TURBOMACHINERY PROJECT MANAGEMENT FRAMEWORK IN OIL AND GAS INDUSTRY IN MALAYSIA

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This is for you: my beloved wife, children and mother, as well as my late father, who was the main inspiration behind this masterpiece.

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ABSTRACT

Turbomachinery is a crucial equipment for oil and gas (O&G) facilities. Therefore, efficient and effective management of turbomachinery project is very critical towards the overall success of any O&G project. Nevertheless, studies on turbomachinery project management are limited and only focus on overall O&G project execution. There is no established framework related to management of turbomachinery projects found in the literature although Petroliam Nasional Berhad (PETRONAS), the Malaysian national O&G company has procured more than 100 turbomachineries with some success and failure. Hence, this study is undertaken with the aim of developing a framework of turbomachinery project management in O&G industry. From a population of 11,354 O&G industrial players in Malaysia, intended sample is chosen based on sample size determination table and 95 percent confidence level. Through a survey on the sample of 183 respondents and expert focus group interview with five turbomachinery professionals with minimum 12 years of experience, this study finds that: turbomachinery is always identified under project critical path; problems in turbomachinery project management include turbomachinery process selection and configuration, availability of detailed vendor data and developing turbomachinery total cost of ownership (TCoO) or life cycle cost (LCC) ; and presence of client during kick off meeting, proper procurement strategy and tender plan, as well as well-defined project feasibility study and concept are expected to solve the aforementioned problems. Finally, using the combination of problem-solution bow-tie diagram and Critical Success Factors (CSFs) principle table, a framework of turbomachinery project management in O&G project in Malaysia consisting of 9 problems, 13 solutions and 43 CSFs are grouped into seven related factors: effective project management, human, internal management, technical and contract related, Original Equipment Manufacturer (OEM) dependency, progression and external related factors being developed. This framework would enable the decision makers to take appropriate actions in achieving the desired outcomes in turbomachinery project management, thus would lead to the success of turbomachinery project in O&G industry, which is prolifically known as the most expensive industry worldwide.

ABSTRAK

Mesin turbo dikenali sebagai pusat fasiliti minyak dan gas (O&G), justeru pengurusan mesin turbo yang cekap dan berkesan adalah sangat kritikal ke atas pencapaian kejayaan keseluruhan projek O&G. Walau bagaimanapun, kajian mengenai pengurusan projek mesin turbo sangat terhad, di mana kajian yang sedia ada hanya memberi tumpuan kepada pelaksanaan keseluruhan projek O&G. Tiada kerangka kerja yang berkaitan dengan pengurusan projek mesin turbo yang ditemui di dalam literatur walaupun Petroliam Nasional Berhad (PETRONAS), syarikat O&G Malaysia telah membeli lebih daripada 100 mesin turbo dengan beberapa rekod kejayaan dan kegagalan. Justeru, kajian ini dijalankan dengan matlamat untuk membangunkan rangka kerja bagi pengurusan projek mesin turbo dalam industri O&G di Malaysia. Dari 11,354 populasi pemain industri O&G di Malaysia, sampel yang dikehendaki dipilih berdasarkan jadual penentuan saiz sampel dan 95 peratus aras keyakinan yang ingin dicapai. Melalui kajian soal selidik ke atas 183 responden dalam kalangan pemain industri O&G dan temubual kumpulan tumpuan pakar ke atas lima profesional mesin turbo yang berpengalaman minima 15 tahun, kajian ini mendapati bahawa: mesin turbo sentiasa dikenalpasti di bawah laluan kritikal projek; masalah dalam pengurusan projek mesin turbo merangkumi pemilihan dan konfigurasi proses mesin turbo, ketersediaan data vendor terperinci dan membangunkan jumlah kos pemilikan (TCoO) atau kos kitaran hayat (LCC) mesin turbo; dan kehadiran pelanggan semasa mesyuarat permulaan, strategi perolehan dan pelan tender yang betul, serta definisi yang jelas tentang kajian dan konsep pelaksanaan projek dijangka mampu menyelesaikan masalah yang disebutkan di atas. Akhirnya, dengan menggunakan kombinasi prinsip gambarajah *bow-tie* masalah penyelesaian dan jadual rangka kerja CSF untuk melaksanakan pengurusan projek mesin turbo yang lebih baik dalam projek O&G di Malaysia yang terdiri daripada 9 masalah, 13 penyelesaian dan 43 CSFs yang dikelompokkan kepada tujuh faktor berkaitan: pengurusan projek efektif, manusia, pengurusan, teknikal dan kontrak, kebergantungan ke atas Pengeluar Peralatan Asal (OEM), kemajuan dan faktor luaran telah dibangunkan. Rangka kerja ini akan membolehkan pembuat keputusan mengambil tindakan sewajarnya untuk mencapai hasil yang diinginkan dalam pengurusan projek mesin turbo, lalu akan membawa kepada kejayaan projek mesin turbo dalam industri O&G, yang dikenali sebagai industri paling mahal di dunia.

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3D	-	Three Dimensional
ACG	-	Azeri-Chirag-Gunashli
AFC	-	Approved for Construction
AHP	-	Analytical Hierarchy Process
AIM	-	Aspiration Interactive Method
ALARP	-	As Low as Reasonably Practical
API	-	American Petroleum Institute
ASME	-	American Society of Mechanical Engineers
CAPEX	-	Capital Expenditure
CCS	-	Carbon Capture and Storage
CO_2	-	Carbon Dioxide
CSFs	-	Critical Success Factors
CV	-	Curriculum Vitae
EFA	-	Exploratory Factor Analysis
EOR	-	Enhanced Oil Recovery
EPC	-	Engineering, Procurement and Construction
FEED	-	Front-End Engineering Design
FEL	-	Front End Loading
FPSO	-	Floating, Production, Storage and Offloading
FTA	-	Fault Tree Analysis
GDP	-	Gross Domestic Product
HSE	-	Health, Safety and Environment
ITP	-	Inspection and Testing Plan
KMO	-	Kaiser-Meyer-Olkin
kW	-	Kilowatt
LCC	-	Life Cycle Cost

LNG	-	Liquid Natural Gas
MCC	-	Motor Control Centre
MMHE	-	Malaysia Marine Heavy Engineering
MoF	-	Ministry of Finance
MW	-	Megawatt
NEP	-	New Economic Policy
NPV	-	Net Present Value
O&G	-	Oil and Gas
OEM	-	Original Equipment Manufacturers
OPEX	-	Operating Expenditure
PAF	-	Principal Axis Factor
PCA	-	Principal Axis Factoring
PETROBRAS	-	Petroleo Brasileiro S. A.
PETRONAS	-	Petroliam Nasional Berhad
PMBOK	-	Project Management Book of Knowledge
PMI	-	Project Management Institute
PMT	-	Project Management Team
PPMS	-	PETRONAS Project Management System
ROI	-	Return of Investment
RRI	-	Relative Importance Index
SD	-	Standard Deviation
SGPMP	-	Stage Gate Project Management Process
SPSS	-	Statistical Package
SRS	-	Simple Random Sampling
TCoO	-	Total Cost of Ownership
UCP	-	Unit Control Panel
UK	-	United Kingdom
USA	-	United States of America
USD	-	United States Dollar
VDI	-	Vendor Data Incorporation
VDR	-	Vendor Data Review

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CHAPTER 1

AN INTRODUCTION TO RESEARCH

1.1 Background

Oil and gas (O&G) industry contributes to the Malaysian economic as one of the most important sectors by taking into advantages as being the most demanding, challenging and exciting engineering and technological advances which interests the engineers at large. In 2016, O&G has contributed to 14.5 percent of Malaysia Gross Domestic Product (GDP) and 14.7 percent towards the government revenue (PEMANDU, 2017). Petroliam Nasional Berhad (PETRONAS) as the Malaysia fully integrated O&G multinational company wholly owned by the Malaysian Government has become a consistent contributor towards Malaysia economy. According to PETRONAS (2017), the yearly contribution to the Federal and State Government of Malaysia from 2013 until 2017 were ranged from RM73.4 billion to RM42.7 billion per year, consisted of export duty, cash payment, taxes and dividends. The amount itself signify the importance of O&G industry towards Malaysia economy.

Similar to most of industrialised countries that depend on oil and natural gas (Salazar-Aramayo *et al.,* 2013), the country's O&G industry has developed from mere production of crude for export involving the front-end engineering design (FEED) of oil production facilities to the design and construction of chemical plants (Mehden and Al Troner, 2007). However, the decline of oil price since June 2014, which falls due to multiple factors (Lim and Rashad, 2015), has significantly brought a big impact towards the O&G industries worldwide including Malaysia. The O&G industries face one of the toughest periods in the history of O&G due to prolonged drop in oil prices

and fell below USD 50 per barrel from the peak of USD 112 per barrel (Zuoqian *et al.*, 2015), where the industry is undertaking control measure to collectively shape and execute a decisive and transformative response (Nurul A'in *et al.*, 2016) in order to persevere until the oil prices starts to pick up again.

The drop towards the low point of oil price have occurred three times for the past 20 years, with the lowest point of USD 9.80 per barrel back in November 1998, USD 36.60 per barrel in December 2008 and USD 40 per barrel in December 2015 (Armacanqui *et al.*, 2016). Based on the current world oil price hovering around USD 77 per barrel (OilPrice, 2018), it is indicating a sign of short term recovery with no guarantee of oil price will stabilise in near future. Nevertheless, the current oil price will allow some O&G projects which has been put on hold due to economic reasons (Armacanqui *et al.*, 2016) to be re-instated and subsequently allow more new projects to be implemented.

Looking at the Malaysian O&G practices, which are split into upstream and downstream sectors, the upstream is observed as the most critical sector (Martén *et al.*, 2015) to be improved in the aspect of project management implementation since the upstream sector is the first ever sector traditionally developed in the industry (PSAC, 2017). As per Petroliam Nasional Berhad (PETRONAS) (2016) definition; upstream sector covers the exploration, development, production, and Liquefied Natural Gas (LNG) business. As for the downstream sector, according to Feblowitz (2015) it can be classified into five categories: (1) Onshore Gas Processing Plant; (2) Onshore Gas Compressor Station; (3) Onshore Oil Refinery; (4) Onshore LNG Plant; and (5) Utilities Plant. Regardless to both sectors, turbomachinery is known as the heart of project management as the success and failure of the sectors operation is eventually determined by the turbomachinery delivery, one of the most critical equipment in any O&G facilities project (Schneider Electric, 2016; Deshmukh, 2017).

This is due to the fact that although major turbomachinery service provider or Original Equipment Manufacturer (OEM) in Malaysia, such as Rolls Royce, General Electric, Solar Turbines, Siemens, Dresser Rand and ManTurbo are recognised

internationally and based worldwide, major issues related to turbomachinery project management are still being recorded with the overall project delays will eventually lead to revenue losses to the project owner due to deferral of production as well as higher project cost (Josia and Anggono, 2015). These key issues that are related to project management of turbomachinery, have caused various high-profile problems of poor Front End Loading (FEL), cost and time overruns, numbers of variation order and changes during project execution, poor workmanship, quality, equipment delivery to site and overall project completion delay (Mohammed Saad, 2016; Emmanuel and Mounir, 2015). These have eventually led to the additional cost incurred and loss of business opportunity to the client side (Parker *et al.*, 1996) as well as cost impact on the O&G facilities project in Malaysia as a whole, where on the contrary, PETRONAS, as the client, should have a set of skilled specialist to review and assure the technicality portion of turbomachinery attributes (Emmanuel and Mounir, 2015) and specific project management framework in order to address the key issues while dealing with major turbomachinery OEM.

Since turbomachinery has been recognised being one of the long lead items during project executions as well as proven to be the most costly/expensive equipment (Heighes, 2013) which generally represents 25-35 percent of overall project material cost (Emmanuel and Mounir, 2015), there is a significant need to determine the necessary factors that are crucially required to further improve the management of turbomachinery project, whilst at the same time are capable of driving the O&G project towards success. These critical factors, integrating with the project management of various stakeholders of multi-disciplinary (including contractors) throughout the project life cycle, ranging from procurement, engineering, construction and commissioning stages (Robb, 2017; El-Reedy, 2012) will be able to solve high-profile problems and properly manage the turbomachinery projects in the O&G industry.

Based on various studies conducted (Pinto and Slevin, 1988; Fortune and White, 2006), it was recognised that the successful project implementation can be resulted from the application of critical success factors (CSFs), which consist of project management processes, practices as well as consistent application. The overall

input can lead to a greater project management performance (Tabish and Jha, 2011; Cooke-Davies, 2002). Due to difference in various type of projects as highlighted by Cooke-Davies (2002), unique industrial operations (Thorogood, 2000), cultural and environmental difference (Pinto and Slevin, 1988; Fortune and White, 2006), there is currently no list of CSFs that can be generalised to address all project situations (Ika *et al.* 2012). Despite it was identified through literature review that lists of CSFs have been derived for multiple O&G exploration and production projects (Ernst and Young, 2012; Boschee, 2012), currently there is a significant gap in terms of identifying the list of CSFs for O&G turbomachinery project, specifically in Malaysia O&G industry.

1.2 Research Questions

With the intention of improvising the performance of oil and gas (O&G) industry in Malaysia as a whole, by measuring performance from the perspective of the project management triple bottom line (TBL) principle as proposed by Project Management Institute (2008) and Linger and Owen (2010) consisting of cost, time and quality, the research question arose in line with the research gaps observed via this study are as listed below:

a) What are the current practices of turbomachinery project management in the O&G industry?
b) What are the problems in turbomachinery project management that affect the performance of O&G project as a whole?
c) How can the problems in turbomachinery project management be solved and what are the proposed solutions?
d) What are the critical success factors (CSFs) for better execution of turbomachinery project management in O&G industry?

1.3 Problem Statements

With a larger demand for gas and new technologies, which has made the oil and gas (O&G) industry becoming financially attractive (Falomi *et al.,* 2017), O&G project industry has become the focus of many studies around the globe, for instance Yahaya *et al.* (2012) who investigate the relational study of supply chain agility, competitiveness and business performance in the oil and gas industry. Doherty (2011) who identifies the economics, execution and management of complex offshore projects, whereas Martin (1998) and Boschee (2012) had determined the list of criteria for success in O&G industry. However, literature review focusing on the turbomachinery project execution, the most critical equipment in any O&G facilities project (Schneider Electric, 2016; Deshmukh, 2017) is missing, which demonstrates a big gap in between the literature especially when the critical success factors (CSFs) of properly managing the turbomachinery project are essential in assisting the O&G company, like Petroliam Nasional Berhad (PETRONAS), towards success in its overall project management.

Even though as mentioned beforehand that turbomachinery is the heart of any O&G facilities project, no academic study has been carried out pertaining to its practices. Most of the studies available around the globe focus on the overall O&G project execution, namely platform design and construction (Ernst and Young, 2012) with no interest to turbomachinery although it is observed as the most essential equipment, where the success or failure of the implementation of the turbomachinery project will have a significant impact towards the O&G overall project performance.

Therefore, it is seen by this study that Malaysia, and in particular PETRONAS, would need to develop a support base that can effectively and efficiently manage the turbomachinery project in O&G industry. This is based on the fact that during actual project execution, a lot of project challenges are faced by PETRONAS while managing the turbomachinery covering the whole project phase as defined by Eweie *et al.* (2012) starting from the conceptual design phase involving Original Equipment Manufacturer (OEM) selection, front-end engineering design (FEED) and detailed design (technical

specification, procurement, vendor data engineering review and incorporation, interface with disciplines, namely process, electrical, instrument, piping, structural, safety, equipment inspection and critical testing), construction (installation, pre-commissioning and commissioning) and finally the operation and maintenance of the turbomachinery (Nasir *et al.*, 2004).

Albeit PETRONAS is currently running 198 producing fields and 355 offshore platforms in Malaysia alone (PETRONAS, 2016), where based on the number of offshore platforms, more than 100 turbomachinery have been procured, there is no framework developed for the turbomachinery project management yet. This is because each turbomachinery Project Management Team (PMT) will do their own approach of management as a part of the solutions to solve problems within individual turbomachinery project without having specific guideline of CSFs for turbomachinery, although PETRONAS has established the PETRONAS Project Management Standard known as PETRONAS Project Management System (PPMS) (PETRONAS, 2009) that merely explains about O&G project management in general without governing any equipment procurement through specific CSFs.

It is the current practice in PETRONAS, where once project is completed, the lesson learnt of the project will be issued out, project will be closed, and PETRONAS will start all over again a new turbomachinery project from the scratch without having a well-documented set of CSFs to be referred to for the subsequent O&G project improvement. This is apparently wasting resources, knowledge and efforts by the project management team (PMT) as everything has to be done all over again since the database of turbomachinery project management is absent and no initiative is undertaken by PPMS to kick-start a study on establishing these CSFs. Therefore, it is important for a study to be carried out to develop a framework consisting of the problems, solutions and CSFs of previous turbomachinery project management collected from the lesson learned project so that it could be used as the guide and reference for succeeding turbomachinery project management undertaken by PETRONAS in particular.

The importance of CSFs for turbomachinery project management would lead to a proper overall project execution, as well as avoiding specific project from ended up with major problems. According to Ernst and Young (2014), in Asia Pacific alone, a total of 68 percent of O&G projects are facing cost overruns, 80 percent are facing schedule delays and 57 percent are having project budget overruns. The cost overrun may have a significant impact towards the company overall performance in terms of negatively affecting the CSFs of revenue and financial year performance as well as shareholders' expectation, which may deter investors in long run, and finally the specific project economic itself. Project delays usually resulted in higher capital expenditure (CAPEX), and the company might require longer period to obtain the return of investment (ROI) for the CAPEX that has been invested for the O&G projects. As mentioned by Doherty (2011), the average cost overrun on new O&G upstream construction projects is 35 percent, with the average schedule delay of seven months. The cost overrun was mainly contributed by various risks, which include insufficient engineering information and equipment delivery to construction site. Both risk elements will be heavily involved as part of turbomachinery project management in the O&G industry. Therefore, it is critical to determine the CSFs of the turbomachinery project management in O&G industry in Malaysia due to significant impact towards overall project delivery.

1.4 Objectives

The main objective of this study is to develop the framework of turbomachinery project management in oil and gas (O&G) industry in Malaysia. The objective can be successfully achieved via the following, which are outlined based on the research questions arose in the previous section:

a) Identify and define the current practices of turbomachinery project management in O&G industry
b) Investigate the problems in turbomachinery project management that affect the performance of O&G project

c) Propose solutions to the problems in turbomachinery project management in O&G project
d) Establish the critical success factors (CSFs) and development of the framework for better execution of turbomachinery project management in O&G project in Malaysia.

1.5 Scope of Research

Fundamentally, this study covers the scopes of both the upstream and downstream operations of the oil and gas (O&G) industry.

The turbomachinery project management is being selected as the main scope of this study since turbomachinery is the heart of any O&G facilities project, where its success or failure in any of the upstream and downstream operations affects the overall performance of the O&G project. A set of the upstream and downstream operations with both significant or non-significant problems of turbomachinery project management, such as delay, cost overruns and poorly constructed facilities, is selected as the main reference in establishing the framework for the management of turbomachinery project.

On top of that, for the purpose of developing this framework, it is paramount to address that the generic project management phases in O&G are focusing on: 1) conceptual; (2) feasibility; (3) detailed design; (4) material procurement; and (5) construction/start up following the suggestion by Alvarado *et al.* (2002), Eweie *et al.* (2012), Technip (2014) and Bjorn *et al.* (2005), where Project Management Body of Knowledge (PMBOK) 6th Edition with Ten Knowledge Areas is used as the main context of this study. This is very substantial in providing a clear picture of the current application of the turbomachinery project management in the upstream and downstream operations based on the world-recognised and established practice of

project management so that the significant of undertaking this study in improving the turbomachinery project management via the framework is apparent.

It is therefore substantial to underpin that this study is only limited to the turbomachinery project management of the O&G project facilities. It does not cover the turbomachinery application for other industries, such as power plant, utilities and others. The study is also limited to new equipment procured during whole project phase as defined by Eweie *et al.* (2012) from the conceptual design phase, front-end engineering design (FEED), detailed design, construction, installation and commissioning work, but does not cover the upgrading/retrofitting project for turbomachinery. The study does not does not cover the operation and maintenance phase of the turbomachinery equipment. In terms of equipment size, the study is limited to turbomachinery, which is within acceptable range for O&G facilities, which normally ranges between 1 Megawatt and up to 40 Megawatt per each gas turbine. It does not cover the larger industrial gas turbines of 60 Megawatt and above.

1.6 Significant of Study

This study is very significant to the oil and gas (O&G) industry in general and company in particular, for instance Petroliam Nasional Berhad (PETRONAS) in enhancing the current standard of procedure (SOP) for the turbomachinery project management during the equipment procurement as well as the installation and commissioning works. The driving motivation of the study is to avoid overall project cost overrun, schedule delay and budget overrun for turbomachinery project management in O&G projects in Malaysia. This study is able to identify and define the current practices in turbomachinery project management, investigate the problems that affect the overall O&G project performance, propose solutions and establish critical success factors (CSFs) before the framework for turbomachinery project management is developed. The framework developed by the study will be useful for future guidelines in managing turbomachinery projects and providing opportunities for others to expand the study to other industries or larger turbomachinery.

1.7 Structure of Thesis

In general, this study is structured into six chapters as the following:

a) Chapter 1 discusses about the introduction and background to this study content
b) Chapter 2 confers about the literature review supporting the research methodology of this study by covering the subjects of oil and gas (O&G) industry, its facilities, the project management of the turbomachinery based on Project Management Body of Knowledge (PMBOK) 5th Edition project stages, the critical success factor (CSFs) in general and finally CSFs for the project management of turbomachinery for O&G industry in Malaysia.
c) Chapter 3 elaborates about the research methodology adopted throughout this study
d) Chapter 4 discusses about the findings of this study based on the research questions, aim and objectives set beforehand
e) Chapter 5 confers about summary of findings and the framework validation
f) Chapter 6 concludes the study, where whether or not the aim and objectives of the study are fulfilled or vice versa and discusses the contributions of this study to the body of knowledge, limitations obstructing the completion of this study as well as the way forward for future studies to be undertaken.

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