>
<td>Exchange lessons learned</td>
<td>Resource requirements Status Finical outcome</td>
<td>Demonstration presentation Revision Final report</td>
<td></td>
<td>Continuously</td>
<td>Project team members</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Project review experience</td>
<td></td>
<td></td>
<td></td>
<td>Quality assurance managers</td>
</tr>
</tbody>
</table>

Table 4: Communication plan (Tonnquist, 2008)
can easily control the file access to different group people. And it is also possible to access with no territorial restrict. This platform can facility the communication within the project efficiently.
4 Chapter 4 Introduction of Six Sigma Tools

4.1 QFD

QFD (Quality Function Deployment) is also known as the House of Quality matrix (Akao, 1990). It is a systematic approach to design based on a close awareness of customer desires, coupled with the integration of corporate functional groups. It is also an important tool for translating customer requirements, demands, and expectations into appropriate design and product characteristics (Michalski, 2003). It requires to be integrated with the product development teams, cross-functional communications and teamwork in the planning, engineering, and manufacturing activities and aligns them to achieve quality and customer satisfaction (Michalski, 2003).

The 3 main goals in implementing QFD are (Akao, 1990):

1. Prioritize spoken and unspoken customer wants and needs.
2. Translate these needs into technical characteristics and specifications.
3. Build and deliver a quality product or service by focusing everybody toward customer satisfaction.

Quality Function Deployment has helped to transform the way many companies (Akao, 1990):

- Plan new products
- Design product requirements
- Determine process characteristics
- Control the manufacturing process
- Document already existing product specifications

QFD uses some principles from Concurrent Engineering in that cross-functional teams are involved in all phases of product development (Michalski, 2003). Each of the four phases in a QFD process uses a matrix to translate customer requirements from initial planning stages through production control (Becker Associates Inc, 2000). We are going to introduce how these four phases work in a QFD process in the following section.
Each phase or matrix represents a more specific aspect of the product's requirements. Relationships between elements are evaluated for each phase (Akao, 1990). Only the most important aspects from each phase are deployed into the next matrix.

Ultimately the goal of QFD is to translate often subjective quality criteria into objective ones that can be quantified and measured and which can then be used to design and manufacture the product (Akao, 1990).

The chart below is the template of the QFD (Park, 2003). In the left column which is marked yellow, is the list of Voice of Customer (VOC). In the upper row which is marked blue is the list of Quality Characteristics (QC) of a product. In the middle section which is marked green is the Rate of Co-relationship between VOC and QC. QC stands for any functional or appearance characteristic which can be used for measuring the quality of product or process. Weighting is the importance rate of each VOC; it should be determined based on the actual needs and requirements of the customers. The main goal is to calculate the total score of improving rate of VOC and improving effect of VOC.

<table>
<thead>
<tr>
<th>QFD</th>
<th>Weighing</th>
<th>QC</th>
<th>Improving rate of VOC</th>
<th>Improving effect of VOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5: The general model of QFD**

4.1.1 **Approach of implementing QFD:**

Below is one specific approach of implementing QFD. This is also based on the knowledge which Sakao (2010) provided.
Phase 0: Gather and prioritize the customers’ needs/VOC

The phase 0 in a QFD project is to determine what market segments will be analyzed during the process and to identify who the customers are. In this phase, practitioners should mainly do two things. First, they should collect the VOC from the customer, through negotiations and meetings. Then they should give each of the VOC an importance rate base on the actual needs of the customers, so that all the VOC can be prioritized. These group rates will be used later in the relationship matrix.

Phase 1: Determine which kind of quality characteristic is more important

In the first phase of QFD, the team needs to identify the Quality Characteristics of the product. Then they should identify the rate of co-relationship between VOC and QC through meetings and discussions. The last step which the team should do is to do some easy math to calculate the relative weight of each QC. This group of weights will be used later in the phase 2.

Phase 2: Translate QC into key components of the product

The first step in phase 2 is to identify the key components of the product. Then, based on the same theory in phase 1, the team needs to give the rate of co-relationship between key components and QC. According to the data input, the team further needs to calculate the relative weight on key components. This group of rate will also be used in the phase 3 of QFD process.

Phase 3: Generate design or improving options and calculate the rates

In this phase, the team generates several design or improving options of the product according to the results of the first two phases, and calculate the improving rates on QC of each option. The rates will be used in the phase 4 of QFD process.

Phase 4: Test the effect of each option based on the VOC, and then compare them

In the phase 4, the team needs to take the improving rate on QC, which is calculated in the phase 3, back to the VOC, to testify the improving effect of each option based on the VOC. Finally,
compare among the several options according to the VOC, and draw the conclusion about which option has a better improving effect on the production.

4.2 CTQ

CTQs (Critical to Quality) are the most important, measurable characteristics of the finished product or process whose performance standards or specification limits must be met in order to satisfy the customer (Michalski, 2003; White, 2006). CTQs represent the product or service characteristics that are defined by the customer (internal or external). They may include the upper and lower specification limits or any other factors related to the product or service. A CTQ usually must be interpreted from a qualitative customer statement to an actionable, quantitative business specification (White, 2006).

The measurement takes place not only on the finished products but also during the whole process. Examples of the measurable characteristics of a product would be like length, width, and height, and product performance measurements like capacity, write time, or error performance (White, 2006). Examples of the measurable characteristics of a process would be like duration and time consuming, expenditure and cost, etc. Establishing CTQs is vital for a company to meet customer needs and keep up with the competition.

The purpose of Critical-To-Quality trees is to convert customer needs or wants to measurable requirements for the business to implement. The figure shown below is an example of the CTQ tree. It has five main aspects which are Need, Diver, CTQs, Measurement, and Target. The project team members need to sit together and conduct the discussions and meetings, in order to identify these five aspects accurately.
Figure 8: Template of CTQ from SIT Six Sigma project management model

4.3 SIPOC

SIPOC is a Six Sigma tool used for obtaining a high level of understanding of the scope of the organization process, and the acronym SIPOC stands for supplier, input, process, output and customer (Shankar, 2009). A SIPOC diagram or chart is usually expressed as Figure 9 and the customer requirements in an additional column are always added. This tool is usually used at the beginning of the project to define the project scope and scale and this method is used in the D (design) and M (measure) phase of the DMAIC methodology which includes design, measure, analysis, improve and control (Shankar, 2009).

SIPOC provides a structured way to discuss the process and draw consensus on what it involves in the whole process. It is always interesting to find out that the same process in different departments may be interpreted differently. As the different perceptions existed for the process, misunderstanding could exist during the performing the process (Breyfogle, 2003). Adding and merging the diverse experience or perspectives from different department could make the process more consistent and integrated. And also the SIPOC method can define the clarify boundaries of roles, responsibility and requirements of those working on the process to avoid the ambiguity (Soleimannejed, 2004).
As the traditional SIPOC diagram is divided into blocks with one direction connection, the communication between company, customers and suppliers can be in poverty. The problems can happen from the beginning and detected at the end, thus the internal and external feedback loops can be added referring to Michalski (2003). The aim of the feedback loops is to minimize the misunderstanding problems by increasing the communication within and out of project.

Based the synchronization of parallel metrics with the traditional SIPOC model, an improved model can be advised to take into the implementation (Smith et al., 2008). This model can synchronize the quality, cost and time metrics with the process inputs, process and outputs. The control of the metrics can be taken during the whole process. The model can be shown as in Table 6.
Step 1: The team use brainstorming or meetings to develop a SIPOC diagram, list out the interconnected five blocks of the suppliers, input activities and resources, process, out activities and products, customers. This can be taken as the traditional SIPOC process (Shankar, 2009).

Step 2: The internal feedbacks can be made between the long-term relationship suppliers and the project execution from input and output (Michalski, 2003). The suppliers can always participate into the interactive process to quickly solve the problems that may happen. External feedback loop contains the communication between the customer, supplier and the input of the projects (Michalski, 2003). The involvement of the customer can minimize the misunderstanding problems from the project initiation. However, confidentiality can be a big problem here. Thus to what extend should the communication goes into can be a critical issue to consider carefully.

Step 3: Synchronize the quality, cost and risk metrics with the process inputs, process and outputs (Smith et al., 2008). The input figures can come from the CTQ model result. The data is divided into detail steps in the process phase. The output metrics is the target value in the CTQ result. The buffers for data estimation are suggested to reach the targets value with less deviation.
Step 4: Use the diagram as a guide to find out potential problems and process improve suggestions (Rath & Strong, 2005).

4.4 FMEA

FEMA stands for Failure Model Effect Analysis and is “a technique used to identify, prioritize, and eliminate potential failures from the system, design or process before they reach the customer” (Stamatis, 2003). It helps the team to identify the potential failure of the modes based on the experience from the product design or process (Borror, 2008), enabling the project to defect and design the failure with the minimum of effort to reduce the time and cost spent.

4.4.1 Traditional FMEA

The most wildly used FMEA is the Mil-Std-1629A procedure, which was developed by Navy in 1974 (Brue & Howes, 2005). The task of FMEA can be divided into three categories: identify failures, prioritize failures and reduce risk as in Table 7 (Kmenta & Ishii, 2000).

<table>
<thead>
<tr>
<th>FMEA Task</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify failures</td>
<td>Describe Failures: Causes - Failure Modes - Effects</td>
</tr>
<tr>
<td>Prioritize Failures</td>
<td>Assess Risk Priority Numbers (RPN): ( RPN = \text{failure occurrence} \times \text{effects severity} \times \text{detection difficulty} )</td>
</tr>
<tr>
<td>Reduce Risk</td>
<td>Reduce risk through: reliability, test plans, manufacturing changes, inspection, etc.</td>
</tr>
</tbody>
</table>

Table 7: Three major tasks of FMEA

The elaborate procedure of the FMEA spreadsheet is illustrated in Figure 10 (McDermott et al., 1996). This form can provide all the important information about the FMEA to be a good communication tool.
### Figure 10: The traditional FMEA Worksheet

According to the basic of FMEA, the detailed implementation of traditional FMEA worksheet is shown as follows (McDermott et al., 1996):

**Step 1: review the process**
All the group members should have the same understanding of the process. If they are conducting a product FMEA, they should have a review of the product and see the physical or the prototype of the product. If the process FMEA is conducted, the team members should have a review of the detailed flowchart and physically go through the whole process flows. The experts of the product or the process are recommended to help the team with the problems that may occur.

**Step 2: brainstorm potential**
Team members should participate in the brainstorming meeting with a list of their ideas. And it is better for each member to focus on one element, for example: people, material, methods and etc. This will result in a thorough list of potential failure modes.

**Step 3: list potential effects of each failure modes**
With the possible failure modes listed out, the team review each failure mode and identify the potential effects of the failure. There can be only one effect for some failure modes, while several effects for the others.

**Step 4, 5 and 6: assigning severity, occurrence and detection ratings**
- Occurrence (O) – how often is the failure mode happened?
- Severity (S) - how serious is the result effect?
- Detection (D) – what is the probability of the failure detected before it reaches the customer?

All of these three ratings are from 1 to 10 scales, with 1 as the lowest and 10 as the highest. It is important to make clear scales, so all the team members can have the same understanding of the scales. The definitions and detailed measurement of the three elements will be described in the following sections:

Probability of Occurrence (O)
Occurrence is related to the probability of the failure mode and cause. The Occurrence values are arbitrarily related to probabilities or failure rates (Table 8).

<table>
<thead>
<tr>
<th>Probability of Failure</th>
<th>Failure Rates</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High: Failure is almost inevitable</td>
<td>&gt;1 in 2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1 in 3</td>
<td>9</td>
</tr>
<tr>
<td>High: Repeated Failures</td>
<td>1 in 8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>1 in 20</td>
<td>7</td>
</tr>
<tr>
<td>Moderate: Occasional failures</td>
<td>1 in 80</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>1 in 400</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>1 in 2000</td>
<td>4</td>
</tr>
<tr>
<td>Low: Relatively few failures</td>
<td>1 in 15000</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1 in 150000</td>
<td>2</td>
</tr>
<tr>
<td>Remote: Failure unlikely</td>
<td>1 in 1500000</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 8: Occurrence criteria (adapted from AIAG, 1995)

Severity of Effect (S)
Severity measures the seriousness of the effects of a failure mode. Severity categories are estimated using a 1 to 10 scale (Kmenta & Ishii, 2000), and the detail criteria are shown in Table 9.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No effect</td>
</tr>
<tr>
<td>Index</td>
<td>Severity Description</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>Very minor (only noticed by discriminating customers)</td>
</tr>
<tr>
<td>3</td>
<td>Minor (affects very little of the system, noticed by average customer)</td>
</tr>
<tr>
<td>4/5/6</td>
<td>Moderate (most customers are annoyed)</td>
</tr>
<tr>
<td>7/8</td>
<td>High (causes a loss of primary function; customers are dissatisfied)</td>
</tr>
<tr>
<td>9/10</td>
<td>Very high and hazardous (product becomes inoperative; customers angered; the failure may result unsafe operation and possible injury)</td>
</tr>
</tbody>
</table>

Table 9: Severity criteria (Kmenta & Ishii, 2000)

Detection (D)
Detection definition: What is the chance of the customer catching the problem before the problem results in catastrophic failure? The rating decreases as the chance of detecting the problem is increased, for example: 10 means the problem is almost impossible to detect and on the contrary, 1 means the problem is almost certain to detect (Palady, 1995).

Step 7: calculate the risk priority number for each effect and prioritize the failure modes
The RPN (Risk Priority Number) used to access risk is calculated based on the three criteria:

\[
RPN = O \times S \times D
\]

O, S and D are rated on 1 to 10 scales. The big risk priority number stands for high priority level.

Step 8: take action to eliminate or reduce the high risk failure modes
The team members should make some plans or actions to reduce or eliminate the high risk failure modes.
4.4.2 Expected cost FMEA

The RPN number has no clear meaning, and O, S and D can have different meanings for each FEMA, so it is hard to sharing the data between different companies.

Recently there are some criticisms about the original FMEA, such as FMEA is performed too late and doesn’t affect the key product and process decisions (McKinney, 1991), FMEA often missed the key failures (Bednarz et al., 1988) and Harpster (1999) considered that RPN is not a good measurement of risk. Steven Kmenta (2002) proposed a scenario-based FMEA by using expect cost (Figure 11). According to the risk definition in Webster’s dictionary, risk is the possibility of loss or injury. He found that occurrence is related to probability; severity is related to the cost and there are too many confusing definitions for detection. Thus he proposed a new way to measure the risk –“expected cost”.

\[
\text{Expected cost} = \text{(probability)} \times \text{(cost)}
\]

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Function/ Requirement</th>
<th>Potential Failure Modes</th>
<th>Potential Causes of Failure</th>
<th>Probability</th>
<th>Occurrence</th>
<th>Local Effects</th>
<th>End Effects</th>
<th>Cost</th>
<th>Severity</th>
<th>Detection</th>
<th>exp. Cost</th>
<th>RPN</th>
</tr>
</thead>
</table>

Figure 11: The cost-expected FMEA model

Based on this model, the priority can be given based on different focus. While the situations such as high RPN number with low expected cost and low RPN number with high expected cost happen, the decision for the priority of the risks and response plans can be made based on the overall consideration.
5 Chapter 5 Empirical Findings

5.1 Current situation of project management in SIT

Our surveys and interviews have been designed based on the six important aspects of the project implementation as we explained above; which are cost, time, quality, customer satisfaction, risk and opportunity, and communication. The methodology will help us understand the current situation and difficulties which the project managers and team members are facing in their daily management works.

5.1.1 General process map of SIT project management

First of all, Figure 12 is showing the general process map of SIT project management.

![General process map of SIT project management](image)

Figure 12: General process map of SIT project management

After we have conducted the surveys and interviews, we have gained a general and clear understanding of how the projects in SIT work. Normally, a whole project in SIT contains three phases, which are sales phase, project execution phase, and warranty phase. In our case, we only focus on the first two phases. The Figure 12 above shows every step the team members
should do in these two phases. After each step, there is a milestone, which is shown as PM100, PM200 and etc. These milestones are set in order to facilitate the team members to review the work previously. There are also three Quality Gates (QGs). They are used for checking out all the work which has been done between the two QGs, and to make sure that everything of the project is still under control. There is a common idea among the project managers that the difference between QG and Milestone is that QG is more formal than Milestone. A Milestone may be conducted by individual. On the contrary, QG has to be conducted in a formal meeting by the whole team. The main work which should be done in QG is to fill out the checklists, review the schedule, and do the written documentations.

5.1.2 Current situation and difficulties of SIT project management

From the results of the surveys and interviews, we have summarized 5 common management difficulties which most of the 9 interviewed project managers have stated. Due to the confidentiality issue, in the following text, we use the expression of “GT/ST/SOL + Number” to refer to the different manager in different department who was interviewed by us, such as: ST2 referring to the second manager in Steam Turbine department who was interviewed. These management problems are:

- **Unclear project scoping**

Unclear scoping is mostly reflected as no clear project boundary. Project members sometimes are confused about who should do what at when. Manager GT2 said that there were lots of specifications and some were easy to be missed. Manager GT3 stated the contract was not been studied in detail in the early phase of the project. Manager ST1 pointed out that sometimes the lack of investigation with clients and sales teams caused the unclear scoping. Talking about the improvement methods, most of the managers suggested that they needed a more detailed planning and action in project scoping, such as more communication, feed-back from clients, suppliers and sales team, more internal meetings and brainstorming, more investigation in the early phase. Manager SOL3 indicated that his team was using a management tool: ABA-list to define the scope and customers’ needs. He also pointed out that this tool was not detailed enough. Some of the important specifications were missing in
this tool, such as the definition of the handover from sales to project teams. Many problems occurred during the handovers. Furthermore, there was not an interface control in this tool.

-  **Misunderstanding the customers’ needs**

Sometimes the project teams misunderstood what the customers’ really wanted and caused the customer unsatisfied. For this reason, Manager SOL1 stated that the team missed some of the customer requirements. Manager GT3 said customers were not really involved in the projects. The communication among the customers, sales, and project teams were lacking. According to these facts, some managers made suggestions for improvement. Manager GT2 said that project teams should quantify the customers’ needs in order to get a more clear understanding of VOC. Manager GT3 suggested that customers need to get involved in the projects, and more meetings for exchanging the information should be conducted.

-  **Risk assessment and response**

Some of the project managers seldom had a clear strategy of dealing with the risks which they were facing. They stated that some project teams seldom conducted the risk identification and measurement after they have received the risk list from the sales teams. Therefore, the response to the risk was not efficient or proper. However, some of the project teams were dealing with the risks proactively. SOL3 stated that after their team received the risk list from sales, they would sit together, conduct the risk assessment, and add more risks based on their own situation. During the process of assessment, all the team members participated. According to the explanation of these nine project managers, the frequency of the risk assessment conducted by the project team was different. Some of them assessed the risks monthly, while others did this every three months. Most of the project teams use Risk Matrix, a formalized tool in SIT, to analyze the value and probability of the risks. All these activities were conducted in PACT, Project Acceleration via Coaching and Teamwork. It was the workshop meeting, and was mandatory for level A and B projects in GT and SOL, and level C projects in ST. During these workshop meetings, project teams did project planning, target identification, making project chart, risk assessment, stakeholder analysis, communication and organizational chart. As for the improvement of the risk assessment, both SOL3 and GT2 indicated that it was very important to gather all the team members together and have the discussions. During the discussions, team members should share the
knowledge and personal experience with each other. GT2 also said that risk assessment was not that hard, the hardest part was to let everyone in the team to be aware of the potential risks and get prepared. Some of the managers felt positive if there was a more detailed tool for assessing the risks and response even if they have already had a proper strategy when dealing with the potential risks, since they intended to continuously improve the performance of risk assessment.

- **Late and wrong delivery**

This is a problem mentioned by most of the project managers. Manager SOL1 pointed out there were incomplete or missing parts of the product (bolts, clamps, small items) which caused the wrong delivery. The internal reason can be that all parts of the system were not defined well (no detailed items and parts list), while no inspection from the sub-suppliers before the delivery can be the external reason. Manger SOL2 mentioned that there is no common way of reporting from sub-suppliers. Manger ST1 suggested that a periodical review with sub-suppliers was necessary. Manger GT3 mentioned that two different time schedules were used in production and sales phase for one project.

The current tool that most of the managers used for time control was Gantt chart in the program of MS-project. Although most of the managers were satisfied with this tool, there were some problems. Manager SOL2 said that it was difficult to reschedule the Gantt chart, and manager SOL3 pointed out that only Gantt chart was not sufficient and a link should be made between the sub-supplier schedule and the whole project schedule.

- **Cost problems**

Most of the managers have done the reviews of project costs quarterly. The cost estimation is under good control by the managers due to the fact that the degree of the cost sensitivity of the customer is low. However, some problems still exist in the cost estimation and a more detailed description of them follows.

Due to time issues, manager GT3 and SOL1 mentioned that too much material need to be delivered. The change of the material price from sub-suppliers would lead to the wrong estimation. Manager GT2 mentioned there was always something missing in the sales phase and manger SOL2 said that the cost estimation in the sales phase was not made based on the consideration of the production and clear scope, thus the deviation of the cost estimation
could happen. Bad updates from sale phase to the project execution phase could also be one of the major problems related to cost. The reason for this could be no clear responsibility among the project team members. Since SIT is a company with business distributed all over the world, manager SOL3 mentioned the difficulty to manage unplanned activities due to culture difference, such as tax regulations, policies and different component standards. He made suggestions for building a relationship with the local company, setting up the platform of the learning lessons from different countries.

The current tools used are PROCON, Material Index and SCS checklist. PROCON is a tool for cost estimation in sales phase, but it is badly updated because unclear responsibility for updating and also the cost differs over time. Material Index is used to smooth the cost buffer in budget. The project managers usually do the cost estimation manually, and based on the checklists from SCS systems. SCS is a tool from sales phase, used to make cost estimation based on the value of each component in the database checklist.

5.2 A Model for improving the unclear scoping and misunderstanding customer needs

5.2.1 The model introduction

Based on the first two PM problems which are unclear project scoping and misunderstanding the customers’ needs, we provide a model which we think can to some extent improve the current situation in SIT project management. This model is called: “VOC-CTQ-SIPOC” in which we implement some of the Six Sigma tools we have explained in Theoretical Framework.

Figure 13 below is the working process of this model.

![VOC-CTQ-SIPOC Model](image)

Figure 13: Working process of the VOC-CTQ-SIPOC model

According to this model, the first step is to gather the customers’ needs and requirements from the sales phase. In order to have accurate information about the VOC, the project team still
needs to have a thorough communication with the sales team. After the list of VOC is verified, in the second step, the project team should transfer the list of VOC to CTQ which are the key measurable characteristics of a product or process whose performance standards or specification limits must be met in order to satisfy the customer. In the process of transfer, QFD is being used. We think that QFD is a proper tool for quantifying the data, and having an accurate understanding of the customers’ needs and requirements. In the third step of this model, after the project team has the CTQ, they can generate the chart of SIPOC based on the information which CTQ provides to have a clearer project charter and scoping.

5.2.2 The phase of integrating the model

From the statement of the PM problems in SIT we can see that unclear scoping and customer dissatisfaction problems often happen in the early phase of the project. We also know that it is very important that the project team can solve as many problems as they can in the early phase of the project. The Figure 14 below is the co-relationship among the Freedom of action, Product knowledge, and Modification cost.

![Figure 14: Co-relationship among Freedom of action, Product knowledge and Modification cost](modified-from-Ullman)

As the project is on the processing, the modification cost goes up dramatically, and the team’s freedom of action decreases. A common idea is that it is always better to improve the current
situation as early as possible. According to this idea, we decide to integrate the VOC-CTQ-SIPOC model into the very early phase of the Siemens project plans. The Figure 15 below shows the integration of VOC-CTQ-SIPOC model into the general process of Siemens project management.

Figure 15: Integration of VOC-CTQ-SIPOC into general SIT project management

The precise integrated position of VOC-CTQ-SIPOC model should be between the first Quality Gate of the project execution and the process of Detailed Planning, which also is between Milestone PM100 and PM200. In this phase, the project team has just received all the information from the sales phase in the process of Project Handover. In order to get the accurate detailed data of the customers and products, a communication feedback loop between the sales team and project team should be embedded. The project team use formal and informal ways, such as meetings, e-mails to communicate with the sales team during and after the Project Handover.

Fully understanding of the handover information is very important for the implementing the VOC-CTQ-SIPOC model.
5.2.3 Example of implementing the model

After all the work explained above has been done correctly, it is time for the project team to implement the model in the Detailed Planning phase. In order to have a better understanding of how this model works, we generate a simple example of the whole working process.

We take Hair Dryer, a kind of simple electric equipment for daily use, as the example. First, we should know the key components of the Hair Dryer, which are:

- Motor: transform the electricity into motion energy
- Heater: increase the temperature of the air
- Package / Housing

Now, we use QFD to transfer the VOC into CTQ.

Phase 0: Gather and prioritize the customers’ needs/VOC.

After conducting feedback communication with the sales team, the project team has gathered all the customers’ information which includes the VOC. Normally the VOC contains dozens of the customers’ needs. We only list 5 of them in order to simplify the example and make it easier to understand. The Table 10: The list of VOC below is the list of the VOC.

<table>
<thead>
<tr>
<th>LIST OF THE VOC</th>
<th>IMPORTANCE RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 The Hair Dryer must operate safely.</td>
<td>9</td>
</tr>
<tr>
<td>2 The Hair Dryer must operate quietly.</td>
<td>9</td>
</tr>
<tr>
<td>3 The Hair Dryer must dry the hair quickly.</td>
<td>3</td>
</tr>
<tr>
<td>4 The Hair Dryer must be good-looking.</td>
<td>3</td>
</tr>
<tr>
<td>5 The cost must be low.</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 10: The list of VOC

In these five VOC, first four of them, are related to the product quality, and the last one of them is more related to the process quality which refers to the performance of process, such as
delivery time and cost control. The next step is to prioritize the importance of each VOC; the project team should conduct meetings with sales team, use methods of brainstorming to eventually set the importance rate. In the table above, 9 points stand for very important, 3 point stand for medium important and 1 point stand for less important.

**Phase 1: Determine which kind of quality characteristic is more important.**

QC has to be determined by the project team members through discussions and meetings, etc. In our case, we listed four QCs of the hair dryer which are rotation speed, material used, air temperature and number of parts. In this phase, the project team needs to transfer the importance rate of VOC into relative weight of QC to see which kind of QC is more important. The Table 11 below is the presentation of the QFD phase I of our example. It shows the co-relationship between the VOC and QC. The correlation rate, which is shown in the yellow section, is marked by the team members after they have the efficient knowledge exchange and brainstorming. The rating theory is the same as the theory of the importance rate of VOC. 9 points represent high rate of relation, while 0 point represents no relation.

The calculation procedure is explained below:

1. Calculate the raw score of each Quality Characteristic. For example: *Raw Score of Rotation Speed* (RS₁) equals the sum of *Weighting of each VOC* (Weighting VOC) multiply *Co-relationship rate* (Rate Co-relationship) between Rotation Speed and each VOC.

   \[
   RS₁ = \sum (\text{Weighting VOC} \times \text{Rate Co-relationship}) = 9 \times 3 + 9 \times 9 + 3 \times 9 + 3 \times 0 + 1 \times 0 = 135
   \]

2. Normalize the Raw Score of QC into percentage number. After the calculation, the team has got a group of data which is called Relative Weight of each QC. This group of data is the percentage number which the sum is 1, and will be used in the next phase of QFD.
<table>
<thead>
<tr>
<th>QFD Phase I</th>
<th>Quality Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting</td>
<td>Rotation speed</td>
</tr>
<tr>
<td>Operate safely</td>
<td>9</td>
</tr>
<tr>
<td>Operate quietly</td>
<td>9</td>
</tr>
<tr>
<td>Dry quickly</td>
<td>3</td>
</tr>
<tr>
<td>Good-looking</td>
<td>3</td>
</tr>
<tr>
<td>Low cost</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VOC</th>
<th>Raw score</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operate safely</td>
<td>135</td>
<td>0.34</td>
</tr>
<tr>
<td>Operate quietly</td>
<td>123</td>
<td>0.31</td>
</tr>
<tr>
<td>Dry quickly</td>
<td>54</td>
<td>0.14</td>
</tr>
<tr>
<td>Good-looking</td>
<td>84</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Table 11: QFD Phase I: translate VOC into QC

**Phase 2: Translate QC into key components of the product.**

In this phase, the project team needs to consider the co-relationship between QC and the key components of the hair dryer. Then, based on the relative weight which they have got from the phase I, the team can calculate another group of relative weight of each key component which is shown in the lower-right row of the table. This group of relative weight is also percentage number and will be used in the phase III of QFD.

The calculation procedure is explained below:

1. Calculate the raw score of each Key Components. For example: Raw Score of Housing ($RS_1$) equals the sum of Relative weight from Phase I($Weight_{p1}$) multiply the Co-relationship rate ($Rate_{Co-relationship}$) between Compressor and each QC.

\[
RS_2 = \sum (Weight_{p1} \times Rate_{Co-relationship}) = 0.34 \times 0 + 0.31 \times 9 + 0.14 \times 0 + 0.21 \times 3 = 3.43
\]

2. Normalize the Raw Score of Key Components into percentage number. After the calculation, the team has got a group of numbers which is called Relative Weight of each Key
Component. This group of number is the percentage number which the sum is 1, and will be used in the next phase of QFD.

<table>
<thead>
<tr>
<th>QFD Phase II</th>
<th>Relative weight from Phase I</th>
<th>Key Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC</td>
<td></td>
<td>Motor</td>
</tr>
<tr>
<td>Rotation speed</td>
<td>0.34</td>
<td>9</td>
</tr>
<tr>
<td>Material</td>
<td>0.31</td>
<td>3</td>
</tr>
<tr>
<td>Air temperature</td>
<td>0.14</td>
<td>1</td>
</tr>
<tr>
<td>No. of parts</td>
<td>0.21</td>
<td>3</td>
</tr>
<tr>
<td>Raw score</td>
<td>4.77</td>
<td>2.16</td>
</tr>
<tr>
<td>Relative weight</td>
<td>0.46</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Table 12: QFD phase II: translate QC into Key components

**Phase 3: Generate design or improving options and calculate the rates**

In phase III, the project will generate some design and improving options through the discussions and meetings, and then testify the improving rate of QC of each option. In our case, we generate two options, which are:

Option 1: change the shape and material of the heater
Option 2: Redesign and improve the housing, in order to reduce the noise.

Table 13 below is the testifying result of Option 1. Due to the fact that the modification of Option 1 is only occurring in the heater, the team just needs to focus on the improvement of heater; the rest of the two key components have not been taken into consideration. After the team has marked the co-relationship rate between QC and Key components, the improving rate of QC can be calculated. We should note that the numbers of improving rate of QC are not percentage. The higher numbers the team gets, the more effect they can expect. Based on the
same theory, Table 14 is the testifying result of Option 2. The improving rate of QC will also be used in the last phase of QFD.

The calculation procedure is explained below:
For example in Table XX: The improving rate of Material (IR\textsubscript{material}) equals the Rate of Co-relationship (Rate\textsubscript{Co-relationship}) between Heater and Material divided by the sum of Material in Phase II (\text{Sum}\textsubscript{MaterialP2})

\[ IR\textsubscript{material} = \frac{Rate\textsubscript{Co-relationship}}{\text{Sum}\textsubscript{MaterialP2}} = \frac{3}{3 + 3 + 9} = 0.2 \]

<table>
<thead>
<tr>
<th>QFD</th>
<th>Key Component</th>
<th>Improving rate of QC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase III(Option 1: change the shape and material of the heater)</strong></td>
<td>Motor</td>
<td>Heater</td>
</tr>
<tr>
<td>QC</td>
<td>Rotation speed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Air temperature</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Number of parts</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 13: QFD Phase III: testifying result of Option 1

<table>
<thead>
<tr>
<th>QFD</th>
<th>Key Component</th>
<th>Improving rate of QC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase III(Option 2: redesign the housing)</strong></td>
<td>Motor</td>
<td>Heater</td>
</tr>
<tr>
<td>QC</td>
<td>Rotation speed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Air temperature</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Number of parts</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 14: QFD Phase III: testifying result of Option 2
**Phase 4: Test the effect of each option based on the VOC, and then compare them.**

In the last phase of QFD, the project team should take the improving rate of QC in phase III back into VOC, in order to test the improving effect of each option. When the team gets the final score of each option, they need to compare among them to identify the advantage and disadvantage of each option which will facilitate the team to choose a proper option based on VOC. The tables below: Table 15 and Table 16 show the final results of potential option. The total score of each option has been marked in red in the lower-right row of the table. The total score do not have an upper limit which means the higher one option gets, the better it fits to the improvement based on VOC. In our case, Option 1 gets 5.18 points while Option 2 gets 7.94 points. Our preliminary conclusion is: generally, if the team design or improve the Hair Dryer by following the instructions of Option 2, the customers will be satisfied with the final product than the team follow the Option 1.

The calculation procedure is explained below:
For example: Improving rate of Operate Safely (IRos) equals the sum of Co-relationship Rate of Operate Safely and each QC (Rate Co-relationship) multiple Improving Rate of QC from Phase III (IRP3), then be divided by the sum of Co-relationship Rate of Operate Safely and each QC (SumOS)

\[
IR_{os} = \sum \left( \frac{Rate_{Co-related} \times IR_{P3}}{Sum_{os}} \right) = \frac{0 \times 3 + 0.2 \times 9 + 0.9 \times 3 + 0.17 \times 3}{3 + 9 + 3 + 3} = 0.278 \approx 0.28
\]

<table>
<thead>
<tr>
<th>QFD</th>
<th>Phase IV (Option 1)</th>
<th>Weighing</th>
<th>QC</th>
<th>Improving rate of VOC</th>
<th>Improving effect of VOC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operate safely</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Operate quietly</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Dry quickly</td>
<td>3</td>
<td>9</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Good-looking</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Table 15: QFD Phase IV: final score of Option 1 according to VOC

<table>
<thead>
<tr>
<th>QFD Phase IV (Option 2)</th>
<th>Weighting</th>
<th>QC</th>
<th>Improving rate of VOC</th>
<th>Improving effect of VOC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rotation speed</td>
<td>Material</td>
<td>Air temperature</td>
<td>Number of parts</td>
</tr>
<tr>
<td>V</td>
<td>Operate safely</td>
<td>9</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>O</td>
<td>Operate quietly</td>
<td>9</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>Dry quickly</td>
<td>3</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Good-looking</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Improving Rate of QC</td>
<td>0.00</td>
<td>0.60</td>
<td>0.10</td>
<td>0.50</td>
</tr>
<tr>
<td>Total score of option 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 16: QFD Phase IV: final score of Option 2 according to VOC

**Outputs of QFD**

The Figure 16 and Figure 17 are the two kinds of comparison outputs after the team have conducted all phases of QFD.

Figure 16 is the improvement comparison between Option 1 and Option 2 with each VOC respectively. In our case, except for the “drying quickly”, the improving rate of Option 2 is higher in the rest of the VOC which Option 1 improves. It means that if the project team chooses the Option 2 as the solution to design or improve the hair dryer, the customer would be more satisfied than they choose Option 1.

Figure 17 is the total improvement comparison between Option 1 and 2, considering the weighting of each VOC. It gives the project team another angle to look into the improvement of
VOC. In our case, Figure 16 also shows that if the project team follows the Option 2 to design or improve the hair dryer, they might receive a better customer feedback than Option 1.

Selection of the option

Based on the outputs which these two charts provided, the project team can decide to choose option 2 as the product improvement direction which is “Redesign and improve the housing, in order to reduce the noise”. From this point, the major focus of the whole project team will be set on improving the product characteristics which are related to housing of hair dryer. In our case, the product characteristics which are related to housing are hardness of the material, thickness of material, number of parts, and of course, the cost and time-used of improving the housing. The project team has a common knowledge that redesigning and improving these product characteristics will improve the VOC significantly. Therefore, in the next section of project which is setting up the CTQ, the project team will identify these characteristics as the CTQ.

![Improving rate of VOC](image_url)

Figure 16: Output of improving rate of VOC
Why we choose QFD

We should note that there are plenty of methods for transforming VOC to CTQ; others are Pareto chart, surveys, etc. QFD is just one of them. The reason of choosing QFD as the tool and method for transforming VOC to CTQ is that we think such a quantitative tool measuring the VOC would more accurately provide legitimate information to the project team preventing them from going to the wrong direction. We summarize three benefits which QFD provides:

1. Quantitative data facilitates the project team to understand the VOC accurately, assures that the target of design and improvement is identical with the customer’s requirements.
2. Gaining the knowledge about which part’s modification will improve the customers’ satisfaction significantly. Focus on the more important parts.
3. The outputs of QFD are the inputs of CTQ. QFD facilitates the project team to identify the CTQ closely depended on the VOC. In our hair dryer case, the basic process is shown below in Figure 18.
5.2.4 CTQ Driver Tree Model for Option 2

As we mentioned before in the tool description of CTQ, the target of CTQ is to convert customer needs and demands to measurable requirements for the business to implement.

After the project team has conducted the QFD to find the best option, it can proceed into the next section which is identifying the CTQs of the Hair Dryer based on the information QFD provided. The Table 17 below is an example of how to identify the CTQ. We should note that all the work must be done by team members. They should use any method necessary to finish this section, such as regular meetings, benchmarking, surveys, interviews with expertise and customers.

The project team divides the driver into three main CTQs, which are Design/Quality, Cost, and Time. Each one of the CTQ should be furthermore divided into several Sub-CTQs. For instance, hardness and thickness of the plastic and metal are two Sub-CTQs for the product characteristics which are related to housing. Once the Sub-CTQs have been identified, the project team need to set up the measurement, current value, and target value. Take the thickness of the metal as an example, the thickness of the metal of the current product is 1.6mm, through regular meeting and expertise advises, the project team has decided to increase the thickness to 1.8mm. Therefore, this kind of improvement can reduce the noise, to some extent, and also make the hair dryer operate more safely. Based on the same theory, the current housing contains 25 individual units which the project team thinks that it should be reduced to 20 individual units, so that the hair dryer could have a better appearance, and also reduce the noise, due to the vibration of the joints reduced.

The Table 17 below is the demonstration of the CTQ Driver Tree of our case.
Table 17: Demonstration of the CTQ Driver Tree

<table>
<thead>
<tr>
<th>DRIVER</th>
<th>CTQ</th>
<th>SUB-CTQ</th>
<th>MEASUREMENT [UNIT]</th>
<th>Target value</th>
<th>Current value</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve the Housing to make the Hair Dryer operate quietly</td>
<td>Hardness of material</td>
<td>Plastic</td>
<td>Shore hardness [D]</td>
<td>75</td>
<td>70</td>
<td>Operate safely and operate quietly</td>
</tr>
<tr>
<td>Design/Quality</td>
<td></td>
<td>Metal</td>
<td>Brinell hardness [HB]</td>
<td>130</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness of material</td>
<td>Plastic</td>
<td>mm</td>
<td>1.5</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Metal</td>
<td></td>
<td>1.8</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. of parts</td>
<td>Unit</td>
<td></td>
<td>20</td>
<td>25</td>
<td>Good-looking and operate quietly</td>
</tr>
<tr>
<td>Cost</td>
<td>Design cost</td>
<td>Modelling cost</td>
<td>EURO</td>
<td>3,000</td>
<td>3,200</td>
<td>Low cost</td>
</tr>
<tr>
<td></td>
<td>Labor cost</td>
<td></td>
<td></td>
<td>5,000</td>
<td>5,100</td>
<td></td>
</tr>
<tr>
<td>Manufacturing cost</td>
<td>Material cost</td>
<td></td>
<td></td>
<td>2,300</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labor cost</td>
<td></td>
<td></td>
<td>3,000</td>
<td>3,200</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Design time</td>
<td>Day</td>
<td></td>
<td>30</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manufacturing time</td>
<td></td>
<td></td>
<td>10</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

5.2.5 SIPOC model

The purpose of using SIPOC is to reach a common understanding within the team by using the system approach. By using SIPOC, the roles, task responsibility and system requirements are clarified. The metrics from CTQ can be spread into the five blocks of the SIPOC diagram. Thus the metrics can be paralleled with the process to give a clear overview of the process.

Suggestions for SIPOC in SIT process map

SIPOC can be used after the sales phase, before the project initiation. In the process map of SIT, it is suggested to locate between PM100 and PM200 (Figure 19). After the project opening and clarification, the project team performs the detail planning, and SIPOC can be done during the detail planning to give an overview of the project scoping. The PACT and the kick-off meeting can be the good ways to implement SIPOC model. As the modification cost would be very high at the late period of the whole project, it is suggested to implement the SIPOC in the early phase and clarify the scoping and responsibility of supplier, input, process, output and customer.
When the project is complicated or in large scale, it can be a large number of activities if all of them are listed out in detail on the diagram. This can make the whole project lousy and the group members may lose interest in reading and understanding the diagram. As it is performed during the detailed planning, the SIPOC diagram can summarize the major activities based on the analysis of each detailed activities. Make SIPOC focus on the major activities can make the diagram clear and give an overview of the whole project. This big picture can make all the group members speak the same “language” and decrease the misunderstanding between the members with different functions. Thus the misunderstanding problem of the cross functional team can be solved based on the same understanding of the clear scoping diagram.

Figure 19: The suggestion of implementing SIPOC in process map

If the supplier has a long-term relationship with the company, the internal feedback loop can be added with the link of the supplier and the input and output of the project. The input and output of the project can always give feedback with the supplier to check the schedule and the requirement for the raw material of the product. The suppliers can always participate into the interactive process to give customized service that suits the company. This can make continuous improvement for the relationship with the suppliers. The external feedback loop is between the customer and input of the project. Collecting the voice of the customer can be the foundation for
the product improvement. After analysing the voice of customer and understanding the customers’ really need, all these needs can be transferred into the characteristics of product. All of the metrics from the customer voice and product improvement can be used as the data for the input of the project. The confidentiality can be a big problem as the depth of feedback loop needs to be considered and discussed carefully before initiated. The schedule of the internal and external meeting and reporting system should be planned and clear responsibility should be assigned.

**SIPOC diagram for Option 2**

SIPOC diagram for Option 2 is shown in Table 18. The five blocks of SIPOC are identified by the project team members through kick-off meetings. Supplier, input, process, output and customer can be listed out and the diagram is approved by all the group members from different functions. This consensus can prevent the misunderstanding of the group members with different functions.

As in this option 2, the company needs to produce the new package of the hair dryer. The mainly supplier is the material supplier, such as plastic and metal. Then the company uses the material and the new design solution of the package as the inputs of the whole project. The main process can be product design and test, manufacturing and product delivery. The output includes the new housing/package of the hair dryer and the new design solution accompanying with the final product. The customer can be the company who requires the order or the customer who buys the product.

The indicators from the CTQ can be used in the parallel metrics below the five blocks. The current values are the input metrics for the quality, time and cost. The target value of the CTQ can be set up as the future output metrics. The process metrics are the metrics that divided into the detailed activities with smaller numbers. For example, the design time in planning is 35 days in total, which can be divided into modelling with 20-25 days and model test with 5-10 days in the process metrics. The buffers for time estimation aim at reaching the target time with less deviation. The situation is the same for the quality and cost. The synchronization of the quality, cost and risk metrics with SIPOC five blocks can list out the metrics to give the project members the overview of the whole project.
After finishing the diagram, some corrections of the wrong estimation from the detail planning can be checked through the communication between different function members. Some potential problems that have not been noticed before may arise to the surface. The project manager can based on this diagram find the improve suggestion on the process development.
### SIPOC Diagram

#### Supplier
- Material supplier
- Design team

#### Input
- Plastic
- Metal
- Product design

#### Process
1. Product design and test
   - New product design
2. Manufacturing
   - New housing
3. Product delivery

#### Output
- Internal Feedback loop
- External Feedback loop

#### Customer
- Order company

### Table 18: SIPOC diagram for Option 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
<th>Response plan</th>
</tr>
</thead>
</table>
| **Quality** | Hardness of Plastic= 70 D  
Hardness of Metal= 150HB  
Thickness of Plastic=1.3mm  
Thickness of Metal=1.3mm  
No. Of parts=25 Unit | Material (plastic) amount of Part No. 1 = 500 g  
Hardness of plastic control > 70 D  
Thickness of plastic control >1.3 mm  
Material (metal) amount of Part No. 2= 550 g  
etc... | Hardness of Plastic= 75 D  
Hardness of Metal= 130HB  
Thickness of Plastic=1.5 mm  
Thickness of Metal=1.8 mm  
No. Of parts=20 Unit | Material backup supplier |
| **Cost** | Design Modelling cost= 3200 €  
Design Labor cost = 5100 €  
Manufacturing material cost=2500€  
Manufacturing Labour cost = 3200€ | Material of plastic cost= 1000-1100€  
Material of metal cost= 1100- 1200€  
Labor cost < 6200 €  
Model cost < 3200 € | Design Modelling cost= 3000 €  
Design Labor cost = 5000 €  
Manufacturing material cost=2300€  
Manufacturing Labour cost = 3000€ | Risk cost backup |
| **Time** | Design time= 35 D  
Manufacturing time= 12D | Design modelling time between 20-25 D  
Model test time between 5-10D  
Manufacturing set up time between 1-2 D  
Manufacturing operate time 8-9 D | Design time= 30 D  
Manufacturing time= 10 D | Buffer time backup |
5.3 FMEA model

The risk problems from the result of interviews and surveys in the SIT project could be listed out as following:

- #1: Seldom identify the risks
- #2: Seldom estimate the risks
- #3: Receive the risks from Sales phase, however, not dealing with them properly

Current tools used for the risk identification and control are:

- Risk Matrix: is a brainstorming with the team members during the PACT.
- PACT: is an internal workshop (usually used in the level C project in steam turbine, while this method in gas turbine is optional) and held after 5-6 weeks of handover. The group members need to read the contracts and prepare ten issues before PACT and the structure, planning, charter, risk and opportunity, stakeholder, schedule and communication process would be discussed during the pact. Result of contract reading, lessons learned.
- Clamato: is a database that the customer claims located in.

5.3.1 FMEA model in SIT

- Why

Based on the situation in SIT, the tool that we suggest to use is the cost-expected FMEA model. The major objectives of using FMEA are to identify failure, prioritize the failure mode and reduce risk. Two numbers are important in the FMEA model; these are RPN (Risk Priority Number) and expected cost. RPN is based on the occurrence, severity and detection and expect cost is based on the probability and the cost for failure modes. Both of them can give the criteria to prioritize the risk. This can facilitate to make decision through more comprehensive consideration from different perspectives.

- when

The FMEA can be done during the detailed planning phase, which is between PM100 and PM200. Usually the failure identification is performed by project manager, with the
checklist of the previous risks and the experience. The project members can make some additions if some vital risks are missing. The value for the occurrence, severity and detection are estimated based on the experience, and the deviation can be large easily. To minimize the deviation, the value can be decided after the discussion of the whole project team and the approval of the project manager.

Figure 20: FMEA in the process map of SIT

- How

Identify the functions, all the possible failure modes for each function, the causes for each failure mode and the local effects on the product, user and systems. This results in two diagrams of product and process.

Estimate the occurrence, severity and detection, based on the causes and local effects of all the scenarios. Estimate the cost for each scenario and the probability of the scenario identified.

Calculate the PRN and the expected cost. RPN = Occurrence × Severity × Detection, Expected cost = Probability × cost.

Place the result of RPN and expected cost in ascending order. If cost budget is tight, the expected cost number can be the criteria to depend on. If the quality of the project is more important, the emphasis can be spent on the risk priority number.
5.3.2 Implementing FMEA model

The case of hair dryer will be used to exemplify FMEA in this chapter. The FMEA are divided into product FMEA and process FMEA, and the aim is to make the failure mode analysis both for the product and process failure modes. The two diagrams are shown in Table 19 and Table 20. Detailed descriptions of analysis process are stated below.

Product FMEA

Two functions were randomly picked as the simple examples of the hair dryer product, which are converting electricity to rotation and heating the air. Based on the two functions, 7 scenarios were identified from the possible failure modes and the potential causes of the failure.

For function of converting electricity to rotation, there were two potential failure modes, no rotation and low rotation. Three causes exist for no rotation, which are power failure, motor failure and obstruction impeding the rotor and two causes are listed out for low rotation, which are rotor/stator misalignment and friction increasing. The function of heating the wind can have no heating and low heating failure modes with the causes of heater failure and thermal resistance. The occurrence number is the frequency of the scenario. The severity numbers were estimated based on the local/end effects. The detect number is the chance to find this failure. The probability was calculated from the occurrence. It changes the occurrence numbers into decimal numbers. The cost can be the value for the whole failure scenario. The final step is to use the equations of expected cost and RPN mentioned before and to multiply the probability with cost and multiply occurrence, severity and detection. The product FMEA table is shown in Table 19.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>convert electricity to rotation</td>
<td>No rotation</td>
<td>Motor failure</td>
<td>0.001</td>
<td>6</td>
<td>No energy transformation</td>
<td>30</td>
<td>8</td>
<td>4</td>
<td>0.03</td>
<td>192</td>
</tr>
<tr>
<td>2</td>
<td>convert electricity to rotation</td>
<td>No rotation</td>
<td>Power failure</td>
<td>0.001</td>
<td>6</td>
<td>No airflow</td>
<td>70</td>
<td>9</td>
<td>5</td>
<td>0.07</td>
<td>270</td>
</tr>
<tr>
<td>3</td>
<td>convert electricity to rotation</td>
<td>No rotation</td>
<td>Obstruction impeding the rotor</td>
<td>0.0001</td>
<td>4</td>
<td>Motor overheated</td>
<td>25</td>
<td>9</td>
<td>1</td>
<td>0.0025</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>convert electricity to rotation</td>
<td>Low rotation</td>
<td>Rotor/stator misalignment</td>
<td>0.01</td>
<td>8</td>
<td>Noise generation</td>
<td>30</td>
<td>2</td>
<td>1</td>
<td>0.3</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>convert heat to rotation</td>
<td>Low rotation</td>
<td>Friction increasing</td>
<td>0.1</td>
<td>10</td>
<td>Low efficiency</td>
<td>20</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Heating the wind</td>
<td>No heating</td>
<td>Heater failure</td>
<td>0.001</td>
<td>6</td>
<td>No heating wind</td>
<td>15</td>
<td>6</td>
<td>6</td>
<td>0.015</td>
<td>216</td>
</tr>
<tr>
<td>7</td>
<td>Heating the wind</td>
<td>Low heating</td>
<td>thermal resistance</td>
<td>0.01</td>
<td>8</td>
<td>No adjustable heating wind</td>
<td>15</td>
<td>3</td>
<td>4</td>
<td>0.15</td>
<td>96</td>
</tr>
</tbody>
</table>

Table 19: Product FMEA
Process FMEA

Six functions were picked for the process of FMEA, which are phasing the material, dispatch the material, manufacturing, delivery and warranty. 9 scenarios were identified from the possible failure modes and the potential causes of the failure based on the six functions.

For function of phasing the material, there were two potential failure modes, wrong material and not qualified material. Two causes can be the wrong order and not properly chosen suppliers. If the material dispatch has some problems, the material won't be on site. The main reason for this can be not clear responsibility for the dispatching. Thus the effects of failure in material dispatch can be lack of resources to produce, and the whole manufacturing process can not start. The manufacturing failure modes are the scenarios of the defective product and machine broken down. This can cause the quality problems and production stop. The material failure can have high severity. The transportation has the delivery wrong and late. No inspection before transport and using the wrong transporting way can cause both customer dissatisfaction and product return. If no warranty service or inappropriate or deficient warranty is provided in the after - sale service, the customer requirements can't be met and this can cause the customer dissatisfaction of the product as result.

The value for each item is according the same criteria as in the product FMEA analysis. The process FMEA table is shown in Table 20:
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Purchasing the material</td>
<td>Wrong material</td>
<td>Wrong order</td>
<td>0.00001</td>
<td>2</td>
<td>New material needed purchased</td>
<td>5000</td>
<td>9</td>
<td>6</td>
<td>0.05</td>
<td>108</td>
</tr>
<tr>
<td>2</td>
<td>Purchasing the material</td>
<td>Not qualified material</td>
<td>Supplier not well chosen</td>
<td>0.001</td>
<td>6</td>
<td>Low quality products</td>
<td>4000</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>3</td>
<td>Dispatch the material</td>
<td>Material not on site</td>
<td>Unclear responsibility for dispatch</td>
<td>0.0001</td>
<td>4</td>
<td>Resource not ready</td>
<td>5000</td>
<td>4</td>
<td>4</td>
<td>0.5</td>
<td>64</td>
</tr>
<tr>
<td>4</td>
<td>Manufacturing</td>
<td>Defective product</td>
<td>Machine operaition problems</td>
<td>0.01</td>
<td>8</td>
<td>Low quality</td>
<td>600</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>64</td>
</tr>
<tr>
<td>5</td>
<td>Manufacturing</td>
<td>Machine failure</td>
<td>Machine broken down</td>
<td>0.00001</td>
<td>2</td>
<td>Production stup</td>
<td>10000</td>
<td>8</td>
<td>4</td>
<td>0.1</td>
<td>64</td>
</tr>
<tr>
<td>6</td>
<td>Product delivery</td>
<td>Delivery late</td>
<td>Wrong transportation ways</td>
<td>0.00001</td>
<td>2</td>
<td>Customer dissatisfaction</td>
<td>300</td>
<td>5</td>
<td>2</td>
<td>0.003</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>Product delivery</td>
<td>Delivery wrong</td>
<td>No inspection of product</td>
<td>0.01</td>
<td>8</td>
<td>Product returned</td>
<td>400</td>
<td>9</td>
<td>1</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>8</td>
<td>Warranty</td>
<td>No warranty</td>
<td>No responsible contact</td>
<td>0.0001</td>
<td>4</td>
<td>Customer dissatisfaction</td>
<td>200</td>
<td>2</td>
<td>2</td>
<td>0.02</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>Warranty</td>
<td>Warranty not well provided</td>
<td>Meeting customer requirements</td>
<td>0.01</td>
<td>8</td>
<td>Customer dissatisfaction</td>
<td>100</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 20: Process FMEA
Ascending sort of the RPN number

The final results of the two important variables which are expected cost and RPN are used for prioritizing the risks. Thus ascending sort or descending sort of one variable is necessary for clear vision of the trend for another variable. In this example, ascending of the RPN numbers was made. The focus on RPN and the value of RPN is used as the indicator to prioritize the risk. The expected-cost value is another aspect for consideration. Keep an eye on the damage cost besides the occurrence, severity and detection numbers. The table after ascending sort of RPN number is shown in Table 21.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>exp. Cost</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.3</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>0.0025</td>
<td>36</td>
</tr>
<tr>
<td>7</td>
<td>0.15</td>
<td>96</td>
</tr>
<tr>
<td>1</td>
<td>0.03</td>
<td>192</td>
</tr>
<tr>
<td>6</td>
<td>0.015</td>
<td>216</td>
</tr>
<tr>
<td>2</td>
<td>0.07</td>
<td>270</td>
</tr>
</tbody>
</table>

Product FMEA

<table>
<thead>
<tr>
<th>Scenario</th>
<th>exp. Cost</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.02</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>0.003</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>0.5</td>
<td>64</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>64</td>
</tr>
<tr>
<td>5</td>
<td>0.1</td>
<td>64</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>72</td>
</tr>
</tbody>
</table>

Table 21: FMEA result with RPN in increasing order

Result analysis

After sorting the RPN number in ascending order, a histogram combined with points chart was generated in Figure 21 and Figure 22. For the product RPN, scenario 7 is larger that scenario 5 while expected cost scenario 5 is more than scenario 7. Making the decision based on different
perspectives can facilitate the risk priority. If the budget of the project is tight, it is necessary to take actions to avoid the high cost risk happening.

Figure 21: Product FMEA result

Figure 22: Process FMEA result
5.4 Model of dealing with the Time and Cost problems

Unlike the unclear scoping problem, customer satisfaction problem, and the cost problem, the last two problems which are Time and Cost problems are much tougher and trickier to be handled. The controlling of time and cost is running through the whole life-time of the project. It is a systematic approach which requires great efforts and collaboration from many different departments and cross-functional teams within the company. When a tiny part of schedule or expenditure has been changed; it may lead to a larger part of change such as rescheduling the rest of the timeline and re-estimating the production cost. Due to its complexity, we do not think it is feasible or efficient for the project teams to use some specific and simple Six Sigma tools to improve the current time and cost management situation in Siemens. For instance, control chart is an appropriate Six Sigma tool monitoring and controlling the cost change. However, it is relatively complicated which needs the users to be well trained. It would require more efforts from more expertise personnel and more budgets.

In our point of view, we suggest that the Six Sigma expertise and professionals should be involved into early phase of the project planning. In SIT, the project teams conduct the PACT in the planning phase. PACT is the Project Acceleration via Coaching and Teamwork. It is not just a tool; instead, it is more like a method or approach with the workshop meetings. During the meetings, the project teams do: project planning, target identification, making project chart, risk assessment, stakeholder analysis, communication and organizational chart, project process and lessons learned. PACT is mandatory for level A and B projects in G.T and SOL department, and level C project in S.T department.

Our recommendation is that Six Sigma expertise should be involved in the early planning phase of the project by participating in the PACT. Thus, Six Sigma expertise will acquaint the detailed knowledge of the project which will facilitate them to find the root causes of the problems whenever the time and cost are out of control or have the tendency of losing control. These expertise need to monitor and control the time and cost issues throughout the whole project. Whenever they feel the process is losing control, the Six Sigma expertise will use their experiences and knowledge to intervene, looking for the root causes of the process and product fault, identifying them, and eventually eliminating them, to make the process and product go back on track once again.
Figure 23 below is the general process of the Six Sigma expertise involved in the project in the Detailed Planning phase to monitor and manage the cost and time issues.

![Diagram of Six Sigma process]

We also provide the simplified control chart which we think it may be used in some small or less complex projects. This kind of project we define as:

- Similar projects as the teams have conducted. The general model of the previous project is still applies for the on-going projects. The level of difference of considerably low.
- Projects with low risks, low level of technological innovation.

In this kind of projects, it may not be necessary for the Six Sigma expertise to be involved. The project team can use this simplified control chart to control the cost. In order to have a clearer picture about how this chart works, we generate an easy example for the explanations.

Due to the facts that we have signed the confidentiality agreement with SIT, we cannot use the actual data from projects in SIT as our example. The table below is the fabricated data of cost which we generated. In the first row, we list the initial cost from Month 1, Year 1 to Month 12, Year 1. The second row is the actual cost from Month 1, Year 1 to Month 12, Year 1. The third
row is the differences between actual cost and initial cost. Since the costs of these months are considerably different, such as the highest initial cost is 50,000SEK, while the lowest is 3000SEK, the differences between actual cost and initial cost are not comparable; the best alternative option is to transfer the differences into percentage number of cost which is shown in the last row of the table.

<table>
<thead>
<tr>
<th>Initial cost</th>
<th>Cost Y1M1</th>
<th>Cost Y1M2</th>
<th>Cost Y1M3</th>
<th>Cost Y1M4</th>
<th>Cost Y1M5</th>
<th>Cost Y1M6</th>
<th>Cost Y1M7</th>
<th>Cost Y1M8</th>
<th>Cost Y1M9</th>
<th>Cost Y1M10</th>
<th>Cost Y1M11</th>
<th>Cost Y1M12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual cost</td>
<td>5000</td>
<td>5500</td>
<td>4000</td>
<td>6000</td>
<td>3000</td>
<td>7500</td>
<td>50000</td>
<td>8000</td>
<td>9000</td>
<td>12000</td>
<td>3000</td>
<td>6000</td>
</tr>
<tr>
<td>Difference</td>
<td>5000</td>
<td>5000</td>
<td>4000</td>
<td>6000</td>
<td>3000</td>
<td>7500</td>
<td>50000</td>
<td>8000</td>
<td>9000</td>
<td>12000</td>
<td>3000</td>
<td>6000</td>
</tr>
<tr>
<td>Actual cost</td>
<td>5000</td>
<td>4000</td>
<td>8000</td>
<td>4000</td>
<td>5000</td>
<td>60000</td>
<td>10000</td>
<td>5000</td>
<td>4000</td>
<td>8000</td>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td>Difference</td>
<td>5000</td>
<td>1500</td>
<td>1000</td>
<td>2000</td>
<td>1000</td>
<td>2500</td>
<td>10000</td>
<td>2000</td>
<td>-4000</td>
<td>-2000</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>Actual used cost/target cost</td>
<td>110.00</td>
<td>72.73</td>
<td>125.00</td>
<td>133.33</td>
<td>133.33</td>
<td>66.67</td>
<td>120.00</td>
<td>125.00</td>
<td>55.56</td>
<td>83.33</td>
<td>133.33</td>
<td>133.33</td>
</tr>
<tr>
<td>Variation percentage of the cost</td>
<td>0.1000</td>
<td>-0.2727</td>
<td>0.2500</td>
<td>0.3333</td>
<td>-0.3333</td>
<td>0.2000</td>
<td>0.2500</td>
<td>-0.4444</td>
<td>-0.1667</td>
<td>0.3333</td>
<td>0.3333</td>
<td></td>
</tr>
</tbody>
</table>

Table 22: Fabricated data of cost

After we have got the percentage number of the differences, we generate the simplified control chart by using Excel or some other tools. Figure 24 which is shown below is the demonstration of this simplified control chart. If the limit of deviation of the cost is set to be 30 percent, then any deviation of the cost which exceeds the upper or lower limit, we consider it as out of control, for instance Month 4, 5, 6, 9, 11, and 12. In these months, the project teams need to investigate the reasons which lead to the exceed of costs; and come up with the contingency methods to improve the situation. Furthermore, we think it is better for the project teams to conduct the actions earlier. For instance, as soon as the project teams sense that there is a trend of losing control in Month 3 since the deviation locates very close to the upper limit, the deviation of cost in Month 4 may not be out of the limit if the project teams take the correct actions to prevent this from happening.

As we mentioned before, this simplified control chart can only be used in small or less complex projects. For those large and complex projects, we recommend that it is always appropriate that the Six Sigma expertise get involved in the early phase of the project.
Figure 24: Simplified control chart based on the data from Table 22
6 Chapter 6 Discussion

In today’s business world, as the rapid growing of the global economy, most of the companies have put their concentration not only on the innovation of the technology, but also on the quality of the products (Porter, 2000). With the concept of Six Sigma that has been introduced by Motorola, more and more manufacturing companies have implemented Six Sigma in their process of production (Dahlgaard and Dahlgaard-Park, 2006).

Plenty of research and literatures have analyzed the Six Sigma projects and traditional project management separately (e.g. Bertels and Strong, (2003)). However, the research on the relationship between them or how to combine them is limited and doesn’t provide enough details (Sandholm and Sörqvist, 2002). Six Sigma project can bring the higher performance with a higher quality level, while the corresponding cost of project is much higher (Bertels and Strong, 2003). On the other hand, the traditional project management uses lower cost but the quality and performance of the project cannot be guaranteed. This thesis’s aim was combining the two different management methodologies together, trying to provide a new managerial way in which the performance and quality of the projects can be ensured, meanwhile the cost is maintaining low. Through the empirical study, we focused on providing some specific Six Sigma tools which can be integrated in the general process of the project management in SIT.

Six Sigma is used as a tool for continuous improvement in many large manufacturing and producing companies (Sandholm and Sörqvist, 2002). One important part of the Six Sigma methodology is using statistical methods to identify the problems, and find out the root causes, and finally improve the whole performance. However, unlike the goods quality, the project management performance is hard to measure.

In this thesis we presented three models to solve five problems of project management in Siemens Industrial Turbomachinery AB. The three models are the VOC-CTQ-SIPOC model, the FMEA model, the model of Six Sigma expertise. The five problems include unclear project scoping, customer satisfaction problems, risk problems, cost problems and late and not completed delivery. For the five problems in project management in SIT, each model can facilitate to solve one or two problems (Figure 25).
The discussion of the proper implementation of these models will be made in this chapter. The model shown in Figure 25 suggested the tools that are suitable for solving each problem. SIT are proceeding to implement the model into several projects. While implementing the tools, it is valuable to find the strength and weakness for each tool – to know what can be implemented well and what can be improved for the future.

6.1 Pros and Cons of Six Sigma tools suggested

During our research and analysis, we have found that there were some strength and weaknesses of the recommended tools which we have listed out in Table 23.

The upside of QFD is that it is a quantitative tool which can be used for measuring the VOC in a more accurate way. Based on the quantitative data that QFD provides, the project team can better understand the customers’ real needs. Furthermore, QFD is a step-by-step method which facilitates the users to track the process finding out the error once the process has gone to the wrong direction. As for the disadvantages of QFD, it is more complicated than any other tools, and there are lots of calculations need to be done by the project teams.

Another tool that we suggested was CTQ. The advantage is that through the process of CTQ, the project team can identify the critical points which are vital to the product or process, so that the project teams can put their focus mainly on these critical points instead of covering up that
whole area. However, as the projects progress, some less important points to the product or process which are often ignored by project teams may change into the critical points. If the project teams still not put their focus on these points, it would jeopardize the project.

As for the strength of SIPOC, a clear project boundary can reach a common understanding of the responsibility within the project teams; and also decrease the misunderstanding between the members in the different functional units. The weakness of SIPOC is that it would get very complex when the project is big, because too much data needs to be input into the chart of SIPOC.

We see two advantages of FMEA. The risk identification method has taken RPN and expected cost into consideration, so that the risk prioritization is more seasonable than the old ways. Also, FMEA has different failure modes for the same function, which make the estimation more precise. However, if the user is lacking experience, it could easily miss the failure mode.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>QFD (Quality Function</td>
<td>1. Quantitative tool, measuring the VOC in a more accurate way.</td>
<td>1. More complicate than other tools, lots of data collection and calculations have to be done</td>
</tr>
<tr>
<td>Deployment)</td>
<td>2. Understand the customer needs properly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Step-by-step method, facilitate the users to track the process.</td>
<td></td>
</tr>
<tr>
<td>CTQ (Critical to Quality)</td>
<td>1. Visualize the points about what is vital to the Quality.</td>
<td>1. Easy to have a tendency of making the team ignores some less important points.</td>
</tr>
<tr>
<td></td>
<td>2. Guide the right direction of the project.</td>
<td>2. Over time and under some specific circumstances, these less important points will become to the CTQs.</td>
</tr>
<tr>
<td>SIPOC (Supplier, Input</td>
<td>1. Reach a common understanding of the project within the project team.</td>
<td>1. Confidentiality can be a big problem; to what extent should the company have the feedback</td>
</tr>
<tr>
<td>Process, Output, Customer)</td>
<td>2. Decrease the misunderstanding between the members with different functions</td>
<td>internally and externally.</td>
</tr>
<tr>
<td></td>
<td>3. Continuous feedback loops with the customer and supplier</td>
<td>2. If the project is too big, it would be very complex with the SIPOC data input.</td>
</tr>
</tbody>
</table>
Based on the strengths and weaknesses identified, each recommendation should be made individually. In table 24, the underlying causes for the weakness can be found and some suggestions were made to avoid these weaknesses. The remarks for each model are also listed out in Table 24. Each model is not just using one or two specific tools; it is more about how to combine these tools with the project team and project execution.

For implementing these models and methods into several SIT project, we have generalized several remarks which the project teams should keep in mind. For example, the model of VOC-CTQ-SIPOC should be integrated in the general process of PM in SIT. Since QFD is more complex than any other tools, the quality manager in the project needs to be trained in this tool. CTQ must be updated and controlled so that if some of the less important points become important, the project team member notice the change in the very first place. In order to avoid that there are too much data input in the chart of SIPOC, the project team should just focus on the major activities.

For FMEA, there are two remarks we should be aware of. First, the identification process is different from the traditional one, so the project team should not miss the vital scenarios which might be less important in the traditional process of FMEA. Second, the value for O, S, D and cost are based on estimation, the project team should decrease the variation of estimation as much as possible.

At last, for the involvement of Six Sigma expertise, we think it is important to let the Six Sigma expertise involved in the projects in the very beginning of the execution phase. Furthermore, a thorough and frequent communication between Six Sigma expertise and project teams is needed.

Table 23: Strength and weakness for each tool

6.2 Remarks of Six Sigma tools usage
1. The process need to be integrated in the general process of PM in SIT.
2. Quality manager in project (QMIP) need to be trained the using skills, especially QFD.
3. Quality manager in project (QMIP) need to control and update the CTQ, in case it changes.
4. SIPOC should be focus on the major activities.

1. Not missing the vital scenarios
2. The value for O, S, D and cost are based on estimation, the team should decrease the variation of estimation as much as possible.

1. Six Sigma expertises should get involved in PM in the very early phase of project execution.
2. The communication between Six Sigma expertise and project teams can be frequent and thorough.

Table 24: Remarks for each model
Chapter 7: Conclusion

The purpose of this thesis is trying to make suggestions and recommendations for improvements of the project management performance by using some specific Six Sigma tools in SIT. In order to reach this purpose, we proposed three research questions. The first research question was: based on the current situation and problems of project management in SIT, what kind of Six Sigma tools can be recommended to improve the performance of project management; the second research question mainly focused on the approaches of implement of these tools; the third one concentrated on the advantages and disadvantages of these tools.

In the theoretical framework, we have done some literature reviews regarding to the knowledge of Six Sigma and project management. In the Six Sigma section, we have reviewed the development history of Six Sigma and a classic process model of Six Sigma which was called DMAIC. According to these theories, we have gained the basic idea and concentration of Six Sigma. In the project management section, we have reviewed some common understanding knowledge such as the triple constraints, risk management as well as the communication issues.

In order to address the first research question properly, some empirical approaches have been conducted.

1. Based on the theoretical study of Six Sigma and project management, we have developed the survey which was aimed at identifying the current situation and problems of project management in SIT. The survey was mainly divided into several sections: background information of the respondents; questions about the project management which contained six parts: cost, time, quality, customer satisfaction, risks and opportunities, and communication. With the help of our supervisors, we distributed the survey to nine project managers from three departments in SIT and received all of the answers.

2. According to the information we gathered from the surveys, we have conducted a series of interviews with the same project managers who responded our surveys. The target of conducting the interviews was to have a deeper understanding of the current PM situations and problems in SIT.
3. After we have had the detailed knowledge and information regarding to the PM problems, we started to analyze them and tried to recommend some proper Six Sigma tools aiming to improve the current situation.

Dealing with the second research question, due to the facts that we have signed the confidentiality agreement with SIT, we could not implement these Six Sigma tools into some actual on-going projects. Thus, we have generated an easy understanding example to demonstrate the implement approaches. We chose hair dryer as our product. Our target was to improve the performance of project of redesign the hair dryer. We have developed three models and methods for implementing these Six Sigma tools. The first model was called “VOC-CTQ-SIPOC”, it was aimed for addressing the unclear project scoping problem and improve the customer satisfaction; it contained four Six Sigma tools which were VOC, QFD, CTQ, and SIPOC. The second one was actually only one tool: FMEA for dealing with the risk problems. The last model was the involvement of Six Sigma expertise in order to have a total control of the time and cost change.

As for the third research question, we have discussed the advantages and disadvantages of each Six Sigma tool in the discussion chapter. We further posed some remarks regarding to usage and implementation of these Six Sigma tools.

Finally, regarding to the limitation of this thesis, due to the fact that we have not received the implementing-test feedbacks of the actual performance of these Six Sigma tools in the real projects, we think that there might be some slight differences when integrating these tools into the PM process in SIT. Therefore, it would need extra efforts to discuss about which tools are appropriate and how they are going to be implemented. Additionally, this thesis only focuses on addressing the specific problems which are occurring in SIT. However, the problems occurring in SIT are concluded based on the traditional and classic knowledge of project management, and they are, to some extent, happening in other companies as well. Still, further research should be need for expanding the scope of implementation.
Reference list


Appendix 1: Demonstration of the survey

Instructions

Hello!

We are master students from Linköping University and now writing our thesis in Siemens Industrial Turbomachinery AB in Finspång. Our thesis topic is about “How to improve the project management by using Six Sigma”. We would like to give you some questions and those answers will be used as a proof in our thesis.

Thank you!

Lin and Guannan

Part 1: General Information

1. Your division: _________________________
   Your position: _________________________

2. Please rank the importance of these three aspects (Cost, Time, Quality and customer satisfaction) during the project management.
   1._________;
   2._________;
   3._________;
   4._________
   If the total amount is 100%, please specify each
   Cost _____%    Quality _____%    Time_____%    Customer Satisfaction ____%

3. Was the six sigma project implemented before? □Yes □No
   If yes, please give the percentage of the following results of Six Sigma implementation in project management? (Total sum is 100%)
   No effect       ______% 
   Negative effect ______% 
   Small Improvement _____% 
   Significant Improvement_______%

Part 2: Questions about project management

Notice: The options “□0 □1 □2 □3 □4” stand for “□Never □ Rarely □Sometimes □ Often □Always”)

Cost

1. How often is the budget estimation correct?
2. How often do you have cost follow-up and review, including audition and control?
   ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
3. Please scale the frequency of the expenditure of budget
   Overspending ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
   Under spending ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
   Appropriate spending ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
4. Name some factors which you think is causing the significant deviation from the budget estimation:

5. How do you solve these problems?

Time

1. How often is a detailed schedule prepared which includes activities, activity duration estimation, milestone and etc? (0: none-5: often)
   ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
2. Please scale the frequency of the project delivery time
   Overdue ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
   On time ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
   Before deadline ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
3. Name some factors which you think is causing the significant deviation from the prepared schedule:

4. How do you solve these problems?
Quality

Definition

• Quality planning involves identifying which quality standards are relevant to the project and preparing plans that will satisfy the requirements.
• Quality control (QC) is the appraisal of specific project outcomes to determine if they comply with quality requirements and taking corrective action if non-compliance is found.
• Quality assurance (QA) is the periodic review of actual project performance to ensure that quality plans have been implemented and that quality procedures are being followed correctly. QA also involves taking corrective action if non-compliance with established procedures is found or modifying the quality plan if QC results show that it is inadequate.

1. How do you feel about the implementation situation of quality planning method?
   □ Not satisfied  □ Tolerate  □ Neutral  □ Satisfied

2. How do you feel about the implementation situation of QC method?
   □ Not satisfied  □ Tolerate  □ Neutral  □ Satisfied

3. How do you feel about the implementation situation of QA method?
   □ Not satisfied  □ Tolerate  □ Neutral  □ Satisfied

4. Typical quality problems happened most in SIT projects, including product and process quality:

Customer Satisfaction

1. How often are the following types of customer involvement happening in the projects
   - Transactional
     □ 0 □ 1 □ 2 □ 3 □ 4
     (Only in the early phrases, design for customer)
   - Facilitative
     □ 0 □ 1 □ 2 □ 3 □ 4
     (In the early and testing phrases and occasionally others, design with customer)
   - Integrative
     □ 0 □ 1 □ 2 □ 3 □ 4
     (In all phrases, design by the customers)
2. How often do you use the following methods for the **Voice of Customer** research?
   - Open source method
   - Focus groups / meetings
   - Surveys
   - Participation of customer in the development team
   - Interviews

3. Please evaluate how often the following aspects cause the customer dissatisfaction.
   - Meet the functional requirements
   - Availability (deliver in time)
   - Durability
   - Innovativeness
   - Prices worth the overall value

4. Typical problems that affect customer satisfaction:

<table>
<thead>
<tr>
<th>Definition</th>
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<tbody>
<tr>
<td><strong>Risk</strong>: events or uncertainties which may affect the project in a negative way.</td>
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</table>

   1. How often is the risk identified during project planning phrase?
      - 0 1 2 3 4
   2. How often is the risk estimation during the execution? (quantitative method to measure the value of the risks and prioritize them)
      - 0 1 2 3 4
   3. How often is the risk response plan prepared?
      - 0 1 2 3 4
   4. How often did the risk happen in the projects?
      - 0 1 2 3 4
   5. Name the risk which happened the most: __________________________
   6. Name the risk which had the significant impact: __________________________
   7. Tools which you currently use dealing with risk: __________________________
**Definition**

**Opportunity:** events or uncertainties which may affect the project in a positive way.

1. How often do the projects miss the opportunities and realize later that these opportunities could bring advantage?
   - 0 1 2 3 4

2. How often does the opportunity identification happen during the projects?
   - 0 1 2 3 4

3. How often does the opportunity estimation happen during the projects? (quantitative method to measure the value of the opportunities and prioritize them)
   - 0 1 2 3 4

4. Specify some reasons which cause the projects miss the opportunities.

**Communication**

1. How often did the following communication ways occur within the projects?
   - Project team meetings
     - 0 1 2 3 4
   - Project meeting with clients
     - 0 1 2 3 4
   - Written documents and reports
     - 0 1 2 3 4
   - Make the formal appointment with other team members
     - 0 1 2 3 4
   - Telephone calls
     - 0 1 2 3 4
   - Unexpected face to face discussion (e.g. in the dining hall or over coffee)
     - 0 1 2 3 4

2. How often do you use following to exchange and distribute information?
   - Website
     - 0 1 2 3 4
   - Paperwork
     - 0 1 2 3 4

3. Specify the communication problems happened most frequently:

**Part 3: Open Questions**

1. What project management tools are you using?
2. Are there any other tools that would be useful? Any suggestions?

3. Do you know any six sigma tools that could be useful in project management?

4. Anything else you want to put forward/comment on?
Appendix 2: Example of the questions and answers of interviews

**Background questions**

- As we know there are four management levels in Siemens career Model, can you tell me which level are you now? (Project director, senior PM, PM, project coordinator)
  PM
- Which level of the projects do you usually carry out? (A-F)
  Most projects are level C, few are level B. The contracts are ranged between 10M-100M Euro.
- You usually in charge a whole project or just a part of the project, like the installation, commissioning or other phrases in the project process?
  The whole execution phase of the projects
  From contact signing to the project closure (PM080-PM650). 6 projects ongoing, too many, 4 is perfect.

**Cost**

The survey indicates that you consider the cost is the most aspects among these four. However, the projects have a low rate on the estimating cost correctly and spending budget appropriately even if you follow-up and review the budget spending frequently. You mentioned some reasons: wrong data input in the cost tools and limitation of time during the sales phase.

The questions are:

1. What kind of tools you are using?
   Two stakeholders: management (interested in financial) and customers (time and quality are important aspects, cost is not so much important.)
   Methods: receive project and budget received, follow up each quarter and month (if major deviation). It works fairly well; there is buffer cost overrun – 90% of cost overrun is our fault, 10% is from customers.

2. Are you satisfied with the performance of these tools? / Are these tools difficult to handle?
   Improve: errors will be for sure
   Always something missed in the sales phase;
   Issues from purchasing: database can be improved. It is changing now.

3. What facts cause the wrong input data in these tools? Can it be avoid? How do you think?
   Timing, hard to foresee the cost, these things can be accepted
   Difficult to accept: budget changes for engineers working hours.

Due to the legislation problems, you mentioned a better feedback from old projects and standardization will be helpful to solve these.

4. What actions have you used to improve the feedback already? Have these methods documented, standardized, or quantified in order to have a better way to review? How?
   Feedback: no official forum and documentation, no place for sharing information.
   Most of the feedback is informal.
   Have lesson learned database. Keep it simple because PMs do not have much time.

5. You have the comprehensive global program which is called PM@Siemens. It is used for standardization and documentation. How do you think they are working in your projects?
What are the problems? Do you have more suggestions or opinions on how to improve the documentation work in your future projects?
Hard to make sure that everyone has the same picture.
Improvement: solve this on the process level instead of people level.

Risk
You mentioned that “missed specifications” is the risk which happened most and has the biggest impact.
6. What kind of specifications?
7. Is it because the wrong scope definition during the early phase of the project, or are there anyone root causes?
   Lots of specification, easy to be missed.
   Wrong scoping: Yes, rather big.
   Improvement: sit together and discuss, brainstorming, also it is necessary go through all the specifications.

8. Is Risk matrix a quantitative or a qualitative method? How does it work? What’s the performance?
   Quantitative analysis tool in database.
   Improvement: sit together and discuss, brainstorming, go through all the specifications, let everyone aware of the risk, because risk assessment is easy, what is more important is that people need to be aware of risk.
   Need to handle the risk analysis in the sales and contract phase.

9. The survey indicates that you have managed risk better than some of others, what is your experience which other managers could gain, in order to improve their risk management?
   Successful experiences: Follow the process exactly
   Showing all the risk which might happen instead of cutting down the less important risks.

Quality
10. How do you interpret the term “Quality”? The quality which you are focusing on, does it refer to product quality or process quality? Or is there something more about “Quality”?
   Process quality – based on the customer’ needs

11. How do you ensure the quality (product and process) in your projects?
   Make sure that you follow the process.

12. The survey indicates that you have managed quality better than some of others, what is your experience which other managers could gain, in order to improve their quality management?
   Successful experiences:
   Internal time schedules, side activity schedule, do it earlier to have time to discuss

13. In your process map of the project, we notice that there are 4 Quality Gates. What are they used for and what kind of work should be done in these QG? Do you have any comments or suggestions regarding to this process map?
   QG 2 everything according to the sales.
   QG 3 provisional acceptance needs to be standardized.
   Delivery time is very good.
**Customer satisfaction**
Due to the customer satisfaction, you mentioned that “slow engineering responses to customer” was one problem which caused the customer dissatisfaction.

14. Have you had a principle or standardization regarding to the response time?
   - No standardized methods, but we are using “Three days policy”.
   - Increase the customer focus and awareness

15. What cause the late response? Can it be avoid? How?
16. Any other factors which cause the customer dissatisfaction? Such as: misunderstand the needs of customers?
   - More communications can improve the misunderstanding
   - General comments and suggestions: customer needs and service can be quantified to know them better. Also, customer surveys can help us know the customer better.

**Communication (Back up question)**
The survey shows that you have a high frequency of formal and informal communications; yet you still mentioned the lack of communications is one of the problems.

17. What kind of communications do you think are lacking?
18. Is it the communications which are knowledge sharing through website and paperwork (low rate in the survey)?