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Six Sigma Implementation and Integration within Project Management Framework in Engineering, Procurement, and Construction Projects

A Case Study in a Southeast Asian Engineering, Procurement, and Construction Company

Master's thesis in International Project Management

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Master's thesis 2017:BOMX02-17-95

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Typeset in LaTeX
Gothenburg, Sweden 2017

Abstract

This thesis was carried out in a Southeast Asian EPC company based in Indonesia, as a mandatory requirement for Master's degree in Chalmers University of Technology. The thesis was conducted from January 2017 until June 2017 by a student from M.Sc. International Project Management course.

In 2015, a survey from PMI found that there were only 64% of projects which met their goals. The projects included ones conducted in Engineering, Procurement, and Construction (EPC) companies. The bigger projects were more likely to encounter bigger problems, which results in poor performance which ultimately affected the quality of projects. As a result, more companies are seeking quality improvement methodologies like Six Sigma and merging it within the project management framework. This provided an excellent opportunity for a thesis study, which was to investigate how an EPC company works with quality management and what leads to successful integration of Six Sigma methodology in EPC project management framework. The aim of the study was to identify the success factors, benefits and constraints of Six Sigma implementation in project management, so as to successfully merge it to the knowledge areas within project management framework.

A qualitative approach was used to perform this study. The study included state of the art literature review and a case study. Data for the study was gathered through semi-structured interviews with employees from the case company. In addition to the interviews, data was also obtained from internal documentation. There were three main theoretical frameworks used in this study: the Six Sigma DMAIC Methodology, Six Sigma Project Management, and Six Sigma Implementation Success Factors. The foundation for the findings and discussions in this study are generated through these theories.

The study disclosed that quality has not been the main concern in EPC projects. Albeit there has been sets of standardisation to achieve a certain level of quality, the EPC company has not really felt the necessity in enforcing it rigorously. Also, there are several challenges connected to the project management practices such as poor communication, inefficient project processes, disintegrated and complicated workflows, and limited access to project information. After challenges were identified, the existing framework within Six Sigma DMAIC was updated based upon the expected success factors for ideal vision of project lifecycle from the empirical findings, to accommodate solutions for the identified challenges. This thesis resulted in providing an updated framework for Six Sigma project management in EPC context. The identification of success factors for Six Sigma implementation in EPC projects and its benefits are seemed to outweigh the constraints. It is recommended for future research to further investigate the real cause of the low awareness of quality management in EPC projects, formulate a better standardised workflow for EPC industry, and investigate the suitable type of organisation structure for EPC projects.

Keywords: quality, Six Sigma, Six Sigma implementation, Six Sigma in EPC, project management, engineering procurement construction, EPC, Southeast Asian EPC industry

Acknowledgements

I would like to thank my supervisor, Christian Koch, for his guidance, valuable feedback, and the time he has devoted throughout this research.

I would also like to thank my case company supervisor Andhika for his patience, guidance and support regarding the case company resources. A grateful thank you is also directed to all the knowledgeable engineers at the case company, the Six Sigma consultant, Asrizal, and the Construction Management researcher, Kajsa, for their supports, insights or advices in the making of this thesis.

Lastly, I would also like to dedicate this thesis to my friends and family for their endless love, support, and encouragement.

Diviezetha A.F. Thamrin, Gothenburg, August 2017

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NOMENCLATURE

Acronym

CSF	Critical Success Factor
DoE	Design of Experiments
DMAIC	Define, Measure, Analyze, Improve, Control
DMADV	Define, Measure, Analyze, Design, Verify
EPC	Engineering, Procurement, and Construction
FMEA	Failure Mode and Effect Analysis
KPI	Key Performance Indicator
PM	Project Management
PMBOK	Project Management Body of Knowledge
PMO	Project Management Office
SPC	Statistical Process Control

1
Introduction

This chapter begins with the background of the thesis. The background is then followed by purpose of the study, statement of the problem along with the research questions, demarcations, and thesis outline.

1.1 Background

Many large infrastructure projects have strikingly poor performance records, where it is mostly caused by cost overruns (Flyvbjerg, Bruzelius, & Rothengatter, 2003). In 2015, there was only 64% of projects which met their goals (PMI, 2015), including the construction projects conducted in Engineering, Procurement, and Construction (EPC) companies. Big projects usually encounter big trouble in their projects, which affect the performance and quality of projects. These poor performance might have been caused by ineffective project management methods under the classic project management framework, as they are unable to quantify the value added activities within those projects (Harrington, 1991). Therefore, more companies are seeking for quality improvement methodologies to be implemented in the projects, in order to avoid project failure and to enhance the project success (Dahlgaard & Mi Dahlgaard-Park, 2006), where Six Sigma is one of them.

Tenera and Pinto (2014) suggest that a great potential for integration between project management practices and Six Sigma is available, where solutions to problems and opportunities will be found by Six Sigma, whilst the formal procedure for the implementation of the solutions will be provided by project management standards. With Six Sigma tools, project managers will also be able to perform more effectively and achieve innovative results (Rever, 2010), thus will enhance project success through the reduction of completion cost and time throughout the entire project life-cycle; from design in engineering, supplying and allocating resources in procurement, to the construction phase itself. Applications of the Six Sigma method will allow integration of the knowledge of the process with statistics, engineering, and project management, thus will enhance the competitive advantage of an organisation (Anbari, 2002). The benefit of applying Six Sigma method to technology-driven, project-driven organisations are great, despite of the challenges that the organisations have to undergo in the initial phase (Kwak & Anbari, 2006).

1.2 Purpose of the Study and Objectives

The purpose of this study is to investigate how EPC companies work with quality, and to explore how Six Sigma can be integrated into the traditional project management framework in EPC firms' projects. The results will be used to provide recommendations to future EPC project-based firms to improve the project quality by implementing Six Sigma.

The above aim will be accomplished by fulfilling the following study objectives:

1. Review the literature of project management framework, applications of the Six Sigma, and concepts of quality management within projects to identify the challenges project managers encounter and to show in what way the Six Sigma can influence the quality of projects.
2. Evaluate current practice from literature review of how Six Sigma has hitherto been implemented in EPC firms' projects to identify relative factors in regards to project management framework.
3. Interview a sample of project engineers, quality engineers, construction engineers, or persons who possess the relevant competencies from EPC firms to find out their views on quality improvement in projects and the possibility along with the effects of Six Sigma implementation in EPC firms' project environments.
4. Produce a critical reflection of how Six Sigma can be integrated within the traditional project management framework to improve project quality.
5. Suggest ways in which EPC project-based firms can conduct more profitable projects through implementation of Six Sigma.

1.3 Statement of the Problem

EPC projects are becoming more complex with large contract values, and implemented on a larger scale. Consequently, most of large EPC companies face common issues which hinder their projects, which mainly caused by five major factors: 1) incompetent designers and/or contractors, 2) poor change management and estimation, 3) technological and social issues, 4) site related issues, and 5) improper tools and techniques (Long, Ogunlana, Quang, & Lam, 2004). Therefore, more and more project-based companies—including EPC firms—find it is vital to find a more innovative and effective method which can be integrated into the project management framework (Pyzdek, 2003). The new innovative and effective method is expected to draft and manage the projects, as well as to enhance the company's competitive advantage by supporting its project in any manner.

Madu and Kuei (1993) proposed that a company could enhance its competitive advantages by strengthening the quality management through implementation of quality improvement methodologies. Implementing quality improvement methodologies could improve their products and/or service characteristics, decrease costs, and perfect their processes (Tenera & Pinto, 2014). The aforementioned quality improvement methodologies could vary from Total Quality Control, Lean Production, and also Six Sigma (Dahlgaard & Mi Dahlgaard-Park, 2006).

Initially, Six Sigma was designed as a pure quality management method for production and manufacturing processes (Brue and Howes, 2004). However, with the heavy pressure from globalisation, more organisations and companies have discovered the advantages of Six Sigma in management as they have to maintain their competitive advantages. Therefore, more projects executed in organisations have become Six Sigma projects, as those projects were integrated with the principles of Six Sigma management which can lead to the improvement of quality and reduction of cost (Bertels, 2003). A lot of companies have benefited from implementing Six Sigma in their projects; namely Ford Motor Co. who saved $300 million (Paton, 2000), Kodak who increased its productivity by 85% and Vertek who generated $6.8 million for its annual savings (Kwak & Anbari, 2006), and many other companies in various industries.

There have not been many literatures which show how Six Sigma can be integrated within Project Management framework then enhance the EPC projects. Therefore, there is a need for a structured framework that can meet the gap that exists between Six Sigma and its use in EPC projects. The statement of problem for this research would thereby revolve around how Six Sigma can be implemented and integrated within Project Management framework in EPC projects.

1.4 Research Question

Since there have not been many literatures which show how Six Sigma can be integrated then enhance project in EPC firms, the main research question is:

How can Six Sigma be implemented and integrated within project management framework in projects in EPC firms?

Several prerequisites need to be understood beforehand in order to define clearer and more apropos directions for reaching the objective of the study. Having the clear overview of the main characteristics of EPC firms, the quality improvement methodologies, and the framework and features of Six Sigma methodology will provide a solid basis for the study. Therefore, the main research question is broken down further, as investigating this concern leads to other sub research questions:

1. What is Six Sigma and how does it relate to quality improvement projects?
2. What are the characteristics of EPC firms and how do they manage their quality at present?
3. What are the key success factors in implementing Six Sigma in EPC firms' projects?
4. What can be the possible benefit and constraints of the implementation of Six Sigma at the beginning and how can these constraints be overcome?

1.5 Limitation and Delimitation

The scope of this study is limited to a case study in a Southeast Asian EPC firm. This firm was rewarded as The Top 250 International Global Contractors by The Engineering News Record 2016 (News-Record, 2017), and the study started from January 2017 up to June 2017. The respondents of this study consist of project engineers, quality engineers, construction engineers or persons who possess the relevant roles and competences from this EPC firm and seek for project quality improvement with quality management tools, as well as several professional practitioners. Nonetheless, the sample size from the case company is limited to seven interviews due to the limitation of a single case company and the availability of given resources. The two additional interviews from professional practitioners intend to gain a broader perspective of Six Sigma implementation within project management framework from the practitioner's point of view. As such, the study will only explore the implementation and integration of Six Sigma methods in traditional project management framework and project management practices in this particular EPC firm. Therefore, limitation will occur in the generalization of the findings. The generalization limitation is whether the findings are applicable for other projects which share similarities with the type of the observed EPC firm's projects, and also for other regions who share cultural and geographical similarities with Southeast Asia.

The nature of study used is semi-structured interviews with each interviewee. As a cross-sectional study, the research data will be collected at a single point in time. The responses which will be received from the interviewees will probably be influenced by their subjective experiences, as the interviewees will be limited to only one interaction. Hence, there is a possibility of different results of the interview if the study is conducted in a longer term. The study covers only one EPC project-based firm located in Southeast Asia, thus the findings may also not be applicable to the broader range of project-based organisations who run their business in different areas of industry. In addition, the focus of this study is purely on the integration of Six Sigma methods in traditional project management framework and project management practices, hence the findings may not be applicable either to project-based companies which conduct different project management ways such as agile project management.

1.6 Thesis Outline

The structure of the thesis is presented to the reader in this section and illustrated in Figure 1.1 below.

The first chapter provides the introduction to the project, including the statement of problems and the purpose of the research. The methodology of the research is elaborated in the second chapter, where it consists of the research strategy approach and research method throughout the study. The third chapter presents the literature review regarding the topic of the study, which are project management, Six Sigma, Six Sigma project management. In this chapter, the theoretical framework which are presented by other researchers and authors is compiled to provide reference for different areas of the topic. There will be a section which elaborates the characteristic of EPC firm itself along with how Quality Management and improvement projects are conducted in EPC firm. This section is intended to bridge the framework of understanding in the literature review and the empirical findings, and is presented in the fourth chapter. Based on the first four chapters, the findings of the empirical study based on conducted interviews is presented in the fifth chapter. The results are then discussed, analysed, and contrasted against the literature in

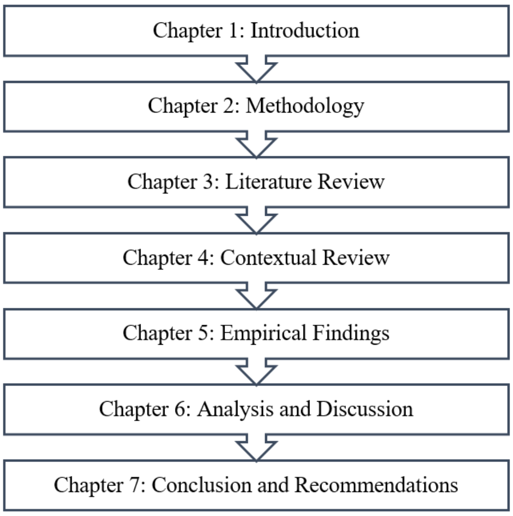

Figure 1.1: Thesis outline

the sixth chapter. The seventh chapter concludes the research by providing conclusions, presenting the outcome based on the methodology, and suggestion for further research in the future.

2 Methodology

This chapter begins with the introduction of this research methodology, which follows abduction approach. The research strategy is then presented by justifying the nature of the study, which is exploratory by building upon the existing knowledge with a case study. Literature study and empirical study are used as the research method, followed by data collection method which consists of interviews and secondary data collection. Lastly, the method of data analysis and data validation is presented.

2.1 Research Methodological Approach

With the current theory in research methodology, this study research choice lies on the qualitative research. Procedures and techniques from a research orientation wer be used, which was interview. Generally, qualitative research is linked to interpretivism, where the underlying meaning of events and activities need to be interpreted (Bryman, 2015). Qualitative data analysis is associated with inductive approach, where it is mostly concerned with the generation of theory. However, Bryman (2015) states that there are some studies which employ qualitative research as a test or explorative study instead of generation of theory. Björklund and Paulsson (2003) argued that an explorative study is suitable when there is little existing knowledge in the field of study. Based on the aforementioned backgrounds in the first chapter, an exploratory research based upon the existing knowledge is chosen for this study.

As an exploratory research, this study adopts an abduction approach. According to Dubois and Gadde (2002, p. 559), this approach is *"a refinement of existing theories than on inventing new ones"*, a combination of an induction and deduction approach which switches between theory and reality. Dubois and Gadde (2002) argued that a study will have a deeper understanding from both literature and empirical sides if it is done back and forward between literature and empirical part. In deduction approach, many variables are varied and the effect afterwards are analysed in order to investigate the relations. On the other hand, in induction approach, there is little possibility of varying the factors as the effect is known already, where the factors will then be analysed.

2.2 Research Strategy

As mentioned in the previous section, the nature of this study is exploratory by building upon the existing knowledge or findings, since the aim is to enquire more of how Six Sigma can be integrated into the traditional project management framework. Exploratory research provides the flexibility to the researchers to adapt the research based upon the collected data and the findings (Coster & Van Wijk, 2015). Moreover, exploratory research allows both assessment and compilation of new ideas and insights on the topic in which the researcher is interested (Stebbins, 2001).

Furthermore, to complement the exploratory research, a case study was chosen for the research design, where a specific entity is analysed in detail. According to Bryman (2015), a case study is an intense study and investigation of a single person, single organisation or single community, to name a few, through analysis of documents, observations, and semi-structured interviews with relevant professionals. The aim of this study was achieved by examining the company from the perspective of the people who work closely with projects in the company. There was a need to acquire a personal perspective of how these people perceive and outlook the company and the projects itself in particular. However, qualitative research design in a form of case study has a consequence in the context of the generalization of the outcome, due to its interviews are conducted with a limited number of participants within one particular organisation (Bryman, 2015).

2.3 Research Method

There have not been many research done on how Six Sigma is integrated within EPC firms, especially in the Southeast Asian industry. It can be considered that the research done on this particular subject is insufficient, thus it was necessary to examine both the current industry practice and previous research. This was to investigate how Six Sigma can benefit and be implemented in Southeast Asian EPC firms. Furthermore, as this research follows abduction approach, it was essential to contrast the literature with the collected empirical data, then develop the result from the previous literature throughout the study. Therefore, this research consists of two major parts, which are literature study and empirical study. Both studies were done in parallel in order to investigate the applicability of Six Sigma implementation in Southeast Asian EPC firms.

The first sub research question is answered through literature study, as the aim is to understand what Six Sigma is and how it relates to quality improvement projects. The second sub research question is mostly answered through literature study as well for the characteristics of EPC firms, and the combination of literature study and empirical study for how the EPC firms manage their quality at present. The third and fourth sub research question are mostly answered through empirical study, which are based and developed upon literature study.

2.3.1 Literature Study

A literature review is essential to be conducted in any research project in order to have an understanding of the previous research which has been done by other researchers. Besides showing areas which have already been studied, a literature review also shows areas which should be studied further (Webster & Watson, 2002). Dubois and Gadde (2002) also state that literature review provides a chance to define the relevant variables for a particular research, as well as how the predetermined variables are connected to each other. The literature review are mostly done with the concept-centric approach, where it focuses on a concept which links relevant literature (Webster & Watson, 2002). For this study, searching the research journals and papers were mostly conducted in different database such as Google Scholar, Science Direct, and Emerald. Books, articles, journals and relevant literatures which were provided by the library of Chalmers University of Technology and used in courses within International Project Management program were also reread and used to support the gained knowledge. The literature study was an iterative process that lasted during the entire study.

The literature study regards several main fields concerning Project Management, Six Sigma, Six Sigma Project Management, Six Sigma Projects in EPC firms, and some other relevant theories for developing the working method. Elements which PM consists of such as the basic principles, project success measures, core competencies and knowledge areas, methodologies and lifecycles, as well as several relevant terms and concepts within PM are highlighted. In Six Sigma field, the focus are primarily on reviewing the concept and the classic model of Six Sigma, the prominent tools used in Six Sigma methodologies, and Six Sigma implementation framework. Meanwhile in the Six Sigma Project Management field, the focus are mainly on Six Sigma projects development, the existing framework of Six Sigma project management, success factors of Six Sigma implementation, and different roles within Six Sigma projects. Lastly, in Six Sigma Projects in EPC firms, the current practice of Quality Management in EPC firms is described briefly, as well as the examples of Six Sigma implementations in EPC firms.

2.3.2 Empirical Study

Empirical study was conducted with the case study to gain a deeper understanding about the current practices of quality management in EPC firms and how Six Sigma can be implemented within Project Management (PM) framework in EPC firms. This case study was conducted to add up to the attained knowledge from literature study, with a Southeast Asian EPC company. As the case company was one of top 250 international and global contractors of the world according to The Engineering News Record 2016 (News-Record, 2016), the results could be considered adequate to represent how major EPC firms manage their quality and to study how one of quality improvement methodologies—which is Six Sigma—could be implemented in EPC projects. More explanation for the empirical study is further elaborated in the subsequent section.

2.4 Data Collection Methods

2.4.1 Primary Data: Interviews

Interviews were conducted with seven engineers from the case company. These engineers were from Quality Assurance and Quality Control Division, Project Control Division, Engineering Department, Procurement Department, and Construction Department in order to gain in-depth qualitative material. The information was specifically obtained from the aforementioned divisions and departments on their levels within the company's organisation. Engineers were chosen as the interviewee as they possessed not only specific competencies correlated with engineering decisions which interlinks with quality, but also relevant experiences and insights which were valuable for the study. However, the interviewees were also selected based upon the given and available resources from the company itself. The interviewees were asked about how the company views, works with, then develops quality, the level of implementation of quality management tools within their projects, the way they conduct their projects within project management framework in their company, then to identify in which way Six Sigma attributes could be utilised within the company's projects, where the responses contributed to the exact ways of development of the integration.

In additions to engineers from the case company, other interviews were conducted with two professional practitioners, who were a Master Black Belt and has been working as a Six Sigma consultant for 8 years and a Construction Management researcher from a prominent Swedish construction company. A Master Black Belt is an expert in Six Sigma tools and methods and has managed several Six Sigma projects by utilising these tools, and will be described further in the next chapter. The purpose of these second cycle interviews was to gain their insights of the possibility of Six Sigma implementation and integration within traditional PM framework in EPC firms from the professional practitioner's perspectives. Similar questions with the interview questions for the case company's interviewees were asked. This was to compare the state of the art of the quality management according to an expert, and the one which was exercised in the company.

Set of questions for the interview were designed to enquire the possibility of implementation of Six Sigma and their related components. The list of interview questions for both the case company and the professional practitioner was developed under the framework of Define, Measure, Analyze, Improve, Control (DMAIC). The framework of DMAIC will be presented further in the next chapter, in regards to Project Management life cycle. The questions which were used are semi-structured questions in order to provide both the interviewees and the interviewer with some format, to help direct the responses, and to gauge the interviewees' perceptions of how they think Six Sigma could be integrated within traditional project management framework and practices in order to enhance the project success. With semi-structured questions, the interviewees would be able to clarify questions and vice versa, where the interviewer would be able to clarify responses as well. The list of interview questions is presented in Appendix C.

Skype Interview

Access to global research participants could be facilitated by online methods such as Skype, which enable the online interview. As the case company is based in Indonesia, the interviews were conducted through Skype. Face to face interviews with potential respondents who domicile in different geographical areas are possible to be conducted, as Skype has made communication over large distances more feasible (Deakin & Wakefield, 2014). Moreover, Skype interviews allow the researcher and respondents to create an artificial and virtual space and time in order to construct the research result for the researcher (Bertrand[1] & Bourdeau[1], 2010).

According to Bertrand[1] and Bourdeau[1] (2010), Skype interview protocol has the advantage by enabling the interviewer to record video as well as voice calls, as long as the interviewees have given their consents. Skype interview with video let both the interviewee and researcher participate in an exchange of relationship that is visible to each other such as gestures, facial expression and verbal cues, which can be considered as a successful interaction (Sullivan, 2012). With the voice calls, verbatim can be produced in the same way as traditional interviews. However, albeit research interview by Skype offers what it seems like freedom space to the interviewees to end the network session, this provides a challenge for the interviewer to gain a higher degree collaboration from the interviewees.

The Skype interviews were carried out on a one-to-one bases instead of a small group. In order to select the appropriate interviewees, several discussions were done with the supervisor from the case company to clearly address the purpose of the study and the need of the data that was expected to be obtained. Afterwards, the supervisor was able to connect and arrange several interviews with the relevant and potential persons who work closely with quality and projects, which were the case company's engineers. According to the supervisor, these engineers already possessed adequate knowledge and experience. Moreover, they worked closely and directly with the quality in the projects. Therefore, the supervisor considered these engineers as the suitable respondents for the interviews with their capacities. Along with the recommendation from the supervisor, an email with the attachment of the abstract of the study was sent to the prospective interviewees, requesting their willingness to be interviewed. Afterwards, the list of interview questions was sent beforehand when the schedules were already fixed, in order for the interviewee to fully understand and reflect upon the questions before the interviews.

Ethical Consideration

This study involves interaction with the research participants who were interviewed as the source to obtain the required information. Therefore, this study incorporates ethical considerations throughout its lifecycle. The level of confidentiality of the data was clarified, where the information obtained from the interview was used solely for the research purpose only. The interviews were proceeded after the research participants' willingness to participate were confirmed and were recorded with the given participant's consents to avoid missing any essential data which can alter the result of the interviews. Participants were notified about their rights to keep confidential information regarding how the company runs the projects off the record before the interview. Afterwards, the obtained information was clarified to the research participants along with the presentation of analysed information to prevent the misunderstanding and the faulty data.

2.4.2 Secondary Data

Before developing the list of interview questions, case company's core activities and their project execution processes were studied. The purpose was to obtain an insight and a deeper understanding of the setting and the context, to enhance the knowledge of the case company and how projects are conducted in general within the company. Company homepage, annual reports, news articles, and internal documents were compiled for background material. Through the secondary data, interview questions could be developed more accurately and maturely. The knowledge gained from the secondary data gathering was implemented directly into the interview guidelines to provide list of interview questions. However, some of the internal documents are confidential and thereby is not attached nor presented in either this study or the Appendix.

2.5 Data Analysis

A mass of words is commonly generated from qualitative research, which needs to be structured and ordered. The data obtained from the interviews was structured and analysed based on the main topic and area of discussions by using content analysis. To ensure that the collected data was accessible after the interviews to transcribe it, an online recording equipment was used to record the interviews, after having the consent from the interviewees. According to Doody and Noonan (2013), recordings can be an effective tool to interpret and reflect the data, as it can be used to listening back to the recording of the interview. By listening to multiple interviews, the researcher will be most likely familiar with the key points described by the interviewees, thus it will be easier for them to identify the patterns (Doody & Noonan, 2013).

Bryman (2015) suggested that the transcription of interviews ought to be done as soon as possible to give the researchers the most amount of time to clearly interpret the data without messing and/or tweaking it with other data obtained from other interviews. The results of the interviews were handled confidentially, and would be handed to the interviewees who requested it. The data analysis highlights the most critical points or key activities and key factors that an EPC firm should take into consideration when implementing Six Sigma and integrating it within traditional project management framework in their projects. In addition, the analysis also reveals how EPC firms nowadays work with quality management, as well as the benefit and barriers of implementing Six Sigma within projects in EPC firm. The findings obtained from the analysis of the interview data are then presented and discussed.

2.6 Data Validation

There are two main criteria which are ought to be taken into consideration in order to assess a qualitative research, which are authenticity and trustworthiness. According to Bryman (2015), trustworthiness consists of four different criteria as follow: 1) conformability, how the researcher is expected not to mix their own values in the survey; 2) transferability, how the researcher is expected to describe culture and milieu in enlarger terms thus the findings can be applied in different settings; 3) credibility, how the researcher ensures that the studied environment is understood correctly by engaging the participants to make comments on the attained data while using good practice; and 4) dependability, how the researcher keeps all the data for reviews in the future study. The validity of this study was ensured by posing unbiased and clear questions to the interviewees. Afterwards, the validity of the attained results from the interviews were examined thoroughly. Lastly, a way to ensure the validity of this study was achieved through having regular supervision sessions and peer review.

3

Literature Review

This chapter provides the framework of understanding for the study, which presents brief and relevant literatures in regards to Project Management, Six Sigma, and Six Sigma Project Management.

3.1 Introduction to the review of the literature

The project management practices are widely received by different industries and organizations. Project management has become a focal point for undertaking several of the business activities, thus its success and productivity is immensely important in order to create economic value and competitive advantage of organizations (Aziz, 2012; Shenhar, Dvir, Levy, & Maltz, 2001). However, according to Aziz (2012), over budget and behind schedule delivery—which are parts of the definition of project success—have been one of the most significant concerns with projects lately.

Madu and Kuei (1993) proposed that a company could enhance its competitive advantages through their projects by strengthening the quality management, through implementation of quality improvement methodologies such as Six Sigma, total quality control, and Lean Production (Dahlgaard & Mi Dahlgaard-Park, 2006). Among these quality improvement methodologies, Six Sigma has gained more attention (El-Haik & Roy, 2005; Bertels, 2003). There are previous studies which attempt to expand Six Sigma cycle to project management practices and process improvement, among them are Tenera and Pinto (2014), Cheng and Chang (2012), (Wiklund & Wiklund, 2002), and so on. The optimization and efficiency to finalize project within planned time, budget, and scope, has been the main goal of the traditional project management (DeCarlo, 2004; Wysocki, 2006), while achieving the quality level and promoting comprehensive management framework has been the main focus of Six Sigma (Snee & Hoerl, 2003).

3.2 Project Management

3.2.1 The Basic Principles of Project and Project Management

There are several definitions of project and project management. Project has been defined as *"a temporary endeavor undertaken to create a unique product, service or result"* (PMI, 2013, p.3), and *"a unique, transient endeavor undertaken to achieve planned objectives [...] outcomes or benefits."* (APM, 2012, p.12). Furthermore, project management has been defined as *"the application of knowledge, skills, tools and techniques to project activities to meet project requirements"* (PMI, 2013, p.5), while APM (2012, p.12) defines project management as *"the application of processes, methods, [...] the project objectives"*. According to Kerzner and Ebrary (2013), a project has several characteristics, which are: 1) any series of activities and tasks; 2) has specific objectives to be completed within certain specifications; 3) has defined start and end dates; 4) has funding limits; 5) consume human and nonhuman resources; and 6) multifunctional.

Kerzner and Ebrary (2013) states that project management is the planning, organizing, directing, and controlling of company resources for a relatively short-term objective that has been established to complete specific goals and objectives. Project management is essentially management of change, thus designed to make better use of existing resources by getting work to flow horizontally as well as vertically within the company. It is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements (PMI, 2013). Several relevant terms and concepts within Project Management are presented in Appendix A.1.

3.2.2 Project Success Measures and Dimensions

In the past few decades, the definition of project success has been revolving around the completion of set of activities within the constraints of time, cost, and performance (PMI, 2013); which is also known as the 'iron triangle' or 'triple constraint'. The triple constraint is about balancing each constraint as they affect project quality. The more detailed typical project constraints are also included scope, quality, schedule, budget, resources, and risks, but it is not only limited to those. The change in any of the parameters will likely affect at least one of the other project parameters as well (ibid.).

Over the time, the definition of project success has been modified to include *"completion within the allocated time period, the budgeted cost [...] without changing the corporate culture"* (Kerzner and Ebrary, 2013, p.7). Boddy (2002) also states four dimensions that can be used to measure project success: 1) the project efficiency, 2) impact on customer, 3) business and direct success, and 4) the readiness of the firm or organization to prepare for the future. A Key Performance Indicator (KPI) can also be used as a particular part of the project success measures. It can be a milestone which must be met, a predetermined design, delivery, installation, production, testing, erection or commissioning stage, a payment date (in or out) or any other important stage in a project (Lester, 2007).

3.2.3 Project Management Core Competencies and Knowledge Areas

Project Management skills are organized around the nine knowledge areas described in the Project Management Body of Knowledge (PMBOK). A knowledge area represents a complete set of concepts, terms, and activities that make up a professional field, project management field, or area of specialization. It provides a detailed description of the process inputs and outputs along with a descriptive explanation of tools and techniques most frequently used within the project management processes to produce each outcome (PMI, 2013). The following Table 3.1 summarises the ten knowledge areas in project management and their objectives.

Table 3.1: Project management knowledge areas and their objectives, based on PMO Treasury Board of Canada Secretariat (1998)

Knowledge Area	**Objective**
Project Integration Management	To co-ordinate the diverse components of the project by quality project planning, execution and change control to achieve required balance of time, cost and quality
Project Scope Management	To create quality product by including only the required work, and to control scope changes
Project Time Management	To ensure timely completion of the project
Project Cost Management	To ensure that the project is completed within allotted budgets
Project Quality Management	To ensure that the product will satisfy the requirements
Project Human Resource Management	To employ quality leadership to achieve quality teamwork
Project Communications Management	To distribute quality project information
Project Risk Management	To identify, analyze, control, and respond to project risk
Project Procurement Management	To ensure quality service or product acquisition
Project Stakeholder Management	To identify, plan stakeholder management, adn manage and control stakeholder engagement

3.2.4 Project Management Methodologies and Lifecycles

Traditional project management involves very disciplined and deliberate planning and control methods. Tasks are completed one after another in an orderly sequence, requiring a significant part of the project to be planned up front (Hass, 2007). The traditional project management main process follows the waterfall model, which is summarized in the flow chart in Figure 3.1 below:

In traditional project management, once a phase is complete, it is assumed that it will not be revisited. The strengths of this approach are that it lays out the steps

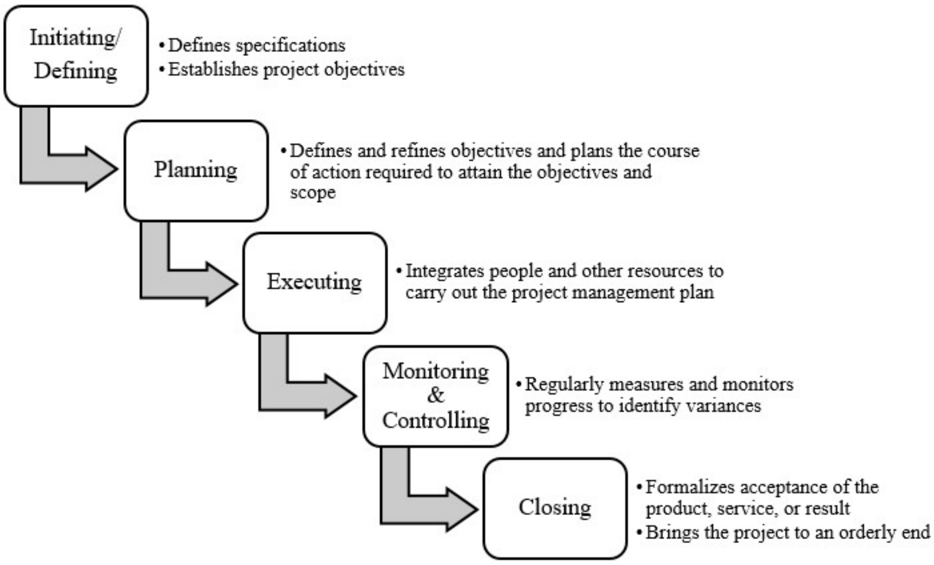

Figure 3.1: The waterfall model

for development and stresses the importance of requirements (Hass, 2007). However, this approach also has limitations, where projects rarely follow the sequential flow, and clients usually find it difficult to completely state all requirements early in the project.

3.3 Six Sigma

Six Sigma has been defined and redefined in many ways since its success commencement at Motorola. Hammer and Goding (2001) defined Six Sigma as a set of structured and disciplined methodologies and techniques to reduce cost and improve quality for solving business problems. The reduction of unwanted variations has been the focus of Six Sigma (Klefsjo, Bergquist, & Edgeman, 2006), as it strives to have no more than a corresponding number of defects per million opportunities (DPMO), or percentage of defects (Keller, 2011).

Six Sigma helps to direct management actions and decisions across an organisation through its data-driven philosophy (Feld & Stone, 2002), and put considerable focus on financially measurable results for improving processes, reducing waste, and increasing customer satisfaction (Caulcutt, 2001). According to Sörqvist and Höglund (2007), Six Sigma has five focus areas which forms the basis for improvements, which are: 1) identify and solve chronic problems; 2) understand the underlying process; 3) understand and reduce variations; 4) focus on achieving measurable results; and 5) make improvements from customer needs and expectations.

3.3.1 Six Sigma Framework and Features

Six Sigma has been recognised as a systematic framework for quality improvement and business excellence (Yang & El-Haik, 2003). According to Pyzdek (2003), one of the most widely tested approaches available today to focus on process improvement and recognised in Six Sigma is the DMAIC methodology. DMAIC phases stands for Define, Measure, Analyse, Improve and Control as shown in Figure 3.2, which are the key processes of a standard framework for a Six Sigma project. In order to succeed while conducting a Six Sigma program within this framework, it is necessary to finalise each phase before starting the next phase (Dirgo, 2005). Generally, each phase is connected to a set of specific tools which will provide a solid base for the program.

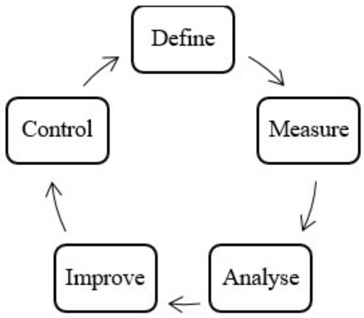

Figure 3.2: The DMAIC cycle

The focus of the Define phase is to determine the magnitude of the project, along with the project's scope, problem statement, goals, stakeholders, milestones, schedule, budget, resources, and expected project output (Gupta, 2006). In this phase, tools which will be used during the upcoming phases start to be considered. The Measure phase follows the Define phase, with focus on identifying the inputs to the process which will affect the outputs. Identifying these inputs are done through planning and developing data collection plans, gathering the necessary data and selecting the proper Six Sigma tools (Magnusson, Kroslid, Bergman, Häyhänen, & Mills, 2003). In the Analyse phase, various methods are used to gain a deeper understanding of the outputs as well as the effect of the identified inputs to the outputs based on the examination from the gathered data in the Measure phase. The main cause in the problem statement is analysed in this phase, and the problems is prioritised based on each of its impact to the quality (Dirgo, 2005; Gupta, 2006). The fourth phase, Improve, focuses on selecting the best design solutions to the problems then subsequently implement it to achieve the goals (Park, 2003). Lastly, the selected solutions which have been implemented should be monitored to ensure the achievement of the improvement targets in the Control phase (Magnusson et al., 2003). This last phase of DMAIC framework is vital, as the goal is to keep the continuous improvement while preventing the backwards at the same time (Park, 2003).

Another popular framework which is associated with Six Sigma follows DMADV phases, which stands for Define, Measure, Analyse, Design and Verify as shown in Figure 3.3. DMADV is used to develop new products or services, whereas DMAIC is primarily utilised to eliminate waste and improve existing process (Jones, Parast, & Adams, 2010).

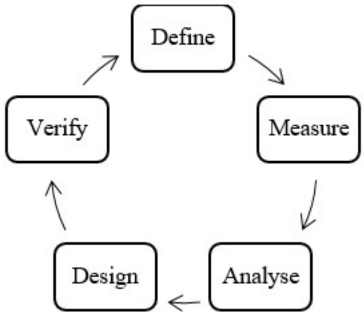

Figure 3.3: The DMADV cycle

3.3.2 Six Sigma Techniques and Tools

There are numbers of techniques and tools which can be utilised in Six Sigma methodology in DMAIC phases, where some practitioners refer as seven-times-seven toolbox or known as the Six Sigma toolbox. Divided into seven groups with seven tools in each group, this toolbox consists of 49 different improvement tools which can be utilised during the whole project. The various tools within the Six Sigma toolbox are presented in the Figure 3.4 below.

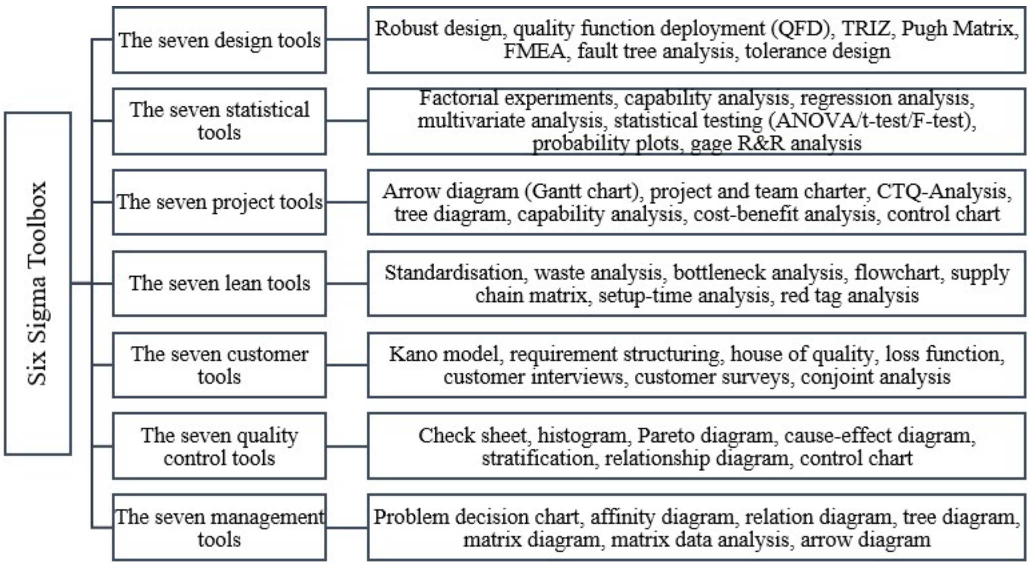

Figure 3.4: The Six Sigma Toolbox, adapted from Magnusson et al. (2003)

Several tools which have been widely used include Cause-and-Effect Diagram, Pareto Chart, Process Mapping, Failure Mode and Effect Analysis (FMEA), Design of Experiments (DoE), Statistical Process Control (SPC), and other prominent tools. Several most common tools which are usually utilised for Six Sigma program are described in Appendix A.2.

3.4 Six Sigma Project Management

Dating back to the mid-1980s, many organisations were able to sustain their competitive advantage with the application of the Six Sigma methods through integration of their knowledge of the process with engineering, statistics, and project management (Anbari, 2002). Six Sigma projects mostly aim to achieve enhancement of organizational performance and profitability, as well as greater customer satisfaction (Jones et al., 2010). These are done by attempts of achieving specific goals through defining quantifiable measures by focusing on customer needs (Jones et al., 2010). Kwak and Anbari (2006) also stated that Six Sigma is a project-driven management method with focus on improving productivity, financial performance, business systems, and understanding of customer requirements by continually reducing defects in the organisation.

There have been some attempts to enlarge the DMAIC cycle of Six Sigma to process improvement and project management practices. Tenera and Pinto (2014) stated that a great potential for integration of project management practices and the DMAIC is available. Finding solutions to problems and opportunities is provided through DMAIC, whereas project management standards will focus on the implementation of the solutions through the formal procedure (Tenera & Pinto, 2014). Moreover, Rever (2010) argued that innovative results will be achieved through the incorporation of DMAIC steps in each project, as Six Sigma provides:

- Better understanding and improvement future results through suitable statistical process knowledge;
- Process improvement through a set of solid tools;
- Reduction of instinctive reactions through variability knowledge;
- Concrete quantitative analysis based on decisions making on facts.

McKenna (2005) also proposed a Six Sigma project management framework based on DMAIC cycle. The proposed framework with the suggested Six Sigma tools which are usually used for several certain activities is illustrated in Figure 3.5 below. This framework puts a more considerable focus on a project-change frame, which describes the stages that a project needs to make to secure success, or in other word, to improve its quality to avoid poor performance.

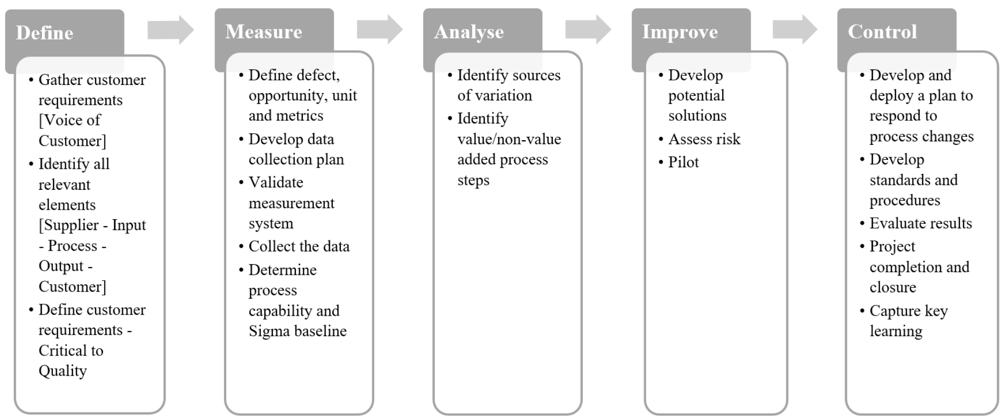

Figure 3.5: Six Sigma DMAIC Project-Change Framework, adapted from McKenna (2005)

Financial terms are usually the expected form of the outcomes of Six Sigma projects, as they lead to a direct measure of achievement which provide a distinct calibration of progress as well as a better measure of the impact of improvements (Goh, 2002). However, Jones et al. (2010) stated that there have not been many literatures of the design and structure of Six Sigma projects, despite of many reference to Six Sigma implementation as a systematic and structured process improvement methodology.

3.4.1 Critical Success Factor (CSF) of Six Sigma Implementation in Project

There have been extensive researches conducted to identify the critical success factors (CSFs) of Six Sigma approach, such as researches by Anthony and Banuelas (2002), Sharma and Chetiya (2010), Knowles et al. (2004), Yang et al. (2007), Lee and Choi (2006), and many other researches. These CSFs are essential for the success of quality improvement projects, as the identified factors will encourage firms to develop appropriate implementation plans for their projects (Mann & Kehoe, 1995). The following Table 3.2 summarises the CSFs of Six Sigma implementation which have been identified in different publication particularly pertaining to Asian environment, then grouped into six categories by Sharma and Chetiya (2012). Each of the CSFs has their own scale items. These scale items are more detailed variables identified through the literature survey by the author, then grouped into the seven groups of underlying CSFs.

Table 3.2: Summary of factor analysis on Six Sigma implementation success factors, adapted from Sharma and Chetiya (2012)

Factor	**Scale items**
Right tools, measurement innovation and supplier collaboration	- Capability assessment and enhancement of the supplier - Innovation management and design capability - Long-term supplier collaboration - A good measurement assurance system - Application of the right tool mix - A creative problem solving approach
Cross-functional organisation, preocess re-engineering and the "strategic fit of Six Sigma"	- Formation of cross-functional teams - Linking Six Sigma to corporate business strategy and goals - Process mapping and reengineering
Education to customers, metrics and measurement and workflow management systems	- Intensive education and training of workforce - Linking Six Sigma to customers - Linking Six Sigma to employees - Identifying and developing appropriate metrics and deliverables

	- An integrated process flow and management system
Work and organisational culture	- Development of right work culture - Motivating the workforce
Project choice and leadership	- Quality of project leadership - Selection of the right project
Project championship and staffing	- Choice of the project champion
Management commitment organisation and availability of resources	- Availability of infrastructure and resources - Level of management commitment

In addition to the aforementioned main factors, Kwak and Anbari (2006) also identified four key elements of successful Six Sigma applications: 1) management involvement and organisational commitment; 2) project selection, management, and control skills; 3) encouraging and accepting cultural change; and 4) continuous education and training.

3.4.2 Roles in Six Sigma Project

In order for the project to be successful, it is critical to incorporate the support from the management, where the management shows and communicates the underlying reasons for deploying Six Sigma (Magnusson et al., 2003). Different roles are required in addition to strong management support in conducting Six Sigma project efficiently. The personnel executing a Six Sigma project can be classified into several levels according to their amount of knowledge in Six Sigma, competence, and their responsibilities within the improvement project (ibid). These different hierarchical roles are illustrated in Figure 3.6 below:

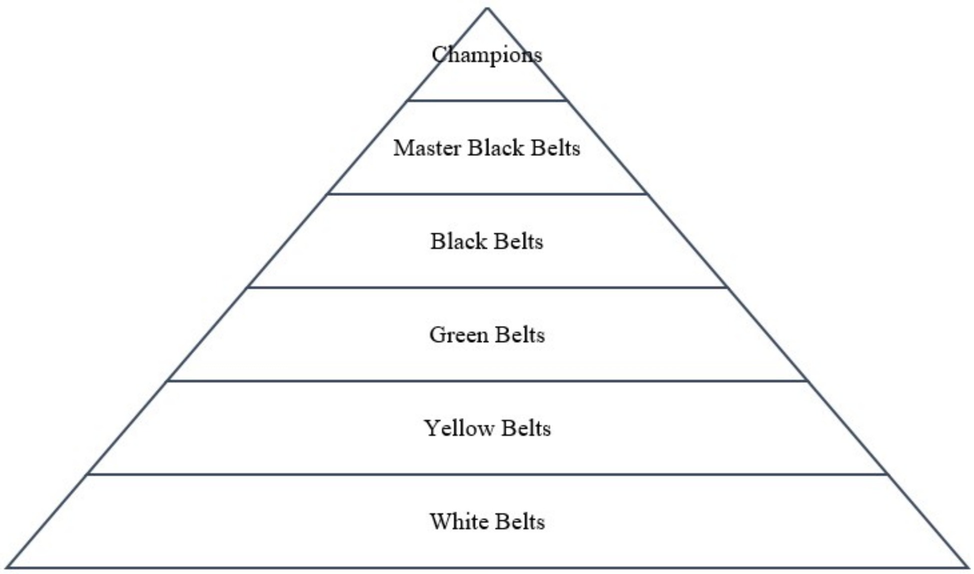

Figure 3.6: Six Sigma Belt

The lowest hierarchical level of the roles in Six Sigma project is White Belts then followed by Yellow Belts, which are commonly not used. However, White Belts refer to frontline staff, operators, and clerks in improvement projects. Yellow Belts then followed by Green Belts, which are mainly project leaders for small projects, or member of the improvement project itself. Green Belts are mainly responsible in applying Six Sigma tools in improvement projects (Magnusson et al., 2003), familiarizing Six Sigma to local teams, and identifying as well as recommending improvement projects (Pyzdek, 2003).

The next higher level in the hierarchy is Black Belts, which mostly a team leader of Six Sigma projects or large cross-functional projects and a full time professional. Black Belts are responsible for coaching Green Belts with local and smaller projects, as they are considered as the specialists within Six Sigma and thereby have the most important role for the daily execution activities of improvement projects (Magnusson et al., 2003; Sörqvist & Höglund, 2007). The highly experienced Black Belts are then called Master Black Belts, whose responsibilities are being a supporting function for Black Belts and Green Belts by mentoring and coaching them, as well as helping the Champions and Six Sigma leader to keep the project on track. Master Black Belts are experts in Six Sigma tools and methods and have managed several projects by utilising these tools. The highest level of Six Sigma hierarchical roles is Champions, who are members of the senior management team and lead the Six Sigma steering committee in general. Champions are responsible to ensure the availability of resources, the resolution of cross-functional issues, and the start and execution of the chosen improvement projects (Magnusson et al., 2003).

3.4.3 Six Sigma and Project Management Knowledge Areas

A basic idea of the integration of DMAIC steps from Six Sigma methodology within Project Management phases is proposed by Rever (2010) as an iterative process as illustrated in Figure 3.7 below.

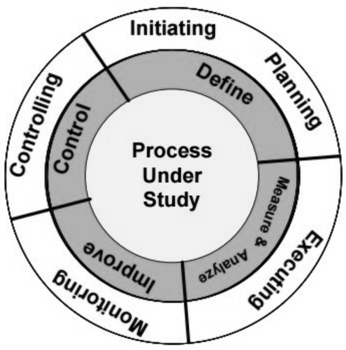

Figure 3.7: Project Management Phases and DMAIC Steps, source: Rever (2010)

The Six Sigma define step includes extensive scoping and planning by developing the project charter, ensuring proper sponsorship, and acquiring suitable cross-functional team members. In this phase, project manager agrees upon key measures which sustains improvement and link to the project success. Afterwards, a data-collection plan is developed in measure step as a basis for process decisions based upon accurate measurement system to provide clues and key metrics for building up improvement path in the analyze step. In the improve step, recommendations are validated, verified and demonstrated before the final implementation of final process. Lastly, a new process is implemented in control step to hand off the final recommendations of the verified improvements (Rever, 2010).

In addition, Kulkarni et al. (2007) also evaluate a set of the tools within DMAIC phases which has been proven to have been integrated within Project Management areas as depicted in Figure 3.8 below.

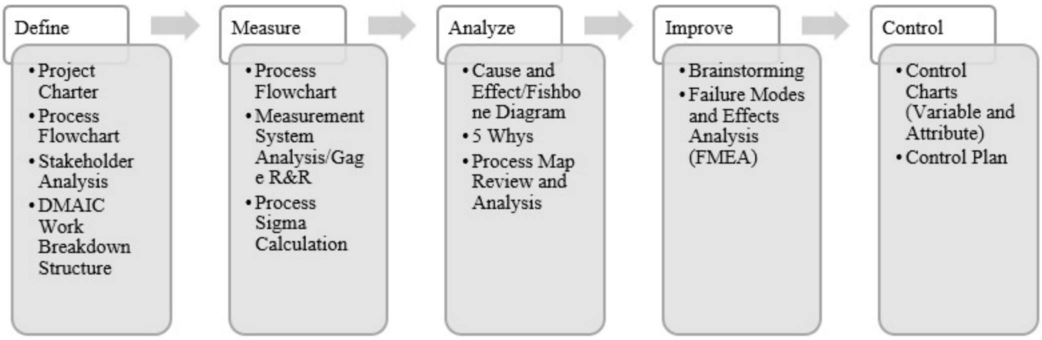

Figure 3.8: Integrated Project Management level in DMAIC phases, adapted from Kulkarni et al. (2007)

However, there are still room for improvement for the Project Management knowledge areas which have not been integrated and missing in DMAIC phases, such as Project Management Plan, Risk Identification, Human Resource and Communication Planning in define phase, Stakeholder Management, Cost Control and Risk Monitoring and Control in measure phase, Scope Control and Verification, Cost Control and Quality Assurance in analyse phase, and Schedule Control and Information Distribution in each phase (Kulkarni et al., 2007).

3.5 Summary of the framework of the study

After an extensive literature research was conducted, four major frameworks were chosen to provide a structured direction for analysis and discussion for the study. The frameworks are the Six Sigma DMAIC methodology, which was combined with Project Management Phases and DMAIC steps by Rever (2010). Having DMAIC methodology and Project Management Phases as the main structure for analysis, this study used Six Sigma implementation success factors which were summarised by Sharma and Chetiya (2012) from several different authors to investigate the CSFs of Six Sigma implementation and integration with EPC project management context for the case company. This list of success factors is chosen as the main framework for the basis of the analysis, as it was developed through an extensive literature review and has been validated through an empirical research. Moreover, the list was proposed in Asian context, which is more suitable with the case company which operates in Southeast Asian market. Lastly, Six Sigma Project Management framework proposed by McKenna (2005) was also used as the basis of existing knowledge. The findings and analysis would be used to build upon this existing framework. The framework of Six Sigma Project Management by McKenna (2005) is chosen due to its relevance with the topic of this study, and also because it covers the frameworks of project management provided by PMI and its knowledge areas.

These all frameworks are used as they complement each other in synthetising the analysis needed to reach the aim of the study. DMAIC cycle is an improvement method in quality, whereas the CSFs proposed by Sharma and Chetiya (2012) provided discussion for Six Sigma implementation success factors to investigate whether these CSFs from literatures are also suitable and for the case company and found within their project management practices. These provided a comprehensive approach for the case study to build upon the existing knowledge in form of Six Sigma Project Management framework by McKenna (2005).

4

Contextual Review

This chapter serves as the bridge of the framework of understanding for the study in the previous section with the empirical materials which is presented in the next chapter. In this section, characteristics and attributes of EPC firms in general will be discussed, as well as the current practice of quality management in EPC firms nowadays and several examples of Six Sigma implementation in EPC firms' projects.

4.1 Energy, Procurement, and Construction (EPC) Firms and Projects

According to Spencer Ogden (2014), EPC firms are companies in the construction industry who run their projects in a certain form of contracting agreement, where *"the engineering and construction contractor will carry out the detailed engineering design of the project, procure all the equipment and materials necessary, and then construct to deliver a functioning facility or asset to their clients"*. Drawings and specifications are supplied by Engineering to Construction, whereas requisitions detailing fabricated items, equipment, and bulk materials which are need to be purchased and specialised services which are need to be contracted are supplied by Engineering to Procurement (Ballard, 1993). In addition, external suppliers and service providers could be suppliers to Construction as well, where all these three functions form the interdependency.

EPC firms are commonly known as EPC contractors as well, and provide a detailed and integrated engineering, procurement, and construction services. As it offers integrated services, EPC projects tend to be complicated and therefore require special knowledge and expertise. Most of them are obliged to execute and deliver a qualified project within a predetermined budget and time under Lump Sum Turn Key (LSTK) contract, where the EPC firm also has to accommodate the risk in regards to budget and schedule (Kaewchainiem, 2011). EPC firms mostly cover interdisciplinary areas of engineering such as process, civil and structural, plant layout, mechanical, electrical, geo-technical, and instrumentation and controls (Fox, 2014); thus its main advantage is having a reduction of the total project duration through tis overlap in design, procurement and construction phases (Kaewchainiem, 2011).

According to Villanueva and Kovach (2013), EPC firms are typically granted projects by other firms to construct or build a plant, such as a refinery, a petrochemical plant, an offshore drilling platform, or a power plant. Many resources including material, people, and other financial support are required to execute these types of projects, as various discrete activities are required to construct plants (Villanueva & Kovach, 2013; Choi et al., 2008). EPC projects are in general highly schedule driven, as its mechanical completion date based upon the project deliverables, specifications, and client's requirements. In the projects, the Instrument and Controls Engineering/Design Department plays a critical role in project design, as designing or building a facility typically account for relatively 20 to 30 percent of project cost (Sinnott & Towler, 2009). During the project execution, the client or project owner is customarily present to ensure that the project is carried out in accordance to the predetermined scope (Spencer-Ogden, 2014).

Yeo and Ning (2002) state that an EPC project can be a complex product development which depends upon financial commitment and considerable human efforts, as its activities are time-phase in accordance to resource requirements and constraints as well as specified precedence activities. The fact that EPC project has to manage phase overlaps, interdependence of activities, complex organizational structure, and uncertainty of desired outcomes has made conducting EPC projects is challenging to some extent (Yeo & Ning, 2002), thus there is a necessity to have a well-established project management system in order to run the EPC projects without significant issues, especially due to frequent project changes and variations (Ogunlana, Promkuntong, & Jearkjirm, 1996; Chan & Kumaraswamy, 1997).

4.2 Quality Management in EPC Firms

Nowadays, the focus of the business has shifted to customer satisfaction through customer-oriented management, rather than higher productivity through production-oriented management (Song, Lee, & Park, 2004). Therefore, quality management has emerged as one of the main concerns for competitive advantage improvement for many corporations in various industries, including EPC firms. Nonetheless, (Song et al., 2004) argue that most of the firms still neglect the quality management aspect in their substantial action programs albeit the realisation of the significance and importance of quality, including in EPC firms. In most of the EPC project life cycle, quality has not been prioritised compared to cost and schedule due to the consideration that the detection of quality problems can be done only after the problems occur (Garvin, 1988). During the construction phase of EPC projects, disruption may still often occur followed by waste of resources to a certain extent due to poor quality planning, which lead to poor delivery of specifically design documents, offsite resources, and permanent plant materials and equipment (Ballard, 1993).

Quality itself can be defined as the conformance of characteristics and features of an entity to satisfy the established requirements and stated needs (ISO9000, 2000), where the entity itself can be a product, a process, a component, or a service (Ledbetter, 1994). From merely product-related quality control, quality management then has been evolving to Total Quality Management, Six Sigma, Lean, and so on, which aims for continuous process improvement (Seaver, 2003; Song et al., 2004) and has started to be applied in EPC projects as well. However, Song et al. (2003) state that in EPC projects, the quality objects which is likely to be achieved through quality management vary according to project phases, construction methods, project client, and other various factors which are determined by the characteristics of project. In construction phase in EPC project, quality covers the program of required procedures, policies, and responsibilities to provide assurance that the desired characteristics are obtained to ensure the project will perform as predetermined scopes over its life-cycle (Gransberg & Molenaar, 2004).

However, as mentioned earlier, quality management has not been well incorporated in most of firms' applied strategy, including in EPC firms (Song et al., 2004; Tutesigensi & Pleim, 2008). Albeit most of EPC projects focus on the results of works and revealed that they have applied quality management system such as ISO 9001 and other self-checking methods indeed (Samman & Graham, 2007), labours or equipment which affect the quality tend to be not included in the scope of quality management (Lee, Yu, & Kim, 2004). According to Tutesigensi and Pleim (2008), one of the cause of the lack of quality improvement in the construction industry is insufficient quality requirements from the clients themselves. Similarly, Samman and Graham (2007) also mention that the needs and wants of the clients are always taken into account and play a big role in improving the quality in construction phase, thus the lack of quality management might be traced back to the lack of clients' requirements and specifications in regards to quality. Several issues and concerns of quality management in EPC projects have been summarised by CMII (1994), which cover:

- Projects are seldom developed by the full project team which consists of engineer, owner, and contractor
- Projects tend to focus on isolated phases with minimum integration
- Most measurement processes conducted in projects are a non-predictive manner of measurement instead of process steps
- Projects are geared for short-term improvements rather than long-term strategic goals
- Projects are not well-suited for benchmarking

However, series of measurement tools are still found to be developed and implemented in EPC projects for project quality planning, quality performance, and quality assurance at certain level, such as Quality Performance Management System, Quality Cost Matrix, and Quality Performance Tracking System (Love & Irani, 2003).

4.3 Six Sigma in EPC Context

Initially, Six Sigma has historically been regarded as a model used merely in manufacturing industry. However, the growing need of sustaining the competitive advantages for firms in various industries has consequently made Six Sigma is widely used and adapted in many industries nowadays. An analysis of an internal process usually initiates the improvement project in manufacturing (Magnusson et al., 2003), whereas in engineering and construction industry, an improvement project is still not common to be found (CMII, 1994). Tchidi et al. (2012) mention that to overcome insufficient technology and poor management which account for low quality of project, Six Sigma can potentially benefit projects in engineering and construction industry greatly, as the methodology aims to increase the perceived quality by the client.

Engineering and construction industry can utilise Six Sigma methodology as an additional approach to analyse firm's current work-processes. Overall EPC projects from planning phase to delivery phase can benefit from Six Sigma, as it is suitable for not only higher organisational level as strategic quality tools, but also for lower level as quality measurement and improvement system (Tchidi et al., 2012). Furthermore, Stewart and Spencer (2006), Kashiwagi et al. (2004), and Tchidi et al. (2012) believe that overall design, procurement, and construction process time can be lowered by incorporating Six Sigma within projects, in addition to costs reduction and the fulfilment of predetermined quality and requirements, as well as waste and energy decrease.

Several EPC firms—albeit still not as many as manufacturing firms—have implemented and benefited from Six Sigma, such as Kelogg Brown and Root (KBR), a world-wide EPC firm, who achieved world class results through its improved project delivery process. In a case study which was conducted by Tchidi et al. (2012), it was found that shifting to Six Sigma based prefabrication from traditional on site construction led to company saving by 26% of the project duration and almost 85% of material waste. Another firm who has successfully benefited from this approach is Saudi Aramco, who has been implementing work-process improvements by adopting several principles of this approach (Villanueva & Kovach, 2013; Patty & Denton, 2009).

In addition, Kwak and Anbari (2006) and Eckhouse (2003) also reported the success of Bechtel Corporation, one of the largest global EPC companies in the United States, in implementing Six Sigma program. Bechtel has been working with Six Sigma since 2000 and was among the first EPC firm to do so. It utilises Six Sigma to minimise project risks, hence it is able to deliver project within a higer certainty of budgets and schedules. In one of its prominent successful project, The Ivanpah Solar Facility, Six Sigma was used to analyse design, procurement and construction challenges, thereafter to develop new processes to execute the project successfully and thus reach performance goals (Gillespie, 2013). This approach resulted in savings of $200 million with an investment merely of $30 million by identifying and preventing rework and defects from design to construction as well as on-time delivery of employee payroll. Another example is the utilisation of Six Sigma to help optimising the management of cost and schedules, and to streamline the operational process in a chemical plant (Kwak & Anbari, 2006; Moreton, 2003).

4.4 Case Company Profile

The case study is conducted in a Southeast Asian integrated EPC service company. The company handles major multimillion dollar projects for both major national and multinational clients, primarily in the construction of infrastructure plants of petrochemical, oil and gas, power, mineral, geothermal environment, and infrastructure sectors. Several strategic business units based on the type of industry categorise how the company runs it projects, which consist of: 1) refinery and petrochemical, 2) oil and gas onshore and offshore, 3) mineral, environment and infrastructure, 4) geothermal and power, and 5) portfolio department. The company offers comprehensive EPC service for all types of projects, starting from turnkey, expansion, revamping, relocation, to plant operations and ongoing maintenance projects. Its project activities cover building design engineering, where it provides and implements activity services in the phases of project initiation, project implementation and project operation.

This study was primarily performed in The Operation Unit and Project Control Unit under The Project and Operation Directorate, which covers the general responsibilities of project management activities. The Operation Unit is divided into three main departments where the study focuses on. These departments are Engineering, Procurement, and Construction; and two additional supporting departments, which are Health, Safety, Security and Environment (HSE) Department, and Offshore Operation Department. Furthermore, each department is divided into several divisions which serve different functions based on its disciplines. Since the focus of this study also relies significantly in quality, a study in Quality Assurance and Quality Control Division under the Project Control unit is also performed in order to supplement and support the understanding of how quality in projects is managed. Figure 4.1 visualises the organisational structure of The Project and Operation Directorate.

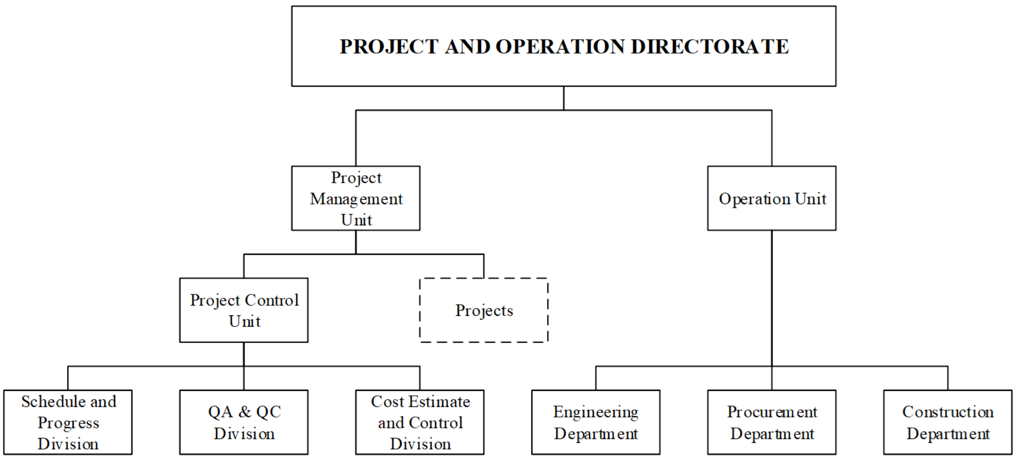

Figure 4.1: Company's Project and Operation Directorate Organisational Structure

This directorate performs high level of complexity projects that are core to the company and familiar, with project budget over 15 million USD. Projects commonly take more than 18 months to complete due to its large scale, where the core project teams have 11-20 team members including the project manager. As the company primarily executes large scale projects, the company limits itself to only handle between one to ten projects at the same time.

The company is certified under several certifications in regards to quality management, environmental management, and occupational safety and health management system. To ensure that it complies with all the quality management standard, the company is ISO 9001:2008 certified, which was issued by PT Lloyd's Register. The Quality Management emphasises that the company operates in compliance with all relevant domestic and international safety and environmental standards.

5

Empirical Findings

This chapter presents empirical material gathered from interviews, company's internal documents and secondary data, which are divided into three major sections. The first section covers quality management and improvement in the case company. The second section covers project management practices in EPC projects in its three main phases, which are Engineering, Procurement, and Construction. The last section provides the views from professional practitioners in regards to the implementation of Six Sigma in EPC projects.

5.1 Quality Management and Quality Improvement in EPC Projects

According to one of the Construction Engineers (CE1), EPC projects carried within this company have four main priorities where quality comes the second after safety, then followed by schedule and cost. To ensure that all departments comply with the ISO 9001:2008, the company has evaluated and transcribed the certification into a set of established guidelines of various types of reports for each functions within each different departments. All functions have to follow the established documents, where each tasks will be reviewed by checker functions. In addition to the company's general standardised documents, Quality Assurance/Quality Control (QA/QC) Division always develops a QA/QC Execution Plan (EP) for every project. QA/QCEP comprises of detailed targets which needs to be fulfilled during the whole project lifecycle, as well as the maximum target of rejection.

The Project Control Engineer (PCE) also mentioned the importance of incorporating 'cost of quality' into account, where management has to be able to deliver the expected product to the client optimally while preventing the occurrence of cost of non-conformance for rework, repair, and excessive scrap materials. This prevention for non-conformance is done by giving training to all vendor, subcontractors, and internal organisation, audit, inspection and testing, and additional planning. *"The expense for the project planning which incorporates this prevention system will of course slightly higher than the regular project expense. However, the end result will minimise rework, repair, and other non-conformance,"* explained the PCE.

According to the QA/QC Engineer (QA/QCE), another practical way to manage quality of projects is by limiting the number of participating vendors in the bidding stage to only three to five reputable vendors, who are already well known for their qualified works. The bidding process could be challenging when having too many participating vendors, as the Procurement Department has to assess each vendor which takes some amount of time. After the bidding stage, it is important to have a well-defined proposal which is agreed by the project owner in planning stage. A well-defined proposal serves as the guidelines to define project budget and project schedule. *"We have to be able to negotiate with the project owner to ensure we have adequate resources in terms of budget and time to deliver a qualified project deliverables in accordance to the agreed project requirements,"* stated QA/QCE. Moreover, *"Quality management and assurance is necessary to execute a project more efficiently without reducing its quality by doing the right thing, right in the first time,"* said the PCE.

5.1.1 Driving Factor for Quality Implementation

By having "focus on customer" as one of its values, the project owners have been the main driving factor which encourages EPC firm to be concerned about quality. The PCE stated that quality is the matter of conformance to the requirements to reach customer satisfaction, which will benefit the company in the long run by gaining the trust of the customer. *"By maintaining the quality of our project outcomes, we will keep project owner contented, thus will affect our firm's profitability indirectly,"* said one of the Engineering Engineers (EE1). This statement is supported by one of the Construction Engineers (CE2), which stated that implementation of quality management in each project depends heavily on the project owners, whether the project owners puts considerably emphasis on quality or not. In addition to that, the Procurement Engineer (PE) also described that *"All the quality related elements always go back to the project owners"*, where most of the project owners guarantee the quality of project deliverables by strictly requesting the usage of certain certified materials only.

According to the QA/QCE, the quality element is highly related to the project specifications. The project owners frequently use licensor such as Kellog Brown Root (KBR) as the reference to define the project specifications. The defined project specifications from the third party are then adapted again to a set of agreed final project specifications, which covers the acceptance criteria and guidelines for expected project deliverables in more detail. It is then revealed that the level of awareness of quality management for each project is different, where it depends on the project owner and their willingness to implement quality management. However, the PE revealed that there is no such things as 'the best quality' of project output in EPC projects. *"In EPC projects, quality is about delivering output which meets project owner's expectation, instead of delivering sophisticated project output with the highest up-to-date quality where it far surpasses the project specifications. Quality has to highly take project cost into account, as we also have to be concern with project profitability,"* admitted the PE. The QA/QCE also emphasised the importance of keeping the credibility and winning the project owner's trust by delivering a project output in accordance to the defined project specifications on budget and on time.

From the Construction Department perspective, drivers to implement quality management in projects mostly comes from the QA/QC Department. According to CE1, the QA/QC encourages the Construction Team to enforce quality management within the project execution. The force from QA/QC Department most likely comes because they want to promote the quality awareness for the company's image. It also presents due to the pressure from project owner to deliver a good quality product based on the specifications. CE1 revealed that another big force for implementing quality management also comes from the partner within consortium, or also well-known as alliance integrated team. The alliance integrated team is where the company works together with other parties of contractors to work on one particular project. If one of the parties within the alliance integrated team has a high standard of quality management, the company would likely follow the highest standard that one of the contractor promotes. This high quality standards which are enforced by one of the contractor in alliance integrated team are sometimes even higher than the specified quality specifications from project owner.

5.1.2 Management Support and Projects' Quality Improvement

QA/QCE highlighted the importance of management support, particularly in solving dispute items case which still occurs once in a while and may disrupt a project. In addition to that, *"management support also plays a critical role to ensure that the project is on track in terms of budget and schedule. They also monitor whether the project is going to the right direction to achieve the expected project outcome,"* explained QA/QCE.

The CE1 mentioned that there have been a lot of reworks during the execution in Construction phase, which is mostly caused by the substandard quality of deliverables. He suspected that this is caused by the lack of rigorous implementation of PMBOK which also covers Quality Management area, albeit the company refers to PMBOK as their standard and guidance for project management activities. There has not been any discourse of initiating neither Six Sigma nor any other similar quality improvement method within their project management in the near future.

However, the QA/QCE argued that if there will be any intention to initiate the quality improvement methodology such as Six Sigma, the cost consideration can be overlooked. The cost consideration can be compromised if the benefits of the implementation are believed to be greater than the cost, after further study to scrutinise and to ensure that Six Sigma implementation plan is aligned with the company's business process. Nonetheless, top management must consider the adjustment of routine for project team members if Six Sigma will change the work culture significantly. Conclusively, CE1 mentioned that albeit the company has been trying to incorporate most of the quality management aspects within their project practices, quality is not the most concerning element in the project management.

5.2 EPC Project Management Practices

5.2.1 Engineering Phase

According to the QA/QCE, Engineering phase can be considered as the most influential phase in the project, as all designs and decisions made within the project planning in Engineering phase will affect other major aspects in Procurement and Construction process respectively. Project goals, scope, and specifications are mainly defined by the project owner prior to the project planning. Project specifications become the main guidelines to plan and set initial engineering drawing which serves as the basis of a project. Engineering Team will develop a comprehensive report calculation covering every division's estimation of resources and workloads based on these project specifications, which will be checked internally to review its quality prior to handing it back to project owner for preliminary review.

In planning phase, the EE1 highlighted the importance of having clear project specifications, project data and requisition documents, and existing condition of prospective project site. EE2 also supported this statement by mentioning, *"The most crucial thing is we have a clearly defined project goals, (thus) we can plan ahead and have an idea of how the processes will look like and what the project will comprise of."* Beside the view from Engineering Department's Engineers, the PCE also agreed upon the statement that the most important factor in project planning is clear project specifications, in addition to identification of client's culture, risk, and available resources for better planning.

One of the Engineering Engineers (EE1) mentioned that the work of interdisciplinary divisions tend to be disintegrated in the organisation, and sometimes lead to conflicted engineering designs. This is caused by the lack of understanding of other interdisciplinary divisions' specifications, as the division manager tend to put more focus only on the specifications for their particular division without really heeding other divisions' specifications. Therefore, there could be a chance that the specifications requested by the project owner are incompatible between divisions. Hence, according to the EE1, it is essential for all managers in related divisions to scrutinise the tender proposal document and term of specifications of not only their own division, but also other divisions. This is to ensure the technical feasibility of the project and to assess if there is a need for adjustment and deviation from the initial project specifications.

Additionally, *"It is important to have project data, as project data serves as the basis and foundation of developing overall engineering designs in accordance to the existing field condition,"* said EE1. Thus, it is also substantial for Engineering Team to be involved in prospective project site survey in order to be able to produce suitable designs for the project. Process data sheet from the initial proposal should be produced beforehand in order to start producing design and engineering drawing. Within this stage, support from management could be seen from how top management holds control of credential electronic documents in the server, as most of the documents which are going to be used for designs are considered to be vital. The Engineering Team utilises historical data and lessons learned from previous projects to produce a Project Execution Plan (PEP), which has to cover execution policy and numbers of plans.

Having access to all the necessary data is one of the most critical factors for Engineering Team. This is to ensure that the project is executed in the right direction, starting by providing the engineering drawings and designs to be followed by other departments. It is also necessary that all teams are aware to follow and refer to the same project documents regardless the number of its revision. EPC projects deal with numerous documents, spanning from engineering designs, data sheets and numbers of plans. In this company, there has not been a robust data management system which enable straightforward tracking and retrieval data and documents. Therefore, the EE2 mentioned that it could be challenging to keep track that all teams follow the same version of project documents. The CE2 also mentioned that there could be disintegration due to confusion of referral document, because of the number of project document updates and the quantity of the various documents itself.

Project meetings are essential as the media of update and sharing project progress, and is attended by every department. Management support is also mostly shown in project meetings, where they can assign and allocate additional resources for necessary activities or merely give feedback and reviews based on routine project reports. However, CE1, CE2, and EE1 all gripe about the inefficient meeting which tend to take more time than needed. After producing designs, data sheets, and engineering drawings, the role of the Engineering Team continues in assisting the Procurement Team to purchase the required tools and equipment based on the designs, and also to assist Construction Team should it have any trouble or issue during the execution phase.

Both EE1 and EE2 stated that good coordination and communication within intra-division are necessary to ensure the effective information flow between many internal divisions. *"Coordination and excellent communication flow will minimise and reduce misinterpretation of information in form of designs, engineering drawings, and other project documents"*, stated EE1. Beside coordination within its own department, Engineering Team also coordinates and works closely with Procurement Team after vendor document has been approved, and Construction Team in the project site to ensure the plant as the project output operate and function as expected according to the project specifications.

In addition to that, EE2 also put an emphasis on the role of Engineering Team together with Procurement Team to: 1) monitor delivery time of each equipment, tools, and instruments; 2) put pressure on delayed suppliers to deliver the required materials and resources. Both are to ensure the project can be executed smoothly according to the PEP. Variance analysis is utilised to analyse resource usage if there is discrepancy with project plan. *"It is crucial that we rigorously stick to our planned schedule from the very beginning,"* said EE2. Each division's work and activity is highly interrelated to each other, thus a slack in one division will ultimately lead to delay for other division's tasks. The EE2 mentioned that there have been many cases where project is below quality because one division slacked. This made other division tried to compromise their delayed schedule by working faster and thus slightly neglected the quality of their work, in order to still meet the planned project schedule.

Numbers of unfortunate circumstances which cause delay may occur as well, both that have been foreseen and those which have not been expected. For the risks that have been foreseen, EE2 mentioned that the project team should follow the PEP, as the contingency plans for those circumstances are covered in PEP. The unexpected circumstances have to be dealt effectively by taking flexible and innovative approach, then recorded for lessons learned in the future. During the construction phase in project execution, Engineering Team mainly receives reports from subcontractors and therefore is not involved heavily in maintaining project progress in construction phase. However, all the data in form of designs, engineering drawings, data sheets, and other documentations are utilised for benchmarking and guiding purpose for similar projects in the future.

From the Engineering Team point of view, implementation of a new quality improvement methodology will theoretically be embraced, as innovation is one of the main pillars of an EPC firm's values in order to maintain its competitive advantage. *"EPC firm is ought to always embrace new innovative methods to promote its quality improvement. We are versatile, adaptable, and fluid; thus always open to change,"* said EE1. The versatility and adaptability is shown by how the company always combines its company's standards with the proposed standards and specifications from project owner to reach the same common ground of a set of standards. Introducing a new quality improvement methodology such as Six Sigma is perceived as a good idea, as it may accelerate the project duration and enhance the knowledge and experience of project team members.

However, EE2 stated there is a need to consider resistance based on routines, as most of project team members have had experiences and routines for years. Therefore, introducing a new quality improvement methodology such as Six Sigma might be a bit challenging, as most of the project team members have accustomed to the way they have been working with. In addition to that, if there is a plan for introducing a new methodology, *"We need somebody who encourages us to implement those theories into application,"* said EE2. In general, EE1 admitted that quality management has been indicated and can be seen through its set of standards and specifications. This statement is also supported by EE2, which stated that most of the project team members usually work based on the job descriptions and follow all the SOP and WI in executing their tasks to achieve the requirements and project specifications which have been defined since the beginning; which can be seen as achieving the expected quality of a project. However, there is always room for improvement to promote more effective and efficient project management activities.

5.2.2 Procurement Phase

As Procurement Division is a supporting system according to the Procurement Engineer (PE) himself, he argued that one of the core in project planning phase lies in Process Subdivision within the Engineering function. Within Procurement Department, it is critical to develop an Inquiry Plan which covers detailed plans of when Purchase Orders have to be sent out, the time for kick-off meetings for every vendors, and the duration of material inspection. PE also added the necessity of enforcing an organised transportation mechanism as well as transportation method to ensure the quality of materials when they are shipped to project site. In addition to a detailed Inquiry Plan, the PE also emphasised the importance of minimalizing error in material take off to avoid repurchase which ultimately will lead to delay. Therefore, it is important that every PE are familiar with every required material as well as their delivery lead times, whether it has long or short lead time. EE2 also highlighted the importance of knowing the delivery time of each instruments, equipment, and tools.

Having adequate knowledge of each of the required resources and their delivery time aims to prioritise their certification for delivery. This to ensure all the procured materials comply with the specifications and quality, where the prioritisation is made based on the length lead time per items. Moreover, this is necessary to maximise preparation of project budget and schedule after ensuring it complies with the expected quality from project owner. The PE mentioned that there were some cases where projects were delayed due to inadequate knowledge of lead times and incomplete purchase. This resulted to the Procurement Department had to make another request for the required equipment, which created more delay—especially for equipment with long lead times.

Procurement Department has to be selective and has to do preliminary surveys as well in deciding qualified vendors as their main supplier, as the main supplier will affect the quality of project. To ensure that the prospective main suppliers will be able to supply qualified materials, they have to prove their financial capability by providing their bank statements to show they possess the required available fund resource. *"Lastly, it is also important to plan ahead the methods of transportation and material transfers based upon the availability of transportation and the location of project site,"* said the PE. PE explained that it would be helpful to have a real time supplier database management which will help expediting procurement process in planning phase. This kind of database management is expected to be able to assist engineers to distinguish materials lead times to plan procurement activities ahead. The PCE also supported this statement by mentioning that having tools, system and progress measurement procedure will enable the procurement phase to expedite procurement stages from inquiry, technical feasibility study, award, and purchase order.

When the execution phase has started or when construction phase has begun, it is necessary for Procurement Department to proactively follow up all suppliers to deliver project materials based on Inquiry Plan and according to schedule. Besides cost, time of negotiation in procurement activities has to be suppressed as well, as most of suppliers tend to have delay when delivering materials. Therefore, Procurement Department has to be able to mitigate this tendency by providing time allowance for material deliveries. In addition to that, PE argued that it is important to have a logical payment scheme for main suppliers. Therefore, they will be able to purchase the required materials for project succeeding activities without any financial obstacles.

The PE also mentioned that in execution phase, another challenge is a project always tends to be delayed due to the complicated administration and bureaucratic mechanism. Most of the administrative and bureaucratic activities are still done manually with paper works and has not been digitalised using an integrated system in a software such as Systems, Applications and Products (SAP), which will improve all the procurement processes and activities to be more effective and efficient. Another thing which was highlighted by the PE is about decision making process and role delegation. *"In this complicated administration and bureaucratic system, the lack of proper role delegation also leads to project delay, as nobody wants to make a decision for urgent matters,"* said the PE. The PE predicted that having a more simplified administrative system will help speeding up most of project activities in general.

Conclusively, the PE emphasised on the needs of a standardisation where every project team members who are involved in procurement activities has to have a solid product knowledge for required materials and their lead times, current market price, and networks for material acquisition. Moreover, from the Procurement Department's perspective, the integration of quality improvement methodology such as Six Sigma will always be welcome in spite of consideration of company's assets and capital, especially if it helps simplifying the slow and complicated administrative processes in procurement activities.

5.2.3 Construction Phase

In the construction phase of most of the projects, there are incentives for every project milestones which are provided by the project owner. These project milestones become the project gates for construction and defined by the project owner, with discussions and agreement with the related departments and functions based on the project schedule.

Communication and Coordination

From the Construction Department's perspective, the most important factors to be taken into consideration in the project planning phase is the inter-department communication. The whole inter-department communication will affect the accuracy of resource allocation estimation, project budget planning, and project scheduling. CE1 and EE1 mentioned that inter-department communication in planning phase is needed to produce resource allocation plan based on bill of contracts, where each department is involved in estimating their own resources. It is also essential to keep the Engineering Department more aware with the actual condition of the project field environment to produce suitable engineering drawings and designs which can be implemented optimally.

According to the CE1, poor communication in their projects leads to over budget and overschedule, which still happens once in a while. Lack of inter-department communication is mostly occurred in update of project information, and cause a great deviation of project resource allocation. This poor inter-department communication mostly happens in revision of drawings' from Engineering Department, new substitute vendors, and new estimation of resource allocation. Beside the excellent inter-department communication, a sufficiently clear set of project scopes, requirements and tasks assignations are also crucial in the project planning phase. Nonetheless, the CE1 stated that from the Construction Department's perspective, the top management support in project planning has not been adequate in spite of its cruciality. This might be caused due to the intangible deliverables in project planning in construction phase.

Similar with project planning, the CE1 highlighted that communication is one the most important factor which needs to be taken into account seriously in project execution. He admitted that in most of projects, most of the project team members are confused to whom they should report or from whom they should obtain information and clarification. Supporting the opinion from CE1, CE2 also mentioned the importance of following the Project Execution Plan (PEP) rigorously, where a communication and coordination plan within Construction Execution Plan (CEP) has been defined well. *"Within PEP, coordination plan, clear tasks of each departments, and the Work Breakdown Structure (WBS) are already covered in detail. Following PEP and its detailed plans helps project to run smoothly,"* said the CE2. The importance of communication in project execution—especially in construction phase was also highlighted by the PCE, who argued that a project will not be able to run smoothly without excellent coordination between interdisciplinary divisions in project site. Both CE1 and CE2 also highlighted the importance of effective and efficient project meetings as the most crucial tool of communication and the accuracy of project forecasting. *"We have to be able to forecast the unseen, and not only rely on the historical data. Otherwise there will be a lot of reworks due to the inaccuracy of forecasting,"* stated the CE2. In addition to that, CE2 also believed that work flow management amongst the three different departments could be improved to be more aligned and integrated.

Another important thing which should be taken into account in project execution according to the PCE is the resources in terms of management, man, money, market and machine. These resources should work hand in hand in collaboration to understand the requirements from project owner, thus will be able to deliver a project output which meets project owner's requirements.

Project Data Gathering

During the project execution, The Construction Team rarely record any kind of data. *"We only record data if the project owner requests for it, and the project owner only requests for a particular set of data if it is going to be used for their operational activity,"* stated the CE1. The type of data which sometimes is requested by project owner usually revolves around drawings from Engineering Department and drawing revision during the execution, which is documented by a tool called Field Sketch. This revision data shows the deviation from the engineering drawing with the actual instalment in the field. The PC Team actively records and reports project data daily in Microsoft Excel, where the measurement usually emphasises on project productivity and project outcome. However, this data is still stored in a manual database.

This inputs in Microsoft Excel then are sent to the relevant management and Project Control Team to be processed. Based upon the recorded data, productivity analysis and progress monitoring are performed by using Earned Value Analysis which will give Schedule Performance Index (SPI) and Cost Performance Index (CPI). Beside Earned Value Analysis, Variance Analysis is also performed to detect any deviation from the baseline plan and to find the respective solutions for each obstacles of measured work items. The analysed data is utilised for the basis of decision making, technical comparison and improvement; especially when the data shows concerning progress of project, i.e. intolerable over budget and delayed, where management will put considerably more focus and concern on a particular area to allocate more resources to speed up the progress of project or to shift to another construction methods, and other decisions. For the long run, the recorded data is utilised for project performance forecast in the future and lessons learned to avoid any similar issues to occur again in the rest of a project.

According to the QA/QCE, QA/QC Division utilises non-conformance reports from the overall project, which is the comparison between the initial targets defined in QA/QC Execution Plan within PEP and the actual implementation on project site and project owner's satisfactory. Based on this, mostly project managers will be advised by Project Control Team to take action if there is any deviation based upon the recorded data. However, The PCE also pointed out the inefficiency of project data gathering, where the Project Control Team has to meet every person in charge (PIC) from each sub-divisions to have the update for their works due to the collection of data progress is still done manually. The PCE stated this inefficiency in data recording could be improved by having an integrated data system where every PIC can update their work progress through this system, thus the Project Control Team will be able to monitor the progress through this server. In addition to that, a project needs to be monitored and scrutinised on a continual basis whether it has followed the initial design from the engineering drawing throughout the entire construction phase. *"The Inspection Test Plan and Site Acceptance Procedure which have been defined and agreed at the beginning of the project should be utilised as the main guidelines to monitor and to detect any deviation,"* stated the QA/QCE. When it has reached its mechanical completion, the focus of project monitoring is slightly shifted to the safety of the project output and its operational ability.

Project Improvement

In CE1's opinion, the project organisation which is mostly matrix based inhibits efficiency of project. As most of the project members work on many projects in parallel at the same time, they tend to be less focused on one project due to the multiple assignments that they need to complete. Project human resource is also lacking of training to develop personnel competence. Most of the project team members relies on independent self-development and self-taught learning due to the inadequate human resources training. According to CE1, introduction of a new improvement quality methodology such as Six Sigma theoretically will always be welcome especially by management level, as this kind of methodology is foretoken for more competent project team members and increased project productivity, which will enhance the company's profitability and competitive advantage. The PCE also stated that this may of course bring improvement of quality if it is executed successfully, which will ultimately lead to not only the efficient use in budget and resource, but also effectivity in the context of project execution duration.

However, the cost of the trainings should be considered, as well as the resistance to change. *"Not everybody in a project team is open to change, especially those who think that they are already experienced. Therefore, high level management needs* *to be highly involved in order to enforce the middle and lower level to accept the change,"* stated the PCE. According to both CE1 and CE2, apparently there are some numbers of project team members who tend to be sceptical and pessimistic as well with project management knowledges and framework; and perceive it as merely a theory albeit the fact that the company is mainly project based. This might be caused due to the lack of awareness of quality management and quality improvement by project team members, as they have not really engaged and felt the necessity in implementing nor improving quality.

5.3 Views from Professional Practitioners on Six Sigma Implementation in EPC Projects

5.3.1 Current Condition of Quality Management in EPC Projects and Construction Industry

According to the Construction Management (CM) researcher who is also the manager of operations and project support at one of the biggest Swedish construction company, there is a great variety in the standard in nowadays EPC projects in the context of the procedure and the methodologies, despite of the fact that it still follows the same main framework. Therefore, there is an urgent need of standardisation for established working procedures to collect and to share information, as information flow is very important. The CM researcher argued that albeit most of the companies self-proclaim to strive to comply with the same procedures under some particular standardisation frameworks, a great variety in the project process when conducting the project is still found when the project is scrutinised in details. Therefore, she mentioned that it is important for most of the companies who run in construction industry—including EPC firms—to establish a robust standardisation system then to manage their projects in accordance to it. Without a robust standardised system, there will be no solid measurement which can be utilised as the basis of implementation of Six Sigma or other similar quality improvement methodology or tools.

Hitherto, the quality in EPC firms is commonly assured by following up the procedure requirements from the client constantly, in addition to having Project Quality Assurance and Process Quality Assurance. However, this activity mostly still relies on having very skilled persons out in the projects who are capable in assuring that the projects reaches quality, instead of having a standardised system which can be followed upon. Therefore, the QM researcher claimed that this cannot be considered as a robust Quality Management system, as it depends on the human instead of on a standardised system.

The Six Sigma consultant also mentioned that *"It is highly important that the firm is aware how Quality Management can support a firm in monitoring and ensuring their projects are on track"*. One of the biggest factor which drives a firm to implement a quality improvement method is this awareness of utilisation of Quality Management and attempt of implementing quality improvement method, which may lead to the less hassle project execution. By having a Quality Management system, possible failure modes—particularly in the middle of project execution phase—can be identified at the beginning of project planning. Hence, prevention, mitigation, and contingency plan can be developed once these failure modes have been identified through the Quality Management system, integrating it with Risk Management Plan. Failure in project processes due to the absence of Quality Management will affect other critical elements of project execution.

Furthermore, according to the Six Sigma consultant, having Quality Management will enable a project based firm—either fully project based or partly project based—to map the Critical to Quality (CTQs) for every project process. Hence, this CTQs can serve as a basis for choice of measurements and guidelines which will be used in the project to monitor the project against the quality plan and project control plan. *"Identifying CTQs, which is part of Quality Management, will further provide us a dashboard to monitor whether the project is on track or not,"* stated the Six Sigma consultant.

According to the CM researcher, unfortunately not every firm is fully aware of how significant the result of implementing a Quality Management system let alone a quality improvement method, as they do not really feel the necessity and urgency of incorporating it at present. Rather, the CM researcher mentioned that there is a small suspicion that most of EPC firms or other construction company are certified under some certain institutes' standards to merely have a certified status. This certification and status are beneficial to ensure the prospective clients the quality of their services.

5.3.2 Critical Success Factors

In order to pinpoint the critical success factors (CSFs) for implementing Six Sigma then integrating it with project management framework in EPC projects, The Six Sigma consultant argued that there is a need to identify each project process first in EPC projects to produce the relevant CSFs, then to transform it into CTQs in order to define the suitable measurement tools for the project dashboard to monitor the project. Since Six Sigma is commonly applied in manufacturing industry instead of in construction—or more particular—EPC projects, there might be a slight difference of CSFs in more detailed levels, albeit the general concept framework is the same.

"This may sound cliché and very theoretic, but I cannot deny that top management commitment is one of the CSFs of Six Sigma implementation," said The Six Sigma consultant. With the top management commitment, most of resources required for Six Sigma implementation can be obtained easier, as it will have more supports from all different yet integrated departments of projects. Top management commitment will also encourage project team's engagement to contribute or even to certify themselves to be a belt and to support the implementation of Six Sigma within their projects. According to The Six Sigma consultant, all of the explanation of initial implementation of Six Sigma may seem overwhelming, as it looks like it requires a lot of efforts for commitments and resources for initial investments at the beginning. However, he assured that the gain which will be obtained at the end of the project is so much greater, that even all of the efforts and resources which have

been put in the beginning will not account for more than 10% of the gain in terms of cost saving.

In the defining phase, it is highly important that the Champion or Project Manager identifies and creates a statement of opportunity for improvement for the project. A solid project charter is also mentioned to be one of the most important factor that needs to be defined carefully, as all of the project objectives, scopes, and specific requirements are stated in the project charter on an official paper. An adequate knowledge for the project deliverables, the existing business process, and a robust communication plan is also one of the key of successful project, as the communication channel for the information flow has been made clear. This supports the statement from The Construction Management researcher which mentioned the importance of *"sharing knowledge and information to ensure that not only every successful actions, but also abnormality is captured in each of the project process."*

Other important aspect that needs to be taken into account seriously is the awareness of every project team member of the project schedule, which has been mapped at the beginning in the planning phase. The project schedule has to be socialised to the project team and attached to their outlook agenda for daily reminder. By having the project schedule in their mind, project team will have tendency of performing in a quick pace to meet project milestones, as they are more aware with critical things in regards to the project milestones. To ensure the information flow, both The Six Sigma consultant and The Construction Management researcher emphasise the importance of daily face to face meeting for reviewing, updating daily plan, addressing results and issues, and reporting progress based on the S-curve for monitoring. Again, this will ensure the stable information flow, which plays one of the most critical role in Six Sigma implementation and in project execution in general.

Another thing which is still relevant to project schedule is gate review, which is an activity for every project milestones to discuss, review, and revise project progress. Gate review is necessary to be conducted in every project phase with the top management involvement. In gate review, the project manager has the opportunity to address project's obstacles, then requesting supports from project owner and project sponsor. Gate review also helps the project team to monitor whether the project is on track based on the schedule. However, there is a need of establishing a 'quick win implementation' in each phase of DMAIC, which is a quick, yet practical and feasible to do list to be implemented with a bold result. Quick win has to have several factors to be eligible as quick win implementation, such as easy to be implemented in regards of cost and time without deep and intensive analysis, quick and has bold result, easy to be monitored, and has the approvals from the impacted process owner. *"This quick win is very handy for a project which is likely to have changes in its scope, which mostly happens due to immature planning and lack of commitment from project stakeholders especially from the top management or Champion, project sponsor, and the project leader itself,"* said The Six Sigma consultant. Having quick win implementation will enhance project manager's opportunity to obtain more support for the project. Therefore, it is important that the gate review meeting is attended by the top management which possesses power decision to agree upon the quick win implementation.

The need of having an appropriate analysis through data stratification was also emphasised in the interview. Prioritisation is mapped in Paretto Chart, then hypotheses for quantitative data are used using various relevant statistical tools according to the type of data. On the other hand, qualitative data is analysed using nominal group technique and consensus mechanism, where every function of project cross-functional team has to be present to represent the view and need of their own function and analyse the data objectively.

5.3.3 Considerations, Benefits, and Obstacles

The most influencing consideration of implementing Six Sigma within a project management framework in a construction industry—including in EPC firms—is the cost saving factor, as it is the most tangible outcome which can be evaluated. However, before starting to plan the implementation of Six Sigma or starting to initiate a Six Sigma project, companies have to consider their current resources in the context of time and financial resource, as well as their human resources. A small feasibility study ought to be developed to evaluate the worthiness of incorporating Six Sigma within their project management framework or initiating a Six Sigma project. To start implementing Six Sigma, there is a necessity to have at least a Black Belt certified as the Project Manager, not to mention other belts. Certifying human resources to be Black Belts need training, which requires time and financial resources. In addition to that, every internationally-certified belt requires incentives, as these people work harder than others. Thus, a company has to be really sure that implementing Six Sigma within their project will yield to much greater gain compared to their initial investment through their resources.

According to the Six Sigma consultant, the most tangible benefit from implementing this method is equal with the benefit consideration, which is cost saving. Reducing errors and defects in the construction project will lead to the more effective use of both tangible and intangible resources such as material and time, and will avoid the need of rework due to the substandard deliverables. *"Moreover, client's satisfaction will be enhanced as well, thus the company will be seen as a bonafide company and will most likely have a good image in the construction market,"* added the Six Sigma consultant. In addition to that, Six Sigma will provide other benefits which are more intangible in multi-disciplinary areas of project. Generally, the project team member will have more structured mind sets to identify problem quicker with more compliant and disciplinary work attitudes.

However, introducing then implementing Six Sigma within a project management framework in an EPC project is not without obstacles. The Six Sigma consultant stated that most of the obstacles lie on managerial level, as the Six Sigma is not initiated from the top management. Rather, it may be initiated from the Managing Director or Quality Manager who tends to be more aware with the necessity of having a quality improvement method embedded within projects. If this is the case, the Six Sigma will become less prioritised and thus will have very limited support from the top management, which leads to inadequate or even no resources provided from the top management for the human resource training and other required facilities. The Six Sigma consultant also mentioned, *"There will most likely be conflict of interests* *amongst managers in each different department, if Six Sigma is not initiated from the top management.”*, as they will not really feel fully-integrated to support the Six Sigma, and thus will lack of the sense of belonging of the Six Sigma implementation in the project. Other obstacle that may arise is the low interest of the project team towards Six Sigma implementation, due to the resistance towards change that they need to face when incorporating Six Sigma. Some people will feel under pressure with targets that Six Sigma project strives for, and thus will be reluctant to support it in the first place.

5.4 Summary of Empirical Findings

All the interviewees agreed upon the statement that the main driving factor of implementing Quality Management is the project owners or the customers itself, as one of the company’s values lies on “focus on customer”. In EPC projects, quality is the matter of conformance to the defined requirements to reach customer satisfaction, instead of delivering the highest quality of project deliverables. Another driving factor for implementing quality rigorously is believed to come from a partner within consortium (alliance integrated team). It is also revealed that EPC firms have not put a considerably emphasis on quality within their projects, and merely follow the project specifications from the project owner.

There have been some challenges that the company faces in conducting their EPC projects. The following Table 5.1 summarises the most often encountered challenges in each phase of project lifecycle and in which phase of project they appear.

Table 5.1: Summary of most often encountered challanges in EPC projects

No.	Challenges	E	P	C
1	Conflicted intra-divisions engineering designs/incompatible specifications			
2	Unfit drawings & designs with the existing project site			
3	Time consuming bidding process			
4	Inadequate knowledge of equipment lead time			
5	Incomplete purchase			
6	Complicated administrative & bureaucratic process in project activities			
7	Encouraging on time delivery to suppliers			
8	Unclear command line			
9	Disintegrated inter-departments work flow			
10	Additional and overlapping works, re-works			
11	Less focused on tasks			
12	Access to update, share, and retrieve project data and project information			
13	Inefficiency: project data gathering, meetings			

The following Table 5.2 summarises the most important factors and highlighted concerns that needs to be taken into account in conducting EPC projects according to the interviewed engineers, who deal directly with EPC projects every day. These factors contribute to the ideal vision of project lifecycle to deliver a smooth project according to the interview results. The factors are divided for each phase of project lifecycle based on Engineering, Procurement, and Construction phases.

Table 5.2: Summary of important factors for ideal vision of project lifecycle based on EPC phase

	Engineering	**Procurement**	**Construction**
Initiation	• Sufficiently clear project goals		• Agreement upon revised project goals, scope, specifications
Planning	• Sufficiently defined project specifications from project owner • Top management support for access of necessary data • Adequate project data, process data sheet, and requisition documents • Knowledge of existing condition of prospective project site	• Adequate process data sheet • Selective decision process for qualified suppliers • Supplier database management • Development of a logically sturdy Inquiriy plan • Product knowledge for required material/resource and their delivery time	• Inter-department communication • Clear project technical requirements • Knowledge and deep understanding of engineering drawing • Clear tasks assignations
Execution	• Project meetings • Access for all necessary data • Intra-division coordination and communication flow	• Minimisation of error in material take off • Follow ups for resource deliveries • Logical payment scheme for suppliers	• Clear communication channel and non-ambiguous command line • Coordination and collaboration between sub-divisions and intra-disciplinary • Compliance to planed schedule and PEP rigorously

		• Less complicated administration and bureaucracy mechanism	• Aligned and integrated workflow management amongst E,P, and C Departement • Flexibility and adaptability to improve based on project versatile condition • Stakeholder management
Monitoring and Control	• Awareness of resource delivery time • Compliance to planned schedule and PEP rigorously	• Role delegation for contingen decision making	• Accurate and fast project report → integrated real-time project data system • Familiatrity of Inspection Test Plan and Site Acceptance Procedure

Drawing a rough preliminary conclusion from most of the interviewees-particularly from The Six Sigma consultant, the key success factors in implementing Six Sigma in EPC projects might lie on the support and commitment from top level management. This is to encourage the engagement for reformative change within the system when introducing a new quality improvement methodology such as Six Sigma, against the potential resistance from the experienced project team members who might be reluctant to change. There is a need to have somebody who is competent to be able to drive the project team to implement theories into application, preferably a certified Black Belt. However, long before that, the Six Sigma consultant suggested that EPC projects need to identify relevant measurement tools from each project process beforehand. These measurement tools will be used for creating a project dashboard to ensure the traceability of a project. Moreover, it is also important to have a well-established system for knowledge and information sharing.

According to the Six Sigma consultant, the benefit of implementing quality improvement methodology such as Six Sigma is greater than its cost of investment. The benefits which are expected by the firm greatly span from acceleration of project duration to increased project productivity, which will result in cost saving. This will lead to efficient use in resource and effectivity in project duration, simplification of slow and complicated administrative processes, and enhancement of knowledge and experience of project team members. However, there are some cost and obstacles which need to be considered as well. These considerations are mainly come from cost of training, resistance based on routines from those who have accustomed to the way they have been working with, and scepticism as well as pessimism towards a novel method which is about to be introduced to EPC projects.

6
Analysis and Discussion

This chapter presents an analysis of the findings from the empirical material in previous chapter, which is contrasted against the theory presented in the Literature Review chapter. The analysis is mostly done based on DMAIC structure of Six Sigma to draw a line for affinity. Furthermore, a discussion for the outcome of the analysis is presented for the reader to have a better perspective and understanding of the analysis.

6.1 Key Activities and Players Involved in EPC Projects

There is a set of main stages in EPC projects which is derived mainly from the secondary data obtained from company's business process document. Within these main stages, the key activities are gathered from guidelines for EPC project management documents, and combined with the materials obtained from the interviews result. The key activities are obtained from the interviews, based on the ideal vision of EPC projects that the engineers wish to achieve.

The main stages along with their key activities, output products for each stage, and key players are listed and presented in Table 6.1 in the next page. These main stages and key activities are sectioned based on the Six Sigma Project methodology DMAIC phases by Rever (2010). Furthermore, these main stages and their key activities are identified based on the Six Sigma implementation success factors summarised by Sharma and Chetiya (2012) from several different authors. Identifying the main stages and their key activities are done to observe whether they have been covered by the theories found in the literature review; and if so, which success factors does each main stage and its key activities support and correlate to.

From the Table 6.1 below, it can be seen that most of the key activities for ideal vision of EPC projects in the case company are covered by the success factors defined by Sharma and Chetiya (2012). Further analysis of the Table 6.1 is divided into the DMAIC. The results show that in the Define phase, the key activities which are considered to be important can be summarised into several main crucial activities. These are the formation of organisation, project specifications gathering from the project owner, then developing a comprehensive and detailed project plans which cover every detailed aspects in different areas of the project based upon the gathered project specifications. The main activities for EPC projects in the case company in Measure phase deals more with designs and documents. Thus, the summarised critical main activities in Measure phase are producing engineering designs according to the requirement and specifications, verifying and validating the alignment of designs, then managing all the produced documents to be accessible by the project team.

Analyse phase in EPC projects continues with verifying designs to be converted into requisition for purchase and most of evaluation activities for suppliers and subcontractors performance, and also for project materials, fabrication, and manufacture. Verifying all the designs including engineering drawings, data sheets, fabrication drawings, and other documents, will allow the project team to decide whether they can proceed to the construction phase with the qualified designs as the basis of their work. Moreover, evaluating suppliers, subcontractors, material, fabrication and the manufacture process will provide the project team with the idea of the status of their project. The project team will have an image whether all the required materials and equipment needed to start the construction of the facility are available, and what required actions should be taken to proceed the project.

In the Improve phase, the EPC projects mainly deal with construction works activities which have to adhere to the predetermined detailed project plans and project Work Breakdown Structure. This also includes mechanical completion, where construction data is recorded for immediate improvement actions for the ongoing project if needed, or for future lessons learned. In the last phase, the Control phase, the main activities mainly cover recording, registering and reporting project data, as well as evaluating and analysing variance and deviation for resource allocation and taking necessary corrective actions.

Table 6.1: Summary of key activities and success factors for ideal vision in EPC projects (on elaboration)

Phase (Rever, 2010) PM	6s	**Stage**	**Key Activities**	**Success Factors (Sharma and Chetiya, 2012)**
Initiating	Define	Project acquisition	• Feasibility study • Project organisation formation • Project launching	• Cross-functional organisation • Project choice and leadership • Project championship, staffing
Planning		Project contract review	• Ensuring technical requirements are well defined and understood • Understanding acceptance criteria	• Workflow management systems • Metrics and measurement
		Requirements documentation and management	• Defining scope of work, deliverables list, requirement management, Work Breakdown Structure (WBS) • Identifying requirement gap analysis	• Richt tools • Workflow management systems
		Compling Project Execution Plan (PEP)	• Producing detailed execution plan (EP) for each division • Identifying schedule and cost management	• Cross-functional organisation • Availability of resources
Executing	Measure	Design, preparation, design requirements confirmation	• Ensuring adequate design input to start design execution • Verifying input	• Cross-functional organisation • Right tools • Availability of resources
		Design execution, verification, review, validation	• Ensuring alignment of designs • Interdisciplinary checking (review, verify) of desgin output documents • Functional testing for all equipment	• Management commitment • Metrics and measurement
		Management and control of document	• Managing all the required documents • Ensuring access to and retrievability of documents	• Cross-functional organisation • Workflow management systems
	Analyse	Verification of requisition, T&C, cost, schedule	• Ensuring Request for Quotation (RFQ) meets contract requirements • Ensuring term & condition for purcase order and clauses are aligned	• Supplier collaboration
		Expediting	• Ensuring and managing fabrication process and in time delivery materials transport • Inspecting and testing equipment	• Supplier collaboration

		Evaluation of suppliers and subcontractors performance	• Evaluating technical and commercial capability of suppliers	• Supplier collaboration
		Material, fabrication, manufacture evaluation	• Ensuring adequateness of material handling procedures • Assessing fabrication environment and prcedures	• Supplier collaboration • Availability resources
	Improve	Field document and field design control	• Ensuring field documents and designs are well-distributed	• Workflow management systems
	Improve	Construction work	• Ensruing project activities follow procedures, WBS, and schedules	• Workflow management system • Work and organizational workforce • Availability of resources
Monitoring	Improve	Field inspection and non-conformance monitoring	• Storing calibration and testing notes • Evaluating conformance to requirements • Inspecting and reviewing construction work	• Right tools • Metrics and measurement • Management commitment
Monitoring	Improve	Mechanical completion	• Collecting construction data record for each design documents • Registering non-conformance	• Right tools • Construction and installation • Metrics and measurement
Controlling	Control	Recording and document control	• Recording and checking data operation plant • Registering non-conformance	• Right tools • Metrics and measurement
Controlling	Control	Project quality audit and operation control	• Ensuring and evaluating quality conformance activities from QMS • Reporting project progress report	• Right tools • Metrics and measurement
Controlling	Control	Cost and schedule control	• Recording data and progress controlling • Analysing variance and deviation • Re-allocating resource, taking corrective actions	• Right tools • Metrics and Measurement • Resource availability • Management commitment

Albeit the success factors are divided into seven groups, they still correlate and support one another instead of abiding independently. One example is how choice of project champion is interlinked with both quality of project leadership and management commitment. This statement is drawn from the case that project champion is chosen by the management and possess the authority to use resources for completion of a certain project, which is related with the capacity and capability of a project leader. The following Figure 6.1 illustrates success factors which are found to be similar and slightly overlap one another.

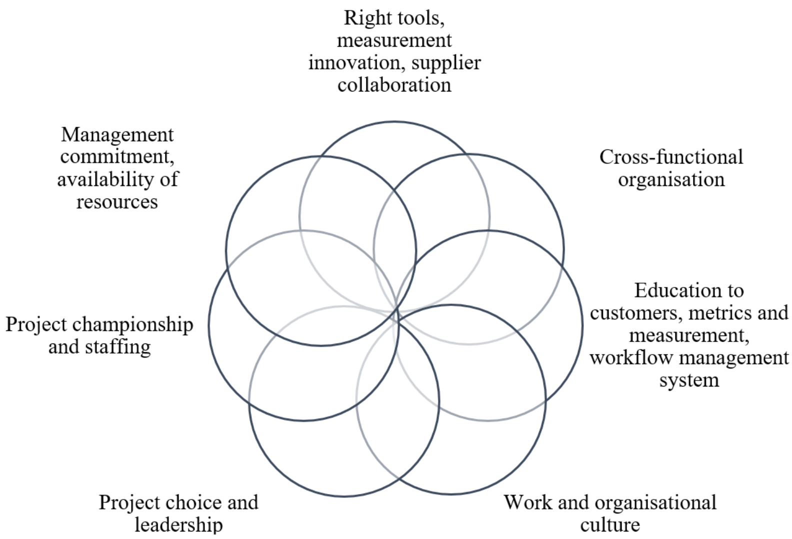

Figure 6.1: Interconnected and interlinked success factors of Six Sigma projects (on elaboration)

The results from the study also support that these groups of success factors correlate and support one another. In one of the interviews, one of The CE mentioned that resources allocation may be increased by the top management when a project is found to be behind schedule, after it is identified by the predetermined measurement. Another interviewee also mentioned that management commitment plays an important role in choosing the project for the team, besides choosing the competent project champion and project leader. Moreover, management commitment also set the basis of education, training, and proper staffing to ensure an excellent workflow between different departments and subdivisions. Cross-functional organisation is also highly related with the work and organisational culture, as mentioned by one of The EE. She stated that having the same common ground of work ethic and similar organisational culture will enable a better-performing team, which can be perceived as an excellent coordination of workflow between cross-functional organisation.

6.2 EPC Project Success Factors in Scale Items and Challenges Faced in EPC Projects

In this section, the aforementioned success factors of the implementation of Six Sigma project management summarised by Sharma and Chetiya (2012) are broken down into its scale items. These scale items are contrasted against the findings from the empirical materials in the Table 6.2 below. The findings are contrasted to find out whether each of the scale items was found in the findings, and whether it was briefly mentioned or even discussed in the interviews in each department and from the professional practitioners. Furthermore, these scale items will be scrutinised whether it may address the challenges which are most encountered in EPC projects according to the interviewed engineers. There are many challenges associated with the EPC projects in regards to the project management practices. Most of the challenges are linked to several project management knowledge areas, such as project integration, scope, human resources, and communication.

Based on the Table 6.2, it can be seen that most of the success factors' scale items are found in the empirical findings regarding the key activities for ideal vision in EPC projects. Some of the scale items for success factors in EPC projects are notably emphasised by most of the interviewees, which are: 1) a good measurement assurance system, 2) linking to customer, 3) identifying and developing appropriate metrics and deliverables, 4) an integrated process flow and management system, 5) availability of infrastructure and resources, and 6) level of management commitment. The scale item which was most discussed and considered to be highly important by all the interviewees is an integrated process flow and management system. This indicates that most of engineers involved in EPC projects believe that the current practices of EPC project management are still lacking of integration and coordination, mostly within its project process and managerial activities.

Table 6.2: Success factors and scale items (Sharma and Chetiya, 2012) found in EPC projects (on elaboration)

No.	Factor	Scale items	Engineering	Procurement	Construction	QC/QA	Project Control	Professional
1	Right tools, measurement innovation and supplier collaboration	Capability assessment and enhancement of the supplier						
2		Innovation management and desing capability						
3		Long-term supplier collaboration						
4		A good measurement assurance system						
5		Application of right tool mix						
6		A creative problem solving approach						
7	Cross-functional organisation	Formation of cross-functional teams						
8		Linking Six Sigma to corporate business strategy and goals						
9		Process mapping and reegineering						
10	Education, metrics, measurement and workflow management system	Intensive education and training of workforce						
11		Linking to customers						
12		Linking to employees						
13		Identifying and developing appropriate metrics and deliverables						
14		An integrated process flow and management system						
15	Work and organisation culture	Development of right work culture						
16		Motivating the workforce						
17	Project choice and leadership	Quality of project leadership						
18		Selection of the right project						
19	Project championship and staffing	Choice of project champion						
20	Management commitment, availability of resources	Availability of infrastructure and resources						
21		Level of management commitment						

Legend	
(white)	Not mentioned
(green)	Briefly mentioned
(blue)	Mentioned and discussed

According to the referenced author, Sharma and Chetiya (2012), an integrated process flow and management system is highly related to information and communication management system. This proves how critical it is to have an integrated workflow, as having an integrated information and communication management system can be the most appropriate solution to address several challenges which are most often encountered in EPC projects. Several challenges according to the findings that can be dealt by having an integrated information and communication management systems are: 1) conflicted designs, 2) unfit drawings and designs, 3) unclear command line, 4) disintegrated inter-departments work flow, 5) additional and overlapping works, 6) access to project data and information, and 7) inefficiency in project data gathering. Conflicted designs and drawings of instruments between departments can be addressed by having access to information and supported with excellent intradepartmental communication, as the engineers will have better and robust channels to verify and validate their works. Having their works verified and validated may reduce the disintegration inter-departments, which will ultimately lead to less additional and overlapping works.

The next scale items which were most discussed are identifying and developing appropriate metrics and deliverables, and management commitment. The involvement of management as one of the most critical success factors has been mentioned in numerous literatures such as Lee (2002), Anthony and Banuelas (2002), Ponce and Zahaf (2004), Anthony (2004), Kumar (2007), Nonthaleerak and Hendry (2007), Davison and Al-Shaghana (2007), Shanmugam (2007), Chau et al. (2009) and Desai et al. (2012), and has also been proven to be critical in EPC projects based on the findings. It is undeniable that management commitment has been overemphasised, and in this case it also may address the challenge of: 1) complicated administrative and bureaucratic process, 2) unclear command line, 3) disintegrated inter-departments work flow, 4) less focused on tasks, 5) access to project data and information, and 6) inefficiency and project data gathering and meetings. Having the commitment of management means more involvement of the top management itself within the project activities. Therefore, they would be aware of any inefficient and complicated administrative and bureaucratic process, and would likely to solve it faster. The management who is involved more in the project would notice as well if the project team is less focused due to too many tasks to be handled, and would most likely support the project team by allocating more resources or work force to. Assuredly, the commitment of management may also serve as the key driver in delivering effective most other success factors. Having appropriate metrics and deliverables was also found to be one of the most important item according to the findings, where the application of appropriate metrics and deliverables may address several of measurement-related problems in EPC projects. Since Six Sigma is a data driven methodology, proper usage of appropriate metrics and deliverables is required.

After the three aforementioned scales, the next two most important scales are a good measurement assurance system and availability of infrastructure and resources, then followed by linking to customer. Again, most of the engineers as well as professional practitioners which were interviewed emphasised the need of having an excellent measurement assurance system. Presumably, they expect that by having good measurement assurance system, several challenges that they often encounter may be addressed as mentioned in previous paragraph, as they have had a structured and systematic process to ensure the achievement of implementation of project activities. Availability of infrastructure and resources may solve the challenge of: 1) inadequate knowledge of equipment, 2) less focused on tasks, 3) re-works, 4) access to project data and information, and 5) inefficiency in project data gathering. With adequate infrastructure and resources—supported by management, project team will have more resource to scrutinise the need of equipment to comply with the requirements, to expedite and deal with the administrative and bureaucratic project activities, and to ensure that the project is done effectively and efficiently with sufficient access to project data and information to prevent re-works.

EPC projects have to link its business to customer and take their expectations into account, as the company puts a considerable emphasis on its customer and its main business deliverables lie heavily on customer's requirements. As suppliers can be considered as external customers as well, linking business to customer may also address the challenge of time consuming bidding process. Moreover, encouraging on time delivery to suppliers and conflicted engineering designs due to incompatible specifications might be solved as well by putting customer's needs and requirements into high priority. Linking to customer means having decent relationships with the customers, including project owners. Therefore, unclear specifications or project requirements can be prevented by working closely with the project owners to ensure the expected and aligned specifications to prevent incompatible specifications, unfit drawings and designs, and re-works. The following Figure 6.2 illustrates how the top six scale items which are considered to be the most important items may address most of the encountered challenges in EPC projects.

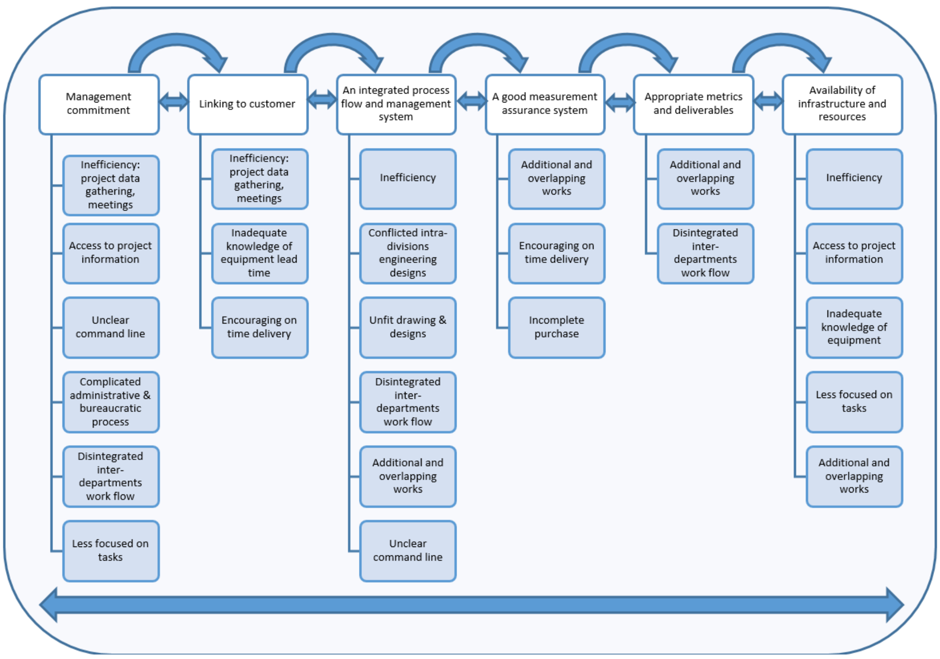

Figure 6.2: The six most emphasised scale items and challanges it may resolve (on elaboration)

Albeit the illustration merely pictures how one major scale item might resolve several most often encountered challenges in EPC projects, this does not mean that other challenges which are put under different scale item cannot be resolved by the others. Like seven groups of success factors which are discussed in the previous section, six of the most emphasised scale items support one another. These scale items are not independent, and one is interconnected and interlinked with each other. Therefore, several particular challenges may be resolved by other scale items as well. However, management commitment as still serves as one of the most important scale items, as highlighted by The Six Sigma consultant as well. Without the management support, it might not be tough to promote other scale items. Management support enables smooth access for linking to customer, enforcing the establishment of an integrated process workflow with management system along with a good measurement system and appropriate metrics and deliverables, and for providing suf infrastructure and resources.

Another interesting finding arises from this finding of similarities. Despite all the success factors seem to be similar and overlapping one another in a certain degree, different perspectives are found within the same department. Not all the scale items are found or mentioned in the interview, nor emphasised on the same level by every department and professional practitioners. One example is how quality of project leadership was not mentioned as one of the most important factor in project execution, whereas choice of project champion was discussed by The Construction Department; albeit these two scale items can be considered to be similar and interlinked. Another example is the scale item of intensive education and training of workforce and motivating the workforce, which can also be considered to be interlinked. Intensive education and training of workforce was not mentioned by The Engineering Department whereas motivating the workforce was mentioned briefly. Different way of perceiving the scale items might be the cause of the different level of depth of discussion within the same department. The interviewed engineers might found one scale item has covered another one as they perceived them to be similar to each other, thus did not mention nor discuss another similar scale item further.

In addition to the different level of depth of discussion for the similar scale items within the same department, different findings are also found for the exact same scale items within different departments. A couple of examples are intensive education and training of workforce and selection of the right project. These two scale items were considered to be important by The Construction Department as both of them were deeply discussed; where on the contrary, they were not mentioned by The Engineering Department. This different level of depth of discussion might be caused due to the different priorities and focus on each department, where they have different perspective on which things matter most for their endeavour. For The Construction Department, it is necessary to have a skilful and highly functioned team who works on a suitable project which fits their expertise. Therefore, education and training of workforce as well as selection of the right project are considered to be important and were discussed during the interview. On the other hand, The Engineering Department might have had adequately knowledgeable engineers for their subdivisions, who mostly have possessed their own specialised knowledge for their corresponding subdivisions. Therefore, the engineers from The Engineering

Department does not find intensive education and training of workforce as highly important as The Construction Department does. The way each department perceives the scale items might be disparate from another one as well as they work in different phases in a project, which makes them have different focus in different context.

6.3 Updated Six Sigma Project Management Framework

The new updated framework based upon Six Sigma Project Management framework by McKenna (2005) incorporates the new findings found from the case company for EPC projects into the existing framework. This also includes the main ideas for key activities for each DMAIC phase and the most emphasised scale items. The new updated framework with a more comprehensive approach to Six Sigma EPC Project Management is shown in Figure 6.3 below.

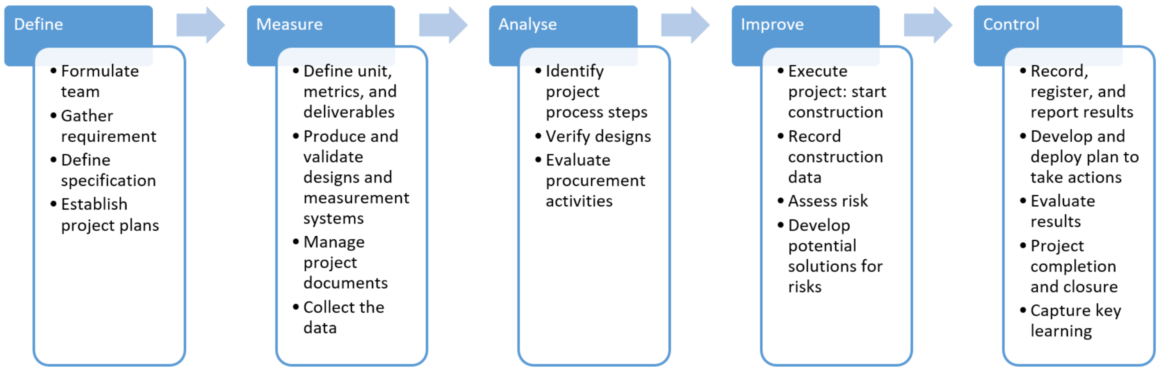

Figure 6.3: Updated Six Sigma Project Management framework

In the new proposed framework, formulate team has been added to the Define phase, as it has been found to be an important element in empirical result. Several interviewees also highlighted the importance of having a solid team, which is started by formulating a favourable project team. McKenna (2005) argued that gather requirements and define requirements are necessary in the Define phase. These are aligned to the findings emerged from the empirical material as well, where most of the interviewees emphasised the necessity of understanding customer requirements. In EPC projects, the requirements from the customer is then translated into specifications. Therefore, define requirement is updated into define specifications in the new proposed framework. The defined specifications from the customer's requirements will set the foundation for all engineering designs which are going to be produced afterwards. Lastly, establish project plans is added into the Define phase, as establishing detailed and thorough project plans also one of the most substantial key activities in the for EPC projects.

In the Measure phase, defect and opportunity are changed into deliverables in the define point. The underlying principal of Six Sigma indeed appertain to defect and opportunity for improvements. However, EPC industry differs with manufacturing industry where Six Sigma methodology was born, where EPC projects deal more with unit, metrics and have more concern in deliverables. EPC projects also tend to deal with different project as every project is unique, and therefore opportunity for improvements can be divergent for different projects. In addition to measurement system, designs is added to be validated after it is produced. Then, manage project document is also included to complement collect the additional required data which has been proposed by the initial framework. However, the additional required data that is indicated in the Measure phase for EPC projects is the additional required data that may be found in the project site.

Adding validation of designs which are produced in the previous phase in the Analyse phase is essential. In the Analyse phase, all the engineering drawings and designs need to be validated to ensure their alignment with the project specifications, as these documents are going to be the fundamental guidelines for construction works. Identifying project process steps are required in the Analyse phase as well to ensure the smooth execution in the Construction phase. Lastly, bridging the Engineering phase with the Construction phase, evaluation of Procurement activities is added. Evaluation of Procurement activities is crucial to ensure the smooth execution of project in the Construction phase as well.

In the Improve phase, develop potential solutions is substituted with executing the project itself by starting the Construction phase, as defect and opportunity are not defined in EPC projects as explained earlier. In the Improve phase, project data during the Construction is recorded to ensure every activities are executed according to the identified project processes which have been analysed before by using predetermined unit and metrics to accomplish deliverables. As proposed in the initial framework, risk is assessed. Furthermore, the new proposed framework adds develop potential solution for risks for the follow up actions for the identified risks.

There is not many new proposed elements for the Control phase in the new updated framework. Most of the findings found in the empirical results are already aligned with the initial framework. However, the new proposed framework also includes record, register and report results, which is mostly aimed in the Construction phase. This is necessary thus the project can be monitored and controlled based upon predetermined unit, metrics, and deliverables to evaluate its performance and the outcome. Develop and deploy plan to take actions is proposed already in the initial framework, as well as capture key learning for lessons learned in the future. These items are aligned with the crucial key activities found in the empirical material, and thus are not changed nor modified.

6.4 Benefits and Constraints of Six Sigma Implementation in EPC Projects

The benefits of having Six Sigma implemented or integrated in EPC project management practices vary and are widely spanned, as long as its implementation plan is aligned with the company's business process. Integrating Six Sigma within EPC project management framework means introducing a new quality improvement methodology. As mentioned by one of the EE, new quality improvement methodology promotes innovation, and innovation lays a foundation for nurturing competitive advantage as suggested by Madu and Kuei (1993). The interviewed engineers also expect Six Sigma will enable acceleration of project duration and efficiency in resource and budget, thus increase project productivity. This apparently aligns with what Wysocki (2006) and DeCarlo (2004) suggested, that optimisation and efficiency has been the main focus of project management, so is in EPC projects. Moreover, optimisation and efficiency will ultimately enhance company's profitability through cost saving, as well as through customer's satisfaction by delivering expected project outcomes. Again, this will promote company's competitive advantage.

Improvement of workflow management system is expected to come with the implementation of Six Sigma methodology. Project team members are expected to have more structured mind sets to identify and solve problem with satisfactory work attitudes. This will more likely provide enhancement of the knowledge and experience of project team members. However, room for versatility and adaptability for fulfilling the customer's requirements is still required along with the standardised workflow management system. A satisfactory workflow management system is also expected to simplify slow and complicated administrative and bureaucratic project processes which are often found in EPC project practices.

However, the idea of implementing Six Sigma within EPC project management framework does not come without constraints. The fundamental constraint lies on the low awareness of the importance of quality management, and the lack of sense of necessity in implementing and improving quality continuously in EPC projects. Therefore, several interviewed engineers pointed out the need of having somebody who possesses the power and ability to encourage the project team to implement these theories into application. Otherwise, the implementation program will become less prioritised and will have inadequate or poor access to resources and other required facilities. This particular person who is expected to initiate the implementation of Six Sigma in EPC projects matches the description of somebody who is at least Black Belt certified by Magnusson et al. (2003), where they have the most important role for the daily execution of project activities and mostly take the role as a team leader. Another constraint might emerge from the engineering culture, a mind-set which was born based on the experience. This culture may create resistance to standardisation, as they most likely suggest what they have known in engineering technical field for solution instead of implementing a new reformative quality improvement method. This also creates resistance based on routines, which happens when most of the project team members have accustomed to the way they have been working with based on their experiences for years. Therefore, the adjustment of routine for project team members is required if the implementation changes the work culture significantly.

Having matrix organisation structure in EPC company who deals with multiple project simultaneously may inhibit the implementation of Six Sigma within their project management practice, as it is considered to be not the best choice. This is due to the fact that most of the engineers tend to be less focused on their tasks, as they have to deal with several projects assignments at the same time. Moreover, the responsibility of having to deal with several projects simultaneously might cause confusion in reporting the progress of a project or in the matter of communication channel, as they are unsure about who is accountable for a particular decision. A project-based organisation structure could be the solution of having less-focused project team members. However, adequate numbers of competent human resources is required for having a project-based organisation structure. Hence, this can be the limitation for implementing a project-based organisation structure to enable a smooth implementation of Six Sigma within EPC project management practices.

6.5 Discussions

The results of the study show that quality has not been the main concern in EPC projects. Quality-related practices in EPC projects is highly driven by project owner and alliance team instead of by company's internal organisation itself. Another interesting finding shows that profitability does not appear in one of the priority in EPC projects amongst safety, quality, schedule and cost. Only one amongst the seven interviewees mentioned profitability briefly. However, an assumption could be made that the interviewees might refer indirectly that profitability can be achieved by prioritising on schedule and cost. Moreover, as the interviewees from the case company are all engineers, there is a suspicion that this is due to the tendency that engineers most likely merely do the best of the technical solutions without really focus on the business goals itself—which is profit. Generally, quality is a competition with cost, where EPC project aims to produce sufficiently good quality of project deliverables which have been compromised with cost.

Besides focusing on sticking to schedule and predetermined budget, avoiding behind schedule and over budget can be achieved through obtaining sufficiently-defined specifications. In reality in EPC projects, ambiguous and unclear interpretation of project specification is recurrently a problem. However, since having clear specifications is unlikely possible, sufficiently defined and well understood specifications from the project owner are therefore unquestionably important. All the data produced in Engineering phase have to ensure the achievability of project specifications which are agreed on the project charter. Thus, Engineering Department plays a critical role in EPC projects as the one who is responsible of producing all the engineering designs and drawings.

A good quality of engineering designs will be able to accommodate customer wants. In some of EPC projects, the Engineering teams are more knowledgeable than the project owner itself due to their experience. Therefore, there is a tendency for the Engineering teams to produce more than the defined specifications or what the project owner demands. However, quality should be perceived as the specifications that the project owner expects, rather than the technical specifications that the engineers feel is suitable. Nonetheless, engineers still of course are able to give recommendations of better technical specifications based on their experiences. This creates the need for engineering and design of project items to be followed by favourable procurement executions from hundreds of suppliers.

Based upon the empirical material obtained from the interviews, Six Sigma DMAIC methodology in regards to EPC projects puts a considerable emphasis on data, integration and standardisation. This aims to be able to measure, then analyse project activities that can be improved. There were some discussions regarding data in the interviews, where some of the engineers requested to have a database system. According to the engineers, data recording, analysis, management, and storage system in EPC projects is still meager, where most of data in EPC projects is still managed through Excel spreadsheets. The meagreness of project data management is due to: 1) lack of sense of necessity, 2) low awareness of quality management where most of the project team members have not realised the correlation between quality management and project data, and how data can be utilised for lessons learned to manage and enhance the quality of forthcoming projects, 3) inadequate communication, and 4) poor planning and contractual misunderstandings between suppliers.

Therefore, one of the challenge faced in every EPC project is having overloaded information and confusion regarding who has access to which data, and retrieval mechanism of a particular data. EPC project documents which are poorly managed create lack of visibility and control of growing data. This leads to inefficiency to integrate, and ultimately leads to over schedule and over budget projects, which decrease project profitability. According to interviewed engineers, a robust database system is envisaged to be an ideal solution to accommodate enormous amount of paperwork produced in EPC projects. This includes engineering drawing, data sheet, and other fundamental documents from the Engineering phase, registration of procurement activities from numerous numbers of suppliers which are scattered geographically in the Procurement phase, and recording project construction productivity in the Construction phase itself. A real-time project data report could be the solution to encourage efficient real-time knowledge sharing across company's multi-projects by utilising intranet.

Having a real-time database system will promote data integration. In Procurement phase for example, integrated database system could reduce paperwork, processing time, and cost of follow up and floating the enquiry. This will enable real-time analysis from data source to enhance the accessibility of having real-time project information for all project stakeholders. Practically, having detailed project analysis during project execution provides the ability to isolate problems and forecast trends. The stored project data in database system then can be utilised to identify problems, what worked well, and areas for future improvements. Therefore, there is an urgent need of standardisation then establishment of robust measurement to collect and manage data, then to be able to implement Six Sigma properly within EPC projects.

Nonetheless, the level of standardisation needs to be examined deliberately first. EPC projects tend to deal with requirements from the customers. Albeit most of the projects are not completely novel projects, each of the project is still unique as they have their own requirements and specifications. Standardisation mostly begins and deals with engineering designs, as the most likely source of variation which takes the project specifications into the foundation of the project plan. Therefore, a rigid standardisation in every detailed aspect of EPC projects would not be a prudent action. This restricts freedom of producing engineering designs which incorporate project specifications. Every project needs to have its own flexibility to some extent to fulfil the project owner's requirement, despite of the necessity of having a standardised workflow management system is still substantial. A rigid policy of standardisation may lead to a failure to fulfil the project specification and satisfy project owner's expectation.

In order to integrate Six Sigma within EPC projects, the management is ought to put more considerable focus and support on human resource training. With adequate human resource training, project team members do not depend on merely self-taught learning. They will have competent knowledge and skills about project management as the basis core before implementing Six Sigma when conducting EPC projects. Furthermore, human resource may encourage project managers to take part and facilitate their training for Black Belt certification. Six Sigma Belts training is generally competence development, where it is a dynamic change to get people to be more aware of quality. Having a Black Belt certified project manager ensures each team member has an established role, knows what is expected from them, and who is held accountable for certain assignments. Moreover, Back Belt as the project manager is the main person in charge to report project progress, in case of confusion. This will provide more clarity in communication regarding reporting and requesting access to a particular data. However, enhancement in communication to establish a clear communication and coordination path is still needed. Communication also enhances synchronisation of many subdivisions that Engineering Department has, which ultimately leads to a solid teamwork. There is a great need of clear communication channel and non-ambiguous command line in construction phase, of who are responsible to whom.

Being flexible and sensitive with the field's actual situation and condition is also essential to develop a contingency plan then to follow it, if the project encounters a certain obstacle. Additionally, managing stakeholder is highly important in project execution to maintain good relationships and to avoid any disputes with the local communities in the project environment, which may lead to the project being halted. Within the execution of each project, there are milestones which have to be reviewed in several particular times. Most of these milestones are mainly a set of substantial sequence of works which cannot be skipped or omitted. Therefore, some activities cannot be proceeded without the completion of the precedent activities. Every project team member has to be able to identify risks in accordance to every taken decision, based on cost and schedule.

Conclusively, having a Six Sigma DMAIC methodological framework will expectantly enable stronger project management and productivity gains. It will also help avoiding reputational damage if project cannot meet client's expectations and loss of revenue. Implementing Six Sigma DMAIC methodology may free up resources to more effective project management, hence unnecessary costs can be cut.

7 Conclusion & Recommendation

In this chapter, conclusions based on the empirical findings, analysis and discussion are presented. The conclusions aim to answer the research questions presented at the beginning of the study in the first chapter. Furthermore, this chapter also identifies the contribution of developed and updated framework of Six Sigma implementation plan in Project Management framework to general project management theory, Six Sigma theory, and the practice of EPC projects theory.

7.1 Conclusions

EPC projects are becoming more complex with large contract values and being implemented on a larger scale. Consequently, most of large EPC companies face common issues which hinder their projects, which results in poor performance records and ultimately affect the quality of projects. Therefore, more companies are seeking for quality improvement methodologies, where there have been attempts to incorporate Six Sigma methodology within the project management framework. The purpose of this thesis is to investigate and explore how Six Sigma can be integrated into the project management framework in EPC projects, and how the existing Six Sigma project management framework could be developed and updated to be more apt in EPC projects' context.

The first sub-research question revolves around the understanding of Six Sigma and its relation to quality improvement. This aims to provide a foundation for frameworks that are used for this study and the discussion of the main subject of this study. In this study, Six Sigma is seen as a structured and disciplined methodology for quality improvement projects. Attempts of achieving specific goals are achieved through defining quantifiable measures by focusing on customer needs. There are many Six Sigma tools which can be utilised for improving the quality of processes, reducing waste, and increasing customer satisfaction through its data-driven philosophy. The most prominent approach of Six Sigma methodology is through DMAIC framework, which stands for Define, Measure, Analyse, Improve and Control. Finding solutions to problems and opportunities could be provided through DMAIC, whereas the implementation of the solutions through the formal procedure could be achieved through project management standards. The DMAIC framework is also used as the main framework which is studied deeper in this study to establish an integrated and systematic flow in EPC firms' project management practices.

As this study is conducted within an EPC industry context, an adequate understanding of EPC firms and projects is therefore necessary. EPC firms are companies in the construction industry who run their projects in a certain form of contracting agreement. Following the contracting agreement, they are obliged to execute a project within a predetermined budget and time, and to deliver satisfying outputs according to the project owner's requirements. Within the projects, detailed engineering designs of the project, all the necessary equipment and materials, and construction of a functioning facility are carried out by the engineering and construction contractor. As the size of EPC projects tend to be big, a quality management system ought to be robust in their project management practices. However, the results from literature review and empirical findings show that quality management has not been well incorporated in most of EPC firms' applied strategy. Two of the most probable causes are insufficient quality requirements from the project owners themselves and low awareness of the necessity of having a robust quality management. There has even been a suspicion that some companies which are certified under quality standardisation obtained the standardisation process merely for having a credible image on the market. This is beneficial to ensure the clients about the quality of their services. Another challenge that the case company of this study as one of the prominent players in EPC industry encounters the most is the amount of rework due to the substandard quality of the deliverables.

There are several success factors of Six Sigma implementation plan in Southeast Asian market which were suggested by Sharma and Chetiya (2012). These are: 1) right tools, measurement innovation, and supplier collaboration; 2) cross-functional organisation, process re-engineering and the "strategic fit or Six Sigma"; 3) education to customers, metrics and measurement, and workflow management systems; 4) work and organisational culture; 5) project choice and leadership; 6) project championship and staffing; and 7) management commitment, organisation, and availability of resources. These success factors were then broken down into their scale items and combined with the results obtained from the empirical findings. This produced the most related success factors for Six Sigma implementation in EPC projects for the case company, which include: 1) availability of right tools, measurement, innovation, and workflow management system management; 2) management commitment and support; 3) availability of infrastructure and resources; 4) availability of a well-established system for project information and knowledge sharing; and 5) establishment of a solid project charter with well-understood and sufficiently defined requirements and specifications. These success factors from the case company are mostly aligned with the success factors identified in the literature review.

Six Sigma project management implementation and integration within EPC project management frameworks comes with benefits and constraints. For the case company, the benefits widely span from enhancing competitive advantage, increasing project productivity through acceleration of project duration and efficiency in the usage of resource and budget, and increasing customer satisfaction by delivering expected project outcomes. Moreover, Six Sigma DMAIC methodology is also expected to facilitate project team members to develop more structured mind sets to identify and solve problems with satisfactory work attitudes. However, several constraints are also need to be taken into considerations. The constraints which may arise are the low awareness of the importance of quality management, the lack of sense of necessity in implementing and improving quality and resistance based on routines. In addition, matrix organisation may also cause confusion in responsibilities, due to its ambiguity of command line for project progress reports and general communication in the case company.

7.2 Recommendation for Future Research

This study has indicated that there is a lack of awareness of quality management in EPC projects, and there is a great variety in EPC projects in the context of the procedure and the methodologies. One of the interviewee also suggested that there is a need of standardisation for established working procedures to collect and to share information. It is also found that the matrix organisation is one of the challenge in EPC project practice in general, and therefore may inhibit the implementation plan of Six Sigma in EPC project management framework.

One recommendation for future research would be to investigate further the real cause of the low awareness of quality management in EPC projects in construction industry, then to formulate ways to improve the awareness of quality management in EPC projects which may also address the causes. Furthermore, recommendations for future research could be to formulate and develop a standardisation for working procedures without diminishing the flexibility, versatility and adaptability of EPC firms to comply with the project owner's requirements. Another recommendation for a potential research could be to investigate the type of organisation structure, which may provide the best support to the project management activities in EPC projects, particularly for EPC projects which are open for the Six Sigma project management implementation plan in the future. Research could also be done to find the most complicated and problematic key stage in EPC projects and how standardisation could address the issues which usually arise in a particular key stage.

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Appendix A

A.1 Relevant Terms and Concepts within Project Management

Resources

Resources can be both tangible assets such as physical items of equipment and material, and intangible assets like knowledge (David & Hakan, 2006). There is a critical need to define the required resources meticulously in order to allocate resources adequately during the whole project lifecycle, particularly in Initiate/Define phase.

Stakeholders and Sponsor

PMI (2013) states stakeholders as "an individual, group or organization who may affect, be affected by, or perceive itself to be affected by a decision, activity or outcome of the project". Managing stakeholders in a project is essential as they may have both economic and social effects on the project and therefore may affect the profitability of the firm (Freeman & McVea, 2001). Ericsson et al. (2009) stated that it is critical to communicate all the substantial yet relevant information regarding the project to stakeholders. There have been various definition of project sponsor and its roles defined by different organizations. Project sponsor itself is "the person or group who provides resources and support for the project and is accountable for enabling success" (PMI, 2013, p. 32). On every project, project sponsor is often recognized as a key stakeholder in most project management bodies of knowledge (Kloppenborg, Manolis, & Tesch, 2009).

Project Gates

Project gate is a follow-up process of a project, where the project's result up to a certain point is evaluated by the project sponsor. Based on the performed evaluation, the project sponsor has the opportunity to reflect upon the achievability of project goals in both short and long term, and thereby make a decision whether the project should be proceeded or closed at a project gate (Ericsson et al., 2009). A project is possible to be terminated when neither enough resources are available nor project goals are no longer reachable. According to Nilson (2010), project gates can be classified into rigid project gate and flexible project gate based on the completion of deliverables. Rigid gate obliges all the deliverables to be completed before proceeding to the next phase, whereas flexible gate allows project to be continued without completion of all the deliverables, as long as there is a limited time for completion and authorisation for starting the next tasks (Nilson, 2010).

Project Milestones and Inchstones

According to Ericsson et al. (2009), milestones are a predetermined dates or times when a certain result which should have been achieved is inspected. Therefore, milestones should be connected to easy and measurable goals, as they ensure that the expected results are fulfilled on time. Barba (2008) suggested inchstones for more detailed planning between milestones, which are subtasks with defined deliverables. Inchstones are utilised to detect delays early in order to initiate corrective measures to prevent further delays.

A.2 Examples of Six Sigma Tools

Several most common used tools for Six Sigma are described briefly in following subsections in order to provide the insights of how can these tools be utilised for Six Sigma program.

Fishbone Diagram / Cause and Effect Diagram

Fishbone diagram is created by Japanese engineer and utilised as graphic brainstorming tools by providing an organised and systematic way of listing the inherent causes for a predetermined effect. With the systematic visual diagram, the possible problems are easier to be identified, along with the specific target areas to be improved. The main effect branches off smaller lines which represents the inherent causes. In DMAIC methodology, Fishbone Diagram is mostly used within Analyse and Improve phases. However, the listed causes generated by Fishbone Diagram are merely potential causes without the usage of measured data. Even so, Fishbone Diagram still can be used to ensure that no inherent causes are neglected (Keller, 2011).

Failure Mode and Effects Analysis (FMEA)

According to Stamatis (2003), Failure Mode Effect and Analysis is "a technique used to identify, prioritize, and eliminate potential failures from the system, design or process before they reach the customer". Based on the experience from the product process or design, FMEA is able to identify the inherent failure of the modes, which therefore enables the project to reduce the cost and time spent by designing the failure with minimum effort (Borror, 2009). The implementation of FMEA follows a set of steps:

1. Reviewing the process
2. Brainstorming potential failure modes
3. Listing potential effects of each failure modes

4. Assigning the rate of Severity: the severity of the impact of the results
5. Assigning the rate of Occurrence: the frequency of the event of failure mode happened
6. Assigning the rate of Detection: the probability of the failure being detected before it happens
7. Calculating the Risk Priority Number (RPN) for each effect by multiplying Severity, Occurrence, and Detection; then prioritising the failure modes
8. Taking action to reduce or eliminate failure modes with high risk

The priority for focus of the improvement can be determined by utilising this tools, as well as the decision for the priority of the risk and failure response plans. According to Friberg and Afanasyev (2011), FMEA enables documentation and standardisation of information as it gives good traceability of actions as well as systematic and brief communication tool for the actions which are going to be taken to prevent failure modes to happen.

Pareto Chart

The purpose of Pareto Chart is to provide the Six Sigma team with a general outlook of the most inherent defects and variation in order to focus on the area which has the biggest impact (Keller, 2011). As a tool to identify problems and its impact, Pareto Chart is mostly used within the Define and Analyse phases in DMAIC framework. In Pareto Chart, categories of interest are represented in vertical bar graph in a decreasing order based on each of its contribution against the measurement, where the measurement are mostly either quantity or cost. The quantity or cost as the measurement is presented along with the percentages, which are connected to a cumulative line of the addition of each vertical bars. Keller (2011) suggests that in order to present a distinctive problems to pinpoint on which problem the Six Sigma team is ought to put its focus on, it is necessary to aggregate the problems into few major categories instead of dividing them into too many categories.

B

Appendix B

B.1 Table of key activities, products, key players, and success factors for ideal vision in EPC projects

The table below is the complete version of Table 6.1 presented in Chapter 6, Analysis and Discussion. The table comprises of key activities, products, key players, and success factors for ideal vision in EPC projects based on empirical materials, both from the interviews and from the filtered case company's internal documents.

Phase (Rever, 2010) PM	6s	Stage	Key Activities	Products	Key Players	Success Factors (Sharma and Chetiya, 2012)
Initiating	Define	Project acquisition	• Feasibility study • Project organisation formation • Project launching	• Post bid Evaluation • Project award proposal	• Proposal manager • Direction/management	• Cross-functional organisation • Project choice and leadership • Project championship, staffing
Planning	Define	Project contract review	• Ensuring technical requirements are well defined and understood • Understanding acceptance criteria	• Final acceptance criteria	• Lead project engineer • Contract management officer	• Workflow management systems • Metrics and measurement
Planning	Define	Requirements documentation and management	• Defining scope of work, deliverables list, requirement management, Work Breakdown Structure (WBS) • Identifying requirement gap analysis	• Work Breakdown Structure (WBS) • Require Traceability Matrix	• Project manager • Quality manager	• Richt tools • Workflow management systems
Planning	Define	Compling Project Execution Plan (PEP)	• Producing detailed execution plan (EP) for each division • Identifying schedule and cost management	• Engineering EP • Procurement EP • Construction EP, etc.	• Interdisciplinary managers • Project manager	• Cross-functional organisation • Availability of resources
		Design, preparation, design requirements confirmation	• Ensuring adequate design input to start design execution • Verifying input	• Engineering drawing • Schedule detail engineering	• Engineering manager • Lead project manager • Control manager	• Cross-functional organisation • Right tools • Availability of resources

Executing	Measure	Design execution, verification, review, validation	• Ensuring alignment of designs • Interdisciplinary checking (review, verify) of desgin output documents • Functional testing for all equipment	• Engineering drawings • Data sheets Bill of material • Requisition, etc.	• Scheduler • Principal engineer Project owner	• Management commitment • Metrics and measurement
		Management and control of document	• Managing all the required documents • Ensuring access to and retrievability of documents	• Document control procedure	• Engineering manager • Document control manager	• Cross-functional organisation • Workflow management systems
	Analyse	Verification of requisition, T&C, cost, schedule	• Ensuring Request for Quotation (RFQ) meets contract requirements • Ensuring term & condition for purcase order and clauses are aligned	• Request for quotation & purcase • Purchase order	• Lead project engineer • Engineering manager • Procurement manager	• Supplier collaboration
		Expediting	• Ensuring and managing fabrication process and in time delivery materials transport • Inspecting and testing equipment	• Material receiving report	• Expediting engineer • Quality control inspector	• Supplier collaboration
		Evaluation of suppliers and subcontractors performance	• Evaluating technical and commercial capability of suppliers	• Suppliers evaluation report	• Procurement manager	• Supplier collaboration
		Material, fabrication, manufacture evaluation	• Ensuring adequateness of material handling procedures • Assessing fabrication environment and prcedures	• Fabrication procedures	• Procurement manager • Quality control manager • Expediting engineer	• Supplier collaboration • Availability resources
	Improve	Field document and field design control	• Ensuring field documents and designs are well-distributed	• Documents distribution procedures	• Document control officer • Engineering manager	• Workflow management systems
		Construction work	• Ensruing project activities follow procedures, WBS, and schedules	• Project deliverables	• Project manager	• Workflow management system • Work and organizational workforce • Availability of resources
Monitoring		Field inspection and non-conformance monitoring	• Storing calibration and testing notes • Evaluating conformance to requirements • Inspecting and reviewing construction work	• Calibration and testing notes • Inspection reports	• Quality control/assurance manager • Chief field inspector	• Right tools • Metrics and measurement • Management commitment
		Mechanical completion	• Collecting construction data record for each design documents • Registering non-conformance	• Design revision documents • Construction and installation reports	• Chief field engineer • Document control officer • Engineering manager	• Right tools • Metrics and measurement
Controlling	Control	Recording and document control	• Recording and checking data operation plant • Registering non-conformance	• Non-conformance and corrective action procedure	• Process engineer • Engineering manager	• Right tools • Metrics and measurement
		Project quality audit and operation control	• Ensuring and evaluating quality conformance activities from QMS • Reporting project progress report	• Project quality report • Daily, weekly, mothly progress repots • Project review report	• Internal audit team • Quality assurance manager • Project control manager	• Right tools • Metrics and measurement
		Cost and schedule control	• Recording data and progress controlling • Analysing variance and deviation • Re-allocating resource, taking corrective actions	• Engineering progress • Procurement progress • Earned value analysis	• Project control manager • Project control engineer	• Right tools • Metrics and Measurement • Resource availability • Management commitment

C

Appendix C

C.1 List of Interview Questions

C.1.1 Views on Quality Management in Projects

1. What are the **drivers** of **implementing** quality management/quality assurance in projects?
2. How do you ensure that all **quality standards** are **identified** and **applied** in accordance to **ISO 9001:2008** (i.e. ensuring that the project applies the defined processes), and quality control is performed (i.e. ensuring that deliverables fulfil quality objectives) in the project?

C.1.2 Define – Initiating and Planning

1. Defining project from client's requirements (mainly in engineering to procurement phase):
   (a) How are project goals, scope and specifications defined?
   (b) How is project schedule/timeline along with its milestone defined?
   (c) How are project budget and resources allocated?
   (d) How are requisition plan and project execution plan (PEP) prepared?
2. What do you think are the most important factors that need to be considered in project planning (in producing data sheet, drawings, vendor data, PEP, etc.)?
3. How important is management support in project planning? How do their roles contribute to project?
4. Based on your experience, what are the most effective and commonly used tools or methods to allocate project budget and schedule and to keep them on track?

C.1.3 Measure and Analyse – Executing

1. What do you think are the most important factors that need to be considered in project execution (also ensuring Engineering and Procurement go in parallel with Construction)?
2. What are the most critical requirements which is need to be fulfilled at each of the decision/project gate?
3. Based on your experience, what kind of measurement are normally used or do you think is suitable for gathering/recording accurate data from the project?

C.1.4 Improve – Monitoring

1. What do you think are the most important factors that need to be considered in project monitoring and control (particularly during the construction phase and after mechanical completion until final acceptance)?
2. How is measured data utilised to improve project performance during its rest project-cyle?

C.1.5 Control – Controlling

1. How are the predetermined tools utilised to keep the project on track and/or to detect any deviation?
2. Based on your experience, is there any project process or activity that in your opinion is less necessary when running a project? How do you think it could be improved?

C.1.6 Six Sigma in General

1. What are/were the (cost/benefit) considerations when deciding to implement Six Sigma or other similar quality improvement method?
2. How do you measure and improve Six Sigma projects in each Engineering, Procurement, and Construction phase?
   (a) Defining measurement
   (b) Implementing measurement
   (c) Improving performance based upon measured data
3. What are the benefits that most likely will be gained in implementing Six Sigma or other similar quality improvement method?
4. What are the constraints that most likely will be faced in implementing Six Sigma or other similar quality improvement method?