OPTIMAL FLOATING PRODUCTION STORAGE OFFLOADING (FPSO) REVAMP PROJECT MANAGEMENT: THE EXECUTION PHASE MODEL DEVELOPMENT

BY

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DEDICATION

This doctoral study is dedicated to God Almighty for the grace and enablement to take up the challenge.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
APM	Agile Project Management
APM	Association of Project Management
BOCR	Benefits Opportunities Cost Risks
BOK	Body of Knowledge
CAPEX	Capital Expenditure
CFT	Call for Tender
CI	Consistency Index
CPI	Cost Performance Index
CR	Consistency Ratio
EIS	Environment Impact Statement
EPCI	Engineering Procurement Construction Installation
EPSRC	Engineering and Physical Sciences Research Council
FAHP	Fuzzy Analytic Hierarchy Process
FAT	Factory Acceptance Test
FEED	Front End Engineering Design
FEL	Front End Loading
FFSD	Full Field Shut Down
FID	Final Investment Decision
FPSO	Floating Production Storage Offloading
HAZID	Hazard Identification
HAZOP	Hazard Operability Plan
HSE	Health Safety Environment
HSE MS	Health Safety Environment Management System
HSEQ	Health Safety Environment Quality
ICT	Information and Computer Technology

IPMA	International Project Management Association
ISAHP	International Symposium on Analytic Hierarchy Process
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LTI	Lost Time Incident
MDR	Master Document Register
NCDMB	Nigeria Content Development Monitoring Board
O&G	Oil and Gas
O&M	Operations and Maintenance
OCS	Outer Continental Shelf
OIM	Offshore Installation Manager
OIMS	Operations Integrity Management System
OPEC	Organization of Petroleum Exporting Countries
OSD	Overage shortage Damage
PDB	Project Design Basis
PFD	Process Flow Diagram
PIC	Person in Charge
PID	Process and Instrument Diagram
PMBOK	Project Management Institute Body of Knowledge
PMI	Project Management Institute
PMT	Project Management Team
POB	Personnel on Board
PPE	Personal Protective Equipment
PRINCE2	Project in Controlled Environment2
PTW	Permit to Work
PVV	Pressure Vessels and Valve

QAQC	Quality Assurance Quality Control
RI	Random Index
ROS	Required on Site
ROV	Remotely Operated Vehicle
SCR	Steel Catenary Riser
STO	Shutdown Turnaround Outages
TAM	Turn Around Maintenance
TQM	Total Quality Management
TUCN	Total Upstream Companies in Nigeria
UFR	Umbilical Flowline Riser
VUCA	Volatile Uncertain Complex Ambiguous
WBS	Work Breakdown Structure

LIST OF APPENDICES

Appendix A: Questionnaire Survey

Appendix B: Interview Survey Guide

Appendix C: Ethical Approval

Appendix D: AHP Analysis

Appendix E: Past Project Close out Extract (Case study 1)

Appendix F: Past Project Close out Extract (Case study 2)

DECLARATION

I hereby declare that the study as presented in this thesis is original and to the best of my knowledge. I can also confirm that neither a section nor the completed thesis has been submitted for another academic qualification in a different institution of learning. All secondary data and information used in the study have been appropriately acknowledged and referenced.

ABSTRACT

In a bid to realise production targets and operational efficiency from ultra-deep offshore areas where the world's oil and gas reserves are situated, the Floating Production Storage Offloading (FPSO) asset is deployed in many parts the world, being the most efficient production means. Judging, especially, from health safety environment performance indicators, the major multinational oil and gas producing organizations is perceived to pursue operational excellence, yet there are indications of unsatisfactory revamp project management performance in the literature. Revamp projects are sanctioned to assure asset lifecycle and improve production performance. Some major multinational oil and gas producing companies have customised the stage-gate project management approach from theory for revamp projects realisation. However, the stage-gate framework, which is generic, tends essentially towards major, capital, or new built projects from the contractor perspective. Since the theoretical approach is not tailored specifically to revamp project development, the application of the stage-gate approach by the oil and gas producing organizations (client or sponsor) perspective therefore does produce optimal results.

The aim of this study is to develop an optimal FPSO revamp project management model from the oil and gas operating company perspective at the execution phase. To address the problem of underperformance in this research, pragmatism research philosophy and the mixed research method, comprising five case studies, four from major multinational oil and gas corporations operating in Nigeria, and a group of oil and gas revamp project experts from across the world was utilised. A panel of experts with over 15 years of experience in revamp projects were purposively selected from each case study. Questionnaire and interview feedback from the respondents were screened for optimality with the use of the Delphi technique to avoid bias in predicting the future revamp project management performance.

The research findings identified four critical criteria for revamp projects - engineering, pre-fabrication and construction, site installation and pre-commissioning and commissioning; nine sub criteria comprising project scope, procurement, cost and schedule, risk, human resources, Health Safety Environment Quality (HSEQ), integration, knowledge, and stakeholder management as well as two compensatory project management options - Lean and Agile project management approaches that can be infused into identified critical knowledge areas within the stage-gate project management model for attaining optimal FPSO revamp project development.

A four level, three steps Analytic Hierarchy Process (AHP) analysis of the research data obtained from the respondents in this research was used to make group decisions concerning FPSO revamp project management for the execution project phase. The study confirms that project management within FPSO asset revamp projects often fail due to uninformed decision making, rather than the hitherto suggested non-compliance with project management theory. It is also revealed that Lean is preferred to Agile Project Management which, seemingly, is the most appropriate from contemporary perspective but with little acceptance in actual practice for revamp project performance improvements.

The research has developed, validated, and tested the proposed optimal project management model from AHP – multi criteria decisions by expert professionals working for major multinational oil and gas companies operating within and outside Nigeria. The research also demonstrated that most of these operating companies and revamp project experts from all over the world are guided by the same ethics, procedures, and theoretical project management frameworks. The findings from this research are reflections of global rather than regional perspective of the industry and therefore, the case studies selected from major multinational oil and gas companies operating in Nigeria does not invalidate the outcomes of the research.

CHAPTER ONE

Research Overview

1.1 Introduction

This chapter introduces the background and aim of the research. It gives an insight into the motivation for the research and defines the objectives leading to the research aim. The chapter also identifies a strategy to achieve the objectives of the research and provides clues to the expected results of the research, as well as the contribution to the body of knowledge for project practitioners and the oil and gas industry.

1.2 Research Background

At the beginning of offshore oil and gas production in the late 1940s, all oil platforms were situated on seabed in shallow waters greater than 100m in depth and the products were exported via shuttle tankers or pipelines. However, as oil exploration moved into deeper waters in the 1970s, Condeep concrete platforms and floating production systems began to emerge. Early Condeeps were mainly built in Norway with a few constructed in the UK (Oladehinde, 2019; Steed, 2014; Gordon, 2012).

The focus of this research is on the floating production system called the Floating Production Storage and Offloading (FPSO) unit. The FPSO is a converted tanker, or a newly built vessel platform facility secured to the seabed by either multiple anchors, a single point mooring called a turret, or by a dynamic positioning system. This offshore production asset is used for processing well stream hydrocarbons fed through flexible pipes from multiple seabed's well formations and/or fixed platforms (Oladehinde, 2019; Gordon, 2012; Oil and Gas IQ, 2019)

As the name implies, this offshore facility produces, stores and offloads crude oil and gas, mainly through pipelines to tankers and to shore for export and further processing into desired end products. Products from FPSOs include crude oil, liquefied petroleum gas (LPG) and liquefied natural gas (LNG). Early FPSOs were mainly built by converting ocean-bound crude oil loading ships otherwise called tankers and the first FPSO, Shell Castellon, was built by Shell in 1977 to operate in the Mediterranean Sea (Oladehinde, 2019; Gordon, 2012; Oil and Gas IQ, 2019).

The worldwide growing demand for more cost effective and reliable methods for deep-water and offshore oil and gas production has led to the demand for the Floating Production Storage

Offloading (FPSO) unit as the preferred facility for deep offshore oil and gas production. This is because FPSOs are currently the most economical and viable option available (Oladehinde, 2019; Muspratt, 2018; Love et al., 2014; Gordon, 2012; Steed, 2014).

With the world's oil reserves situated in ultra-deep offshore areas (Mishar, 2012), and the global quest to reduce production costs and eliminate all forms of wastage, it has become imperative for sustenance and improvement in oil and gas production for more attention and energy to be invested in revamping existing FPSOs, rather than constructing new ones (Khakzad & Reniers, 2018).

Although FPSOs are being deployed all over the world to achieve desired oil and gas production targets from remote offshore locations, the Environmental Impact Statement (EIS) of the Outer Continental Shelf (OCS) of the Gulf of Mexico shows that the United States, a major stakeholder of crude oil, is not disposed to the deployment of FPSOs due to unfavourable weather conditions such as hurricanes (IEA, 2018; Ross, 2003; OPEC, 2018).

Nevertheless, as a result of the increasing demand for oil and gas globally (Guo & Ghalambor., 2012; Sales et al., 2012; Lorincz, 2008, cited in Badiru & Osisanya, 2013), there have been corresponding improvements in technology and huge capital investments by governments and operators within the oil and gas industry. In Nigeria, for example, the major oil corporations – Shell, Agip, Total, ExxonMobil, and Chevron – have at least one FPSO in operation offshore Nigeria. This development is not unconnected with the business gains that an FPSO offers. These include an overall reduction in production costs, the elimination of the long pipeline distance from offshore to shore, the ease of exporting products from offshore, the higher life of field returns compared to conventional fixed platforms, the ease of temporary relocation during adverse weather conditions, and the permanent deployment of the FPSO to a new field following field abandonment (Oladehinde, 2019; Steed, 2014; Gordon, 2012).

In December 2018, Total Upstream Nigeria Limited (TUPNI) commissioned the EGINA FPSO Oil Mineral License (OML) 130. This was built at a cost estimate of over $3 billion, sitting on a water depth of 1.7km, with a production capacity of 200,000 barrels per day, and 2.3 million barrels of crude oil storage. In Australia, Shell launched an initiative to construct the first Liquefied Natural Gas (LNG) FPSO or FLNG (Floating Liquefied Natural Gas) platform (Steed, 2014) – The Prelude ($10 billion investment). This initiative aimed to reduce the need to operate pipelines for the delivery of gas to the shore, thereby driving down the overall cost of production (Offshore Post, 2015).

Records indicate that nearly 200 FPSOs are currently in operation around the world and over 65 are planned to join the fleet of operating FPSO by year 2025 (Oladehinde, 2019; Offshore Technology, 2019; Gordon, 2012). The incentives in favour of the FPSO asset point to the fact that there are high prospects ahead with respect to oil and gas deep-water production (Steed, 2014). Therefore, care and attention are required by the operating companies and indeed all stakeholders in the industry to harness the desired gains.

In Nigeria, there are at least seven FPSOs currently in operation, with nine in Africa as a whole (Offshore Technology, 2019). Almost all these FPSOs are either fully or partly operated by multinational companies. This statistic points to the fact that, although these companies operate in different regions and localities, they possess a good mix of project management standards and practices, with high levels of staff strength that can meet their business objectives (Ocheing et al., 2018).

To maintain the optimal performance of an FPSO, revamp projects are vital. Revamp projects can simply be described as a complex mix of both new construction and modification projects within an existing facility under live or production shut down modes. Revamping projects help to ensure the functionality of installed equipment, including the need to repair or replace defective components or integrate additional components into the existing facility. For this to happen, a plant shut down is usually incorporated into the wider project plan.

According to Whittington and Gibson (2009), revamp projects in the industrial sector have Shutdowns, Turnaround, Outages (STO) as a subset. The authors added that, combining multiple projects and maintenance work together in a single project is complex and poses a serious problem to manage, and a lingering set back with this type of project is that research has barely been carried out in this field.

Additionally, the FPSO is a manned facility with between 150 to 200 personnel on board (POB) for an average-sized vessel. It carries out construction-type activities while producing and storing huge volumes of hydrocarbons at remote offshore locations. This increases the risks during the implementation of revamp projects, although the oil and gas operators and stakeholders have very strict regulations for operating FPSOs, especially during revamp (brownfield) or upgrade projects, to maintain and ensure the desired annual production forecast is met (Whittington & Gibson, 2009).

According to Suardin et al., (2009) fire and explosions are the major potential hazards for FPSO installations in operation and pose a threat to the health and safety of personnel, assets, and the environment. FPSO assets are used for achieving production targets; they represent a huge investment designed for a specific life span and revamp projects aid the sustenance of oil and gas production on FPSOs by ensuring that production targets are met, thereby ensuring optimal returns on investment. However, all the above positive indications are not without the attendant operational hazards that may cause significant impact to humans, the environment, and assets if an incident occurs.

According to Offshore Technology 2019, Africa currently favours the utilisation of FPSOs. Therefore, a focus on Africa, specifically Nigeria in this case, is timely and appropriate for the future of oil and gas development and the findings of this research would significantly address a global industry challenge and contribute to proposed future projects, many of which as seen in Table 1.2 Many future projects around the world have been planned, announced, and are scheduled to be in operation by 2025 (Offshore Technology, 2019).

The fact that a typical revamp project is comprised of a series of complex steps and stages, coupled with the limited information available in the literature concerning FPSOs, it becomes necessary that this research focus on a specific aspect of the revamp process rather than the entire process itself. This will ensure that the results of this research can be precise and detailed.

With this in view, the focus of this research will be on the revamp of topside facilities of the FPSO. This will include the replacement of component piping and other appurtenances including associated tertiary supports, pressure vessels and valves (PVV) that have lost their integrity.

An intervention of this scope requires a full field facilities shutdown (FFSD). Project managers and stakeholders are usually very interested in the management and realization of such projects from start to finish. Another factor is that the FFSD means oil production deferment, which, in turn, impacts financial accruals- a vital link in the overall supply chain.

1.3 Research Problem

Oil and gas remain major global sources of energy supply and are major contributors to export and foreign exchange earnings for countries endowed with these natural mineral resources (Agbonifo, 2016; Akinyele, 2010; OPEC, 2018).

The huge capital requirements for building an FPSO and the economic importance of oil and gas resources to governments, operating organisations, investors and indeed all stakeholders involved in production, are evident in the literature. Revamp projects remain a globally acceptable means of driving organisational performance by operators after the FPSO has been commissioned and is producing at a location offshore (Walkup & Ligon, 2006).

According to Obiajunwa (2007), following functional defects, corrosion and statutory requirements, there is a time when the entire facility must be shut down for necessary repairs and Turnaround Maintenance (TAM). Irrespective of the fact that FPSOs have been in existence for over 40 years and are the most efficient means of offshore oil and gas production, there is limited research information regarding revamp project management and the performance of FPSO plants in the public domain (Love, 2011).

The results of an internet search using the under listed keywords indicated either ongoing or completed oil and gas projects in the public arena:

a. Revamp, retrofit, life extension, brownfield, upgrade, rehabilitation, expansion, and modernization projects.
b. Capital, major, or mega projects
c. Upstream and downstream sector
d. Oil and gas projects
e. Offshore and onshore projects
f. Floating Production Storage Offloading (FPSO)
g. Maintenance, modification, and installation
h. Shutdown, Turnaround Outages project

There are more readily available records of projects such as refinery upgrades in the downstream of the oil and gas sector than there are for revamp and expansion of upstream assets worldwide. Also, the midstream pipeline networks and crude oil loading tankers for transporting crude oil and gas are more plentiful than the upstream sector revamp of FPSO in service. Equally, there are records of major, capital, grassroots, or greenfield projects for building new FPSOs or conversion of tankers into FPSOs than upgrading existing FPSO in operation.

Another fact that further complicates upstream revamp projects is that when the project management approaches used by major projects with large capital outlay in the oil and gas industry yield unsatisfactory performances, there is very limited publicity. Earlier researchers have opined that a failure to deliver oil and gas mega-projects within budget estimates and schedules can often generate negative publicity at an international level, and because of this, organisations are careful when disseminating information that may have the potential to negatively impact stakeholders' perception of their ability to meet project projections (Love, 2011). According to Love, et al., (2014) new build FPSO projects are susceptible to schedule and cost escalation of up to 20% in cost, and delivery delays of up to six months are common, mainly due to rework from design and construction shortcomings.

Many organisations are slow to accept that gaps and challenges exist within their systems and processes, because they don't wish to give their stakeholders the impression that they are complacent and irresponsible. Acceptance tends to set in until the problems become too obvious. Then, the existing practices are reviewed for improvement opportunities (Love et al, 2011). This contributes to the information gap as certain information that could be instrumental to avoiding the recurrence of similar incidences elsewhere is not made available to all.

In a study conducted to assess the least successful types of projects, the process restructuring and reorganisation type of projects (in which revamp projects belong) was among the least successful projects with a record of 24%, with the penultimate category being the modernisation of IT, including system integration projects, with a record of 34% (Buganova & Simickova, 2019). These overruns and delays pose uncertainties for project sponsors, the contracting community, and financial institutions alike (Walkup & Ligon, 2006; Boatright, 2006; Ajayi et al., 2010; Oladokun et al., 2010; Sejebor, 2016; Mckenna &Wilczynski, 2006; Meyer 2014; Rui et al., 2017; Merrow 2012; Balow, 2000; Elinwa & Uba, 2001; Aibinu & Odeyinka, 2006; Derakhshanalavijeh

&Teixera, 2012; Saidoun, 2015; Whittington & Gibson, 2009). One can only hope that project underperformance is not worse for FPSO revamp projects. However, the questionnaire and interview surveys in this research hope to provide insights regarding the lack of FPSO revamp information in the public domain.

1.4 Research Gap and Rationale

The stage-gate project management framework exemplified in PMBOK guide, of which the major multinational oil and gas organizations leverage upon for all project development regardless of region where the project is situated, is structured for greenfield or grassroot capital, major or mega projects. This is from the perspective of the contractor and not the client. Therefore, adopting the stage-gate for brownfield or revamp projects with relatively lesser budget outlay from the operator or client perspective is a potential source of project management underperformance.

The PMBOK guide does not give priority to the executing process group to contribute towards project management constraints of scope, risk, cost, and schedule. It is evident from literature and practice that cost, and schedule equally make up the component of iron triangle. It is, indeed, the contemporary performance indicator for project management success. PMBOK guide identified six knowledge areas that are critical for successful project delivery: project quality management; procurement management; communications management; human resources management; stakeholder's management and integration management. A further four knowledge areas - project scope management, cost management, time management and project risks management are classified under 'other' knowledge areas and are supposedly catered for through project integration management: one of the vital six knowledge areas (PMI, 2013). However, this assertion is not overtly true for revamp projects in the oil and gas industry, as project performance from reviews of the oil and gas literature indicates that project scope management, cost and time management are key parameters for successful project management delivery. Since these important knowledge areas are not specifically mentioned in the stage-gate process in the executing process group, practitioners are not obligated to satisfy these requirements, therefore, there is no standardisation nor are there any definite authoritative recommendations from theory. Project managers and project teams therefore apply experience, scalability, and discretion to their decisions. This development is a gap in the research and could potentially be linked to the underperformance of oil and gas revamp project management during the execution phase. Therefore, an opportunity to examine closer the executing process group by the relevant construction function would potentially amount to gain in project performance.

Also, project values and improvement as per literature is assumed to have been fully implemented during the first three (FEL) stages of project development and therefore, seeking improvement during the execution phase may not yield significant result. This assertion is a divergent viewpoint compared with continuous improvement which is timeless, especially in the case of revamp projects with changes and uncertainties in the current dynamic business environment. Seeking performance improvement at all stages including execution phase is very promising.

Why the Execution Phase of Project Development for this Research?

There are several reasons why this project focuses on the execution phase:

1. This phase produces the finished product of the project prior to start-up and operations. It provides an opportunity to assess the effectiveness of the Front-End Loading (FEL) processes and to explore additional opportunities for improvement. Although, during the FEL phases, the five process groups are meant to be deployed for assuring optimal performance, they are not given the requisite attention due to inexperience, especially of newer oil and gas operators (Mishar, 2012) and potentially due to complacency on the part of the older operating organisations.
2. The execution phase attracts approximately 50% of the total project cost. Therefore, savings in this phase are a significant contributor to the overall success of the project.
3. The execution phase is typically on the critical path of project delivery. It is associated with full facility shut-in which implies oil and gas production deferment during which period no revenue comes into the coffers of the company. Therefore, maintaining the approved shutdown timeline, ensuring no schedule slippage, and striving for an earlier restart are very important to all stakeholders.
4. The execution phase employs the largest amount of manpower and thus it is an ideal opportunity for sharing lessons learned and, by so doing, adding to the project management body of knowledge.
5. This phase provides the best opportunity for the project constraints or knowledge areas and associated project parameters to be validated and tested for optimal revamp project performance by professionals in the field.

Although the stage-gate approach is robust enough to support project lifecycle, two major assumptions that do not support revamp project development are as follows: project scope is fully defined prior to start of the project and project development follows a sequential workflow as planned in the early stages. Most projects do not go by this theory, and it is at variance with revamp projects., Though project management theory provided for scalability or 'tailoring' to meet specific requirements, they may potentially be overlooked or not given the due attention and therefore lacks standardisation in the approach.

1.5 Research Questions

This study seeks to answer the following research questions:

i. Are there documented records and peculiarities in FPSO topside revamp project performances or defined management approaches available in the public domain?
ii. How is the current project management performance of FPSO revamp project executions measured by major oil and gas producing companies?
iii. Can tested contemporary project management approaches be applied to FPSO revamp project management during execution phase for optimisation?
iv. Can an optimised FPSO revamp project management approach be modelled and deployed globally during the execution phase?

1.6 Research Motivation, Scope, and key Constraints

The motivation for this research stemmed from the fact that the oil and gas industry is perceived to have standardised project management systems and generally pursues operational excellence in its processes (PwC, 2013; Mc Creery, 2014; EY, 2015; Rockwell, 2015). However, the existing project management systems and models backed by classical project management theory have challenges when associated with delivering revamp projects satisfactorily. At current stage of project development and growth, it is therefore imperative that the oil and gas industry should close the gap between theory and practice for performance sustainability. According to Zuofa and Ocheing (2017), projects need to be documented, analysed, and utilised to develop a standard execution model for use and applied to similar projects in future.

It would also add value, especially, as a practitioner in the industry, to engage with other experts in the field to reach a consensus regarding the remote and immediate real-life challenges of FPSO revamping projects and offer practical solutions to improve the project management approaches. This will allow for the attainment of optimal performance to the satisfaction of the customer and all stakeholders in the oil and gas industry.

Research Scope

In other to stay focussed on this research, the following scope has been defined:

- Project type: Specific to revamp otherwise known as brownfield project development.

- Industry and Asset: Limited to Oil and Gas, Floating Production Storage Offloading – topsides facilities only and not subsea facilities.

- Project Phase: Execution phase of project development only and not the Front-End Loading and operation phases.

- Organisation: Oil and Gas Producing (Client or Sponsor) and not the services or Engineering Procurement Construction Installation contractor.

- Case Studies: Four multinational (regional) and one international group (LinkedIn) of experts experienced in FPSO revamp project development.

Research Constraints

Identified constraints in this research include the following:

- Scarce literature on revamp project management in oil and gas industry in the public domain.

- Limited experts experienced in revamp project management.

- Assess restriction to project documents due to strict policy on data and information management by the respective multinational case study organisations.

- Cumbersome data and information gathering means from multiple case studies and extra cost.

- Completion schedule impact due to COVID-19 pandemic in 2020.

1.7 Aim and Objectives of Research

The aim of this research is to develop an optimal process model for managing FPSO revamp topside projects during the execution phase.

To achieve the research aim, the following objectives have been defined:

I. To investigate the current approaches used by oil and gas companies to manage FPSO revamp projects globally from the literature.
II. To identify the major work activities and attributes of revamp projects with significant influence on project management performance.
III. To critically analyse and evaluate other project management theories and approaches for application to revamp projects and develop a theoretical basis for new model development at the execution phase.
IV. To develop, validate and test the proposed optimal FPSO revamp project management model based on the applicable theories and approaches.
V. To develop a measurement tool, performance monitoring framework for the new model development and, recommendations based on the study.

1.8 Outline of Thesis

Presented in this study is an eight-chapter thesis outlined for better understanding of the sequence an activity by the researcher for actualizing the aim of the study.

Chapter 1 provided an overview of the significance of the FPSO in the oil and gas industry and its revamping project performance while in service at offshore location. Also, the motivation for the study and the objectives leading to the realization of the research aim has been highlighted.

Chapter 2 will contain the literature review with a view to achieving the objectives of the study. The review will cover the sphere of revamp project management performance as well as the opportunities for improvement and sustainability.

Chapter 3 will focus on the Specific, Measurable, Achievable, Realistic, and Time bound (SMART) methodology adopted for the research. Building upon pragmatic research philosophy, the researcher will progress by making choices and the justifications for the research method, strategy, and technique for the study.

Chapter 4 is about the first of the empirical chapters in which data will be collected and analysed through the Delphi method involving the questionnaire and interview survey of experts in the field. Also, to be highlighted are the analysis of two completed FPSO revamp projects close-out reports to triangulate the data collected from the experts.

Chapter 5 will dwell on modelling development; it is the second empirical chapter and will give an insight into the Analytic Hierarchy Process (AHP) considered by the researcher as appropriate tool for data collection and analysis when challenged with multi criteria decision making in a complex real-life situation the FPSO revamp project development. Also, in this chapter, the as-is and to-be model design will be provided. Again, the performance tool structured from the study and, the control framework for the new proposed model developed.

Chapter 6 will contain the AHP data analysis for all the case study companies or groups and describe the activity flow for arriving at the optimal FPSO revamp project model development, validation, and testing results. Here, the goal, criteria, sub criteria and contemporary project management alternatives will be highlighted.

Chapter 7 will be centred on the discussions arising from the study. It will include the findings, challenges, and surprises. It also includes the relationships between practice, research, and theory in the field of project management performance.

Chapter 8 will highlight the recommendations for continuous improvement in FPSO revamp project management. It will also indicate areas for future research advancement in the oil and gas sector and for the general project management body of knowledge. The researcher will also provide the justifications for the usage of the new proposed model for sustaining excellence in revamp project management performance.

1.9 Summary

This chapter has briefly traced the evolution of oil and gas production from offshore installations to the next frontier of oil and gas production from ultra-deep offshore locations, where the bulk of this natural resource resides.

Looking into the future, the Floating Production Storage and Offloading (FPSO) asset would potentially continue to be the most efficient and cost-effective floating production system.

Therefore, attention should be given to facilities revamp on FPSO topsides for sustenance and for meeting the increasing global need for oil and gas as major energy sources.

In addition, this chapter identified gaps in the industry approach in managing FPSO revamp projects, which are causal factors militating against optimal revamp project performance. The chapter also provided insights into the motivation for the research. Four research questions were posed, and the research objectives that will drive this research and achieve the research aim of optimal FPSO revamp project management model development were outlined.

The proposed model development is focused on FPSO topsides segment during the execution project phase. It is intended to be deployed by project practitioners in the oil and gas industry. In subsequent chapters of this thesis, the strategy for actualising the aim and objectives of this research will be discussed further.

CHAPTER TWO

Literature Review

2.1 Introduction

This chapter summarises the literature on the evolution of oil and gas project management performance, emphasising FPSO revamp project management during the execution phase. It provides insights into the peculiarity of revamp projects and examines current project practices of major industry players relative to the theoretical foundations of project management. The chapter equally reviews past project management practices relative to the present volatile, uncertain, complex, chaotic, and ambiguous global project environment, to identify opportunities for performance optimisation in current oil and gas revamp project management approaches.

2.2 Theory, Evolution and Practice of Project Management

The foundation of project management theory was indistinct from the history of the technique and profession until the articulated collection of best practices drawn from major engineering projects in North America in the mid-twentieth century (Engwall, 1998, cited in Garel, 2013). Some earlier researchers argued that the theoretical foundation of project management is closely tied to the hard paradigm (referring to a positivist viewpoint). However, there have been very few justifications for this claim (Pollack, 2007). Other researchers, on the other hand, argued it is tied to the soft paradigm. The hard paradigm often relates to strict guidelines or methodology and objectivity, while the soft paradigm emphasises contextual importance over objectivity (Pollack, 2007). The existence of either paradigm creates the possibility of mixing them with respect to the objective and subjective dispositions of specific project characteristics. This requires process optimisation where real-life problems are carefully structured and logically solved to the satisfaction of all stakeholders.

As a core business discipline, project management is believed to have been founded when its principles were applied in the management of the US missile programmes. Its origin is also linked to the establishment of project management professional institutions in the US and Europe in the seventies. Since then, the field has evolved into a broader project management perspective through the works of researchers like Morris and Hough (1987) and Pinto and Slevin (1988). However, project management was dominated by technocratic and rationalistic viewpoints of traditional project management concepts despite the increased popularity and importance of projects. This conceptual framework remained relatively static until it was criticised for its inadequacies in addressing issues in practice, alongside a largely non-existent track record of previous projects (Koskela& Howell, 2002; Sahlin-Andersson & Soderholm, 2002; Morris et al., 2011; Garel, 2013; Packendorff, 1995 cited in Svejvig& Anderson 2014).

Modern project management has been described as a tool for responding to or initiating changes (project-based management), emphasizing the use of tools and techniques from the execution phase to the project initiation and design phases." The emphasis for project management now is to start with attention to a project's needs and total risks to anticipate the potential problems and shrink the risks" (Barnes & Wearne, 1993 cited in Stretton, 2007, p 13). This thinking is quite appropriate because mitigations to identified problems applied to the planning at an early stage can prevent occurrences that could negatively impact project performance.

The concept "management of projects" was coined by Morris (1994) to reflect the need for people in a business environment to manage projects through project lifecycles for successful project delivery. However, project management has evolved across various industries worldwide and become of great economic importance to organisations. It has been successfully utilised for organisational restructuring, and as a management model (Winter et al., 2006; Turner et al., 2010; Garel, 2013; Bakker, 2010 cited in Svejvig & Anderson, 2014).

Regardless of the evolution, project management still involves two main theoretical traditions: the engineering sciences, including applied mathematics, and the social sciences. These disciplines develop and validate the frameworks that enable the emergence of project management theory. Lindkvist et al. (1998) argued that traditional project management has a structure that limits it from fully understanding the peculiarities in many projects. Its practice hinges on the PMI guide, which provides a summary of project management theory and principles. The PMBoK Guide (2013), among other features, highlights processes and constraints now known as 'knowledge area'. However, based on modern practices and current realities, the assumptions in the stage-gate relating to the predictability of events have been challenged. This has consequently given rise to competing theories, which is the focus of this research.

The oil and gas industry, to date, has project management frameworks that are tied to the classical project management concept exemplified in the PMBoK Guide. However, modern approaches labelled 'rethinking project management' have been gaining momentum since the mid-1980s. Notwithstanding, research in this new concept is still evolving, despite the dominant classical and often contradictory views (Garel, 2013; Winter et al., 2006, cited in Svejvig& Anderson 2014). On the one hand, classical project management comprises a simple ordered workflow that focuses on actuality, measurability, and controllability. On the other hand, rethinking project management showcases repeatability, adaptability, changes, complexity, and human relations and lessons learned. Nevertheless, the temporary nature of projects has remained unchanged for both project management concepts (Garel, 2013; Svejvig& Anderson 2014).

Although classical and modern project management concepts seem essentially divergent, they have been utilised under different frameworks and methodologies to execute real-life projects with sub-optimal performance records. Since all projects come under different classifications and have unique features and risks that can impact their cost and schedule (Buganova&Simickova, 2019), applying a holistic project management concept for optimal performance remains a challenge. Therefore, it is pertinent to have considered a review of the specific project at hand (Turner, 2007 cited in Garel, 2013) to integrate applicable features of both classical and rethinking project management approaches for overall project performance improvements (Almarar, 2019). This justifies the appropriateness of this research's objectives in the pursuit of continuous improvement in project performance in the oil and gas industry.

Project management performance has been linked to success factors summarised under competence, coordination, methodologies, tools, and techniques (Radujkovic & Sjekavica, 2017). However, Ahmed (2011) found six success factors for Engineering Procurement Construction project management execution in Kuwait's oil and gas industry. They are time, cost, scope, communication, human resources, and integration. Therefore, adequate care is required to identify the critical success factors amongst the applicable project management techniques and principles to suit specific project types and characteristics to ensure optimal project performance. The UK Engineering and Physical Sciences Research Council (EPSRC) funded a research network on rethinking project management (2004-2006) and suggested five research directions: project complexity, stakeholders, value, conceptualisation, and knowledge to further improve the body of knowledge on project management (Winter et al., 2006). Also, the agility theory is relatively modern and relates to the adaptability of the project team's actions and reactions to events and occurrences throughout a project's lifecycle. The agility theory relates to three parts of performance: First, the holistic performance of the project team and not just the effectiveness of a method or practice. Secondly, agility is seen as a combination of factors spanning the organisation, team, and the project's internal and external factors. Thirdly, it is possible to measure the performance level using two factors: rapid planning change and active customer involvement (Conforto et al., 2008).

This research topic is consistent with the broad classification of project management research areas from the literature. It focuses on activities and criteria instrumental to project management performance. It strives for optimisation by modern project management mindsets described by and deployed essentially for technological optimization. Also, this research aims to enhance the body of knowledge through a simple model development. This is essentially necessary due to the need for demonstrated researcher reflexibility in at least one of the five directions in which the current foundations of project management need to develop relative to the evolving theory for practice, as recommended by the rethinking project management network. Additionally, it captures at least one of three key discussion sections covering the evolution of project management: the conceptualisation of organisational project management capability, and practitioner experience in developing organisational project management capability (Winter et. al, 2006; Crawford, 2006). This research work describes the case of mix paradigm - pragmatism to proffer an optimal solution to the current project management challenges in the oil and gas industry during the execution stage.

2.3 Project Management Processes

Different project management bodies have put forward several processes for project development throughout the lifecycle. The PMBOK Guide, for example, recommends discrete processes that ought to interact with specific process groups at any given phase of the project development for effective project management (PMI, 2013). Based on the interactions between the processes, to efficiently manage projects, the planning process group with the highest number of processes indicated that most activities are required in the planning stage, compared to executing, monitoring, and controlling processes. On the other hand, the least number of activities are required during initiation and closing processes. However, strict adherence to the PMBOK standard is unlikely to produce optimal results for every project because all projects have their unique characteristics and peculiarities. Therefore, any attempt to force-fit these guideline requirements into every project is a potential signal for project management underperformance.

Hence, every project, irrespective of its type or industry, passes through the generic project process comprising starting, organising, preparing, carrying out the job, and closing the project. To execute projects effectively, the five process groups of the project management lifecycle must be well coordinated by the project team and all stakeholders (Takagi &Varajao, 2019; PMI, 2013; IPMA, 2018). Therefore, organizations have relied on these processes to build their systems and projects to date, but with the attendant challenges regarding project underperformance.

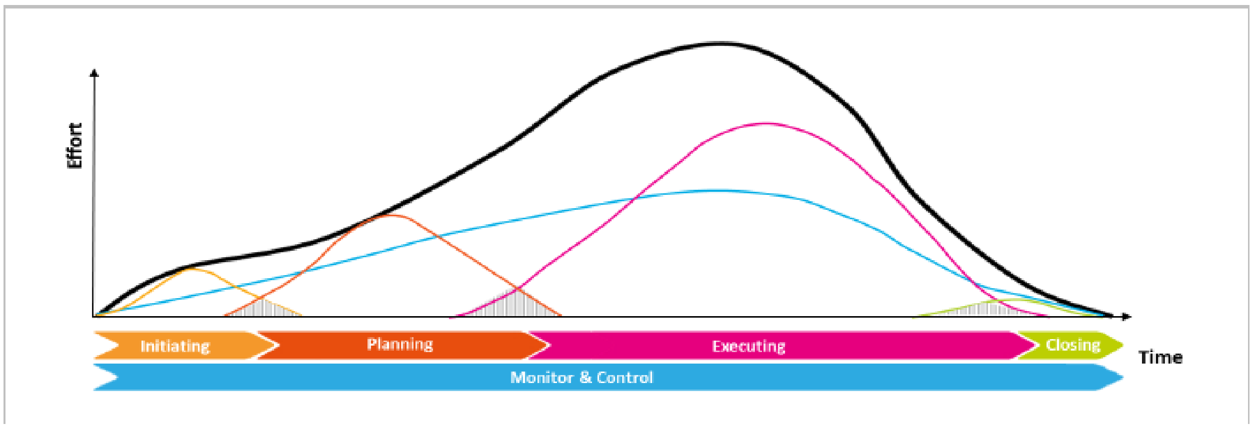


FIGURE 2.1 PM² Lifecycle indicating fast-tracking phases.

Source: Extracted from PM² Methodology Guide v3.0

Initiating: This defines the project scope, objectives, and strategies. At this stage, the project is launched after the appointment of a project manager.

Planning: The planning function involves developing the scope of work into a work breakdown structure (WBS), identifying personnel competence, forming the project management team, and developing project plans and other deliverables.

Executing: This process involves updating and transforming drawings issued for construction into approved drawings and coordinating the actual project plans and engineering design on site.

Monitoring and control: This important process spans the whole project lifecycle. Monitoring and controlling project activities in real-time assists in keeping the project on track. It measures and indicates the project's performance, tracks the project risks and vulnerabilities, maintains an issue register, and keeps tabs on the corrective actions needed until closure.

Closing: This involves the formal completion and administrative end of the project. Following this stage, the project team may be disbanded. Activities associated with this project lifecycle include coordination and review of project management performance, presentation of as-built documentation and work completion packages in both hard and soft copies as per approved project plans, and lessons learned, capture and workshops.

2.3.1 Project Management Process Interactions

A lay description of a process can be advanced as a set of interrelated tasks or events purposefully carried out to produce either a product, result, or service. This suggests that each process has an input, processing tools, and techniques to optimise the gains from both the organisational process assets and mitigate the constraints from the external business environment, prior to the output of the end-product. Also, from a business perspective, a process involves a qualitative description of a sequence of activities captured in either relationship or organisational diagrams, as well as flowcharts or process diagrams. Although the diagrams may become complex as the number of activities increases, they are still preferred as a smart means of communicating and evaluating the current process. In addition, they can be used to easily identify improvement opportunities and guarantee the standardisation of the process (PMI, 2013; Codinhoto & Koskela, 2012).

Project processes are carried out by the project team and applied worldwide across various industries. The project team comprises the project management team, the functional support from different disciplines formed based on the scope of the project, and stakeholders who are mainly the joint venture partners and government agencies of the country where the project is physically located. Project processes are classified either as project management processes that encompass the tools and techniques required to apply skills and capabilities or product-oriented processes in manufacturing (PMI, 2013). While the former ensures hitch-free progression of the project activities throughout the project's lifecycle, the latter specifies and transforms the project components through the various project phases and lifecycles until the project's finished product is physically actualized. Although significant successes have been recorded in oil and gas-producing organisations that adopt various forms of project management approaches, the incidence of project management under performance is still a common phenomenon (Takagi &Varajao, 2019; Lehtonen & Martinsuo, 2006; Wells, 2013 cited in Joslin & Muller, 2014). Therefore, it is recommended that project managers and practitioners take advantage of the combined project processes to achieve optimal project management. This is because a good project management practice is a function of how the project team can tailor the applicable project management processes to suit the specificities and complexity of the project and steward it to achieve the expected objectives (PMI, 2013).

2.4 Project Management Body of Knowledge

There are several projects' managements bodies of knowledge worldwide. These bodies provide guidelines for describing project management lifecycles, project processes and project management knowledge areas. Therefore, a project management body of knowledge represents a standardised, efficient, and systematic project management approach from theory and practice, adopted for consistently managing projects irrespective of the project's geographical location.

Project management bodies of knowledge are developed by groups of international volunteer professionals and organisations formed to foster the growth and development of project management practice as a profession worldwide through certification (PMI, 2013). Three notable project management bodies of knowledge include:

- The PMBOK is the body of knowledge of the Project Management Institute (PMI). The PMI is one of the largest project management organisations in the world, and its PMBOK guide is constantly being reviewed and updated (PMI, 2013; Joslin & Muller, 2014; Garel, 2013). The PMBOK guide is used mainly by multinational corporations (Buganova & Simickova, 2019).
- The United Kingdom's Association for Project Management (APM) Body of Knowledge is like the PMI. However, it has broadened its outlook to include, amongst others, technology and people as important project assets and the environment integrate to develop a clear strategy for realising the objectives of the project. This also includes strong advocacy for agile project management. In the UK, the Office of Government Commerce (OGC) recognises Project in Controlled Environment (PRINCE2), from APM BoK, as a guide of best practices that contains processes and definitions but not techniques for effective project management (Takagi &Varajao, 2019; Joslin and Muller, 2014). PRINCE2 is used mainly by Slovak companies and the public sector for project management (Buganova & Simickova, 2019).
- The European International Project Management Association (IPMA) has adopted a slight variation to the APM Bok. The PM² project management methodology, as published in PM²Guide v3.0, was developed based on IPMA guidelines and principles that are equally linked with the agile project management mindset. The PM² project management methodology guide is built on the foundation of project management best practices, with four pillars of governance, lifecycle, processes, and artefacts (project documents and deliverables), all wrapped around PM² mindsets. These mindsets refer to human behaviour, team building and project collaboration.

Although many PM² best practices can be applied to any type of project and scaled to various sizes, complexities and budget estimates (scalability application) throughout a project's lifecycle, its usage is officially limited to Europe and European institutions as indicated in Figure 2.2 (Takagi &Varajao, 2019; IPMA, 2018; Morris, 2012 cited in Hornstein, 2014).While the three bodies of knowledge guide methodologies to varying degrees, the PMI BoK has the most comprehensive set of tools and techniques.

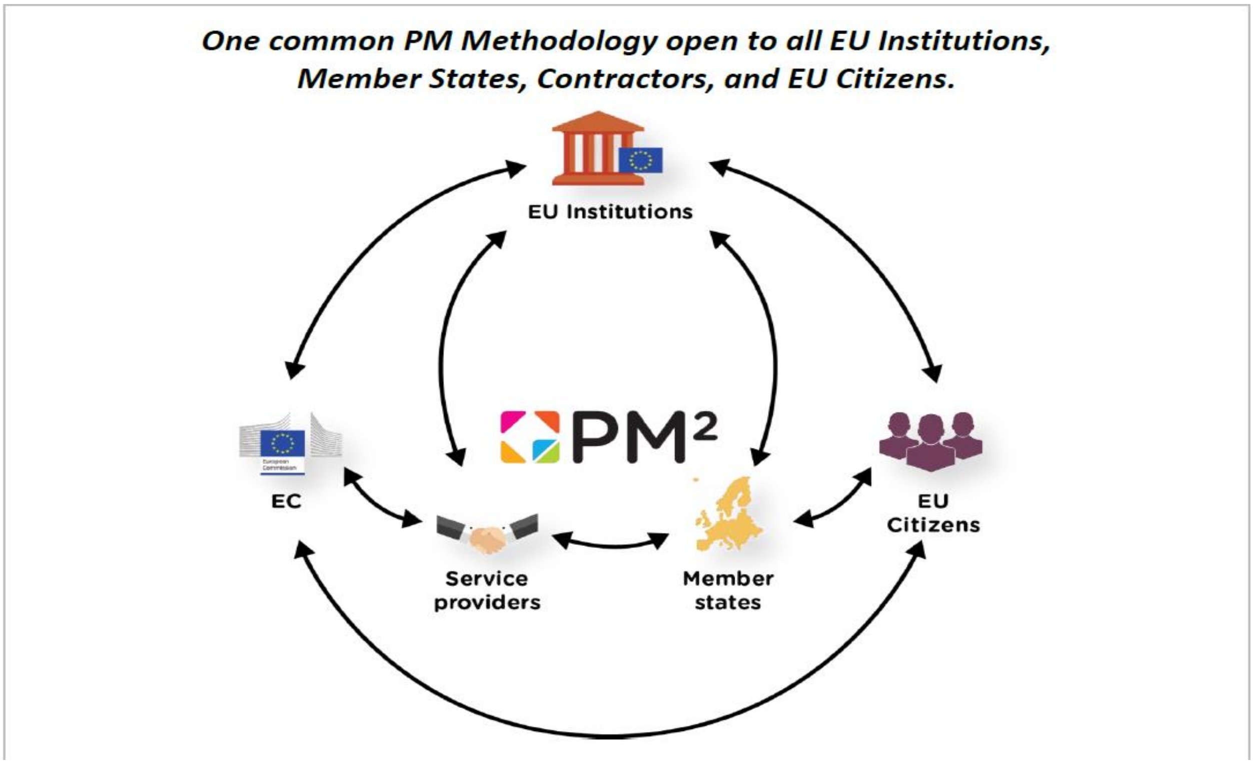


FIGURE 2.2 Open PM² Synergies

Source: Extracted from the PM² Methodology Guide v3.0

2.5 Project Management Constraints

Project Risk Management

Risk is an uncertain event or condition whose occurrence has either a positive or negative impact on project management performance (Shokri & Maloney, 2015). There is risk in every project endeavour, but optimal project risk management can mitigate them. Project risk management encompasses the cyclic processes of organising risk planning, identification, analysis, response, and controlling and monitoring to assess the effectiveness of the risk barriers on a project (PMBOK, 2013; Shokri & Maloney, 2015). According to Buganova and Simickova (2019), it is inevitable for safeguarding a project's internal processes. Although risk management is a broad subject with elaborate qualitative and quantitative attributes, it can be described as the various uncertain events that are either internal or external to the project organisation that could potentially thwart the project's management performance or lead to failure if the proactive measures put in place are inadequate. Failure could also occur if the recovery measures in the project plan are insufficient to cushion the severity of impact. However, the impacts of unforeseen risks can be positive (PMBOK, 2013; Shokri & Maloney, 2015; Buganova & Simickova, 2019). These positive impacts are usually unnoticed or kept silent but taken as an opportunity to recover from negative impacts that may have occurred earlier. Nevertheless, risk management objectives are to optimise the probability and impact of positive project occurrences and reduce, to as low as reasonably practicable, the chance and impact of negative occurrences (PMI, 2013).

Lately, organisations have used projects to manage change and to achieve strategic objectives and growth in volatile, uncertain, complex and ambiguous (VUCA) business environments (Zeng et al., 2007; Shokri & Maloney, 2015; Lima et al., 2019). Flexibility and adaptability have helped organisations remain competitive, in addition to effective risk management. Risk management has been harnessed to predict the chances of success and used as a green light to sanction a project during its initiation phase (Zeng et al., 2007; Shokri & Maloney, 2015; Buganova & Simickova, 2019). Therefore, risk management should be considered an integral part of project lifecycle management and tailored to suit the specific project characteristics and vulnerabilities for optimal project delivery.

Risk, as perceived by organisations, is the consequence of uncertainty in projects and organisational objectives. An organisation or project team's acceptable level of risk is a function of their risk attitude, which is influenced by several subjective factors. This is also called their risk appetite, risk tolerance or risk threshold (PMI, 2013). According to Saldin et al. (2006), uncertainty does not necessarily imply risk. They can defy quantitative expression and can be hastily tagged as 'issues' during project development. It is, therefore, not to be addressed during formal risk assessments. However, risk is measurable, quantifiable and a key element of the analytical assessment in project management. In an editorial on safety, risk and uncertainties, Matsumoto et al. (2019) suggested that safety improvements will always result from innovation because risks will continuously be managed, and uncertainties can only be mitigated.

Figure 2.3 shows the qualitative relationship between the project development phase, uncertainty, and risk. Also shown is the relationship between the project development phase, the project risk management process, and the known or unknown components making up the situation of uncertainty. At the start or initiation of a project, the risk is null as the uncertainty process is unknown and undefined. However, as the project matures, the risk moves vertically from naught to the highest value. In addition, project uncertainty becomes clearer and moves progressively through the stages. Again, at the start of a project, there are either 'unknown unknowns' or 'unknown knowns and the project risk management attitude at this stage is to leverage on experience from previous similar projects. As the project develops further, the likelihood and severity or consequences occasioned by uncertainty becomes clearer; the risk magnitude can be assessed and the scenario gradually transits to 'known unknowns' and 'known knowns' (Zeng et al., 2007; Zizek, 2006; Rumsfeld, 2003 cited in Saldin et al., 2006) where the project is completed and handed over to operations. At both the planning and execution phases of a project, the approved formal risk assessment technique becomes the right tool for effective project risk management. The risks register is updated either as the activities are completed as planned or in the event of a negative incident during the execution phase. At the closeout phase, all contracts are terminated, and the actual project cost is compared to the estimated project cost. The lessons-learned register is updated and archived as a reference document for subsequent project applications (University of Minnesota, 2021).

There are strategies for responding to adverse risks or threats should they occur. They are avoidance, transfer, mitigation, and acceptance. It is recommended to either avoid or mitigate the risk for critical and high impact risks, while for less critical and low-impact threats, transfer and acceptance are good recommendations. On the other hand, strategies for positive opportunities include the need to exploit, enhance, share, and accept. These strategies are in the interest of organisational or project's objectives (PMI, 2013). The 'known knowns' risks are managed via a formal risk assessment technique and mitigating measures are put in place. The ones that cannot be managed are provided for as contingencies. In addition, as the 'known unknowns' cannot be managed, they are assigned a management resolve (PMI, 2013). Whatever the project's attitude to risk may be, the project's risk management approach must be explicitly communicated to all project team members and stakeholders. In addition, the risk management process should be proactive, iterative, and started very early to achieve optimal project management performance.

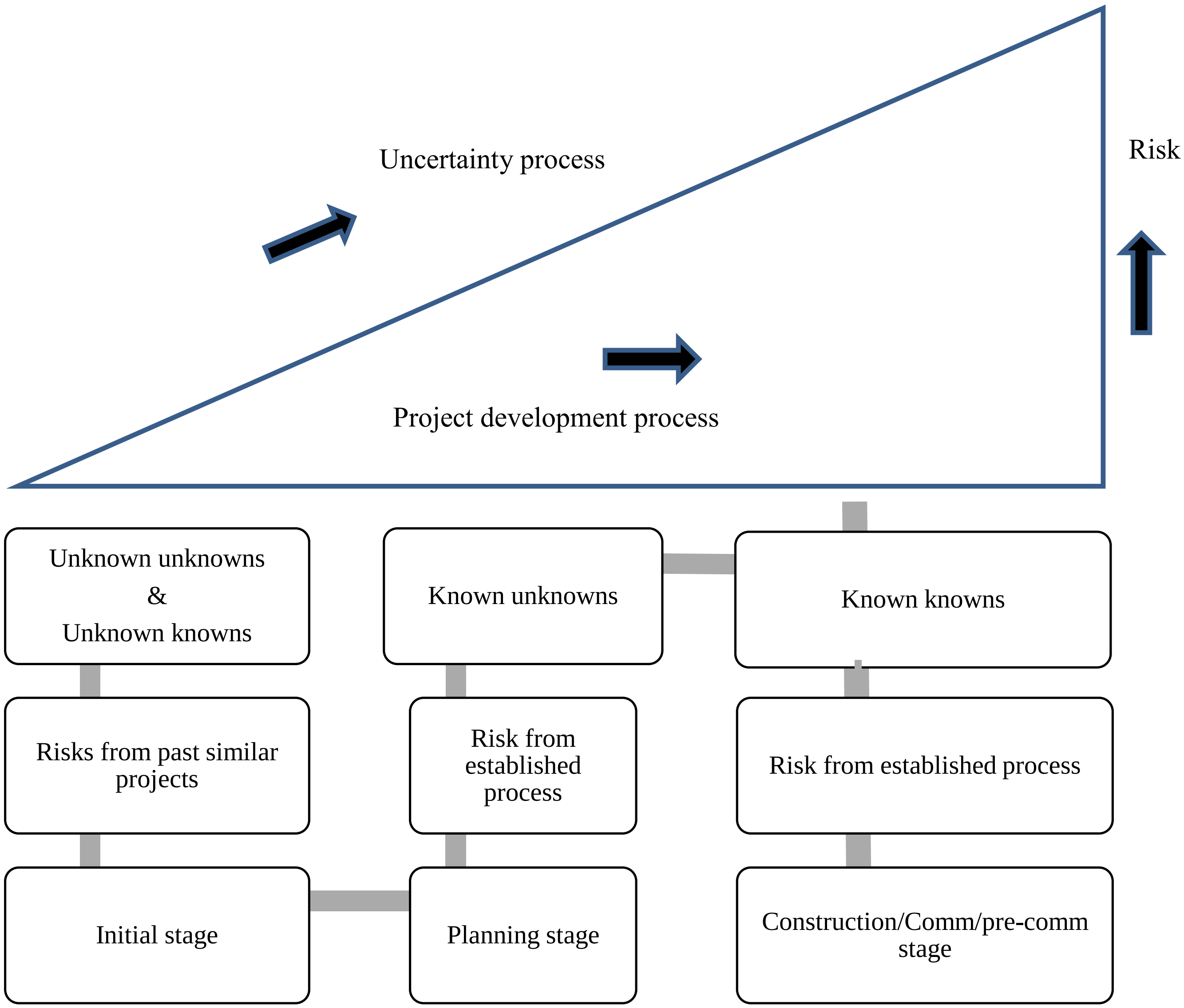


FIGURE 2.3 Relationship between Risk, Uncertainty and Project Development

Source: Usmani (2020)

Project Integration Management

Integration project management is the knowledge area whose input is required in all process groups throughout the project lifecycle. It is about the holistic harmonisation of all elements, activities, project management process groups, and other knowledge areas to stimulate teamwork, effective communication, and synchronisation of project information, bringing about seamless project execution and efficient project management performance (PMI, 2013).

Put differently, the early and effective integration of processes and people on a construction project is a panacea for efficient project management (Demirkesen & Ozorhon, 2017). In addition, integration management ensures that all elements required for project success are brought together (Yazdanifard & Molamu, 2011).

However, as necessary as this knowledge area appears, it is often misconstrued as solely an integral part of the roles and responsibilities of the project manager. It is usually not evident and tangible, which is why the project manager must pay particular attention when reviewing trade-offs and decisions amongst competing alternatives. This requires experience, implementation of lessons learned and input from all project team members and stakeholders (Yazdanifard & Molamu, 2011).

Integration management has components and deliverables comprising the development of a project charter and plan, project work execution, management of change, knowledge management, team building, supply chain management monitoring and control of project work and stewardship to phase or project closure (PMBOK, 2013; Demirkesen & Ozorhon, 2017). While all components of integration management are vital, an early deliverable is the project charter followed by the project plan. The project charter is the document that formalises the start of a project's development and gives authority to the project manager to superintend over project activities and resources. In addition, it documents the project incentives, objectives, and strategies to be used as a basis for subsequent developments and guidance throughout the project's life cycle. A carefully crafted project plan, on the other hand, is the backbone of the whole project and allows project managers to focus and optimise the approved plan, identify potential risks, and proffer mitigation measures early (Yazdanifard & Molamu, 2011). Therefore, there is no project without a charter, plan, and associated integration management components. This shows the importance of integrating management knowledge to project development, irrespective of the project type.

Project Knowledge Management

Researchers have considered knowledge the most sustainable asset for long-term competitive advantage for organisations, including the national economic development of nations in today's volatile, uncertain, complex, and ambiguous business environment. In addition, the inclination to share knowledge reflects an organization's knowledge management strategies and practices (Ali & Dominic, 2018; Murray, 2020). Put more succinctly, it has been argued that knowledge within organisations offers a sustainable competitive advantage in an economy where the only certainty is uncertainty (Nonaka, 1991 cited in Ocheing et al., 2018).

Other than implicit knowledge, which is regarded as unprocessed information but transferable from person to person, knowledge generally, whether tacit or explicit, can contribute to a project's success. However, tacit knowledge takes more time to acquire, and any effort made to reveal it is often a product of individual ideas, beliefs, insights, experiences, and expertise. Therefore, a concerted effort must be put in place to reap the gains of this sustainability factor (Murray, 2020). Commenting on the need to transform the learning culture in British Petroleum, Donegan (1990) argued that integration and strategy are the two factors required for a learning organisation to be sustainable. Donegan also pointed out that the fast-changing business world is making organisations go with the flow of technology or extinct. Therefore, improving the organisation through people creating a learning organisation is critical for remaining competitive. However, implementing a knowledge-based management system can be challenging, considering its dynamic and complex nature, irrespective of how organised or developed the organisation is (Bixer, 2002 cited in Ocheing et al., 2018).

Knowledge management as it relates to project management has been described as the documentation of processed information from experiences and lessons learned, which is systematically collated, shared amongst the project team and stakeholders, and subsequently archived and applied to similar future projects (Demirkesen & Ozorhon, 2017; Murray, 2020; Pereira et al, 2021). However, knowledge may exist within an organisation's repository but remain unknown to the team. It is also important to note that knowing how to utilise knowledge may be a challenge because the management's willingness and ability to identify gaps and exploit these resources gainfully is an integral part of knowledge management (Ocheing, 2018)

Knowledge management gained popularity among major oil and gas companies following advancements in technology and global industrial change. These developments show that innovation and learning are inevitable for business growth and organisational sustainability. Ocheing et al. (2018) suggested that implementing a knowledge management framework relies on people, experience sharing and technology to optimise project performance in the oil and gas industry. FPSO revamp projects have gained from people, effective communication, knowledge sharing, and innovation. Zarkovi, et al. (2014) argued that nations can attain their strategic goals of developing and improving modern society through knowledge building and developing a knowledge society. They further stressed that this growth initiative is achievable by educational empowerment of the people.

Grant (2013) argued that information and computer technology (ICT) has made it easier for organisations to harness the opportunities offered by available knowledge. It is against this backdrop that projects now have an increasing number of geographically or organisationally dispersed members functioning efficiently and delivering on expected tasks and targets by using a combination of telecommunications and ICT, while fostering team interactions that can lead to improved project performance (Peña-mora, et al., 2009). However, most organisations have continued to deploy tools that still trail behind technological advancement and innovation due to a time-lapse in learning new skills and carrying out pilot studies before the final roll out of supposedly new working tools. The importance of knowledge management to organisations includes cultivating a knowledge-sharing culture for the project team and stakeholders, which enables continuous improvement and innovation and fosters learning. In addition, the knowledge management maturity of an organisation is predicated on whether the measures placed to evaluate it are relevant to the desired goals, their adaptability for use and the adequacy of the knowledge created for application (Nazari et al., 2012; Murray, 2020).

Therefore, to create an effective knowledge management system, both management and team members must be actively involved. On the other hand, fostering a conducive atmosphere for learning and knowledge sharing by organising workshops represents a strong top-down management approach. Additionally, professional networking through vehicles such as LinkedIn, teamwork, and communities of practice (such as the Association of Project Management (APM)) can also promote knowledge management (Grant, 2013; Ali & Dominic, 2018). Therefore, a recommended approach for oil and gas companies seeking to remain competitive is to encourage members and stakeholders to capture lessons learned as the project develops and share lessons in a formal workshop after the project. In addition, to be reviewed is the project issues register and how any issues were resolved. On the other hand, workshops by organisations, such as scenario-based or ‘what if’ risk assessments before the start of execution, also offer opportunities for knowledge implementation and continuous improvement. The concept of lessons learned is very important in projects because it refers to the knowledge and experiences gained from the start of the project development through handover to operations. However, it is usually either ignored or treated with levity in projects (Nazari et al., 2012).

Project Quality Management

A finished product’s quality, whether tangible (a physical project completed at a location), or an intangible service, is a measure of customer satisfaction. According to Winch et al. (1998), from a construction project perspective, quality is a negotiated order in which both client and contractor have predefined terms and conditions during design reviews. Therefore, this implies that quality standards are subjective and linked to the approved specifications before the project execution.

Quality management, which has become prominent, encompasses both product and process quality considerations. Product quality requires training, partnering agreements among stakeholders. In contrast, process quality relies on clarity of the scope of requirements and work, drawings and specifications wrapped together by a feedback loop to yield the desired outcomes. However, in both cases, a visible management commitment to quality and continuous improvement must be demonstrated through the three developmental steps of quality planning, quality assurance and quality control, as recommended by the International Organization for Standardization (ISO) (Zijiker, 2007; PMBOK, 2013; Utibe, 2015).

Nevertheless, modern approaches towards realising the set ISO requirements have identified some important factors, including customer satisfaction, prevention rather than inspection, continuous improvement, management commitment and cost of quality (PMI, 2013). This new approach to quality is referred to as Total Quality Management (TQM).Many researchers have expanded and added the requirements for effective quality management to include employee involvement and recognition, training and development, supplier quality focus, teamwork, a scientific approach to problem-solving, effective communication and culture (Arditi & Gunaydin, 1997; Gherbal, et al., 2012; Kessler, 1993; Srinivas, et al., 2020).Organisations aspiring to adopt the TQM concept work towards striking a balance between maintaining high-quality standards and low cost. Cost of quality is the summation of the cost of completing a task or activity to an acceptable standard. This means that the prevention and appraisal cost, together with any potential additional cost, should repair or rework be required (PMBOK, 2013; Arditi & Gunaydin, 1997). For this reason, organisations have come up with the ‘get it right first time’ slogan to avoid schedule or cost escalation, which negates project management performance.

While quality assurance caters to the expected verifiable quality standards before realizing the project’s task, activity or component, quality control addresses the validation of the finished product’s quality. A technique used for validation is inspection, which involves final review checks, and measurements or audits of the project’s components (PMBOK, 2013; Arditi & Gunaydin, 1997). However, since inspections need resources, they are regarded as non-value adding and wasteful (MUDA) by proponents of the lean philosophy, who have suggested instead that inspections should be carried out continuously as the actual task is developed or transformed by the same team or functional group responsible. For example, a welder must conduct the required inspections of the weldment being deposited as the welding process progresses.

Project Health Safety Environment (HSE) Management

In 1984, Shell launched a new campaign to improve safety management in its operations, which yielded positive outcomes in reducing industrial incidents. However, following the Piper Alpha disaster in 1988 and Lord Cullen's report, it became clear that safety management required a more robust and systematic integration with the health and environment (Bentley, et al., 1995; Zijiker, 2007). Today, oil and gas operators have found the need to equally combine HSE and quality management into one entity, HSEQ, which has led to improved management focus and enhancement of further performance improvement opportunities from a social and environmental perspective. This is a deviation from the usual targets of cost savings, increasing efficiency and returns on capital investment (Hajipour et al., 2021). In addition, quality and effectiveness are vital factors that can lead to optimal performance of HSE management systems (Mohammadfam et al., 2012).

Generally, the oil and gas industry are greatly affected by the challenges of producing from remote locations like deep offshore, requiring rapid technological advances within a fast-changing business environment. The corresponding adaptation to these changes increases the operational and integrity risk of an asset. Therefore, an efficient health and safety environment (HSE) management system is the major organisational approach to preventing and reducing incidents (Othman et al., 2015). An HSE management tool integrates all human, financial, and equipment resources to improve the team's health, prevent incidents and accidents, and ensure environmentally clean operations (Farshad et al., 2006). For instance, Shell Exploration and Production's top priority for continuous improvement is HSE standardisation, HSE management system (HSE MS) and human behaviour are central to the business continuity. Since humans are considered the greatest asset of an organisation, an effective HSE management system during project development, operations and maintenance assures competitiveness, business sustainability and strengthens an organisation's license to operate.

Project Scope Management

"Scope is the term used in the management of projects to refer to the totality of the outputs, outcomes and benefits and the work required to produce them" *(*APM BOK, 2019, pp 160*).*

Project scope describes the processed or analysed scope of requirement from the requester or the customer. According to PMI (2013), the scope of requirement includes the quantified, recorded, and anticipated needs of all project stakeholders. Without a clear scope, the project execution is potentially flawed as it has a negative multiplier effect on other project elements, both on the immediate and long-term performance of the project. The concept of scope baseline refers to the official or approved version of the customer's project scope statement, work breakdown structure (WBS) and WBS dictionary (PMI, 2013). Following the issuance of the scope baseline, any further scope additions, modifications, or removals must be secured through the management of change. This is usually a process put in place by the oil and gas operating organisations. While the management of change process is well defined and clear, most project teams would usually try if they can avoid it due to the potential impact on realisation of the overall project. It is on this premise that the importance of project scope management cannot be over emphasised.

"Scope management is the process whereby the outputs, outcomes and benefits are identified, defined and controlled" (APM BOK, 2019 pp 160).

Project scope management encompasses all the processes needed for a flawless project lifecycle. This includes the monitoring and control of both the approved work and possible scope creep, in synergy with other knowledge areas (PMI, 2013), if the successful project management performance of a complex project like FPSO revamp is to be realised.

However, one of the most challenging aspects of revamp project activity is the timely specification of the project's scope. From experience, the baseline scope could escalate rapidly, especially from a defective initial survey in the early life of the project, if the scope never gets frozen or attains its milestones late in the project's execution. In addition, the Operations and Maintenance (O&M) entity and other stakeholders may request scope additions at any time due to human factors. These factors include when discoveries are made, when a forgotten opportunity is remembered due to defective documentation or shift personnel handovers, or when a long lead item or equipment eventually gets cleared by customs and is delivered to the site in the middle of a project. Sometimes, scope creep can result from corrosion or integrity issues that weren't envisaged yet have consequently been risk-assessed as critical for a start-up while working under a full field facility shutdown mode. This additional scope must be accommodated and given a high intervention priority by the project's site management. Nevertheless, whether scope creep is genuine or justified, there is an impact to the project which cuts across cost and schedule. Therefore, project scope management must be taken seriously, as it significantly contributes to project management underperformance if it is not well managed.

Project Schedule Management

Schedule management is one out of the triple constraints of project management, otherwise called the iron triangle. Although it has specific processes and characteristics, it is included by some oil and gas organizations as a cost management constraint under one entity for administrative convenience and coordination being judged as two distinct but related knowledge areas. Project schedule management refers to the time management processes required for full project completion. PMBOK (2013) identified seven effective project time management processes, from schedule management to schedule development and control. An important deliverable of this project management constraint is the schedule model, which represents the plan for executing a project's activities. It also covers the duration, dependencies and other planning information required to develop the project's schedules and associated components (PMI, 2013). The project schedule is a popular reference document during project execution. It is derived from the output of the time management processes, and features of a project schedule are the definition of activities, including milestones that represent key moments in time. They include null durations, activity sequences, estimation of activity resources, durations, and network diagrams. Project schedules for small projects may be completed manually using known scheduling methods.

However, project management software such as Primavera and MS Projects are popular in the oil and gas industry for typical revamp projects.

The baseline schedule is the finalised schedule used as the control schedule process. Keeping up with the baseline schedule is usually a challenge. It is difficult to complete all works on target, especially for revamp project development during the execution phase where scope creep, repairs, modifications, and rework are common due to human involvement in operational exigencies. Nevertheless, these challenges may be mitigated by various schedule compression techniques that allow the project team to shorten the schedule duration without a decrease in the project scope. While schedule compression techniques work well, they require upfront or lookahead planning and attention to change order requests and approval processes, experience and excellent communication from the project leadership and team to be effective. In addition, issues such as activity crashing, for example, are limited to working only for activities on the critical path and do not provide alternatives. On the other hand, fast-tracking only works if activities can be overlapped to shorten the project's duration.

Project Cost Management

Cost management is one of the triple constraints of project management and one of the most discussed in the quest for process optimisation and performance improvement. Project cost management is essentially concerned with the total cost of the resources required to complete a project. It is a quick reference to measure performance and the control of spends within budget cost estimates for the overall project. It typically covers all processes from planning, estimating, budgeting, financing, funding, managing, and controlling costs to enable the project to complete within budget estimates (PMI, 2013). Project cost management is tailored to suit stakeholders' requirements in terms of method and frequency of measurement. According to PMBOK (2013), project practitioners focus on cost management during the Front-End Loading (FEL) stages of project development. They argue that cost is more influenced at these earlier stages than later. The PMBOK explains why early scope definition is important and why cost management processes are recommended in the early project stages. However, there is no link of cost management processes to the executing process group where the execution project phase activities are at peak. This understanding does not seem logical, as the executioners are not formally allowed to input their concerns regarding the important cost constraints, with a potential impact on the project performance.

Cost estimation requires special skills and experiences to develop as it involves an approximation of the monetary value required to complete the project activity based on the amount of information available at a given time. As cost estimation is a function of time, the concept of baseline cost becomes even more important. The baseline cost, according to PMI (2013). is the approved version of the time bound budget per given phase of all the project's activities and it excludes any management reserves. Baseline costs, which, among others, are used for performance monitoring and control, can only be changed through a formal management of change process. Another important aspect of project cost management is forecasting. As the project progresses, it becomes clear that the budget at completion may no longer be viable, hence the need for an estimate at completion. Forecasting in this sense involves making projections of the future conditions and events based on the current performance information and other relevant knowledge available (PMI, 2013). Since forecasts are generated, regularly updated and re-issued at intervals based on the work performance data provided as the project progresses, the need for an experienced project manager and project team becomes vital when making decisions, selecting the appropriate tools and techniques for cost computation, and communicating work performance updates.

Work performance information entails the project's past performance, including any future foreseeable information that could potentially impact the project's cost. The cost performance index (CPI) measures the cost efficiency of budgeted resources and the work completed. A CPI value that is less than one indicates a cost overrun; while a value greater than one indicates a cost underrun (PMI, 2013). Therefore, all hands should be on deck for project teams to aim at least one CPI values, especially on revamp project executions that are vulnerable to scope changes.

Project Procurement Management

Procurement management is one of the key project management constraints and among the ten project management knowledge areas. It has component processes that interact with themselves and with other knowledge areas (PMI, 2013). Effective procurement management processes encompass planning, carrying out procurement, controlling and closing procurement to strive for good project execution, bearing in mind that resources must be procured or purchased before deployment. The objective of procurement management is therefore to coordinate all the activities of buying, selling, contracting, purchase order processing, expediting, interfacing with the procurement value chain to ensure the delivery of the products, services or results when required on site (PMI, 2013; Borges de Araujo et al., 2017; Pheng, 2018). It is the project team's responsibility to ensure that all procurement efforts meet the intended purposes, and this involves reaching out to other disciplines or functional entities for necessary support. Suffice to say, most organisations have a responsibility matrix and structure put in place to support the project team prior to the start of any project. This is equally described in the procurement plan and, as such, should be exploited for improved project management performance.

An important activity in project procurement management is contracting. This involves a mutual understanding or agreement between the buyers and sellers of products and services, having drafted, reviewed, or undergone a systematic approval of the terms and conditions of such agreements. In organisations, major contracts from a cost and size perspective have legally binding clauses requiring a more stringent review and approval by senior management, usually a permanent contract and procurement review committee comprising stakeholders from relevant entities, constituted by the board of the board organisation. This is an important role in ensuring that the procurement risk that could expose the organisation to change orders, claims, cost escalation, and schedule slippages, including litigation, is reduced to as low as reasonably practicable.

Araujo et al. (2017) posited that a new rather than traditional perspective to the procurement process may improve project procurement management. Because most project resources are imported from overseas, the projects executed in developing economies are less likely to benefit from the proposed buyer-seller synergy than projects executed in developed economies, due to socio-economic conditions, freight forwarding, readily available resources, and warehousing challenges. However, the buyer and seller relationship must be cordial, and confidence and trust must be built. It is also useful to cultivate the attitude of a win-win situation, with actors helping each other to succeed throughout the project's lifecycle.

Project Stakeholder Management

Stakeholder management has gained popularity following Freeman (1984). Freeman described project stakeholders as interest groups in an organization that are either part of or impacted by the project development. Also, individuals or organizations whose interests could potentially be affected either positively or negatively during the development of the project are stakeholders (Badiru and Osisanya, 2013). This description suggests that stakeholders in project development are both the internal participants within the organization and the interests of the groups who are external to the organization therefore, in a dynamic and uncertain business world, the ability to integrate the interests of all the groups towards achieving excellent project performance requires an efficient stakeholder management (Srinivasan and Dhivya, 2020).

Two project stakeholder management approaches, management of stakeholders and management for stakeholders, have been identified (De Alencar et al., 2021). While the former is conventional and regarded as resources oriented to address the project requirement, the latter is an evolving proposition intended to create sustainable value to project management through the integration of all stakeholder interests. However, the latter appears a better option since it brings about continuous improvement in the management of projects, sustainability, value-adding and competitive edge of the organization. Put differently, project development has been from the perspective of past knowledge and business information instead of the contemporary information and projection into the future, this line of thought must be changed for the overall project management profitability (Srinivasan and Dhivya, 2020; Freeman, 1984).

Mok et al. (2014) reviewed complex construction projects. They found that stakeholder management is closely linked with the national culture of the project location, where the practices and techniques are conventional. They averred that social networking improves the conflicting interests inherent in project stakeholder management. While acknowledging the fact that inefficient engagement of stakeholders prevents identification and ranking of important values as a challenge to stakeholder management (Jepsen and Eskerod, 2009 cited in Mok et al., 2014) the experience and the skill of the project manager is very important in ensuring that desired project outcomes are realized, keeping in mind that effective communication, information management, and social interaction are parameters for efficient stakeholder management (Yang et al., 2010 cited in Mok et al., 2014).

Stakeholder management requires that the project manager or project leadership play the key role of planning and coordinating, implementing, and monitoring the project performance through the close-out stage to the stakeholders' satisfaction. The interests of the various groups are very important during project development. Their influence could potentially impact or change the course of project management delivery should the project leadership be unable to reach a consensus on issues (Freeman, 1984; Srinivasan and Dhivya, 2020).

Two factors that could form a potential gap in project development are not recognizing the employees of the organization and the local community that the project could potentially impact as stakeholders. The local community should be relevant as company employees to assure overall project management performance (Badiru & Osisanya, 2013). Nevertheless, oil and gas operating companies in Nigeria have keyed into this realization. Employees are seen to a large extent as stakeholders and their voices are heard, especially through trade unions like the Petroleum and Natural Gas Senior Staff Association of Nigeria (PENGASSAN) and Nigeria Union of Petroleum and Natural Gas Workers (NUPENG). Host communities have the Community Development Committee (CDC) to interface with the companies (Ajide, 2017).

Also, the oil and gas operating companies in Nigeria have increased active engagement with the host communities in areas where they operate through their respective community liaison entities and various community development projects like schools, roads, hospitals, markets and so on being part of corporate social responsibilities of the companies are evidence of their recognition of the communities as stakeholders. Therefore, stakeholder management requires continuous engagement to break the complex interlink between the various actors and establishing good relationships between the project team, the functional support, the joint venture partners, government agencies, regulators, and the host communities (Ajide, 2017). However, the failure to accord the local communities the stakeholder status by the oil and gas companies is the reason for agitations globally (Badiru and Osisanya, 2013) and community agitations with oil and gas companies have gone sour in some instances where it was not managed very well.

This study used for organizations as case studies. They are multinational oil and gas operating companies in Nigeria. This suggests that although different national cultures exist at play, there are established working relationships even with Nigeria's parent company's national culture and interests. The government's policies have necessitated this mutual understanding although not without attendant disagreements, distrust, agitations with communities where they operate (Ajide, 2017). Noting that most multinational oil and gas companies operating in Nigeria have had business relationships for over fifty years, the national cultural integration has been effective to date and therefore the challenge from project perspective is for the project team, the joint venture partners, and the interests of other groups to be harmonized by the project leadership, this is a task that must be pursued for every project to achieve overall project management performance.

However, irrespective of the experience and skill of the project manager, the gains from research and discussions on stakeholder management may be far from being realized unless there is the drive for change by the project leadership, the organizational will to embrace change, and the appetite for gradual, incremental, and collaborative change to the contemporary stakeholder management thinking. In addition, good stakeholder management policies help the companies strengthen their licenses to operate.

Project Human Resources Management

The frequently changing business environment has necessitated a corresponding change in human resources management as a means of increasing the project management efficiency, this implies optimization in project cost and overall project management performance (Blaga, 2020; Pasaoglu, 2015).In project development, the human resource is one of the greatest assets for organizational success and bridges the gap between the employees and the employer (Vardarlıer, 2016; Zaouga, et al., 2019; Sing, 2004 and, Budhar, 2001 cited in Pasaoglu, 2015).This understanding has driven project practitioners to consider availability and retention of key project personnel for continuous improvement. Human resources directly affect change and yield returns on investment. All expenditure on human resources for training sessions is for growth and sustainable project management performance. Investments in human resources bring about changes in attitude through the knowledge acquired, employee motivation, and improved performance while the organization gets process and systems standardization and competitive advantage from a well-trained and efficient workforce (Blaga, 2020; Vardarlıer, 2016)).

Employees need to be motivated to get the best of their inherent talents through empowerment, entrusting them with responsibilities and providing a conducive working environment where their initiatives would be recognized and implemented (Akinyele, 2010; Ozkeser, 2019). However, in most project development in the oil and gas industry, a large workforce is required for the task execution. Therefore, majority of the workforce are essentially contracted staff who are presumed to be professionals and are hired on ad-hoc basis to support the advancement of the project development for a relatively short duration compared with the fewer company career staff. Nevertheless, training calendar on safety, health, and environment (HSE) which undoubtedly also enhances personnel wellbeing and performance (Ozkeser, 2019) is a usual practice in most organisations and compulsory for all personnel irrespective of the type of contractual agreement with the organization. Also, safety milestone and outstanding performance awards, tokens, incentives, and gifts are ways used in motivating the workforce by oil and gas operating organizations during project execution.

From an organisational behaviour perspective, human resources management are corporate policies intended to integrate all processes of an organisation under a well-structured working atmosphere that motivates employees to strive for excellence (Guest, 2007 cited in Dubravska and Solankova, 2015). Human resources management is a key project management constraint with definitive processes, techniques, and tools for seamless stewardship through the project life cycle. Therefore, an efficient management of this knowledge area from a modern perspective involves information technology, personnel training, and motivation, bringing about project management sustainability and organisational competitive edge (Vardarlıer, 2016; Ozkeser, 2019).

Typically, human resources management takes charge of the recruitment of eligible personnel and competent ad-hoc personnel during project development. In liaison with the functional entity, the human resources entity stewards the personnel career path. However, for most project endeavours, the recruits are hired on a contract basis for the project's duration. Eligibility attributes considered during recruitment include education, skills, location, availability, knowledge, experience, and cost (Ozkeser, 2019) as would have been stipulated in the project recruitment plan. While most projects at start have limited teams, the workforce gradually increases and reaches peak at the execution phase and subsequently starts ramping down until commissioning and hand over to operations (Vardarlıer, 2016). In a similar fashion, the project team is formed at the beginning and witnesses the learning cycle of storming, norming, performing and disbandment or reforming for the next project.

During project disbandment, many personnel are made redundant. While this development causes anxiety for the impacted ad-hoc personnel who would be temporarily out of jobs, the organization also misses experienced hands and potential implicit knowledge transfer opportunities. For this anticipated loss of knowledge, organizations attempt to retain key personnel by the functional team strategy where key personnel services are shared among various projects at different phases within a program or portfolio of projects. The gains of functional team support to the project management team include process standardization, seamless knowledge transfer through lesson learned, capture and application to future similar projects, retention of implicit knowledge and experience within the organization, timely turn-in of project deliverables, reduction in learning curve and faster team integration. However, these gains are not without the additional cost of keeping the personnel on the payroll (Vardarlıer, 2016). Nonetheless, the cost-benefit analysis is usually conducted and approved by the project leader at the planning stages of the project development. Although the multinational oil and gas operating organizations in Nigeria are perceived as focusing on human resources management, the challenges of human resources management will linger for a long time (Dubravska & Solankova, 2015). These challenges include retaining and rewarding the best employee, building a crop of future corporate leaders, and creating a sustainable organizational culture that attracts the best hires.

Project Communication Management

Communication is very important to every stakeholder. It encompasses gathering, processing, and disseminating relevant information to the target audience or recipients as required. From a project perspective, communication is the means for integrating the triple constraints of project management to achieve final product quality and assumes the base support of all other project management constraints (Zulch. 2014). The importance of communication in project development cannot be overemphasized as it is the means of requesting, sending, receiving, and clarifying pieces of information and instructing and networking with the stakeholders (Burke, 2007 cited in Zulch, 2014). Communication is a two-way street that involves the giver and the recipient, the understanding and acknowledging receipt is important; otherwise, communication is defective (Zulch, 2014). Ineffective communication could potentially lead to poor project management performance (Darmaningrat et al., 2019), communication comprises the initiator, the mode, the receiver, the means of information transmission and it is as effective as the initiator's ability to process, pass and receive feedback seamlessly (Van Staden et al., 2002 cited in Zulch, 2014). According to PMI, the commonest causes of ineffective communication area lack of understanding of the project's objectives and strategies, usually documented during the project development phase. Another cause isthe wrong use of language, the need to keep the terms simple, concise and avoid technical and management jargons for clarity (PMI, 2013).

Going by the above commentaries on the importance of project management, communication can be defined as the dissemination of information in a language and mode that the recipient understands. Two major attributes linked to the project manager's skill for project management success are the ability to lead and communicate effectively with all stakeholders (Zulch, 2014).

All forms of communication are important and used in project development depending on the prevailing circumstances under which they are used. However, while it is advisable to communicate information without delays to save a potential business opportunity, social media arguably has contributed immensely to the informal dissemination of project information in real time. However, verbal communication may not be directly retrievable but can be stored for longer periods by electronic means. On the other hand, written communication can be retrieved from archives, but paper copies are subject to obsolescence. Project documentation and communication is quite popular amongst project practitioners. However, the modern trend encourages electronic storage for better preservation, reduction in handling and materials cost, storage space optimization, and efficient data and information management.

Common events, activities and communication avenues during project development include emails, meetings, progress reports, lesson learned during workshops, risk assessment, constructability reviews and knowledge and information sharing on the organization's repository (Darmaningrat et al., 2019). While the factors mentioned make project management interesting and successful, without them, failure to effectively manage the project is inevitable. Since the lingua franca in Nigeria is English, the official language for project development is English language and communication is considered a major project management knowledge area for optimal project management performance.

2.6 Project Governance

Project governance is an integral process-oriented part of project management approaches, developed and implemented to assure effective governing and administration leading to overall project management success. Project governance can better be described as a stage gated phase model that focuses on the processes and administrative strategy that the project sponsor or client must implement to guarantee success. Therefore, an efficient project governance template will comprise a structured quality assurance guideline, a control system for enforcing compliance to objectives, an approach for issues resolution through the project life cycle, and project document and appraisal review procedures (Samset & Volden, 2014).

2.7 Project Phases

Project phases viewed from a high-level perspective are elements of the project lifecycle, and the terms 'project phases' and 'project life cycles' are often used interchangeably. However, the number of phases, the need for the phases, and the extent of the control applied to a project are dependent on the size, complexity, and potential impact of each project. Figure 2.4 shows that at each project phase, the five project management processes are repeated in an iterative fashion by the processes management groups until the project is completed. Since the various phases have distinct work focuses, the expectations are that the team organisation, skill sets, and locations will be different. Additionally, controls are needed to achieve the objective and for defining the boundaries of the project phase. The closure of a project phase, except for the operation phase which has no terminal stage-gate decision, is normally associated with the handover of some specific deliverables for review, discussions and 'go, no-go' decisions – this is the concept of a stage-gate, milestone, phase review, phase gate or kill point (PMI, 2013). These are used by the major oil and gas producing companies and organisations during project execution. The five-stage-gate model is robust and endorsed by professional bodies and is therefore applicable for adoption within the execution process workflow.

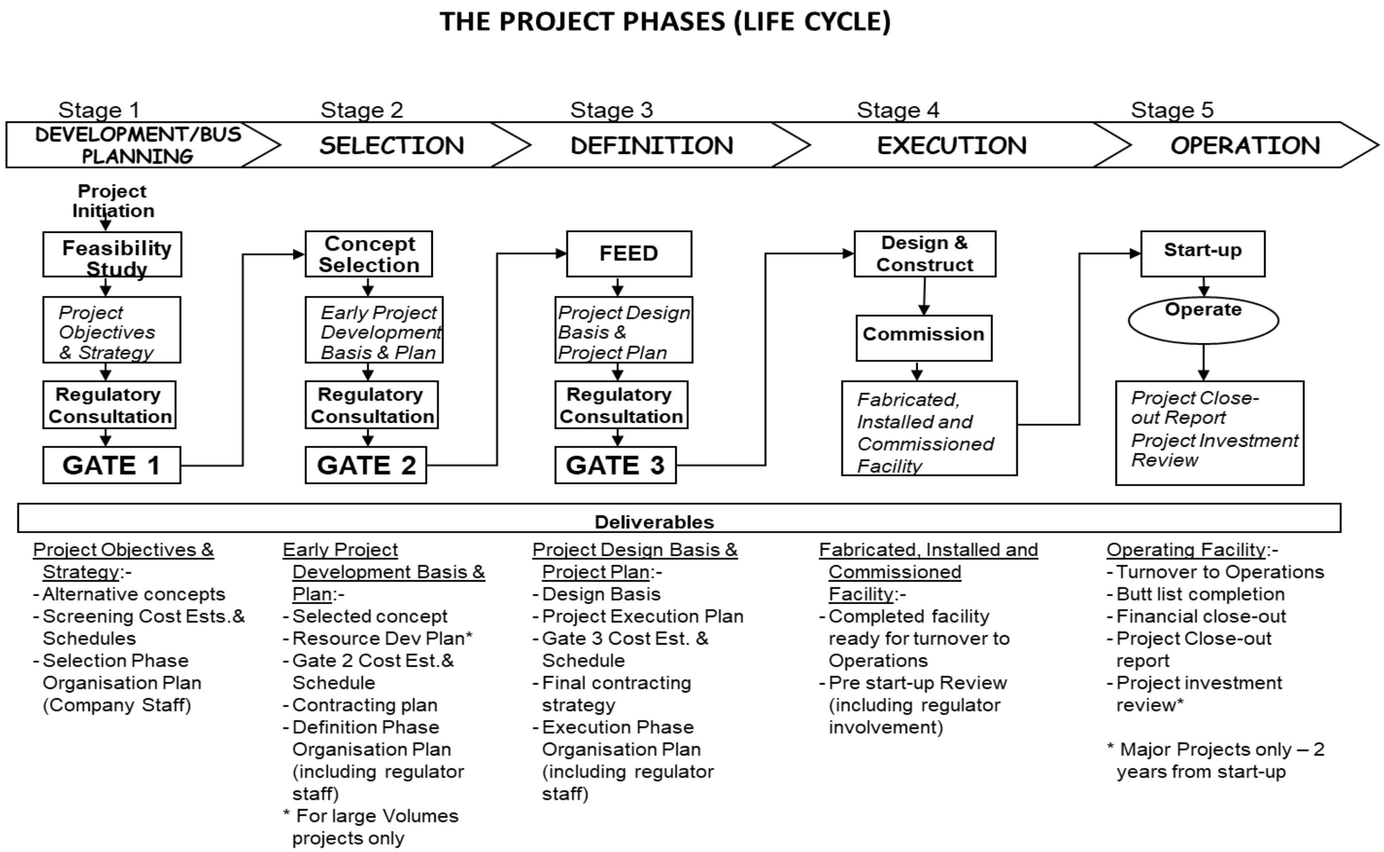


FIGURE 2.4 The Five Stage-gate Project Phases (Lifecycle)

Source: ExxonMobil Project Execution Handbook (2006).

2.7.1 Project Feasibility/Initiation Phase

Projects are broken down into phases for efficient management through the specificities of the project lifecycle. Although different organisations may adopt slightly different names and definitions for the project lifecycle processes, they are all roughly like these five phases. Feasibility, otherwise called the initiation phase, is the first of the five-stage-gate phases of a typical oil and gas capital project. At this stage, the initial business case for the project is developed and the objectives against project risks are carefully justified and finally escalated for consideration and approval by senior management. Then, as contained in the objectives and strategies dossier, the project scope of requirements is developed by the company’s facilities engineers and production personnel.

On receipt of approval from the gatekeeper to move to the next phase, a project manager is appointed to pilot the project's affairs going forward. Although earlier practice recommends identifying and presenting all functional support to the project management team, this population accounts typically for 10% to 20 % of the overall manpower for the project. The reasons for this line of thought include an assurance that all project scope and vulnerabilities are covered early, it assures overall project success, and ensure that later gains far surpass the additional cost of early mobilisation and overheads (Will & Stewart 1991). However, current thinking supports deferring mobilisation of the functional group to the concept selection phase. By this time, the project has been sanctioned and a project manager has been nominated by management. This is so a project can be kept on hold or cancelled at the feasibility stage if it does not meet the organization's objectives and long-term goals or strategic plans, potentially leading to financial losses for the organisation.

2.7.2 Project Concept Selection Phase

The concept selection phase is the second stage of the five-stage-gate project lifecycle. At this phase, the project now has a project manager, who starts building his team and assigns a project engineer. In conjunction with the facility engineer, the project engineer stewards progress of the early project development and prepares the dossier in readiness for crossing the next gate. Here, competing alternatives are critically analysed through internal and external government regulating agencies, and the best option is finally selected. Again, the deliverables are formally presented to be reviewed by a team of experts with relevant experience and are then approved by the gatekeeper to proceed to the next phase. The conceptual deliverables sum up the basic technical solutions obtained from initial studies, input from field surveys, industry standards and specifications, and lessons learnt from previous similar projects (Frankhouser, 1981).

2.7.3 Project Definition Phase

The definition phase is the third phase of the five stage-gate project lifecycles. Here the project management team (PMT) is fully formed, the Early Project Development Basis (EPDB) has now been updated to a Project Design Basis (PDB) and utilised as documentation for carrying out the Front-End Engineering Design (FEED), following the award of a contract for the FEED to a design contractor. In addition, it is expected that a series of site surveys will be conducted by a team of both company and design contractor personnel. Reviews and an agreement to move forward are reached equally between the contractor, company and joint venture regulating agencies. The final deliverables from this phase include the FEED drawings, final contracting strategy and execution phase organisation plan. Following the approval of the dossier for this project phase by the gate three keeper – a company executive –full funding is initiated as a Final Investment Decision (FID) by the operators for the project.

Most operators are quite critical about this phase as it triggers the transition from planning to action. According to Walkup Jr and Ligon (2006), the first three phases of the stage-gate project lifecycle are collectively referred to as Front-End-Loading (FEL) and are the critical considerations for sanctioning oil and gas projects (AlMarar, 2019). Oil and gas operators see the right implementation of FEL and associated action plans and processes to secure the organisations' future (Mishar, 2012). However, the concept selection phase is a transition between value identification, where all the quality assurance inputs and optimisations have been fully harnessed, and the value delivery, which starts at the execution phase.

2.7.4 Project Execution Phase

The execution is the fourth phase of a typical five stage-gate project lifecycle. The full project and support team have been mobilised and key activities, including a detailed engineering design, are completed here. In addition, construction drawings and documentation are released by the main Engineering Procurement Construction and Installation (EPCI) contractor. During this phase, procurement of materials and equipment are launched and partners and agencies regulating the joint venture are fully involved in quality-related activities like the factory acceptance test (FAT) at the original equipment manufacturer's yard and at local fabrication yards. Additionally, the pre-mobilisation of tools and equipment is concluded prior to the mobilisation of materials, hundreds of personnel, and equipment to the site for intervention. The site intervention is well coordinated under a strict permitting system that includes construction site management, installation, pre-commissioning and commissioning, quality control, health safety and environmental management, as well as communication and reporting.

A large portion of the project's budget is expended in implementing the execution process in terms of budgetary allocation. Researchers (PMI, 2013) have estimated that average between 40% and 60% of the total project budget is allocated to this phase in practice. This phase also takes longer compared to the first three phases (FEL) put together due to the requirement for material procurement and construction and site installation activities. Indeed, the execution phase is packed with activities and more time and effort are usually expected from all stakeholders, especially in realising the project management process and ensuring proper monitoring and control (Yazdanifard & Molamu, 2011).

Due to the relatively longer execution phase completion time and the fact that it accounts for approximately 50% of the project's budget allocation, this research anticipates this phase to be the potential window for cost and schedule optimisation. This is in a bid to find a solution to the age-long issue of poor project performance in the oil and gas industry. However, researchers have argued that the FEL offers the greatest opportunity to lower lifecycle cost by utilising value improvement work processes. This is aside from supporting project management to reduce cost by up to 20%, and improve schedule optimisation, rework minimisation and other performance targets that become obvious during the execution stage (Frankhouser, 1981; Batavia, 2001; Mishar, 2012). Nevertheless, although the focus of this research is the execution project phase, there are overlaps with the preceding definition phase and the subsequent operation phase. These overlaps, described as fast-tracking in project management, are carefully coordinated to mitigate potential cost escalations and schedule delays from reworks and other quality-related issues, including wrong material specifications, purchases, and deliveries, as well as start-up delays and other related challenges.

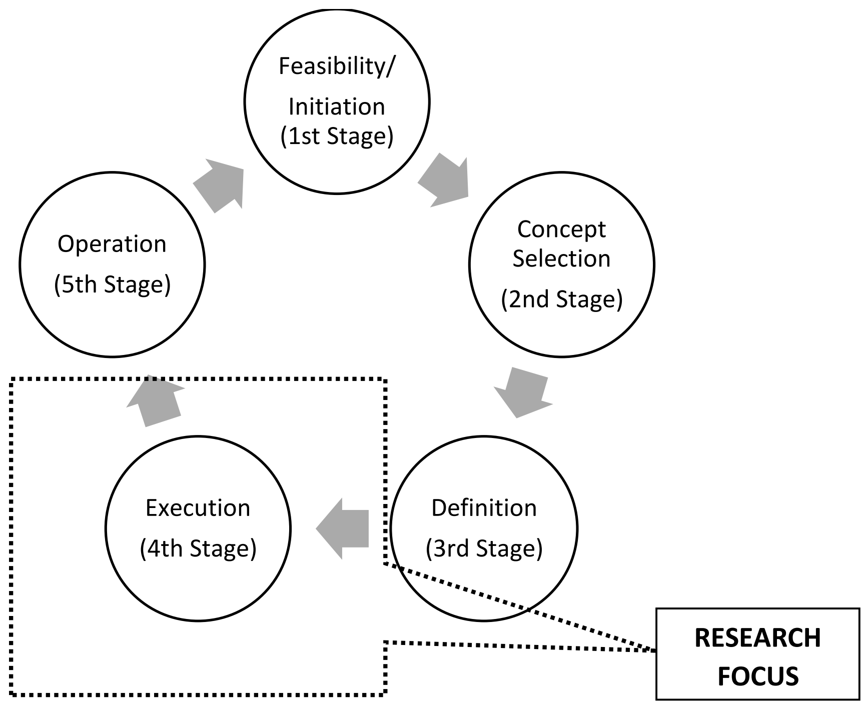


FIGURE 2.5 Research Project Stage – Focus on FPSO Revamp Execution Stage

2.7.5 Project Handover and Operation Phase

The fifth and final phase of the five stage-gate project lifecycle is operation. This phase lasts the longest (years) and longer than the first four phases combined. Here, following the commissioning checks, the plant is started up and subsequently handed over to the company production team to operate the plant going forward. This handover signals the end of the EPCI contractor and company support team's activities on site. These groups are then demobilised from the project location, having been allowed enough time to monitor any initial start-up hiccups, which could be very costly. Twenty percent of large-scale projects fail to meet expected operability targets and, for this reason, due diligence is undertaken during the earlier project execution stage activities to attain top quartile operability performance (Brikho, 2011).This phase equally has provisions for operator training on site, especially if new equipment was added, with close-out documentation handed over to the company, and lessons learned during the project phases shared in a workshop and documented in an archive for subsequent application to similar projects in future.

2.8 Project Classification – Revamp Projects

Project classifications are varied and numerous, but researchers and authors, notably Youker (1999), Shenhar et al. (2002) and Crawford et al. (2002), have made great efforts to classify projects based on their execution strategy. This strategic viewpoint is summarised as "different project types have different strategic importance; each type typically requires different management approaches" (Morris & Pinto, 2007). Other scholars have stated that projects could be either strategic or operational in nature, depending on the project type. They are further classified as either internal or external, depending on the closeness to the customer. These project classes include derivative, platform, and breakthrough projects, also known as commercial development projects (Wheelwright & Clark, 1992). Derivative projects relate to life extension, improving, revamping, or upgrading existing products or facilities for short-term gains (performance improvement) and as such they are operational in nature rather than strategic. Platform and breakthrough projects relate to new products or processes and new facilities development (greenfield) and they require more strategic approaches (although this may not always be the case), looking at the gains from a long-term perspective (Shenhar et al., 2002).

Projects have also been categorised as simple, complicated, or complex. Complex projects can be further separated into three distinctive types: A, B or C. The type 'A' complex project is described as "traditional system of systems (SoS) projects in which there is the inclusion of an existing system into a new project, the existing system being autonomous" (Ireland et al., 2012). Today, most oil and gas operators are inclined to use this classification to describe projects as either having low, medium, or high complexity. Although there are limitations in the literature on the term 'revamp projects', other terms like retrofit, upgrades or brownfields are commonly used in practice. Revamp projects differ from conventional grassroots or greenfield (new) projects where the work execution flows sequentially according to a schedule of activities. A revamp project is constrained by existing infrastructure and stricter HSE requirements since construction-type activities run alongside normal plant operating conditions. Such projects also must minimise plant shutdown duration to allow for hook-up (Golden et al., 2003; Bhattacharjee et al., 2014). According to Golden et al. (2003, p2), "without an exact knowledge of revamp oil and gas project constraints, it's impossible to define an accurate work scope".

Pennock (2001, cited in Obiajunwa, 2007) also described that a revamp involves a full or partial modification of an existing facility. Therefore, the most critical enabler for a revamp project success is an accurate definition of the work scope. Olivier (2001) and Ertl (2005, cited in Obiajunwa (2007), posited that the totality of a revamp project work scope cannot be fully ascertained until the facility is shut down for execution. Gadalla et al. (2013, p454) stated that "revamping an existing plant is a difficult task, more complex than a new process design; many parameters must be considered and sometimes it is not possible to quantify all of them".

Therefore, in other to avert scope identification challenges in revamp project planning, great care, and follow-up with the entities responsible for specific tasks are critical for finalising the work scope early in the project. Associated with revamp projects are shutdown maintenance projects. According to Duffuaa et al. (2004), cited in Obiajunwa (2007), shutdown maintenance projects, also known as turnaround maintenance (TAM) projects, are periodic maintenance periods involving the shutdown of the facility to allow for repairs, jobs on standby awaiting the opportunity for intervention (opportunity jobs), inspection, replacements, and general overhauls. While the definitions of both shutdown and revamp projects are clear and different, a relationship exists between them, as TAM is a subset of revamp projects. It has also been stated that shutdown maintenance projects are the most expensive and time-consuming maintenance projects to execute, due to the additional cost deficit occasioned by the production outage for hook-up and tie-ins (Obiajunwa, 2007).

In the context of this commentary, shutdown maintenance is arguably equal to a revamp project and the overall cost of executing revamp projects can be quite high, even though they are not usually classified as megaprojects. However, according to Albrecht (2016), the essence of revamp projects is production and cost optimisation and plant availability or the minimisation of downtime by either like-for-like replacements or an improved solution. According to SBM Offshore (2017), seven revamp or brownfield services segments include facility conditions assessments; limited pre-FEED studies and FEED; major repairs and upgrades; debottlenecking and capacity increase; tiebacks; life extension and end-of-life solutions.

Therefore, from the above, we can conclude that the categorisation of projects as revamp projects, otherwise known as complex type ‘A’ or derivative projects, is about improving the performance of an existing asset for the overall gain of all stakeholders in the oil and gas value chain. Also, the limited literature on oil and gas revamp projects in the public domain is probably due to the inherent uncertainties and complexities involved (Rahi, 2005). These include simultaneous work operations, an increase in the scope of work, ever-changing work priorities, relatively lower budget estimates compared to mega projects and shorter work duration compared to major projects, as well as the safety risks involved in carrying out construction activities in a hydrocarbon-laden environment (Brikho, 2011). Therefore, oil and gas revamp projects can simply be described as a complex mix of both new construction and modification projects within an existing facility under live and production shutdown modes.

2.8.1 Revamp Project – Floating Offshore Asset

Floating offshore assets are financially intensive oil and gas facilities that operate at various water depths offshore. They consist essentially of floating production and offloading facilities (FSO) and the FPSO. They are moored to the seabed using mooring chains, turrets and/or dynamic positioning systems with redundancy for assurance of the assets' safety, especially on-board personnel. Since these assets are built with steel and, irrespective of their design against corrosion using cathodic protection systems, the harsh salty offshore environmental conditions make them very susceptible to degradation. To continue to deliver the returns on investment to shareholders, a maintenance program must be put in place by oil and gas operators to guarantee that the business objectives are met through the design timeline, which is usually between 25 to 30 years. The beauty of the floating offshore asset is that the FPSO can be relocated to another facility should the reservoir not flow as economically as anticipated or for some other unforeseen reasons, such as government policies or acts of God. The revamp project is deployed to sustain the oil and gas asset offshore to maintain optimum oil and gas production.

Floating Production Storage Offloading (FPSO)

The FPSO, as stated earlier, is the current hope for continuous oil and gas production from deep offshore, where the bulk of the world’s oil and gas reserves currently reside. To remain in business and be competitive, most oil-producing companies have invested in at least one FPSO. The average FPSO has a designed production capacity of around 200,000 barrels of oil equivalent per day and a storage capacity of ten times the daily production. For the FPSO to function effectively, the Umbilical, Flowline and Riser (UFR) components and the Oil Loading Terminal (OLT) facility, for example, the SBM buoy, must be fully commissioned. The FPSO is divided into four major sections: the port, starboard, aft and bow areas. They house several parts, including accommodation blocks, the plant's processing facility, utility areas, machinery space, a heliport, hull, a boat landing for marine logistics, and laydown areas for material reception and loadout using in-built cranes.

The FPSO separates the crude oil into gas, processed crude and water. While the water is further treated and sent back into the well formation to further enhance subsea pressure maintenance, residual water from oily water filtration is sent overboard. Also, the gas is compressed and sent into the sales line to an NLG processing plant onshore. A portion is converted into fuel gas to run utilities on board the FPSO. A third part has the provision to be re-injected into the well formation for pressure maintenance. A portion is also flared because of the production process, and this is highly regulated with a penalty for flaring beyond the approved limit. It is important to point out that one of the ways of assuring optimal performance of the FPSO topsides is to plan interventions through revamp projects. This research focuses on piping and tertiary supports, valves and pressure vessel work execution requiring careful planning, the mobilisation of huge resources to site, and interface challenges that may often require the need for full facility shutdown. Approval for plant shutdown can be costly and it follows review and arbitration by senior management, partners, and shareholders.

FIGURE 2.6 ERHA FPSO Anchored at location Offshore

Source: ExxonMobil (2015).

FIGURE 2.7 EGINA FPSO Anchored at location Offshore

Source: TotalEnergies (2021).

FIGURE 2.8 BONGA FPSO Anchored at location Offshore

Source: Shell (2021)

Umbilical Flowline Riser (UFR):

Following successful drilling and completion of the subsea drill centres, the well streams are commissioned and operated by remotely operated vehicles (ROVs) via flexible flowlines to a common manifold subsea. These communication signals are transferred by umbilical through fabricated jumpers, and the subsea flowline components are connected to the FPSO topsides via the steel catenary risers (SCR).

Oil-Loading Terminal (OLT)

The liquid component – processed crude oil or condensate – is transported through a piping connection from the FPSO storage at the hull through a subsea pipeline an average distance of 1km to crude oil tankers via the OLT. The tankers berth via a single point mooring to receive products and sales from the FPSO. Figure 2.9 indicates the typical complex connection of subsea production facilities to the FPSO anchored at location. Apart from the interface issues during normal operations, the additional marine logistics during a revamp project execution compounds the exposure to incidents. Therefore, care and compliance to procedures and guidelines is important in realising a successful project management performance and delivery.

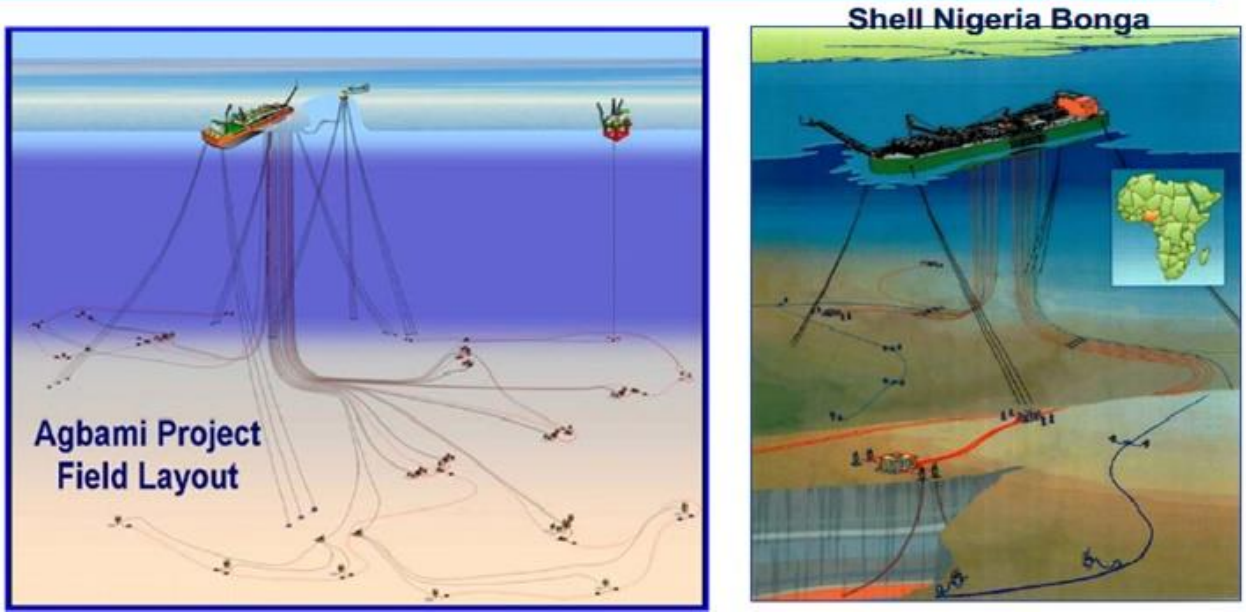


FIGURE 2.9 Subsea UFR, and OLT connections to the FPSO

Source: Brown (2014).

2.9 Revamp Project Management Activities

In a revamp project development at execution stage with the five-stage gated approach, various elements are managed throughout the process groups by project functional entities. Effective management of these elements rests on efficient organisational relationships between the oil and gas operation companies and the engineering procurement construction and installation (EPCI) contractor. A good organisational relationship enables excellence in the FEL stages that leads to lower lifecycle cost. Furthermore, efficient organisational relationships during a project's development hinge on a better understanding of the basic elements of project management (Frankhouser, 1981). During the execution stage, the basic elements of project management in the oil and gas industry have been reviewed under the following project management activities: engineering, procurement, onshore fabrication, offshore construction and installation, project control, field operations and site management, and administration. All these activities are supported by the project support team, who make up the individual functional groups as per established company organisational structures. However, consistent with project management standards, the project management team must ensure adequate monitoring and control to avert slippages and reworks, which are counterproductive, wasteful, and avenues for poor project management performance.

2.9.1 Engineering (Detailed design and Installation Engineering)

The engineering function follows up with completing detailed design, engineering taking off from the Front-End Engineering Design (FEED)in projects delivered through the stage gate or waterfall project delivery approach (Almarar, 2019) with all associated deliverables issued for construction drawings, calculation notes, red line mark-ups and as-built documentation post successful delivery of the project. The engineering function is equally responsible for installation engineering design and providing responses and directions to construction technical queries when what was designed is at variance with the actual site situation. An example is piping clashes with existing structures that were not captured in the as-built drawings, or any modifications made without updates to the as-built drawings.

These scenarios are typical of FPSO revamp projects, giving justification for the concept of overlapping or fast-tracking in project management to support and avert potential delays during construction and installation activities within the execution project phase. Usually, the engineering entity is part of the support function to the core project management team. Therefore, it has discipline engineers headed by an entity head or manager throughout the project lifecycle. Although space constraints, harsh offshore weather conditions and the HSE concerns make the revamp of the FPSO more complicated than other onshore process facilities, the key project deliverables of the engineering function during the execution phase of the project development remains the detailed engineering and the as-built packages. The former is used to transform the conceptual inputs into coordinated systems for fabrication and new components addition, and the latter is issued post-project execution to capture site modifications, technical supports during construction and installation, specific materials specifications and as-built drawings for future maintenance or repair works (Frankhouser, 1981).

2.9.2 Project Control

Cost and schedule, planning, estimating, and document control appear to be on the 'soft side' of the project management process. However, this function contributes to the key performance indicators (KPIs) that are quite traditional, belonging to the 'iron triangle' and they can be quickly referenced by both the project team and stakeholders at every stage of the project lifecycle. Suffice to say that schedule slippage and cost overruns are enemies of good project performance. Therefore, project managers are usually very keen on carefully selecting the personnel in charge of costs and schedules. Diligence, attention to detail, experience and the application of lessons learned are key to taking control in this regard. In addition, constant reviews, follow-ups, and communication with both internal and external customers enable the project manager, for example, to have realistic cost and schedule estimates and to make informed decisions about expediting and making or buying options.

Deliverables associated with costs and schedules include detailed work and execution plans, usually done using software like Primavera P6 or Microsoft Projects. The schedule presentation usually comes in levels from one to four, with the criticality and level of details increasing with level four being the highest. A level one schedule is normally the project plan and indicates milestone dates which are sacrosanct, while a level four schedule is micro in nature, has sequential activities for the complete work scope and is the schedule provided to the team directly involved with execution (Frankhouser, 1981). A key deliverable of the costing, estimating, and budgeting function is the Appropriation for Expenditure (AFE) package. This package is prepared from a careful cost breakdown of the respective components and activities while providing for realistic contingency allowances, cost trends and forecasts to arrive at a total project cost estimate (Frankhouser, 1981). This element is critical to project practitioners and, once approved, becomes a working reference and benchmark for cost monitoring, controlling, and reporting on regular basis throughout the project lifecycle. In addition, it is used to assess the overall cost performance of the project.

In addition, one very important work element is project documentation, although some organisations traditionally still classify them to be engineering. This element has become very popular, especially due to the size and complexity of certain projects, which require documenting every material and equipment with respect to quality. There are cases where project documentation has been handled by a standalone entity, depending on the project's organisational structure and size. However, effective document control contributes towards a seamless progression of the project lifecycle – a continuous document review with updates and issuance of deliverables with transmittal processes assures quality and prevents rework, the wrong drawing being used for construction, or incorrect installation. When the project successfully comes to an end, each document used must be retrievable (Shokri & Maloney, 2015; Frankhouser, 1981).

2.9.3 Construction (Onshore fabrication and Offshore Installation)

The construction activities entail both onshore fabrication and site installation and they attract an important entity in the project lifecycle, especially during the execution phase. It is good practice to begin this activity early in the selection phase to integrate construction input into the design at FEED reviews, meetings, and workshops, including site surveys. The overall intent is to ensure that the engineering design team do not design what cannot be physically constructed and installed without modifications. Comparing the construction functional group and the engineering functional group's involvement, construction involvement begins early during the selection phase. It reaches a climax during the execution phase, while the engineering involvement peaks during the selection phase and is at its lowest ebb during the operation phase. Like other functions, the construction function must be well experienced in technical and human resource management, as there are many interfaces with the EPCI contracting community. These can be quite interesting but challenging, especially during the pre-mobilisation of equipment, the mobilisation of resources to site, and the actual site intervention up to pre-commissioning, start-up, and handover.

Although it has been argued that the execution phase is the longest of the FELs, construction and installation on-site are usually on the critical path, especially as they require plant shutdowns for hook-up. Additional delays in the plant start-up target date may be significant and damaging, and thousands of oil production barrels could be deferred. Key activities and deliverables from the construction function include a construction risk assessment, constructability reviews, construction readiness reviews and cold-eye reviews. These are to assure quality, monitoring and control of activities at every step. Indeed, the construction function plays a major role in supporting the EPCI contractor to succeed during execution by acting as an interface between the various support functions on the company side for engineering, materials, and logistics, as well as between the onshore base office and site management, aside from monitoring the EPCI contractor's work progress, quality control and deployment of resources (Frankhouser, 1981).

2.9.4 Project Procurement

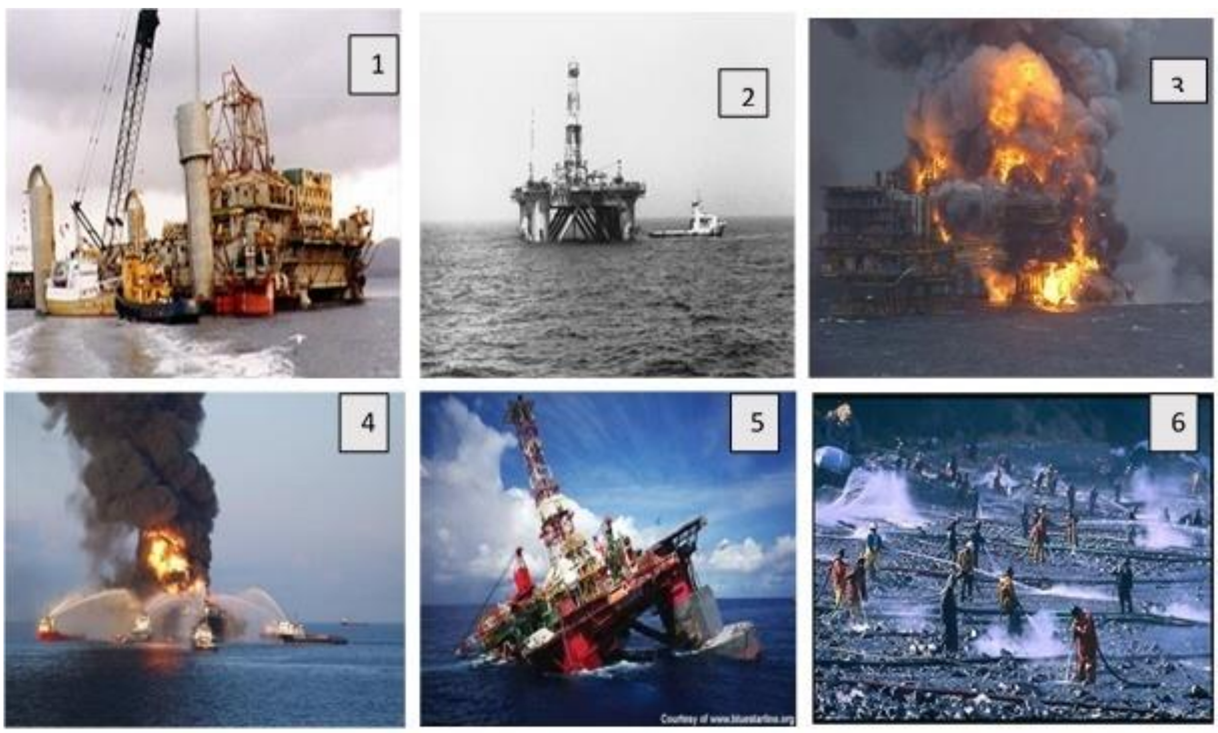
In a broad sense, procurement encompasses purchasing, expediting, transit, materials control (especially long lead items and equipment) and subcontractor administration (Frankhouser, 1981). These elements of procurement demand an efficient functional group that must be carefully stewarded, otherwise no work is executed. Imagine attempting to mobilise for a job when there is no material, or if you have the materials but no means of transporting them to the required location. Identifying the project materials based on their specifications, the ability to handle and manage the materials when they arrive at the storage area, preservation of the requirements, protection from pilferage and damage during handling and inspection, are critical factors for successful project performance. Material requirements begin very early in the project lifecycle and terminate at the post-execution phase (Rahim et al., 2017).

The contracting process with joint venture partners in Nigeria, for example, can be quite protracted, taking between 12 to 18 months on some occasions. The reasons are not unconnected to the local content development initiative. Although it was introduced with good intentions for the overall development and empowerment of the local populace, the management of this process is often far from optimal, especially as thousands of tenders are received for very limited bid opportunities, the platform or mechanism for completing the call for tender (CFT) process is cumbersome and filled with bureaucracy. Even the contracting community have tenderers with limited experience and capacity. The government has encouraged joint venture partnerships with foreign investors and things appear to be moving in the right direction but at a very slow pace. It is hoped that improvements in this area will go a long way towards ensuring that FPSO revamp projects have an improved performance rating going forward.

2.9.5 Health, Safety, and Environment (HSE)

The importance of health, safety and environmental (HSE) considerations during a project lifecycle cannot be overemphasised. The Deepwater Horizon oil spill (Macondo) incident in the Gulf of Mexico on April 20th, 2010, cannot be forgotten in a hurry. All oil and gas operating companies are critical about HSE, and they all have slogans demonstrating that HSE is not just a core value but has now become a culture. Some operators, for example Total Upstream Nigeria Limited and ExxonMobil, begin all meetings with at least a safety moment on any topic on or off the job to share and remind all not to carry out any job at the expense of safety.

The HSE functional group does not comprise only Personnel Protection Equipment (PPE) compliant officers, but essentially looks after both leading and lagging indicators to ensure that there are no incidents during projects. The safety consciousness and practices in the industry are impressive due to continuous training and awareness programs, previous experience in hazardous working environments, and the quest for operators to maintain maximum production and profit optimisation, while striving to maintain a competitive advantage as an operator with outstanding safety performance records. To maintain excellent HSE standards during revamp project execution, it is a practice in the oil and gas sector not just to carry out a detailed engineering design review for hazard identification (HAZID) but also to carry out a hazard and operability plan (HAZOP) to revalidate operational procedures and to verify that the contingency plans have been implemented prior to onshore prefabrication, site installation and commissioning activities (Brown, 2014).



1.) 1980 Alexander L. Kielland Semi-Sub Norway – 123 fatalities

2.) 1982 Ocean Ranger Canada Hibernia – 84 fatalities

3.) 1988 Piper Alpha– 167 fatalities

4.) 1989 Exxon Valdez Oil Spill – 11M gallons (260 KBBL)

5.) 2001 Brazil P-36 Platform Loss– 11 fatalities

6.) 2010 Deep Water Horizon USA GOM – 11 fatalities, 210M gallons

FIGURE 2.10 Real Events on Offshore Facilities and Impact on HSE Management

Source: Offshore Technology (2019); ExxonMobil (2013).

2.9.6 Project Quality Assurance and Quality Control (QA/QC)

The philosophy of the quality function in the oil and gas industry is Total Quality Management (TQM), which literally implies introducing values of quality into project development prior to, during and post project execution. Quality assurance is defined as part of quality management focused on providing confidence that quality requirements will be fulfilled, while quality control is the functional techniques and activities that are used to satisfy quality requirements (ISO 9001, 2021). Quality assurance involves planning and organising a system or product to maintain the anticipated level of performance or reliability over time. Quality control, on the other hand, involves quality assurance implementation by actual physical assessments of components, against established and acceptable standards, specifications, codes, or drawings, as spelt out in the quality management plan (Frankhouser, 1981).

An efficient QA/QC management system ensures a well-developed quality value at a very early stage in the project lifecycle that deliverables, tools, and practices utilised by this functional group include quality audits, procedures, method statements, QA/QC manuals, quality plans and the policies of the contracting community sighted and signed by respective managing directors. On site, it is common to have corrective action reports, non-conformance reports, welding procedure qualifications and procedure qualification records for different materials, welding positions and welding processes as well as material inspection reports, fabrication material released reports, overage, shortage, and damage (OSD) reports, and so on. The purpose of all of these is to ensure that there are no delays coming from rework, repairs, and an additional need for inspection or wrong materials being used for a job. A reduction in rework will reduce to as low as reasonably practicable project costs and schedule propagation, as well as improve operational efficiency and assurance of health, safety, and the environment (Love, et al., 2014).

Even though all of these are practised in different work locations today in most oil and gas companies, quality challenges persist because humans are involved in these processes. The efforts of this research may be used to explore further opportunities for improvement in quality and other project activities. Lean principles quickly come to mind, as some quality practices mentioned earlier, such as inspection, rework, repair, handling, and storage of inventory, have been criticised and described as wasteful and not adding value to project performance. Using lean principles as a performance improvement approach has been further discussed while carrying out this research.

2.9.7 Project Administration

Administration consists of accounting, personnel mobilisation and integrated helicopter travel planning, legal consultations and contract interpretations, and interfacing, which is an area that deals with both internal and external communication and alignment with stakeholders (Frankhouser, 1981). Interface engagement, especially with a government as a joint venture partner, is key and a potential bottleneck to the smooth running of a project. If this work element is not managed effectively by the designated project function, the project could suffer tremendous delays as approvals will not be granted, forming a hold point until all grey areas are resolved.

The accounting element involves invoice processing and payments as per contractual milestones and purchase orders. As expected, the accounting process becomes more challenging with increasing size, project cost, and complexity. In addition, the type of contract being adopted for the "project can be complex" if it is a project with multiple currencies, fluctuating exchange rates due to inflation, unfavourable tax laws and difficult regulatory banking policies regarding currency transfer at the time of the business transaction. During site realisation of a revamp project development, the number of personnel expected offshore reaches the highest number – typically over half a million personnel are mobilised to site for intervention. Due to helicopter seating capacity being limited to less than 15 people per trip, coupled with potential weather challenges, realising the planned personnel in and out of site could linger and thereby hinder the efforts of the integrated mobilisation planning team, the overall project schedule and, eventually, result in project management under-performance.

Legal elements are constituted in the project management framework to support purchase orders and contracts administration, the mitigation of potential patent rights issues, and the interpretation of new laws, as these can affect the project with claims negotiations and avoidance (Frankhouser, 1981). In some organisations, a contracts and procurement conformance committee comprising key stakeholders from different entities (including legal) meets regularly to review and align contractual strategies and to fully understand and interpret rather ambiguous clauses in contract documents before they are validated by the designated authorities.

2.9.8 Production Field Operations

Every oil and gas producing company has well-documented guidelines for running its business. Even though these guidelines have different names, they all relate to carefully documenting an approved way of doing business. For example, ExxonMobil has its Operations Integrity Management System (OIMS), while in Total Upstream Companies in Nigeria (TUCN) it is known as a Standard Operating Procedure. These documents are comprehensive and cover practically all aspects of the oil and gas business (AlMarar, 2019). During revamp project executions on site, the production team are the owners of the facility, and they have the final say on any work carried out.

The facility manager, otherwise called the OIM (Offshore Installation Manager) or simply the Person in Charge (PIC), carries out site control and management through alignment meetings, presentations, site walkthroughs and effective Permit to Work (PTW) systems. These used to be quite manual and cumbersome, but the current trend is to handle these electronically, such as an e-permit in ExxonMobil and eVision in Total Upstream. The operations team are well trained in handling the processes using charts like Process Flow Diagrams (PFD) and Process and Instrument Diagrams (PID). Should any additional equipment be planned to be added to existing facilities, the PMTs ensure that provision for training is factored into the project budget. A KPI for the operating companies is maintaining HSE standards and their operations' integrity, which amongst other purposes helps to strengthen their licence to operate in the regions where they conduct their business.

2.9.9 Project Decisions and Revamp Peculiarities

Further to the introduction of brownfield or revamp projects as outlined in Chapter One, it's imperative to highlight in detail the attributes of this type of project that differentiate it from greenfield and mega, major, or capital projects. When a greenfield or new facility starts up, a new brownfield or revamp project opportunity is created and, through technology improvements, more production can be extracted from existing assets. Despite the impressive returns from engaging in brownfield projects, the emphasis is not always placed on revamp project development but instead attached to larger greenfield developments. Although both greenfield and brownfield projects follow the same stage-gated process to deliver expected value, revamp projects are life extensions of existing facilities and are expectedly prone to many stakeholders to interface with. In addition, like greenfield projects that have records of schedule and cost slippages during execution, it can be significantly worse for brownfield projects (Visser & Brouwer, 2014; Visser et al., 2015; Mukherjee & Palmer, 2006).

Brownfield projects require shutdown for final tie-ins to be made to existing facilities. This activity is critical as it requires a design and scope of work survey, risks and mitigation plans, and stakeholder, integration management and cost management factors can play a role. These characteristics increase the inherent complexity in revamp project executions (Al-jabri et, al., 2014; Al-khaledi &Waheed, 2010; Hotier et, al. 1998) up to the extent that a new proposal for a bottom-up project (as opposed to the traditional top-down approach) has been recommended for managing the project scenarios (Ramana, 2006).Brownfield projects have also been associated with adjectives like complex, uncertain, challenging and risky, because they involve working around live hydrocarbon facilities or assets, crude oil tanker berthing operations, and supply vessel movement, all working within the tight 500m exclusion zone of the production facility (Uyanwune, Oyeniyi & Ejiofor, 2015). This involves a lot of planning and interface coordination.

Another challenge of a revamp or rehabilitation project that requires a different project management mindset relates to the potential changes in scope, approach and the strange situations facing the project team, when compared to greenfield projects. For example, the existing equipment may not be compatible with modern upgrades and spares may no longer be available on the market. This scenario requires thinking outside of the box for adaptability and requires experience and skills to avert sustained downtime (Dunnahoe, 2012; El-Reedy, 2012). From the characteristics of revamp, brownfield, or rehabilitation project realisation, it's evident that the project team and hierarchy are constantly faced with uncommon challenges that require a careful and well-tailored approach. This is where the choice of multiple criteria decisions making amongst competing alternatives becomes appropriate, which is further explained in detail in subsequent chapters of this thesis.

2.10 Project Complexity

The complexity of a project is measured by its ease of execution. Most operating companies have simple classifications of projects, leveraging on their standard risk matrix nomenclature as low, medium, and high, depending on their set criteria. Nevertheless, common features pertaining to complexity include a new or existing location with infrastructure; confirmation of the extent of technology required, whether new or known; the financial burden of the project; production as well as health, safety and environmental impact; extent of interfaces, both internal and external; construction requirements and contractor capability challenges; urgency of the project; and the need to deviate from standard project management processes, amongst others (Brikho, 2011; Whittington & Gibson, 2009; ExxonMobil, 2018).For example, we can consider the Health Safety Environment (HSE) impact from the loss of containment of crude oil from the FPSO (approximately two million barrels storage capacity) released into the environment during a welding activity, or the cost of an additional day's deferred production of 200,000 barrels per day at $75 per barrel due to start-up delays during a revamp project execution. It is obvious that the impact can be high, especially when human beings are involved, which merits a classification as a complex venture.

2.11 Project Performance and Previous Research Efforts

Green and Woolson (2016), in an Environmental Resources Management study on the oil and gas industry, stated that 53% of the capital projects evaluated had schedule delays, which compounded the initial cost overrun already recorded. They posited that delivering capital projects in the oil and gas industry continues to remain a challenge, despite the seemingly robust project management models put in place by operating companies. In addition, Mckenna and Wilczynski (2006), Rui et al. (2017), Barlow (2000), Gomarn and Pongpeng (2018), Reqaishi and Bashir (2015) and Marrow (2012), posited that over 40% of total individual company executed projects have significant cost and schedule overruns. Leaders in the oil and gas companies are very dissatisfied, blaming project management performance, risk management, human resource management and inadequate inter-organisational cooperation, amongst other factors as the major causes of their woes. Meyer (2014) also stated that the largest completed offshore oil and gas project in Australia, the Gorgon project (~ $57 Billion), cost doubled its initial budget estimate.

The oil and gas industry are not the only industry that suffers from poor project performance. A survey indicated that over 60% of complex construction projects experienced slippage in their delivery target dates (CIOB, 2008). Elinwa and Uba (2001) argued that time and cost overruns are common in Nigerian construction projects and that the performance issues worsen when the work scope is not clear; under prevailing economic hardship, disputes emerge, causing more delays (Aibinu & Odeyinka, 2006). However, Gibbs et al. (2017) posited that the risks of common delays could be mitigated by both the proactive management of delays and the improvement of delays in claim information. Derakhshanalavijeh and Teixeira (2012) also stated that Iran, like other developing countries, has suffered cost overruns in the oil and gas industry due to poor risk management, planning and uncertainties, including the unavailability of competent human resources. Additionally, Saidoun (2015) posited that project management success is tied to the intercultural competence of the project manager and, by extension, the organisation, citing Algeria and Morocco as cases.

From the above review, we can see that FPSO revamp projects have limited coverage in the literature, but one can infer that the challenge of poor project performance from schedule delays and cost overruns is an age-long problem. Unsatisfactory project performance cuts across every industry, region or type and size of project being executed, even with seemingly robust project management processes put in place by organisations. Also, the reasons proffered for addressing the project performance challenge are varied and numerous, depending on their peculiarities. Therefore, further investigation and optimisation of existing project management processes are needed to address this complex challenge of poor project performance, with an emphasis on FPSO revamp projects as a case study.

2.12 Projects and Critical Success Factors

Researchers have differentiated between project success and project management success. While the former is linked with the result of the overall project aim and objectives, the latter relates to the traditional measurement of cost, time, and quality – the 'iron triangle.' Radujkovic and Sjekavica (2017); Serrador and Turner (2015); Papke-Shields et al. (2010); Mir and Pinnington (2014) and De Wit (1998). Monteiro de Carvalho et al. (2015), Lock (1992), Farhaj and Mirza (2017) and Atkinson (1992) have also posited that while the traditional index for project management success is the ability to fulfil the iron triangle, project complexity now dictates the project management regime with attention to the impact on both margins and schedules. Measures including a better control of environmental factors through the project life cycle are enablers of project success. However, successful project management can assure project success and, according to Han et al. (2012, cited in Radujkovic and Sjekavica, 2017), project management success is one of the elements of project success, because a successful project is hardly achievable without project management success. This implies that a project could be termed as successful when the project is completed and performing optimally as anticipated, but this could be a project that had both cost and schedule overruns and hence entailed unsuccessful project management.

By and large, the concept of total project management efficiency has been suggested as a means of indicating cost and schedule among other success criteria (Bouras, 2013). In addition, Rui et al. (2017) suggested a set of two-dimensional industry metrics to address the issue of poor performance in this industry. Other researchers, including Zuofa and Ocheing (2017), have contended that leadership style and lessons learned are critical for the successful implementation of a safety culture during the construction phase of offshore oil and gas projects. However, Monteiro de Carvalho et al. (2015) have argued that project management has a significant impact on project success, especially from the perspective of scheduling and margins. Due to the uncertainty constraint in every project from HSE to operations, it is common practice to critically evaluate what could go wrong and what could go right through the project phases with a formal structured process. This is called project risk management and has been proven to mitigate or act as a barrier to poor project performance, including failure.

PMI (2013) has defined project risk management as the processes of conducting risk management planning, identification, analysis, response planning, and controlling risk in a project. This indicates that it is a five-stage process that works in an iterative fashion until the desired outcomes are obtained. However, the risk ranking or classification of a project at the initiation phase is directly related to the success or failure of that project. According to Yim et al. (2013), "the type of risk events occurring in projects does vary based on project classification" but Royer (2000) and Zoufa and Ocheing (2011) have argued that, regardless of project size, complexity or cost, no construction project is devoid of risks. Therefore, a failure to manage risks is an enabler of project failure and according to Agbonifo (2016) practice of risk management brings about overall sustainable development for all the stakeholders. In a similar vein, Akhibi (2012) has stated that executing oil and gas projects in Nigeria, for example, is difficult because of the social-political challenges coupled with the inherent bottlenecks and risks of working in a harsh onshore or offshore hydrocarbon-charged environment. These exposures can be adequately mitigated by proper risk management. Danni-Fiberesima and Abdul Rani (2011) have recommended 13 Critical Success Factors (CSFs), some drawn from megaproject experiences for the improved performance of oil and gas project execution, using cases in Deepwater Nigeria. Omar and Fayek (2016) have equally suggested the systematic methodology of prioritising fuzzy aggregation, factor analysis and fuzzy neutral networks to identify the correlation between project competencies and Key Performance Indicators (KPIs).

From the above discussion, the modern trend of assessing the project management success of a project has undergone a paradigm shift from the traditional KPIs of cost, schedule, and quality, to other indicators concerned with the overall value to both internal and external customers. Although there has been an array of suggestions on how to steward projects to successful completion, all projects are unique and have different challenges and peculiarities associated with them. Therefore, project characteristics must be identified very quickly in the project lifecycle by the project team to select the appropriate measures within the given framework and context to mitigate potential key failure factors.

2.13 Performance Measurement and Improvement

When sets of processes are combined, they form a system called a framework or a model, utilised for performance measurement and improvement. A typical performance measurement model has an infinite loop of performance objectives, measures, expectations, evaluation, and feedback. This infinite loop framework is consistent with the saying that there is always room for improvement, and most companies and sectors have customised their performance tools to be in line with this generic model. Examples of measurement models according to Robinson et al. (2002, cited in Bassioni, 2004) include KPIs from the UK construction industry, made popular by Egan's (1998) report rethinking construction; Balanced Scorecard; the European Foundation for Quality management (EFQM); the Excellence model in Europe; the Malcolm Baldrige National Quality Award (MBNQA) in the USA; and the Deming Prize in Japan. Other customised versions include CMM, SPICE, Total Quality Management (TQM), ISO 9000, and Six-Sigma. Most oil and gas companies, including Shell, ExxonMobil, Chevron and Total, have adopted the KPI standards, which according to a report is a framework of seven elements consisting of time, cost, quality, client satisfaction, change orders, business performance and health and safety, resulting in efficient project delivery through the five-stage-gate project lifecycle (KPI Working Group, 2000).

However, while performance improvement is very much welcome in organisations, there comes a time when iterative and gradual increment in a process no longer yields significant improvement.

At this stage, a significant change would be required to make further impact on the process, and this is when improvement turns into innovation. The mental model in improvement is about existing process optimisation and ensuring quality output. While the innovation mental model is a fundamentally novel creation using a different process, it is still subject to subsequent optimisation over time by improvement (Mate, 2017). The scope of this research work is limited to improvement and not to make drastic changes to the existing operating framework in complex projects such as FPSO revamp executions. Innovation is typically preceded by performance improvement tools and techniques, and a few in use today include building information modelling, Lean philosophy, Total Quality Management, knowledge management and concurrent construction, to mention a few (Batkovskiy, et al., 2016).The improvement method discussed in the literature will be selected for this research, and will emerge from previous experiences, acceptability and application in the oil and gas industry, as well as from the expert participants in this study.

2.14 Project Management Framework of Major Oil and Gas Operating Corporations

ExxonMobil Capital projects management System – (EMCAPS, ExxonMobil)

ExxonMobil Corporation, in a bid to harmonise and standardise the different related approaches of managing both small to medium and megaprojects within different affiliates globally, developed a framework called the ExxonMobil Capital Projects management System (EMCAPS) in the mid-2000s. Like other major oil and gas corporations, ExxonMobil suffered setbacks from the non-usage of standardised project management systems and there was need for improved efficiency and effectiveness in project performance. There are three key incentives for EMCAPS. Firstly, the harmonisation of multi-project management systems deployed across the corporation – these systems had similarities in approach but marked differences in application, causing confusing terminologies that negated improvement. The second incentive was the belief that a common approach is an enabler for effective and efficient realisation of the corporation’s project portfolio. The gains of common approaches become evident in sharing and applying best practices and lessons learned, common standards and terminologies, the availability and flexibility of deploying experienced project resources as needed, as well as common work processes, procedures, practices, and common systems of terminology amongst the personnel and the contracting community. The third incentive for EMCAPS was the drive for a desired level of standardisation over time that would put the corporation on a trajectory of growth and sustenance of top quartile project performance.

The EMCAPS is an integrated system that unifies the five-stage-gate process, otherwise called the project arrow, comprising Stage 1, development, and business planning; Stage 2, select; Stage 3, define; Stage 4, execute; and Stage 5, operate. The system includes 14 elements, 59 work processes and key deliverables; a common cost and schedule estimating framework; references, guidelines, and best practices; processes for system verification, assessment, and improvement; and system governance and administration processes, consisting of gate packages preparation, three gates and three checkpoints with independent reviews and an approval process by the gatekeeper or designate, as required. As part of project governance, EMCAPS defines specific management roles and responsibilities through the gates' package development, review, and approval process. Key functions include the gatekeeper, usually a senior manager, such as a project executive (line manager), project leadership team member, steering committee member or project manager.

In addition, of high importance for the corporation is the consideration of EMCAPS to be deployed for all categories of projects, from large and complex to small and conventional. EMCAPS categorises projects in terms of complexity. Project complexity can be defined by the variety, predictability, vulnerability, risk, issues, and extent to which specific characteristics apply to the project. In addition, scalability involves applicable EMCAPS processes and deliverables that are commensurate with the level of exposure and complexity. This means a focus on only what is needed to actualise the project, such as utilising reference documents as much as possible, considering go-bys as best tools for practitioners, and documenting the level or extent of scaling prior to review and approval by the gatekeeper. Therefore, applicability and scalability processes and guidelines are essentially at the call of the project's leadership. Hence, for small projects like the revamping of FPSO topsides, the project processes and deliverables are tailored by applicability and local needs, and not entirely by the EMCAPS process. Decisions may be subject to the opinion of the project manager.

Nevertheless, the project team systematically considers which EMCAPS processes or deliverables apply to each project and when they apply, to ensure alignment among key stakeholders and secure gatekeeper approval of the project-specific plan. This evaluation process by the team is referred to as the project road map. Despite the huge resources invested in developing formal stage-gate project management processes by many oil and gas operating organisations, the performance of major projects has not appreciably improved, and significant project underperformance continues to be recorded, judging from both technical and economic considerations. Schedule delays often stretch into years and cost overruns range from 25% to as high as 350%, including failures up to 19% (Lima, et al., 2019; Walkup Jr. & Ligon, 2006; Tideman et al, 2014; Shokri & Maloney, 2015).

Opportunity Realization Process (ORP, Shell)

Project management in a broad sense encompasses all associated activities, processes and systems maturing an idea or opportunity to reality. Opportunity Realization Process (ORP) is the customised global project management approach by Shell for project development through its lifecycle. The ORP is tailored to the stage-gate process of the waterfall project management model, and it has processes for quality assurance, excellence in HSE stewardship (including delivering projects within schedule and budget estimate), stakeholder management (encompassing local content development), effective utilisation of human resources, adoption of the appropriate execution, project team organisation and resourcing model as KPIs for project performance. Also included are the adopted models for contracting – a function of different criteria and timing of specific contract restrictions in the country, the level of details or extent of criticality of work scope, the specific project drivers from the PMI's 10 knowledge areas, and HSE (Dorgant & Stingl, 2005).

While all five phases of the ORP (Phase 1, identify and assess; Phase 2, select; Phase 3, define; Phase 4, execute, and Phase 5, operate (performance optimisation stage)) are integral units forming the complete approach, the first three phases (otherwise called the Front-End Loading (FEL) have to do with the planning and preliminary engineering studies. The execute phase is triggered by the approval of the Final Investment Decision (FID), which represents the actual realisation stage of the planning, with designed blueprints, and equally has the highest budgetary allocation. The operate phase is typically the production phase initiated by the start-up, post pre-commissioning and commissioning sequences or the ‘first oil’ milestone for greenfield development. This runs through the useful life of the facility up to abandonment or relocation of the asset to another viable field, such as with the case of FPSOs. The proper development and selection of the appropriate project specific management model and the successful execution of strategies and control processes will not only ensure optimum project management performance but also sustainable development in project delivery (Dorgant & Stingl, 2005).

Projects Developed in Affiliates Process (PDAP, Total E&P)

The Projects Developed in Affiliates Process (PDAP) is the global framework for project development in the Total Group and comes with a provision for adaptability of processes to suit the specific needs of the affiliates in the regions in which they operate. This framework is comprised of a five-stage-gate process: phase 1 (conceptual stage) involves the selection of the optimal concept for further development at the next pre-project phase; phase 2 (pre-project stage) pertains to stage stewardship by a development planning entity and involves the preparation of both technical and financial justifications for review; phase 3 (basic and detailed engineering stage); phase 4 (execution or realisation stage); and phase 5 (start up and close out stage). In addition, part of the project development framework includes descriptions of the roles and responsibilities of each entity involved in the project development: procedures for acquiring requisite technical justifications and approvals at each stage in the process, as well as the required deliverables by each entity in each phase and vigilance point to ensure that the process runs seamlessly. While the first two phases constitute the development studies by a development planning entity, phases 3 and 4 constitute the development project stage under the project group, and subsequently phase 5 (start up and close out) under the purview of the field operation entity. While all entities have clear interface links with each other through the phases, there exists a total of six project reviews (PR 0 to PR 5) and approval gates (vigilance points) (Total, 2020).

In summary, the Total Group, based on the need for improvements in the efficiency of its project management processes, deemed it fit to harmonise the practices in force between entities within its affiliates and developed a global project management system to be deployed in all affiliates with the following objectives:

a. Establishment of a reliable project definition and scope of work at both pre-project and project interface.
b. Clarification of potential interface issues among entities by defining specific responsibilities and deliverables at every stage.
c. Minimisation of inherent project constraints, like the iron-triangle and operating risks

d. Assurance of good practices when several entities work as a group to attain a common goal.
e. Optimisation in the project completion schedule.
f. Reduction in overall project cost.

Chevron Project Development and Execution Process (CPDEP, Chevron)

Irrespective of the size, cost or complexity of the project, Chevron adopts a proprietary project management system called the Chevron Project Development and Execution Process (CPDEP). This framework is deployed for both major and revamp projects within Chevron and consists of five phases used for project management planning, design, and execution (Dumrongthai & Pasikki, 2013). The phases of CPDEP include Phase 1, identify, and assess opportunity; Phase 2, generate and select alternative; Phase 3, develop preferred alternative; Phase 4, execute; and Phase 5, operate and evaluate. Features, processes, and specific milestones of the CPDEP include the development of project deliverables like the Basis of Design (BOD) and Decision Support Packages in preparation for the prominent phase-gate review cycles.

In addition, there abounds a system of Management of Change (MO) dossier preparations for any proposed change to the BOD. Also prominent in the process is the role of the decision executive who makes the final 'go, no-go' decision to move on to the next phase, as well as the Decision Review Board (DRB) that supports the package review and decision making as a group or committee. Also important in the process is the consideration for peer review for full alignment of stakeholders at a very early stage. Also, lessons learned are captured at every stage of the project until final project completion, when it is uploaded into the company database and applied in similar project executions in the future. Typically, the last phase of the project endeavour provides an opportunity to evaluate the finished product and, subsequently, the close out report issued.

The advantages of adopting the CPDEP include effective communication of the planning process; identification of the project timeline up to successful execution; enhancement of collaboration and effective utilisation of multifunctional resources amongst the project team; and avoidance of rework and assurance of quality from effective communication and team collaboration (Etebar, 1997; Breidenthal & Ochterbeck, 2008; Dumrongthai & Pasikki, 2013; Maleevat et al, 2013). In relation to collaboration, which is a strong point of agile project management, Hollister, and Spokes (2004) noted that the co-location of the project team was instrumental to the successful completion of Chevron's Agbami Project in Nigeria.

Additionally, gains from adopting the CPDEP assure the Decision Review Board (DRB) that a single consistent process has been followed to arrive at an optimal and informed decision, for example, with the Salak drilling campaign (Dumrongthai & Pasikki, 2013). In addition, a vital point is the global standardisation of the work process, irrespective of the geographical location of the project. It should be noted that one of the ways oil and gas companies can strengthen and improve their small and large project performance is by establishing common processes and tools (Pessetto, 2005). This global standardisation of typical revamp oil and gas projects is one of the reasons the researcher feels confident that the findings and conclusions from this research are generalisable and could be adopted globally.

Project Development and Execution Program (PRODEP, Petrobras)

The Project Development and Execution Program (PRODEP) is the proprietary project management framework utilised by Petrobras, the Brazilian oil giant that operates in 28 countries. The PRODEP aims to attain performance excellence by following a structured set of guidelines for applying the project management system. These guidelines are applicable throughout the project lifecycle and comprise a five-stage-gated process that establishes a clear strategy and defines a sequential flow of activities or procedures from the planning through to the realisation of the project. The PRODEP functions on four pillars viz; system of deliverables development, review, approval, monitoring and reassessment of investment projects, as required before proceeding to the next stage. The PRODEP leverages on the Project Management Body of Knowledge (PMBoK) model, the organisation, characteristics, and peculiarities of PETROBRAS and fourthly the corporate Health Safety and Environment guidelines for projects development.

Although the PRODEP has been developed to meet pre-set performance parameters within PETROBRAS, large scale projects and revamp projects, due to their characteristics (especially in challenging offshore locations), are noted for their high potential of cost and budget overrun during execution. Thus, the challenge of PRODEP remains to reduce the probability of cost escalation and schedule delays and optimise the chances of project management success (Rahim, et al., 2017; Salazar-Aramayo et al, 2012; Nunes, et al, 2011).

Project Gate System Process (PGSP) – The Kuwait Oil Company (KOC)

To keep supporting business growth and the vision of crude oil and gas exploration and production through capital projects, The KOC has developed and adopted an in-house lifecycle project management system called the Project Gate System Process (PGSP). To date, The KOC has deployed the PGSP in projects with excellent outcomes, assuring top quartile project performance and impacting on risks, cost, schedule, and quality, without compromising safety. These improvements have helped the organisation to achieve its strategic objectives and uphold its reputation and corporate image. However, delays in project completion have been observed to be universal and the KOC is no exception (Al-Hajji & Khan, 2016).

The project lifecycle as per the PGSP of KOC is a five-stage gated process comprising identification stage; feasibility and scope of requirement stage; FEED and contract action stage; execution stage; and operate and monitor stage. These five sequential stages have their unique set of activities that sometimes overlap to avoid delays and rework. In addition, the PGSP assigns a specific stage to an entity or department for full stewardship, up to the successful delivery. A key activity is the capture of lessons learned and application to subsequent projects, in a bid to avoid project risks, ensure continuous improvements in processes and improve business sustainability. This approach also encompasses opportunities for innovation and good practices to be simplified from implicit to explicit knowledge, the elimination of defects and the creation of an atmosphere for collaboration and teamwork by adopting the Lean six sigma methodology to improve business processes. Additionally, real-time innovative Agile project management-inclined methods that re-enforce oil and gas project development as process-oriented make the KOC approach customised and a proprietary approach. The stage gate system has a set of clear objectives as well as the associated activities and deliverables at each stage to be met. Prior to proceeding to each stage, a governance system is in place to ensure that stage decision support packages are reviewed by the Project Review Committee and endorsed by the designated authority.

This sequential approach to managing process-based oil and gas projects has consistently enabled the KOC to achieve recordable project objectives and many successful project management performances. Therefore, the Project Gate System Process can be perceived as the KOC's governing framework deployed for selecting, planning, and executing capital projects in a structured pattern to strive for project management success consistently, although the framing of this project management system hinges on the major capital construction projects in mind. Little to no reference has been made to revamp projects, but the KOC has considered the realisation of both new surface and revamping of existing installations as part of their near to long term goals. It is also understood that the petroleum industry requires both the construction and maintenance of upstream and downstream facilities to remain competitive in the fast-changing business environment. Nevertheless, the KOC acknowledges that there is a need for continuous improvement in project planning, monitoring and adoption of better approaches. It is against this backdrop that the consideration for the specific revamp project management optimisation by this research is not only necessary but timely.

Opportunity and Project Development System (OPDS) – ENI/Agip

Opportunity and Project Development System (OPDS) is used by Eni Exploration and Production, the Italian oil and gas company. It is the company's standardised stage-gate project management process. It is mostly based on the PMI's Body of Knowledge concepts, together with an integrated IT-based support system in operation throughout the project's lifecycle. OPDS comprises five phases: Evaluation, a value assessment of the opportunity in alignment with business strategy; Concept Selection, development and selection of the optimal concept following a structured technical, economic and business risk assessment; Concept Definition, which refines the selected concept, develops the project execution plan and completes detailed engineering design, including a call for tender (CFT) sanctioning the next project phase; Execution, the realisation of a fully mechanically completed facility consistent with the supporting project management processes, integrated IT packages and within the projected constraints of cost, schedule and quality (the 'iron triangle') and; Commissioning, Start-up and Performance Test, the completion of both static and dynamic commissioning, the start-up of the facility and confirmation of anticipated operational performance and readiness to handover to operations (Piantanida& Rossi, 2007).

The IT-based complementary packages of Project Management System (PMS), Value Management System (VMS) and Technology Management System (TMS) make the OPDS a complete framework considered fit for the intended purpose of project development through to close-out. It is worth noting that over 130 projects had been executed utilising this model (Piantanida & Rossi, 2007). Although the authors were silent on the performance of the executed projects, it is important to note that the Eni OPDS has PMI project management processes encompassing a number of features, including initiation, where the need for the project is brought to the fore for subsequent business reviews in alignment with the organisation's strategic objectives and vision; planning processes to address scope definition, schedule development and cost management; executing processes that take care of project execution and the dissemination of information; monitoring and controlling processes where schedule and cost control hold sway and; the closing processes, where lessons learned are captured and organised in Eni's Oracle database.

In addition, the features of OPDS include risk management, stakeholder management and performance reporting. All these are geared towards delivering successful projects in line with sanctioned objectives and to the satisfaction of the customer. However, the idea of performance measurement against some predetermined KPIs and reporting by Eni indicates that the project management system as managed by project practitioners is not flawless but is subject to review in the quest for continuous improvement.

Capital Value Process (CVP) – British Petroleum (BP)

Just over half the number of mega-projects has failed to deliver as expected on approved sanction objectives, measured from KPIs like cost, schedule and first-year operability efficiency (Brownridge, 2016). However, to mitigate against this figure, since the 1980s, British Petroleum (BP) has developed a customised, standardised approach to project management that takes care of a range of projects, from the smallest IT software improvement projects through the complex multimillion-dollar facility brownfield revamps, to mega greenfield construction developments (Spiers, 2007). This process is called Capital Value Process (CVP), originating from experiences and usage on capital projects and, like all major oil companies that use a stage-gate process, the CVP is no exception (Gregory, 2002; Brownridge, 2016).

Firstly, CVP hinges on the framework of five phases, comprising appraise, to produce a business case; select, a review of the feasible technical and business options for the project; define, to carry out detailed engineering design for the project; execute, realising the project physically at location; and finally operate, the critical stage of running the asset profitably from the initial start-up. Secondly, CVP focuses on two key roles: the single point of accountability and the gatekeeper. Here there is a clear understanding that a final decision must be made by the gatekeeper at the end of each stage. The single point of accountability ensures that there is equal opportunity for various projects to compete for project funding, guaranteeing that only the projects with the optimal feasibility and viability appraisals gets approved to move to the next stage.

Thirdly, this customised approach by BP takes into full consideration the fact that personnel are the greatest assets for sustained successful project delivery. According to Donegan (1990), improvement through people is critical for either the survival or death of an organisation incapable of adapting to a dynamic world. As such, BP runs a strategic program developing high quality project management capability, both within the corporation, with affiliate universities and with professional organisations like PMI for PMBoK training courses. As an example, in Angola, BP made a great effort in local content development, as well as in developing the national workforce in a bid to promote work efficiency and win disposition for both the corporation, the Angolan government and the local populace (Donegan, 1990; Gregory, 2002; Spiers, 2007; Schrader, 2005).

Therefore, the standardised CVP approach to project management by BP can be described in the three-prongs vision of a gated decision-making process, common financial approval processes and the development of high-quality project management capability. These three dimensions form a common approach that offers a common language within which projects are judged by their KPIs, including cost, schedule, quality, and so on. Also, important to note is the sharing of lessons learned, an enabler for further development in project excellence and continuous improvement (Spiers, 2007). However, despite the gains of the CVP, projects are still not being delivered optimally. Brownridge (2016) has highlighted that success in the early stages of project development is a panacea for execution stage success. He also argued that project performance can be improved by high quality business framing; early identification and freezing of scope; excellent pre-FEED definitions; and maintaining high calibre project organisation. This is the focus of this research endeavour.

2.15 Program and Portfolio Management

Organisations have gradually shifted from the effective management of a single project to managerial-focused organisations where the simultaneous management of different projects is set up under a common entity for overall business gains. Morris and Pinto (2007) have argued that, although portfolio management is less managerial in its approach, all three types of management (project, programme, and portfolio) sit within the ‘Management of Projects’ framework. Simply put, multiple projects with the same characteristics being managed under a common strategy for organisational benefits fall within programme management. Murray-Webster and Thiry (2000) have described a programme as a collection of transformational projects and/or activities managed together to achieve long term business sustainability. In a similar vein, programme management can be defined as the application of project management approaches, techniques and tools to similar project type or projects in a group for more benefits to the organization compared with managing the projects discretely (PMI, 2013).

On the other hand, portfolio management is defined collection of projects and managed under a common sponsor department of an organization (Archer &Ghasemzadeh, 2009; Morris & Pinto, 2007). Also, PMI (2013) referred to portfolio management as the centralized management style of executing several similar projects towards the strategic objective of the organization. Smith (2013) argued that the applicability of programme management in IT organisations amounts to strategic organisational gains. Gronevall and Danilovic (2014) examined the contemporary challenges in healthcare and suggested that using the project, programme and portfolio system is a better methodology for managing emerging complex systems. DyReyes (2008) argued that portfolio management is an enabler of organisational competencies, capabilities and project leadership management and that organisations need to learn the blend of both business objectives and project strategy (strategic project management) for the sustenance of competitive advantage.

While programme management focuses on issues such as business gains, the quality of finished products, technology and interfaces, portfolio management, ensures that the right projects are executed, that opportunities and business risks taken are effectively assessed for conformity to corporate strategy and values, and that decision making is regulated or balanced. For these reasons, it is therefore recommended that organisations adopt the concept of the management of projects to gain from lessons learned and synergies, using standard methodologies that affect all projects. It is noted from the literature that the current practice in the oil and gas industry seems to be one where the company's approved five stage-gate project management framework is being applied holistically to all classes of projects. Although both programme and portfolio management are outside the scope of this research work, the full understanding and application of the rudiments of both programme and portfolio management by companies could lead to more gains from sharing lessons and process standardisation. This is recommended for further research as it relates to revamp projects execution.

2.16 Stage-gate, Waterfall or Traditional Project Management

The stage-gate management process, otherwise known as the traditional or waterfall project management process, is robust and built from the encyclopaedia of project management best practices (Chin & Spowage, 2010). However, Stadler (2011) has posited that stage-gate models are best suited to situations where efficiency and effectiveness are desired for process-oriented industries like the oil and gas industry, and where the objective function of the company is to work efficiently under clear guidelines and with tacit knowledge. Most oil and gas operating companies, irrespective of their specific given names or acronyms, are aligned to the five stage-gate project phases of feasibility or initiation, selection, definition, execution, and operation, essentially for the management of megaprojects (Walkup & Ligon, 2006; Green &Woolson, 2016; Rahim *et al.*, 2017).A megaproject is a project worth more than US$1bn in capital expenditure (Shokri & Maloney, 2015; Patricia, 2011 cited in Rahim, 2017). However, smaller projects with a lower financial burden, such as FPSO revamp projects, are left in the hands of project executives and managers, who apply scalability to their models based on project cost, complexity, and risk.

This development is a gap in practice and was investigated by the questionnaire survey in this research. However, it has been argued that, rather than have no specific process for managing smaller projects, it is smart to adopt the capital project management approach that has yielded positive outcomes (Rahim et al., 2017; Will & Stewart, 1991). Although, all projects have unique characteristics, complexities, and challenges, whenever a greenfield or capital project is completed and becomes operational, a brownfield project is created (Visser, et. al, 2015). Therefore, a holistic capital project management approach is not recommended to be applied to revamp project management. A disregard or neglect of this reality would continually result in sub-optimal project performance due to the inherent characteristic differences between capital and revamp projects.

2.17 Lean Project Philosophy

Poor overall project performance has been attributed to deficiencies in performance management, among other factors. Although efforts have been deployed for improvement purposes, including production measures, with some success, no one has attempted to apply a holistic Lean production principle for the elimination of waste in construction. According to Monroe (1990) and Saliba and Fischer (2000), product realisation is best evaluated by looking at the value as perceived by the customer. Huovila et al. (2004) indicated that value loss (waste) in product development occurs because of lapses in requirement prescription and enforcement through the process. Ohno (1998) defined seven forms of waste and categorised them under wastes due to material logistics and wastes due to human factors. According to Koskela (2000, cited in Codinhoto & Koskela, 2012), flowcharting, along with the pinpointing and measurement of non-value adding activities, can be a means to directly curtail apparent waste.

It is proposed to critically analyse the research subject using the Toyota Lean production case study. Lean production was developed from both production management and the theories and teachings of Joseph Juran (1979) and Deming (1982) – 'the next process is the customer'. Also, Womack and Jones (1996) defined value, value stream, flow, pull and perfection as the five principles of Lean and posited that the goal of lean thinking is to support organisations in attaining operational excellence. The driver for the Lean production model is customer requirement and the aim is to eliminate all waste ('*Muda'* in Japanese), as well as to control costs from a holistic production standpoint (Codinhoto&Koskela, 2012). According to Liker (2004), the Toyota Production System (TPS) framework stands on 14 principles (Codinhoto & Koskela, 2012). After World War II, the Toyota Company, under the leadership of their then chief engineer Taiichi Ohno (cited in Shingo, 1989), changed the organisation's production concept with the lessons learned from Henry Ford's production line and a 'flow-based' production system, to satisfy customer demands. Toyota has holistically adopted lean principles by combining tools, other methods, strategies, and philosophies for striving optimal performance as the world's greatest manufacturer (Codinhoto & Koskela, 2012).

Although Monden (1992) classified the operations process as value adding, essential and non-value adding, Bicheno (1992) has further broken-down Toyota's seven waste definition into waste of overproduction, waste of waiting, waste of transportation, waste of inappropriate processing, waste of unnecessary inventory, waste of unnecessary movement, and waste of defects. Apart from Toyota, cases where Lean thinking have been applied with significant successes includes the Neenan Company (Colorado, USA), a design and build organisation where project times and cost have been reduced by up to 30%; the Construction Lean Improvement Programme (CLIP), created to support the UK construction industry with over 50% productivity improvements in key processes; and the Pacific Contracting of San Francisco, a specialist cladding and roofing contractor that utilised a specific technology and tool for improvement in the planning of construction processes. This resulted in an increase in their annual turnover by20% in less than two years, with the same staff strength (Constructing Excellence, 2004).

Nowotarski et al. (2016) used Lean methodologies to assess the risk problems in building construction and they posited that Lean thinking significantly reduced the total time and cost of the analysed works. Whether Lean has been applied in the oil and gas industry to achieve significant results is not in doubt. Referencing the structured 'Sweat the Asset' process, Awan et al. (2018) have stated that the incorporation of a Lean management system into their project resulted in significant performance improvements. The Lean concept, from production, manufacturing, or a project perspective, is not just a tool set or method for improvement, but a business philosophy whose gains include reductions in lead-time and cost, quality improvements and customer satisfaction. Value as perceived by the customer for future project development has been suggested to be one which eliminates all forms of waste from reviews, approvals, waiting, inspections, and rework. It has also been argued that additional waste of inspection only improves the value of final finished product, but not the process for realising the product (Moujib, 2007).

Advocates of Lean project management have argued that project improvement processes with the acronym DMAIC (define customer value, measurement of capacity, analyse process for improvement opportunity, improve and innovate the process, and control processes, strive performance sustainability) when aligned with the five project management processes as indicated in Figure 2.11 leads to excellent project delivery. Although Lean could be said to be a household name in the oil and gas industry, today, the full implementation of the principles in revamp projects execution is unknown. While the project management processes are structured and stewarded with excellence in mind, the early definition of customer value in the project lifecycle is an important attribute of lean principles. Value which is the result of the project is seen holistically as what the customer is paying for. Value is not just about the statement of requirements, but it is also specified by identifying objectives, deliverables, and definitions of the acceptance criteria. Also, efforts towards value added and value enabling activities would eliminate delays, otherwise called MURI in Japanese, but cannot satisfy customer need (Moujib, 2007). To continuously improve and innovate requires team efforts and the mindset of all stakeholders to function collaboratively. The project leadership plays a great role here by deploying experience, interfacing, and effective communication.

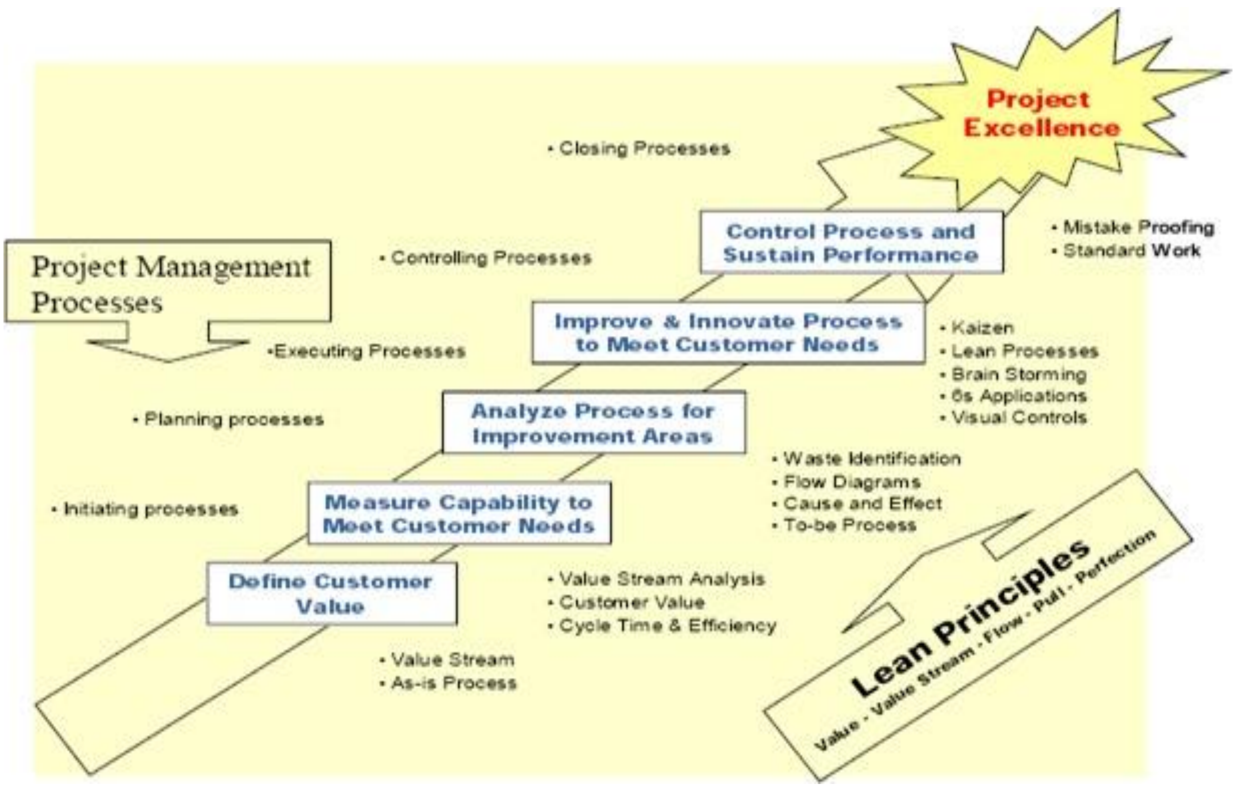


FIGURE 2.11 A Project Excellence Model

Source: Moujib (2007)

2.18 Agile Project Management (APM)

According to Owen and Koskela (2006), the concept of APM stems from the management science of Deming and has since been explored considerably in the information sector. Although APM may have been misconstrued as being the same as both Lean and Agile manufacturing due to their similar characteristics and foundation, studies have proven that they are dissimilar. However, a couple of researchers have argued that Lean construction is a blend of both Lean and Agile production. According to the Iaccoca Institute (1991), agility is defined as “the ability of an organization to thrive in a constantly changing, unpredictable business environment” (Rigby et al., 2000). Naim and Barlow (2003) tried to harmonise Lean and Agile techniques in what they described as “leanagile”. However, researchers have argued that, although their efforts responded to the ‘pull’ characteristics of agile project management demands on the Lean construction supply chain, this response is only partial and not a holistic representation of APM.

Basically, APM could be described as a systematic structured management principle and an approach to respond to project life cycle changes proactively and promptly, utilising every such change as an opportunity for improvement and business satisfaction while achieving the optimum or desired value as perceived by the customer. However, as smart as APM sounds, it does not seem to effectively support complex project executions such as revamp projects, where the processes are rigid. Studies and contributions by Boehm and Turner (2004), Shine (2003) and Stapleton (2003) in favour of APM in the IT industry have indicated a paradigm shift from simply business satisfaction towards product value as perceived by the customer. In addition, positive indications recorded by the application of APM include capability and capacity building of individuals and organisations, productivity improvements, predictability and, by extension, cost, and schedule optimisation.

Again, these attributes can be akin to Lean as they both have the philosophy of improving value as perceived by the customer. The APM philosophy centres around people, organisational culture and practices, recognition of the characteristic project lifecycle phases, as well as project control, lessons learned and continuous improvement. This explains why this project management tool could be applied to various industries with excellent results. APM has been analysed relative to other tools and techniques under specific focus areas such as philosophy, organisational attitudes and practices, attitude to ‘chaotic’ change, and management style. Other themes include organisational type, work group structure, approach to risk planning, nature of planning, requirements capture and work package structure. Execution, development approach, quality approach, customer involvement, value delivery, control, and learning, as well as project metrics and attitude to learning, have equally been subject areas where APM has come under focus.

In all these analyses, indications are that the APM technique results in a win-win disposition for the client, the contractor, and the supply chain, as well as the customer and indeed all stakeholders. However, Chen et al. (2007) have argued that the combination of both Lean and APM is not suitable for complex projects, and they suggested interface management as a better alternative. The perceived complexity of a revamp project could be unravelled by planning, early engagement of all stakeholders, better understanding of the work scope and experience. Therefore, there is no doubt that for any project team to achieve its desired objectives, irrespective of the project classification, efforts to adopt and sustain, APM would certainly deliver the project, but this must be subjected to a careful and selective review prior to its application to oil and gas revamp project executions, as the literature indicates that APM has limitations in its application to complex projects.

2.19 Hybrid Project Management

While Agile project management has been described as the project management approach for modern projects compared to the traditional project management approach, it is now obvious that two opposite approaches of traditional and Agile project managements are in existence. However, there is potential for attributes of both approaches to be combined selectively into a single methodology to form a hybrid approach for the purposes of continuous improvement and attainment of optimal project management performance. On one hand, the project management methodology has been defined as a set of methods, techniques, procedures, rules, templates, and best practices to be used on a project.

On the other hand, a specific project management approach defines a set of principles and guidelines which tailor the way a project is managed (Spundak, 2014). In addition, a project management framework has been described as an operative set of rules, processes, methods, and templates to be used during the project lifecycle (Introna& Whitley, 1997; Office of Government Commerce, 2002; Project Management Institute, 2008; cited in Spundak, 2014). Additionally, the project management system involves the identification and combination of processes, tools, techniques, methodologies, resources and procedures to manage projects while methodology is defined as a system of good practices, methods, rules and techniques deployed by the workforce in a discipline (PMI, 2013).That being said, project management methodology is a subset of the project management approach, which stems from the theory of project management simplified in the project management body of knowledge guidelines of organisations like PMI, IPMA and so on, but essentially project management is applied in practice in the form of project management methodologies often tailored to suit the corporate organisational project portfolio and the specific characteristics and requirement of individual projects (Spundak, et. al, 2011; Spundak, 2014).

In the recommendations for further research, Spundak (2014) tasked researchers to investigate further the possibility of combining different project management approaches within a single project methodology. Also, to probe if there is a single best methodology that would represent an optimal solution for all projects in a specific business environment, or whether some sort of customisation would be required to create a fit-for-purpose project management methodology. Although the records of the application of hybrid project management are uncommon in the public domain, the need to deploy hybrid project management has been highlighted in the case of software development projects (Spundak, 2014). Nevertheless, it is on record that most major oil and gas operating companies have adapted the traditional project management approach or system summarised in PMI Body of Knowledge guidelines and customised it into a befitting methodology to suit their own needs.

This development has no doubt yielded positive results over the years for companies who have keyed into this opportunity. However, it is clear from the literature that project management performances have not been optimal, the one size fits all project management syndrome is unrealistic because projects, like business environments in general, become progressively complex, with higher numbers of tasks and complex interrelations (Aguanno, 2004; Chin, 2004; Shenhar, 1998; Shenhar&Dvir, 2007; Wysocki, 2007; cited in Spundak, 2014). A traditional project management approach on the other hand is inclined mostly towards hierarchical and linear task relations that are incapable of adequately sustaining the current volatile, uncertain, complex, and ambiguous project environment (Cicmil, Williams, Thomas & Hodgson, 2006; Cicmil et al., 2009; Collyer et al., 2010; Williams, 2005; cited in Spundak, 2014). It is against this back drop that FPSO revamp project management potentially requires careful review and adaptation of a customised methodology.

2.20 Building Information Modelling (BIM)

The fundamental concepts of Building Information Modelling (BIM) in disparate forms dates to the industrial revolution in the 18th century when the ideas of Project Production Management (PPM) were introduced. PPM basically refers to the application of operations management to the delivery of major projects. However, transformation into what is known as BIM today started with the works of Charles Eastman and other researchers, who in 1974 published a research article ‘An outline of the Building Description System (BDS)’. The publication suggested a computer-based program with capability for freely representing imaginary complex shapes, a standardised graphic language for editing and sectional assembly of the shapes, the ability to manually draw shapes in orthographic projection on paper and a simple search, sort, format, and analysis database.

However, in the report ‘the challenges of effective representation and communication in 2D shapes’, the requirement for a fresh start for any error made in a 2D manual drawing, the initial high cost of paper documentation, the risk of misplacing paper documents over time and the cumbersome nature of sharing drawings amongst the project team for updates, were highlighted as drawbacks in the report, which made the early development of BDS uninteresting, time-consuming and inefficient. Nevertheless, based on the evolution of BDS, researchers have argued that BIM to date represents the most extensive dynamic digitalised and information coordination framework for successful project management delivery and maintenance of major or capital projects. However, the modern perspectives of BIM have mitigated the earlier shortcomings of the framework, which now have attributes of digitisation and efficient information data processing and monitoring of key performance indicators to assure seamless project delivery. This was described as reaching maturity in a white paper presented in 2003 by Autodesk entitled ‘Building Information Modelling’ (BIM). The three key characteristics of BIM as highlighted are:

Firstly, to create and function on digital databases and collaborate for optimal performance

Secondly, to manage all changes holistically through all aspects of the project functions.

Thirdly, to capture lessons learned for application into similar subsequent projects for continuous improvement.

Building Information Modelling (BIM), also called virtual prototyping or n-D modelling, has been described by many authors and researchers. However, an extensive definition describes BIM as a framework encompassing the digital representation of physical and functional features of a facility; the common repository for information storage, updating and sharing among all project team members; and a measure for decision making throughout the project lifecycle (Azhar et al., 2012; Eadie et al., 2013; NIB, 2007; RICS, 2012). The theoretical development in BIM suggests that its usefulness is not limited to the geometric modelling of a building performance, but generally to construction management as reported across various construction projects in the literature. Both private and government organisations are increasingly recognising the business case and potential economic benefits at micro and macro levels of implementing BIM in architecture, engineering, and construction (Fazli, et al., 2014; Smith, 2014; Bryde, 2013; Takim et al., 2013; Eadie et al., 2014).

BIM requires the development and application of a computer-generated prototype to simulate front-end loading through the execute and operate stages but has been deployed majorly in early stages of the process, rather than in the latter project lifecycle. However, researchers have suggested that collaborative implementation results in better gains by all stakeholders, especially the client in the process aspect of project elements in the software technology (Eadie et al, 2014).In order to demonstrate the span of BIM as both a technology and a process, researchers have referred to it in order of 'nD' dimension modelling due to its disposition to increase with evolving number of dimensions to the building model (Eastman et al., 2011; Karmeedan, 2010 cited in Smith, 2014) thus:

3D dimension represents the object model where the proposed finished product is presented in units and sections as well as a whole in a 3D picture. This is an output of an understanding of the scope of work, the engineering design and materials selection that are defined and developed in the early stages of project development.

4D dimension refers to the planning process. Consideration of time in the BIM framework is necessary to map the construction activities presented in the 3D model against a time schedule to enable better and real time appreciation of project activities.

5D dimension is the cost component of the BIM framework. Cost considerations harmonise the bill of quantities to materials quality and functionality. It provides the opportunity for BIM to provide the needed upfront budget estimates for a client or for corporate decision-making process, such as sanction for a project to proceed. It monitors all spending including supply chain decisions from conception through to execution and cost performance on successful completion of the project. The 5D dimension of BIM integrates people, systems, business structures and practices into a collaborative process to reduce waste and optimise efficiency throughout the project lifecycle. This attribute points to the modern concept of the Integrated Project Delivery (IPD) approach, which is perceived by researchers as an enabler for successful project delivery (Glick & Guggemos, 2009 cited in Smith, 2014).

6D dimension is the operation model. It is a record of the as-built documentation to enhance seamless facility operations and maintenance. Operation manuals are part of the deliverables of this model including storage in the appropriate electronic file for ease of retrieval and use long after the facility is handed over to facility management.

7D dimension is the sustainability model. It provides opportunities for the design team to test and validate specific elements, assumptions and decisions made during the facility design against different competing alternatives. This takes us to the discuss lessons learned capture, continuous improvement, and implementation into future similar projects.

8D dimension concerns the health, safety and environmental considerations that emerged during the design and construction stages of the project's development.

To summarise the nD attributes, the dimensions of BIM enable anticipation of facility performance in the earlier project stages ahead of execution, with the capability to respond to changes in the dynamic business world while optimising designs with analyses, simulations, and visualisations, including delivery of higher quality deliverables throughout the project's lifecycle. This implies that the hope of the future transformation of the construction industry from its present state lies on digital technologies and effective standardised processes, which BIM thinking portends (Singh, V., 2020; Smith, 2014).Since BIM is a tested building construction framework that cuts across the entirety of a project's lifecycle and having the same key performance indicators like all projects, there is an increased probability that this framework will be applied to construction type projects such as FPSO revamp execution projects, in order to strive for performance optimisation.

Despite the gains of adopting BIM in the architecture, engineering and construction industries, the oil and gas industry has been slow in taking advantage of this digitised and information-based framework compared to other competing approaches for large scale, capital, or long duration projects. Over the past few decades, the oil and gas industry has invested in new technologies and processes for the purpose of performance optimisation and to remain competitive. Capital projects in the oil and gas industry require a combination of advanced technologies and efficient processes in addition to effective collaboration amongst the project team. BIM is a promising approach towards meeting the expected cost, quality, schedule, and other performance indicators. Therefore, one expects that interest in BIM to be the reverse, considering the similarities between construction and the oil and gas industry from both technological and workflow perspectives for both onshore and offshore projects. However, this apathy is not unconnected with the relatively large size of the oil and gas corporations with attendant bureaucratic processes, bearing in mind that it is usually easier to fully integrate new approaches in small to medium sized enterprises and organisations with agile mindsets which tend to adapt more to changes and innovations (EPCM, 2020).

However, it has been argued that BIM implementation can improve the coordination of engineering and the operating company's business processes in offshore oil and gas projects, providing solutions to the inherent challenges of offshore project interventions which span from space limitations for construction, equipment and materials footprints, efficient cost, schedule and safety management throughout the project lifecycle, a reduction of rework by leveraging on technology for dimensional control, and in data and information management in design and construction (Grindheimet al., 2018; Bezkorovayniy et al., 2018; Bezkorovayniy & Bayazitov, 2020).Since BIM is a tested building construction framework that cuts across the entire project lifecycle and having the same key performance indicators as all projects, there is likelihood for its application to construction-type projects like FPSO revamps in order to strive for performance optimisation.

2.21 Project Management Approaches Compared

In the quest to improve the existing stage-gate project management approach deployed by most major oil and gas operating organisations, it is important for the researcher to carry out a detailed review of contemporary project management approaches Table 2.1 highlights the attributes of the varying approaches, including industry application, robustness of the approach, ability to deal with complexity, technology requirement and project constraints. In terms of current application, apart from the hybrid model, as would be expected, and Lean, all other approaches are industry specific, although researchers have suggested possible applications in other sectors. Additionally, BIM is generally believed to be independent throughout the project lifecycle, the hybrid approach remains at the conceptual stage, and APM and Lean are not self-sustaining and therefore could complement the stage gate project management approach. While all the project management models under review could deal with complexity and thrive under technological advancement, all these approaches can deal with project constraints but to varying degrees. They could also be tailored to suit specific project requirements using the applicable tools and techniques.

Table 2.1 Project Management Approaches

c	Attributes under Review	Stage-gate/ Traditional/Waterfall Project Management	Lean Philosophy	Agile Project Management	Hybrid Project Management (Stage-gate, Agile PM)	Building Information Modelling (BIM)	Citation
1	Industry Application for project success (organisational vision/goals)	- Process oriented (sequential) e.g., Military, Oil, and gas. - Large, long term stable environment	- Automobile (Toyota) - All industries aspiring process and performance improvement	- Information Technology (IT) – Software development (Agile manifesto) - Alternative for non-IT client-oriented companies -Rising empirical evidence for application in turbulent environment -Limited company-wide application	All industries (conceptual)	Construction Industry	(Cohen, 2017; Conforto& Amaral, 2016; Spalek, 2016; Khan & Al-Hajji, 2016; Gregory et al., 2016; Wirkus, 2015; Spundak, 2014; Laati, Salo, &Abrahamsson, 2011; Serrador& Pinto, 2015; Livari&Livari, 2011; Stare, 2014; Campanelli&Parreiras, 2015; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019)
2	Robustness/Independence through project lifecycle	- Robust and independent (self-contained) through project lifecycle. - Emphasis on planning at beginning of project	Not independent through project lifecycle	Not independent through project lifecycle (Project execution stage before all)	Conceptual- Not independent through project lifecycle (Execution stage before all)	Independent through project lifecycle	(Cohen, 2017; Conforto& Amaral, 2016; Spalek, 2016; Gregory et al., 2016; Ciric et al., 2019; Spundak, 2014; Stare, 2014; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019)

3	Ability to deal with project complexity	Very good (Stability)	Very good	Very good (Flexibility)	- Good for moderately high complexity (Conceptual) - Agility (Ability to balance stability and flexibility)	Very good	(Cohen, 2017; Conforto& Amaral, 2016; Spalek, 2016; Picciotto, 2018; Sohi et al., 2015; Buganova&Simickova, 2019; Spundak, 2014; Papadopoulos, 2015; Serrador& Pinto, 2015; Livari&Livari, 2011; Stare, 2014; Campanelli&Parreiras, 2015; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).
4	Technology Requirement	High	High	High	High (Conceptual)	High	(Conforto& Amaral, 2016; Ju, Ferreira, & Wang, 2019; Campanelli&Parreiras, 2015; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019

5	Project Management Constraints (Knowledge Areas):						
5i	Scope of work management	- Defined and fixed at start of project - Scope change calls for change order	- Well defined and tailored to customer requirement (Value adding activities)	-Defined and flexible for each iteration - Change is incremental, predictable, recognises turbulent project environment and manageable	- Defined at start of project, increased flexibility subsequently - Rapid iterations -Combines structure of stage-gate and flexibility of Agile PM - Best of two PM worlds (stage-gate and APM)	- 3D design - Element-base models - Sectional scope categorisatio n/group	(Cohen, 2017; Conforto& Amaral, 2016; Spalek, 2016; Shokri & Maloney, 2015; Loiro, et al., 2019; Picciotto, 2018; Ciric, et al., 2019; Spundak, 2014; Papadopoulos, 2015; Stare, 2014; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).
5ii	Quality management	- Planned at start of project in detail - Requires confirmatory test post task completion - Checkpoint and gate reviews and gatekeeper approval requirement	- No re-work. Aim to get it right first time (MURA)	- Ongoing implementation plan - Inspections through the various iterations	- Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	- Clash detection, e.g., from laser scan - Lesser rework and improved productivity - Reduce wastage of resources	(Conforto and Amaral, 2016; Spalek, 2016; Shokri & Maloney, 2015; Khan & Al-Hajji 2016; Loiro, et al., 2019; Ciric, et al., 2019; Spundak, 2014; Papadopoulos, 2015; Ciccarelli, et al., 2018; Campanelli&Parreiras, 2015; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).

5iii	Schedule management	- Long term, thorough planning - Fast-tracking between stages	- Keep the flow (MURI) - Discourage all form of delays	-Speed to market critical (1 - 4 weeks)	- More schedule constraints against initial plan for each iteration - Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	- 4D approach -Faster delivery of projects	(Conforto& Amaral, 2016; Spalek, 2016; Khan and Al-Hajji, 2016; Loiro et al., 2019; Ciric D. et al., 2019; Ciccarelli et al., 2018; Stare 2014; Campanelli&Parreiras, 2015; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).
5iv	Risk management	- Risk is null and uncertainty unknown at start of project (leverage on previous lesson learned) - Risk managed through a formalised process subsequently through the stages, therefore higher risk	- Encourages practices to sustain value from customer perspective	- Risk identification and mitigation at every iteration as part of the process. - Stakeholder involvement in frequent changes – therefore, lower risk	- Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	- Constructability reviews prior site implementation	(Cohen, 2017; Conforto& Amaral, 2016; Spalek, 2016; Shokri & Maloney, 2015; Khan & Al-Hajji, 2016; Picciotto, 2018; Buganova&Simickova, 2019; Ciric D. et al., 2019; Spundak, 2014; Ciccarelli et al., 2018; Campanelli&Parreiras, 2015; Rokooei, 2015; Kocakaya, Namli and Isikdag, 2019).

5v	Communication management	- Formal meetings and reviews - Large documentation	- Visual display (Kanban) - Lesson learned - Continuous improvement	- Co-location, Face to face (relationships) - Visual display - Finished work than documentation - Lessons learned - Continuous improvement	- Collaboration beyond start of project - Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	- Structured object information - Visual display - Unified data base sharing.	(Conforto& Amaral, 2016; Spalek, 2016; Khan & Al-Hajji, 2016; Shokri &Maloney, 2015; Gregory, et al., 2016; Loiro et al., 2019; Picciotto, 2018; Ciric, et al., 2019; Spundak, 2014; Papadopoulos, 2015; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).
5vi	Cost management	- Cost estimation at project start - Cost monitoring and control through subsequent stages	- Elimination of all forms of waste (MUDA)	- Cost estimation, monitoring and control at every iteration	-Cost is fixed at start of project. - Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	- 5D approach - Cost effective methods	(Cohen, 2017; Conforto& Amaral, 2016; Spalek, 2016; Khan & Al-Hajji, 2016; Ciric, et al., 2019; Spundak, 2014; Ciccarelli, et al., 2018; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).

5vii	Procurement management	- Defined strategy at early stages - Work Breakdown Structure (WBS)	- Just in Time (JIT), stock sizable just enough quantities - Dependable and reliable supply chain	- Values customer collaboration over contract negotiation	- Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	- Quantitative (Materials Take-off)	(Conforto& Amaral, 2016; Spalek, 2016; Ciric et al., 2019; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).
5viii	Human resources management	- Large team through the stages	- Optimal utilisation of personnel resources (greatest asset)	Development team membership between five and nine	- Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	- Collaboration and team building	(Conforto& Amaral, 2016; Spalek, 2016; Ciric, et al., 2019; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).
5ix	Stakeholder management	- Cordial interfacing and alignment - Actions from previous regular	- Customer satisfaction - Optimise the whole	- Customer satisfaction - Prioritise and deliver most	- Challenge with APM mindset in traditional project	- Recognises control among	(Cohen, 2017; Conforto& Amaral, 2016; Spalek, 2016; Khan & Al-Hajji,

		engagement closed out against agreed timelines	- Tackle high priority first and deliver value	valuable project component first - Regular feedback from stakeholders	management setting - Best of two PM worlds (stage-gate and APM)	project stakeholders	2016; Shokri & Maloney, 2015; Loiro, et al., 2019; Ciric, et al., 2019; Spundak, 2014; Papadopoulos, 2015; Stare, 2014; Campanelli&Parreiras, 2015; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).
5x	Integration management	- Team selection by skill set per specific disciplines - Learning curve and team building (Forming; storming; norming; performing and re-forming)	-Team selection by discipline -Adequate training and authority recognition	- Cross-functional and self-organising team - Experience and lesson learn sharing	- Challenge with APM mindset in traditional project management setting - Best of two PM worlds (stage-gate and APM)	-Knowledge sharing and Lesson learned - Integrated Project Delivery (IPD): Integration of plans, documents, and efforts	(Conforto& Amaral, 2016; Spalek, 2016; Shokri & Maloney, 2015; Picciotto, 2018; Ciric, et al., 2019; Papadopoulos, 2015; Serrador& Pinto, 2015; Stare, 2014; Rokooei, 2015; Kocakaya, Namli&Isikdag, 2019).

2.22 Summary

This literature review chapter summarised the global perspective of this research endeavour. It built upon the original guidewords guiding the extent of coverage of previous researchers in the evolution of project management and revamp projects development with focus on Floating Production Storage Offloading asset. Also, this chapter highlighted the current project management models and practices by major multinational operating corporations in regions where they are in operation worldwide and identified potential modern project management approaches and philosophies to be used for improving the traditional or the five stage-gate project management model. The gap identified between theory, literature, and practice, as well as the research methodology for realising the research objectives will be addressed in subsequent chapters of this research.

CHAPTER THREE

Research Methodology

3.1 Introduction

This chapter highlights the overall methodology that has been adopted for this research. It highlights the research philosophy of pragmatism, with a theoretical framework utilising a deductive-inductive, mixed methods approach with multiple case studies covering four multinational oil and gas operating corporations in Nigeria and a fifth group of experts from various oil and gas operating organizations around the world. This will allow the project to develop an optimised FPSO revamp project management model with a focus on the execution project phase. The Delphi method was used for the research data gathering and the Analytic Hierarchy Process (AHP) was utilised for model development. Also presented in this chapter are the justifications for each method adopted and the limitations to the methods selected.

3.2 Methodology Overview

According to Johnson and Duberley (2000), humans perceive or react to life events or beliefs either from the standpoint of objectivism or subjectivism. This belief is irrespective of an individual's disposition to the nature of reality, called ontology or the nature of knowledge, epistemology. While the subjectivist researcher appreciates qualitative data and stays in the place of critical realism or pragmatism, the objectivist researcher appreciates the quantitative data attitude of positivism in making informed decisions (Crossan, 2012).

The above description therefore suggests that research is a structured academic exercise looking at nature or knowledge, and the choice of either the qualitative or the quantitative approach to research is a matter of disposition and does not make either of the two less attractive. Researchers and authors have argued that the choice of the research methodology is a difficult task and determines how close the researcher is to addressing the defined objectives leading to an actualisation of the aim of the research work (Yin, 2009; Wedawatta et al., 2011; Effah et al., 2014; Hallowell & Gambatese, 2010).

Also, Smith et al., (1997, cited in Crossan, 2012) posited that philosophy in the research methodology is key to streamlining the research focus, evaluating, and selecting methods appropriate for the research, and creating the uniqueness of the research method. A research methodology starts with a detailed review of the relevant literature, followed by careful systematic structuring of the research questions or objectives (Yin, 2009). Robson (1993), Yin (2009) and Jacqueline et al. (2016) also posited that combining different research methods provides excellent results, depending on the research questions.

While research methods or strategies range from case studies, experiments and surveys to histories and archival analyses as ways of doing social science research, each method can be utilised for exploratory, descriptive, and explanatory or causal investigation purposes. This is contrary to earlier misconceptions about the applications of research methods, including their arrangement into hierarchies, as well as the notion that specific methods should be adopted at different stages of the research development (Yin, 2009).

It is against the above that the importance of the research methodology cannot be overemphasised as it involves the entire research process, from formulating the research questions to collecting, analysing, and reporting data (Wedawatta et al., 2011). Therefore, following a careful review of the literature with respect to the aims and objectives of the research, a mixed research methodology has been selected. This involves the Delphi method for data collection and the Analytic Hierarchy Process (AHP), which is an advanced modelling method endorsed by researchers and applicable to this research area. These have been selected as they achieve stronger and more reliable findings for complex issues (Ameyaw, 2016). Also, four multinational oil and gas producing companies in Nigeria have been selected as case studies due to their leadership role in the oil and gas industry globally. These organisations have also been used to validate the research findings and the proposed new FPSO revamp project management model.

3.3 Research Philosophy

Within the classical philosophy of science are beliefs and assumptions about epistemology, ontology, and axiology. These sets of different believes and interrelated assumptions about the social world (otherwise known as paradigms) forms the foundation and direction of a specific research work (Ponterotto, 2005).

Pragmatism is a relatively modern philosophy of knowledge that distances itself from traditional metaphysics but instead focuses on a process-based approach, which relies on inquiry as the defining process. Pragmatism as a paradigm could be defined as social worlds in which the research community projects its strong beliefs over meaningful experiences and over the corresponding actions that are accepted as appropriate (Morgan, 2014).

Axiology: This is an aspect of philosophy that deals with judgements relative to values. It is representative of the way and manner of how research is carried out, with an emphasis on the researcher’s value through the research process (Dudovskiy, 2020; Ponterotto, 2005). The researcher perceives today’s world as volatile, uncertain, complex, and ambiguous (VUCA). This perception implies a continuous quest for knowledge and improvement; therefore, an appropriate research philosophy would be that which provides opportunities for timeless monitoring and review of the current project management practices in the industry against applicable research theory to assure optimum performance in the field of endeavour (Dudovskiy, 2020).

This research aims to review the theory of project management by reflecting on the 10 knowledge areas of the PMI’s Body of Knowledge guidelines for effective project management and asking questions specifically to issues of revamp oil and gas projects, such as how revamp projects are being managed in practice, how their performances measure up so far and how it can be improved. These values point towards what works and constitute the reasons why pragmatism as a research philosophy is considered best to enable the researcher to formulate an appropriate and effective research roadmap (Dudovskiy, 2020).

The researcher's and the participant's world views are an attribute of realism and could potentially cause bias in the interpretation of results (Dudovskiy, 2020) however, the interpretation of results of this research work is neither affected by the researcher's upbringing nor cultural experiences. This therefore makes realism an inappropriate philosophy for this research. The research participants, who are experts from multinational organisations, provided both qualitative and quantitative data using the Delphi method of two iterations comprising questionnaire and interview survey research techniques.

While it may be argued that being a practitioner in the oil and gas industry could lead to subjective result interpretation, to avoid bias the mixed methods approach using multinational oil and gas organisations operating in Nigeria will be utilised. This will mean an interpretation of the findings are not explicitly that of the researcher but reflect an objective global organisational interpretation of viable opportunities for continuous improvement. Therefore, pragmatism enables both objective and subjective viewpoints to be adopted. This is appropriate for this research since pragmatists are known to incline towards pluralistic methods for multiple phase research endeavours (Giacobbi Jr et al, 2005; Dudovskiy, 2020).

Epistemology: This focuses on how a person knows whether something is true. It relates to the theories of knowledge, the nature of knowledge being a true representation of truth, and concerns itself with questions relating to, for example, the chance that research participants have the correct knowledge to adequately answer the research questions and by extension fulfil the aims of the research. Epistemology is a branch of philosophy that is concerned with attainment and sources of knowledge. It deals with opportunities, nature, sources, and depth of knowledge in a focused subject area. In other words, epistemology can be viewed as the understanding of the requirements for classifying what does and does not constitute the knowledge by the researcher (Hamdouni & Joslin, 2019; Childers & Hentzi, 1995, cited in Giacobbi Jr et al, 2005).

Therefore, epistemology can be summarised as an aspect of philosophy opposite to ontology that deals with the channels for arriving at the conceptual truth about a research interest. This essentially captures the relationships between the research participants, who are the experts in this particular research area, and the researcher, who is desirous of answers to the research questions through various sources of knowledge, spanning from either of personal opinion, feeling and beliefs (intuitive); text books and peer reviewed articles (authoritative); conclusions of a research work from facts and objective evidence (empirical); or conclusions of logical reasoning from primary data analysis (logical). It also includes a combination of any two or more of the knowledge sources (Dudovskiy, 2020; Ponterotto, 2005). Based on the accepted epistemology, a research method is crafted to enable the researcher to achieve the aims of the research.

Ontology: This basically refers to what reality is. It relates to the discussions concerning the nature of reality and being. For instance, it provides an opportunity for the researcher to asks questions and interpret facts as to whether the results of the research truly exist or represents objective reality without bias. This thinking cuts across all research processes, especially in the interpretation of research outcomes (Hamdouni & Joslin, 2019; Creswell, 1994 cited in Giacobbi Jr et al, 2005; Ponterotto, 2005; Dudovsky, 2020).

The positivist views ontology from an objective perspective of one true identifiable, understandable, and measurable reality (naïve realism). This ontological position asserts that social events, occurrences, and meanings exist externally or independently of social actors. The postpositivist equally believes that one true reality exists but can only be understood and measured imperfectly (critical realism). The constructivist-interpretivist on the contrary believes in the subjective, relativist position that multiple realities exist subject to the context of the situation, ranging from the social environment or the researcher's experience and values, including the relationships between the researcher and the research participants. Irrespective of the research paradigm, the key to research success is an early definition of ontology, just like epistemology. This also determines the choice of the research design encompassing the research approach, strategy, research element and data analysis. (Ponterotto, 2005; Dudovsky, 2020).

Pragmatism: Pragmatism from an ontological perspective covers the belief that social phenomena exist externally or independently of social actors. The interpretation of results or outcomes is multiple and best tailored to answering the research questions. Pragmatism from the works of John Dewey is summarised as a new paradigm, radically opposed to the debate about the nature of reality and the chances of truth. It has been advanced to replace the age-old pattern of highlighting the differences in the traditional research approaches by abstract philosophical systems of ontology, epistemology, axiology, and methodology, with contextual social continuous loops of inquiry comprising experience, actions, and belief (Morgan, 2014).

In simple terms pragmatism is a later research philosophy different from the traditional research philosophies of positivism (naïve realism), critical realism (postpositivist) and interpretivism or constructivism that have been made popular from the original works of Pierce (1984), James (1907), Dewey (1931) and Rorty (1982,1990, 1991) (cited in Giacobbi Jr et al., 2005). While James (1907, cited in Giacobbi Jr et al, 2005) saw pragmatism from the perspective of practical solutions to contemporary problems, researchers like Rorty (1991) and modern thinking about research philosophy have rejected the hitherto notion of knowledge being an accurate representation of truth, because such views are cursory to human needs and insensitive to the socio-cultural peculiarities of our environment (Rorty 1982, 1990, 1991; Williams, 1985 cited in Giacobbi Jr et al, 2005).

The selected philosophy and paradigm for this research work is pragmatism, being the interplay between knowledge, action, and organisational change. This point is cardinal and appropriate for this specific research work within the oil and gas industry, bearing in mind that the researcher is seeking intervention in a world of challenge as against mere observation of the world (Goldkuhl, 2012). Pragmatism has over time focused on research questions on real life events and occurrences, to its association with practicality. In other words, what works in addressing people's problems, the nature of research questions under investigation and the impact of the research questions.

However, according to Dewey (2008), reducing pragmatism to simply asking about what works has hitherto impacted its usage. This wrong notion shielded the very important aspect of both choices of goals and the means of actualising the research goals. Indeed, pragmatism reveals not just the 'how to' but also questions about 'why to do' research in a particular way. In addition, Denzin (2013) argued against earlier researchers points that pragmatism is directly linked with mixed methods research, or a methodology per se, but instead should be considered as a theory of truth, action, and consequences, of which meaning cannot be understood in advance of an occurrence or event (Morgan, 2014).

Again, pragmatism goes beyond problem solving, although in research endeavours generally and especially with the philosophy of pragmatism, it is deeply rooted in the research design and analysis of human life problems. This makes pragmatism have the dual outlook of both a philosophy and an inclination for problem solving simplified in Dewey's model of inquiry (Morgan, 2014).

Arguing further that pragmatism has been mis-construed as a form of research data collection, researchers have stated that it is indeed a philosophy that focuses on contextual integration of both traditional philosophies, contemporary practices, and dialogues in relationships with theory to solve practical problems within our environment. Therefore, it is time dependent and not just the positivists' understanding of the fundamentals about the nature of reality that is devoid of environmental and social interaction (Dewey, 1931; Rorty, 1990; Cherryholmes, 1992; Howe, 1988 cited in Giacobbi Jr et. al, 2005). The pragmatic researcher is mindful of social, political, and historical underpinnings of the research area and the consequences of the research enquiry while taking care not to compromise ethical decorum through the research lifecycle.

In the works of Goldkuhl, (2008) pragmatism has been described in the following context:

Firstly, as functional as explanations (typical of positivism); understanding (typical of interpretivism); constructive (prescriptive; normative; prospective; descriptive and explanatory) knowledge as basis for action, stretching from local to generalisable knowledge

Secondly, as methodological concerned with how knowledge is created, the role of the researcher in effecting change and

Thirdly, as referential relating to enquiry about the knowledge behind practical actions and changes, for example in revamp oil and gas project execution, the focus is on knowledge about actions, activities, and practices against what works.

Dewey (1931, cited in Goldhkuhl, 2012) describes pragmatism in relationship to ontology as both idealist and realist metaphysics. In other words, it is a paradigm that considers the social world as events and occurrences independent of the researcher, while also recognising the place of reason and thinking as contributors to knowledge. This justifies pragmatism as being in between the positivist and interpretivism dual position, aptly called constructive realism.

Therefore, pragmatism has the typical research attributes of axiology, ontology, and epistemology (Dudovskiy, 2020; Giacobbi Jr et al, 2005) and is an enquiry approach that creates knowledge tailored to changes in our dynamic world that requires continuous improvement (Goldkuhl, 2012). These attributes of pragmatism as a paradigm unravels the ambiguities that there may be in this research project and assures a focus towards answering the research questions of revamp oil and gas projects during their execution stage.

3.4 Schematic of Research Methodology

The research methodology for this research is as structured in Figure 3.1

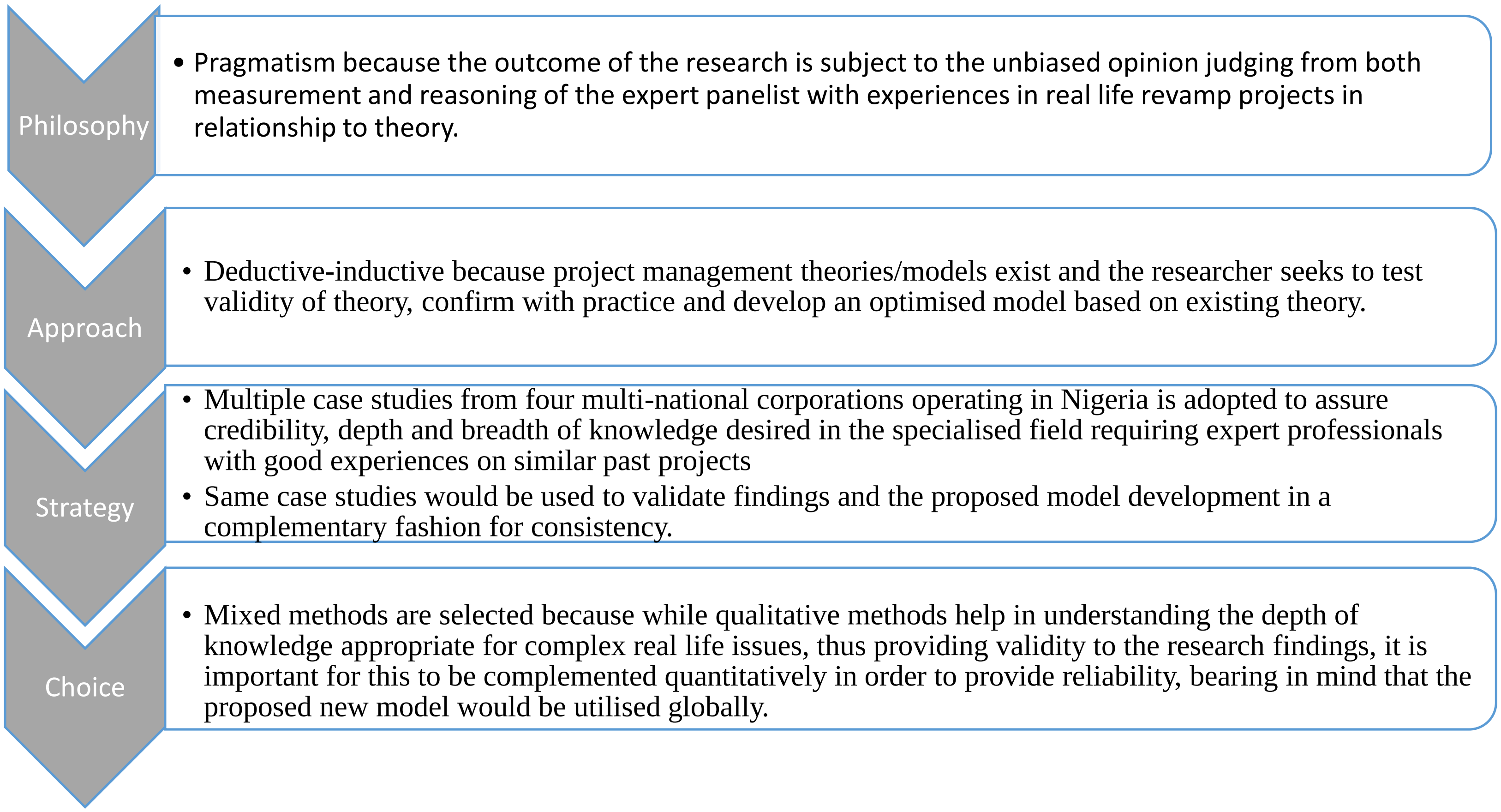


FIGURE 3.1 Schematic of Research Methodology

Time horizon

- Time horizon is cross-sectional because the research focuses only on the execution phase which is one of five stage-gates in the (traditional) project management model.
- The execution stage is selected because it is usually on the critical path of the project lifecycle, have huge work activities and budget allocation and urshers more opportunities for optimal research gains and contribution to the body of knowledge - learning, sharing experiences and process improvement.

Data collection and data analysis

- Primary data would be collected using the Delphi method and secondary by literature review from text books, journal articles, workshops, conferences and company manuals.
- The Delphi method (Questionnaire and Interview) is selected because of the limited experts in this field of research.
- 1st Delphi round is by open-ended questionnaires for achieving the general objective of the research. It is complemented by semi-structured one-on one interview survey in Delphi 2nd round to get deeper insights into the real life issues concerning FPSO revamp project management during their execution phase.
- Narratives by use of simple English language assisted qualitative data analysis from the Delphi method. The key atributes and alternatives identified is further analysed quantitatively for model development using Analytic Hierarchy Process (AHP).

3.5 Research Strategy - Case Study

Case study method as a research method is characterised by private financial burden and methodological rigour. Although this creates a challenge for this research strategy, it remains one of the popular choices deployed by social scientists in various research areas of endeavour. Case study research is an empirical inquiry that focuses on evolving life occurrences in which the context is not explicitly represented in the social environment (Yin, 2009).

Another definition of case study research describes it as a research strategy that examines contemporary developments with respect to real life context from multiple sources of information (Robinson, 1993). A case study refers to a set of data collected overtime of life occurrences of interest and systematically analysed to arrive at theoretical conclusions of the phenomenon under investigation (Mitchell, 1983). In Flyvberg's (2006) 'Five misunderstandings about case-study research', the case-study research method is defined as the "ability to 'close-in' on real-life situations and test views directly in relation to phenomena as they unfold in practice" (Flyvberg, 2006).

In addition, case-study adoption spans through the various stages of research from planning, design and preparation to the collection, analysis and reporting of data (Yin, 2009). Put differently, Eisenhardt (1991) and Dooley (2002) describe case study research as that which enables an understanding of complex issues and reinforces confidence about perceptions.

Case study refers to a rigorous investigation involving a multi-dimensional perspective of one or more records of naturally occurring scenarios and subjecting it to analysis for the purpose of achieving a generalised outcome (Gomm et al., 2000). Therefore, from the various definitions, case study could be utilised to identify causal processes, develop, test, or describe theoretical ideas or explain a life situation. Indeed, the research on developing an optimised FPSO revamp project management model is a response to a real-life phenomenon.

A typical case study design has a conceptual framework, a set of research questions, a data collection strategy, and instruments as well as analysis techniques.

Case study research has been selected to adequately address the research questions as highlighted in the previous section. Since this research is in a specialised area, simply applying the technique of collecting data from the public with analysis alone will not provide the depth and breadth of knowledge required to satisfactorily answer the research questions. The research questions were structured to address the objectives of the research and are consistent with the argument that questions can be classified as either descriptive, normative, correlative, or impactful. The questions were also considered good according to Kerlinger (1986) because they indicated a relationship between variables, are defined and are framed as actual questions (Gray, 2004).

Additionally, Table 3.1 shows an excerpt from the early works of Yin (2009) and describes to the appropriateness of research methods against the form of research question, the control of behavioural events and the focus on contemporary events. The research questions under consideration have only 'why?' and 'how?' action word forms, thereby pointing towards case study research as an applicable method for this research.

Method	1) Form of Research Question	2) Requires Control of Behavioural Events	3) Focuses on Contemporary Events
Case Study	How, why?	No	Yes

Source: COSMOS Corporation, Yin (2009)

Talking about the criteria for the control of behavioural events, the researcher in this circumstance cannot manipulate the relevant behaviours while carrying out the research, thereby further confirming the appropriateness of the selected case study research strategy.

In addition, the case study research strategy is chosen because the subject area focusses on contemporary events, which cut across variability in individual and organisational experiences; the peculiarity of the operating organisations; the complexity of FPSO revamp projects; the multi-cultural mix of the project teams and the challenges of data and information management in a typical developing environment like Nigeria.

However, Yin (2009) has argued that a case study approach may not provide relevant data from population and estimation of frequency, but it does give an aerial perspective of the research area. Additionally, the argument that a single case study is less effective than multiple case studies is equally misleading, as single case studies are multiple in most instances bearing in mind that ideas and evidence have several ways of converging (Ragin, 1992).

While the single-case study method may favour the rare, critical, or revelatory case, Herriott and Firestone (1983) and Ihua (2010) posited that evidence from multiple case studies is regarded as more elaborate and convincing and paves the way for the comparison and validation of single cases, although not without a comparative cost and schedule impact on behalf of the independent researcher compared to single case studies (Yin, 2009). For oil and gas projects, Shakhsi-Niaei et al. (2014) have highlighted the usefulness and applicability of the case study method in practice, and they have proposed an integrated model for making a group of strategic decisions due to the inherent complexity and uncertainties in this field of endeavour. Thus, the case study strategy is no doubt applicable for this project.

In relation to the research questions, four multinational oil and gas operation companies were approached for research data gathering and they consented to their employees providing individual responses to both questionnaire and interview surveys. Documentation related to revamp oil and gas projects during the execution stage was also collected for analysis. This initiative satisfied the recommendations from earlier researchers to conduct multiple case studies.

3.6 Research Techniques

Research techniques are also referred to as 'tactics of enquiry', and the research instrument or data collection methods are means of information gathering to inform the research strategy (Barrett et al., 2012). According to Gray (2004) and Robson (1993), four common techniques include questionnaires, interviews, observations and unobtrusive measures like archival data collection and access audits (Barrett et al., 2012). In addition, tests and using available information have been added to these four popular techniques (Lawal, 2013).

A questionnaire is a research instrument with questions tailored towards information gathering from respondents. Questionnaires can be administered either face to face, by telephone, computer or by post. Where the interview technique seems not to be a reasonably practicable option, the questionnaire is arguably a quick and cheap medium for gathering a large amount of data from the population – the researcher has the option of returning to pick up the questionnaire later. The questionnaire technique gives the flexibility of structuring the questions as either open or closed ended, thereby providing both qualitative and quantitative data. Although the questionnaire technique has downsides, including the potential for respondents to assume second nature in their responses, the difficulty in analysing open-ended questions and sorting out incomplete questionnaires, they remain relatively cheaper and more reliable than other research techniques.

The interview technique provides an opportunity to gather in-depth information. However, it can be quite expensive, the interviewer or interviewee's personality may affect the facts and considerable time is required for obtaining a large enough population size to justify a general statement about a subject area.

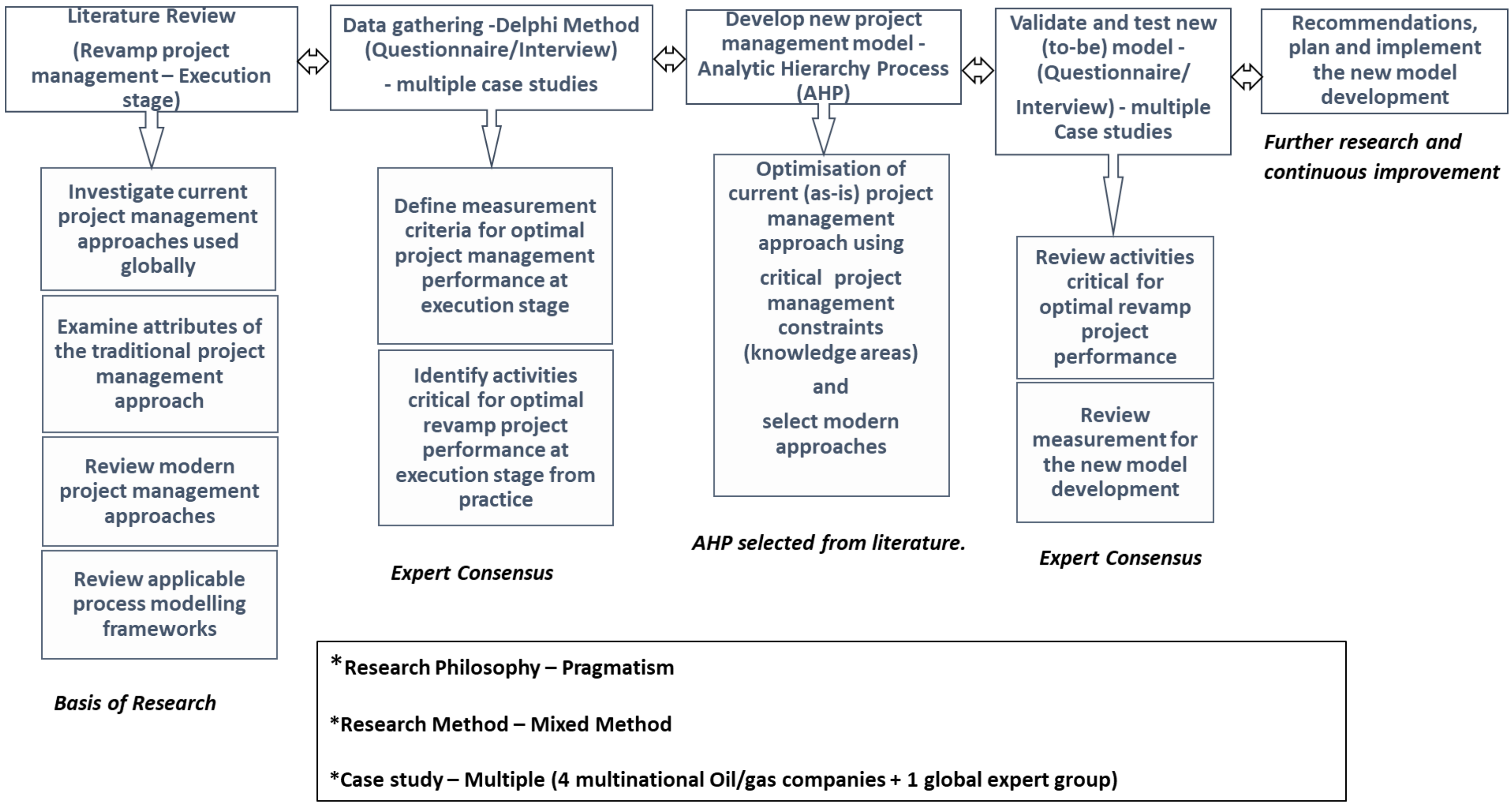


FIGURE 3.2 Theoretical Framework

3.7 Theoretical Framework

Inferences from the literature indicate that the execution stage, which this research work focusses on, would provide avenues for exploring improvement opportunities that would assure the desired overall revamp project performance. The execution stage is witness to lot of work activity by all process groups; it is usually on the critical path of the project lifecycle and attracts huge budget allocations. Since the execution stage is where the finished product of the project is realised, it is therefore a yardstick for measurement of the organisation's reputation and public perception of both client and contractors involved in the project, especially in terms of safety, quality, and overall customer satisfaction. The inability of the revamp project type to showcase these attributes has stagnated the industry and this research work will provide a leeway for the industry to move forward. This research and the outcomes offer a breakthrough that the oil and gas industry has been craving for.

The schematic in Figure 3.2 elucidates the theoretical framework for realising the goal of this research. It captures the relevance of the literature review as a basis for the research, leading to global inquiry into the current approaches used for crude oil and gas revamp project management during the execution stage; examining the attributes of the traditional or waterfall project management approach with respect to revamp project execution; and for carrying out a review of modern successful project management approaches as used both within and outside of the oil and gas industry for potential gains on application into revamp oil and gas project management. In addition, from the literature review a tested approach to process modelling would be selected and deployed to aid in the optimisation of a real-life challenge in the oil and gas industry.

Following an exposition from the literature review in identifying the research problem and research questions, the research paradigm of pragmatism is judged to be most appropriate and was deployed in dealing with required series of enquiries and expected feedbacks from experienced and expert professionals. To support the pragmatism research paradigm, the Delphi approach comes to mind as the appropriate means of obtaining data through both questionnaire and interview surveys to gain expert consensus while eliminating bias in the research protocol. The research participants are products of a purposive selection from four case studies, namely oil and gas operating multinational corporations granted operating licenses in Nigeria. The extent of at least four case studies of major multinational operating corporations is to ensure global coverage consistent with pragmatism that appreciates the social environment as an influencer for the research outlook. This endeavour equally supports the potential generalisation and acceptability of the research in identifying activities critical for optimal revamp project performance at the execution stage from practice and in defining the measurement criteria for optimal project management performance at the execution stage.

A review of the relevant literature was also utilised when arriving at the Analytic Hierarchy Process (AHP) to be used as the process modelling tool for the optimal FPSO revamp project management at the execution phase. Since the research is headed towards process optimisation involving activities in stages, criteria, and alternatives, the AHP is an appropriate simple multi-criteria decision tool that can be deployed. The AHP is an advanced multi-criteria decision-making method that is complementary to the Delphi method for data gathering from expert panellists to achieve stronger and more reliable research outcomes (Ameyaw et al., 2016). Again, the experts are selected from four multinational operating corporations active in oil and gas exploration and production in Nigeria and still in line with the extent of enquiry required and expected of a pragmatism research paradigm, where the optimisation of traditional project management approaches using select modern approaches versus critical criteria from PMI's ten knowledge areas was evaluated.

Following the development of the as-is and the to-be process model using the AHP, the research work progressed onto the validation stage where the same four research case studies corporations are subjected to further enquiry consistent with the pragmatism paradigm to review the final model development. This stage uses the Delphi method and compares the developed model with project close out dossiers from similar, recently completed projects. In addition, the new model development performance measurement method was updated based on feedback from the expert panellists until all comments were incorporated into the final version.

Once the final version of the new model development is completed, the research terminates with recommendations and plans for generic implementation of the new process model for FPSO revamp project management in the execution stage globally, as well as areas for further research highlighted for continuous improvement opportunities.

3.8 Summary

In conclusion, this chapter justified the choice of the research philosophy of pragmatism due to the peculiarities of the field of research requiring cycles of inquiry from expert panellists and their responses to real-life problems in the oil and gas industry. The steps and justifications for the selected research methods were identified and tailored to answer the research questions with an emphasis on using multiple case studies for assurance of research validity. A deductive-inductive approach has been adopted, starting with a review of existing theory of project management and utilising a mixed method approach consistent with pragmatism. A cross-sectional research perspective focusing on the execution project stage as a means of securing maximum gains from the research was provided, as well as an insight into the research technique utilising the Delphi method in two iterations of questionnaire and interview surveys, complemented by the advanced multi-attribute decision making approach of Analytic Hierarchy Process (AHP).

CHAPTER FOUR

Data Collection and Analysis

4.1 Introduction

This chapter summarises the Delphi method, which was the research instrument used for this study. It consists of two iterations of questionnaires and a subsequent interview survey. A questionnaire comprising demography, insights about current revamp project management approaches, potential strengths, weaknesses, improvements, opportunities, and threats (SWOT), as well as data between levels one and four of the Analytic Hierarchy Process (AHP) judgement decision section. The second iteration of the Delphi methodology involved the complementary interview guide which provided the opportunity for a review of the AHP judgement decision made earlier by the participants. This section also covered the collection and review of case study 1 project close out documents as a means of providing more validity to the findings of the study.

4.2 Overview of Delphi Method

The Delphi method is difficult to situate in a methodological category, thus has been described as a qualitative, quantitative, and mixed methods research approach where consensus opinions are obtained from independent rounds of review amongst expert panellists about a complex or real-life problem. The Delphi method has become popular and has been in use by researchers since the early 1960s (Sekayi & Kennedy, 2017; Chan et al. 2001 cited in Ameyaw et al. 2014; Hollowell & Gambatese, 2010). This method is also adopted for this research project.

According to Keeney et al., (2012 cited in Ameyaw et al., 2014), the classical Delphi method originated from the American defence industry, however other researchers suggest it was developed by researchers at the Rand Corporation as a tool for improving decision making in government (Delkey, Brown & Cochron, 1969 cited in Sekayi & Kennedy, 2017). Nevertheless, all agree that the traditional or classical Delphi has three rounds. The first involves soliciting opinions from expert panellists via an open-ended, brainstorming approach exercise. The second-round entails requesting expert panellists to rate statements in a questionnaire from their knowledge and experience about the subject of the study. The third round involves requesting the expert panellists to consider a review of their earlier ratings vis-a-vis the consolidated results from the earlier second round.

A consensus is defined in advance as a ratio or percentage of panellists' agreement with a statement, for example, 75%. Sometimes a consensus cannot be reached. This is the stability point beyond which no subsequent rounds of feedback and opportunity for review would change the expert panellists' rankings. The Delphi method ends with final rankings and a quantitative summary of expert feedback representing group opinions, which are then used as a basis to inform the decision on the topic of discussion.

However, it is worth noting that in the classical Delphi method, there is the possibility to continue beyond three rounds until a consensus that addresses the subject requirement is attained. In addition, the literature suggests that round one may be skipped if the questionnaire in round two could be developed directly from a review of relevant literature and interviews (Sekayi & Kennedy, 2017; Ke et al., 2011; Hon et al., 2012, cited in Ameyaw et al., 2014).

Although some researchers have challenged or criticised the reliability of results from the Delphi method due to inappropriate design of the research instrument, flaws in expert panellist selection, defects in bias control, unreliable data analyses and limited feedback by the researcher in the rounds implementation, the Delphi method still remains a viable option when objective data cannot be obtained from records, where there is lack of empirical evidence, or where experimental research is either unethical or not feasible (Ameyaw et al., 2014; Chan et al., 2001; Hollowell & Gambatese, 2010).

Pointedly, alternative methods to Delphi have been utilised by researchers. These include the staticised group, which is like the Delphi method but gives expert participants no subsequent opportunities for re-evaluation. Furthermore, both the focus group and the nominal group techniques also have marked pitfalls, especially from bias, conformity due to the overwhelming influence of group members, and cost. Conversely, a review of peer-reviewed studies has indicated a preference for the Delphi method when an expert perspective on a real-life phenomenon is desired. It is recommended to consider alternative techniques to Delphi only when the conditions of the Delphi are difficult to achieve, when time is a constraint and when it is feasible for all the experts to be physically at location (Hollowell & Gambatese, 2010).

The Delphi method comes to mind when a research area involves difficult phenomenon and needs access to data for making informed conclusions, but these required data are either restricted or proprietary. According to Haughey (2021) the Delphi technique is recommended for creating Work Breakdown Structures, risks identification and opportunities, compilation of lessons learned and for conducting a brainstorming exercise. The Delphi method therefore provides an opportunity to obtain reliable data from experts through carefully structured surveys and a consensus-building approach, and this represents the strategy for this research.

Although the FPSO is operated in remote deep offshore locations, the Delphi approach has been used in this study as a means of data collection and analysis in iterations that has allowed a group of individuals at different locations, with varying perspectives, experiences, and expertise, to collaboratively synchronise a detailed assessment and feasible solution to a complex problem (Saldin, 2016).

Due to the inherent project complexity within oil and gas revamp projects, the associated uncertainties (especially the hope to discover the ("unknown unknowns" and to unveil the facts which humans intentionally refuse to acknowledge due to social or environmental factors, the "unknown knowns" (Rumsfeld, 2003; Zizek, 2006 cited in Saldin, 2016)), the revamp project has remained a challenge to manage. However, subjective judgements have been harnessed through the Delphi method to strive for optimality in project delivery, even without it being a precise analytical technique.

Equally the Delphi method has been adopted in this research study due to the opportunities provided for a group of experts to independently and without bias share and review lessons learned from their experiences on FPSO revamp project performances. Therefore, the Delphi method offers more credibility to the outcomes of this research work, reflecting a complex problem in actual practice but without undermining the identified potential risks, inherent flaws, or criticisms of the method. Predicting the future is not a scientific calculation, but the Delphi Technique can help a researcher or user understand the probabilistic event forecast and potential impact on research or project outcomes (Haughey, 2021).

Below is the step-by-step sequence of the Delphi method, tailored by the researcher in this study.

Step 1: Choose a Facilitator

The first step is to choose a facilitator. This happens to be the researcher in this instance. The facilitator collates and summarises the responses, discards points that do not add value to the discussion, focusses on common views with a view to building consensus among expert opinion.

Step 2: Identify Your Experts

The Delphi technique relies on a panel of experts. In this study this required a purposive selection of experts in FPSO revamp project execution.

Step 3: Define the Problem

Statement of the problem, which was explained in the introductory section of the questionnaire for administrative convenience.

Step 4: Round One Questions

Questionnaires or interview survey administered to acquire the expert's insights and views on forecast events or outcomes. This was skipped in this study because the literature review was adequate to frame the actual questions in step 5.

Step 5: Round Two Questions

Questionnaires or interviews generated following feedback from the first questions in step 4. These are usually intended to obtain further insights and clarifications on the subject matter.

Step 6: Round Three Questions

The final questionnaire or interview survey is tailored to an agreement decision by the group of experts. This gives the individual expert the opportunity to re-assess his or her earlier discission or viewpoint relative to others in the majority.

Step 7: Recommend action points from the findings.

4.3 Questionnaire Structure and Interview Guide

The questionnaire for the research as captured in Appendix A has been designed in sections for ease of administration and to sustain participant interest throughout the different stages of the data collection. In addition, multiple question types comprising open-ended, dichotomous, and close-ended or multiple-choice questions were used to enhance the number of responses and to engage the participants (QuestionPro, 2021). Two sets of questionnaires were administered: the first set comprised section 1 and 2A, which are intended to obtain qualitative data. Section 1 is made up of six questions and was utilised for confirming that the organisation in which the participant is affiliated or employed is a multinational oil and gas operating organisation. It was also used for extracting information described in the demography Table 4.1. Section 2A of the questionnaire survey used multiple-choice questions used to streamline the expert views regarding the five levels of AHP model development.

Sections 2B and section 3 were used for introducing the concept of Analytic Hierarchy Process (AHP) and to set the stage for the participants to respond to the next set of structured questionnaires designed to produce quantitative data for the model development. Consensus feedback and clarification was progressed by the researcher through telephone communication.

The pre-determined consensus value for the research was set at a 70% majority decision and was the basis for selecting the variables for the model development. The five-step AHP model development comprises the goal at level 0 which is the objective function of improving the FPSO revamp project performance during the execution phase. Level 1 has the four identified criteria – engineering, prefabrication and construction, site installation, and pre-commissioning and commissioning activities. At level 2 are the five sub-criteria comprising project HSEQ, project scope, project cost and schedule, project knowledge, and project procurement management. The sub-criteria are at level 3 and include the following constraints: permit to work, personnel mobilisation and inspection/repair; scope creep/modification; and materials unavailability. Finally, at level 4 are the alternatives Lean and Agile project management for improving the existing stage-gate project management approach.

The interview guide, referenced in Appendix B, was designed to complement the initial questionnaire administered to the experts. It has a total of six major or leading questions and 15 prompt or follow-up questions. Due to the COVID-19 pandemic the formal interview survey was not implemented as initially planned, however useful information about the rudiments of FPSO revamp project execution and data for building the comparison matrix table for the level 4 AHP model development was satisfactorily completed through telephone conversations with the participants.

4.3.1 Questionnaire and Interview Administration

The formal introduction to the project department of the case study companies was the starting point for efforts to persuade potential respondents to answer the questionnaire. It took persistence and follow-ups using email, telephone, in-house and mail communications (QuestionPro, 2021) to achieve the objective of data collection. The experts are either office-based personnel or rotators who are either on a 28-day work cycle on the FPSO or are on 28-day time-off. This tight schedule made the efforts to collect the data quite challenging but at the same time interesting for the researcher due to the flexibility to utilise the various modes of questionnaire administration. Figure 4.1summarises the four different methods that were used to obtained data from the experts.

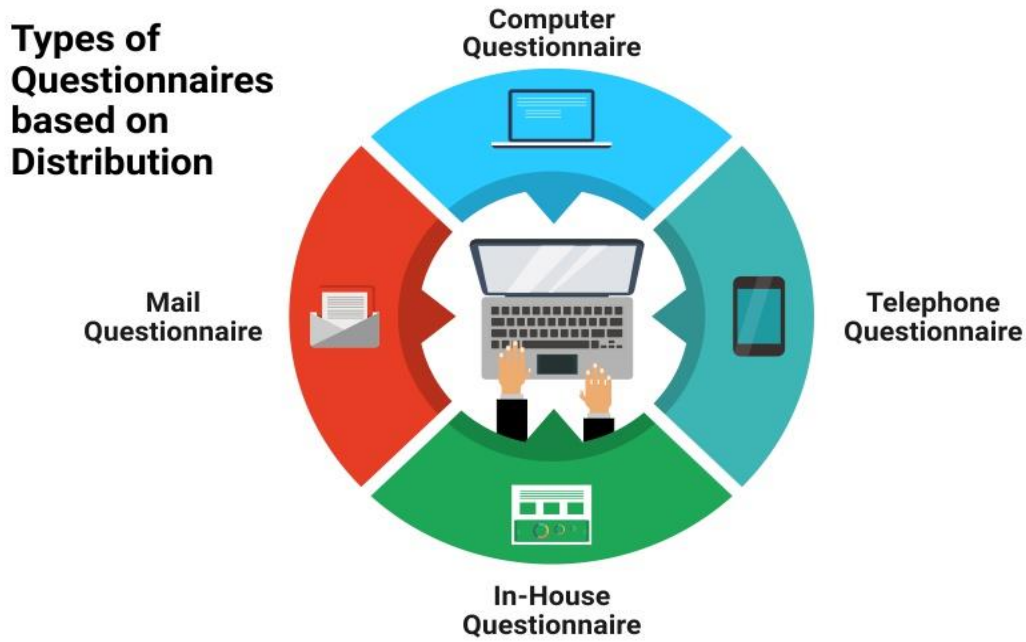


FIGURE 4.1 Types of Questionnaires based on Distribution

Source: QuestionPro (2021)

4.3.2 Participant Selection for the Study

Participants for the study have been selected purposively from the projects department of each of the case study organisations in Nigeria. The organisational structure of each of the oil and gas operating companies is similar and the project executive or designate assisted the researcher with identifying the personnel knowledgeable on FPSO operations, maintenance, and revamp project execution, including cognate experience in full facility shutdown. The composition of the participants for the five case studies is presented in Table 4.1.

The table indicates that approximately 52% of the respondents for this research are expatriates, this statistic explains the respective oil and gas company's expatriation policy where staff are temporarily transferred from their country of origin or employment yet can still function perfectly well with little or no problems, this scenario is made possible especially because job procedures and processes are standardised irrespective of the inherent external challenges faced by new arrivals. Effective expatriate management is critical for the globalised economy, especially in the upstream oil and gas sector where international businesses are predominant across the globe (FDE, 2016). Since large oil and gas reserves now reside in unconventional and harsh environments, such as areas deep offshore this means that experienced personnel from all over the world must be deployed to share their learnings and experiences to get the job done.

This expatriate deployment initiative, which cuts across FPSO revamp project development paves the way for knowledge transfer to the local population. Viewed holistically, it's a win-win situation for all involved. The organisation is assured of employee commitment while maintaining its qualitative and competitive edge. The employees have assurances that the company guarantees their health and safety while working temporarily overseas, in addition to the incentive of working abroad, which can be a booster for career development (FDE, 2016). On the other hand, the host country and local employees of these multinational oil and gas companies are beneficiaries of knowledge transfer, leading to continuous improvement of local capability.

There is a strong commitment by governments in many countries to the development of local talent through the instrumentality of an agency. In Nigeria, for example, the Nigeria Content Development Monitoring Board (NCDMB) is the agency with the mandate to formulate procedures, guide, monitor, coordinate and implement the provisions of the Nigeria Oil and Gas Industry Content Development (NOGICD) Act of 2010, thus ensuring seamless coordination of expatriate movement relative to local employment, amongst other statutory functions (NCDMB, 2020). An example of this is Total's upstream operations in Angola, Uganda or in countries which have no experience of oil and gas production. Total, having gained the approval of the government, sends in its own expatriate resources with the understanding that the company will exploit the natural deposits and develop its business in new countries. In return, the company trains local staff, thereby imparting its knowledge and experiences in the oil and gas industry to the local population (FDE, 2016).

4.3.3 Demography of Expert Participants (Case Study 1 to 5)

Table 4.1 Demography of Experts (Age Range: 35 – 65 Years

S/N	Group Identity	Number of participants	Range of Experience (Years)	Current Job categorisation			Nationality		Purpose of data collection
				Project Coordinators	Senior Managers	Project Executives	Local	Others	
1	Case study 1 (Specific/Oil and gas production)	7	12 - 25	3	3	1	4	3	Development
2	Case study 2 (Specific/Oil and gas production)	9	13 – 32	3	4	2	3	6	Validation
3	Case study 3 (Specific/Oil and gas production)	8	23 – 36	1	4	3	4	4	Validation
4	Case study 4 (Specific/Oil and gas production)	7	15 – 36	2	5	0	4	3	Testing
5	Case study 5 (Non-Specific/Oil and gas production)	8	14 – 42	4	3	1	0	8	Testing
Total no. of participants (Specific and Non-Specific/Oil and gas production)		39	12 – 42	13	19	7	15	24	Development validation and testing

4.4 Case Study 1

Case study 1 is a major multinational oil and gas operating company in Nigeria. This company was approached for the purposes of research data collection and proposed optimised development due to their operatorship of at least an FPSO in Nigeria. The identified and available experienced personnel in this organisation shared lessons learned and provided feedback via the adopted research instruments of questionnaire and interview survey. This multinational company is in active operation in at least five continents of the world and has over one million personnel in their employ. The contractual relationship is both Joint Venture (JV) and Production Sharing Contract (PSC) with the Nigerian government, which is represented by Nigeria National Petroleum Corporation (NNPC).

For the purposes of this research, referencing demography of panellists Table 4.1 a total of seven participants comprising three project coordinators, three senior project managers and one project executive responded to the questionnaire and interview surveys. The data collected has been analysed using levels 1 and 2 of the Analytic Hierarchy Process (AHP) for the model development, which has been presented in the tables and charts attached. The participants' experience level ranged from 12 to 25 years, and the questionnaire responses and interview survey indicated that the company manages the FPSO facility revamp projects utilising a customised project management system or framework, irrespective of the locality of operations by leveraging on the stage-gate project management model.

4.4.1 Questionnaire and Interview Data Analysis (Case Study 1)

Table 4.1 indicates a mix of nationalities in the project team. This is typical in multinational oil and gas organisations even though the geographical location where the FPSO asset is in operation is Nigeria. This shows the extent of integration of experiences under a common approach with the aim of project and operational excellence. The harmonisation of the experts under definitive working principles and standards displays the maturity of knowledge management of the organisation and therefore the findings and model development data from the experts in this study can accurately reflect the global oil and gas sector.

The responses of the experts from question Q1 to Q6 of the questionnaire have been covered under demography in Table 4.1 and Figures 4.2 to 4.16 and worksheets show the schematics of the outcomes of the questionnaire survey. The findings point in the direction of the research objectives as perceived by the experts in case study 1, The same process has been followed for the subsequent case studies.

Your organisation utilises the five stage-gate model comprising initiation, selection, definition, execution and operation framework or model for managing capital or major projects?

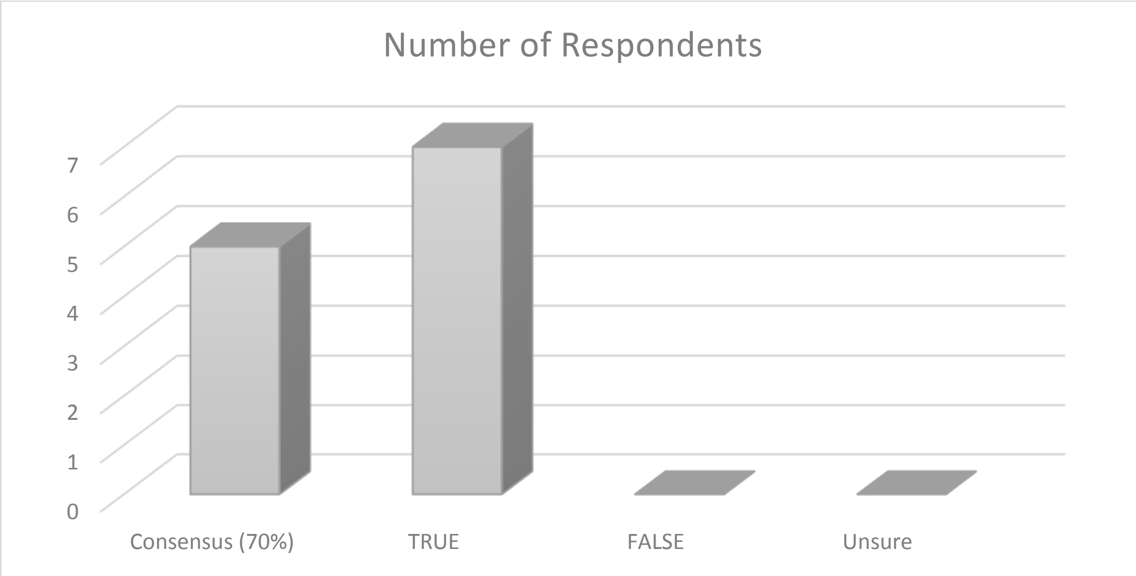


FIGURE 4.2 Research Questionnaire Number 7.

Revamp 'brownfield' projects at execution phase major activities are engineering, prefabrication/construction, site installation, and pre-commissioning/commissioning attracts lower budget estimates but are more complex to manage than capital/mega/major/ "greenfield" projects.

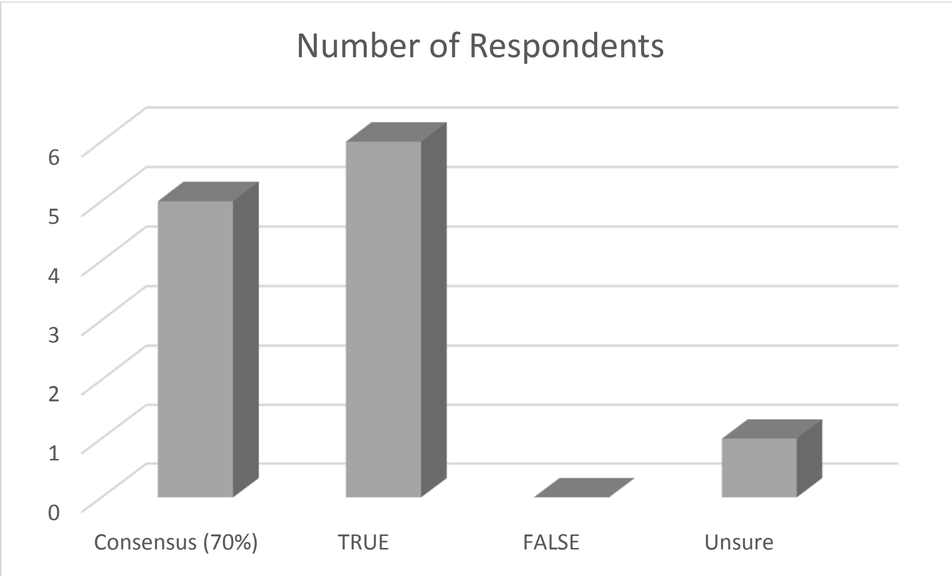


FIGURE 4.3 Research Questionnaire Number 8.

How would you describe your organisation's approach to managing revamp?

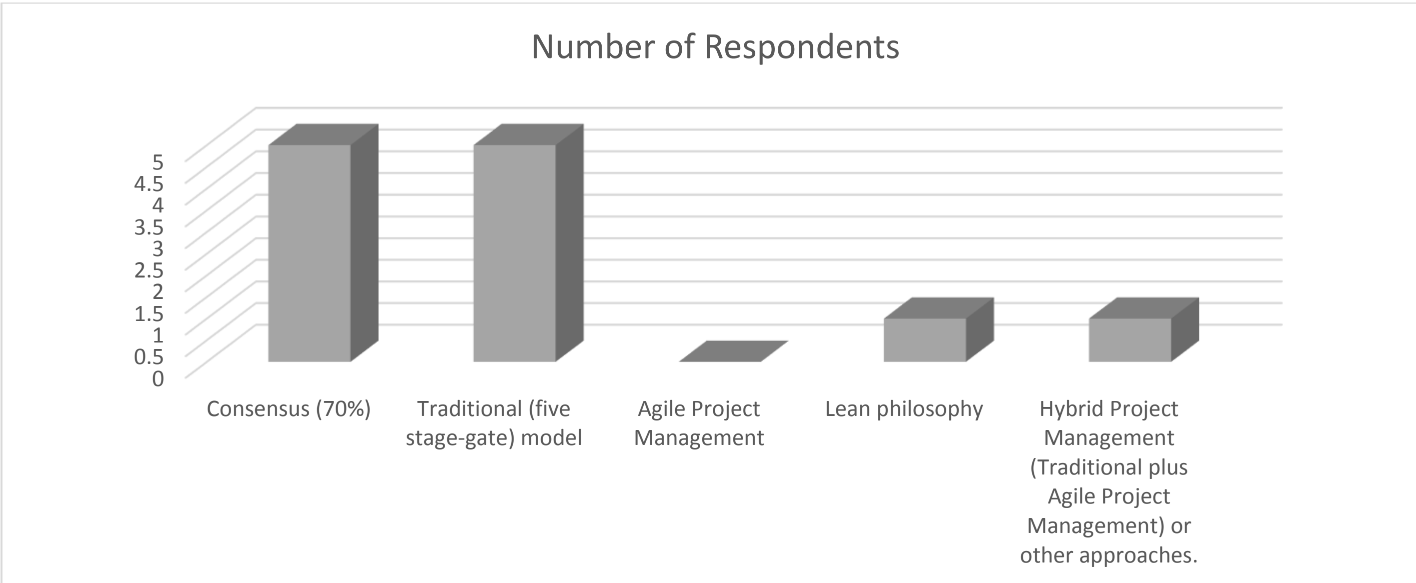


FIGURE 4.4 Research Questionnaire Number 9.

How would you rate the overall FPSO revamp project performance in your organisation judging by project management criteria like cost, schedule, quality, HSE, customer satisfaction etc?

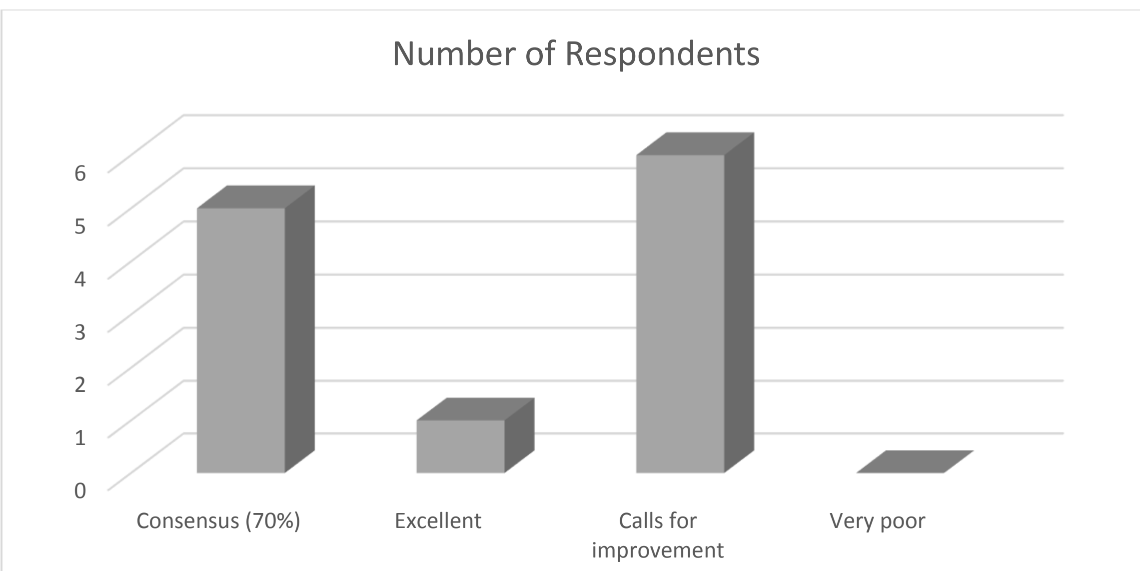


FIGURE 4.5 Research Questionnaire Number 10.

Indicate all the critical project management constraints from HSEQ, knowledge, cost and schedule, scope, procurement, risk, communication, human resources, integration, stakeholder, Interface, Customer satisfaction management and others in your opinion for each of the listed revamp project activities during execution phase.

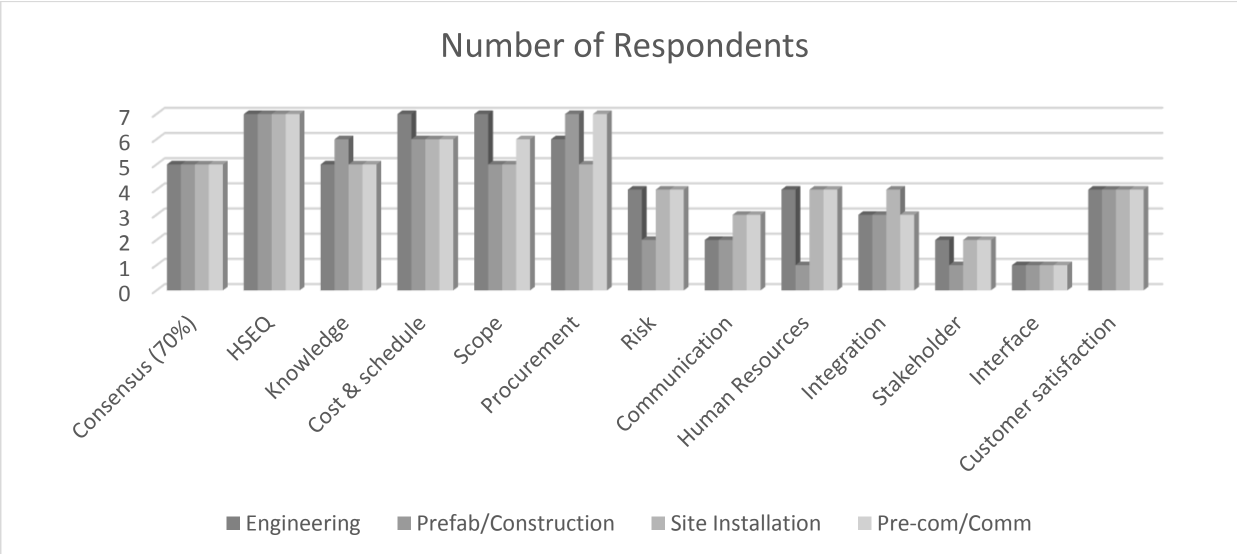


FIGURE 4.6 Research Questionnaire Number 11.

Indicate area(s) or project functions from where your organisation should focus more to improve overall revamp project performance.

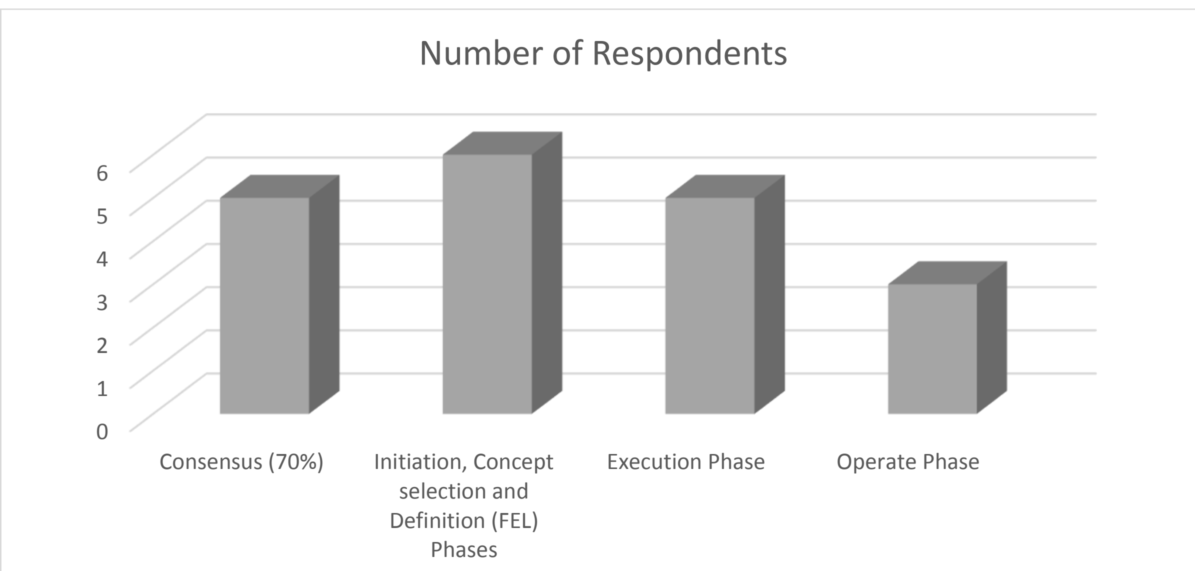


FIGURE 4.7 Research Questionnaire Number 12.

Tick any or all the project management theories or models you have either applied totally or partially in executing previous revamp projects:

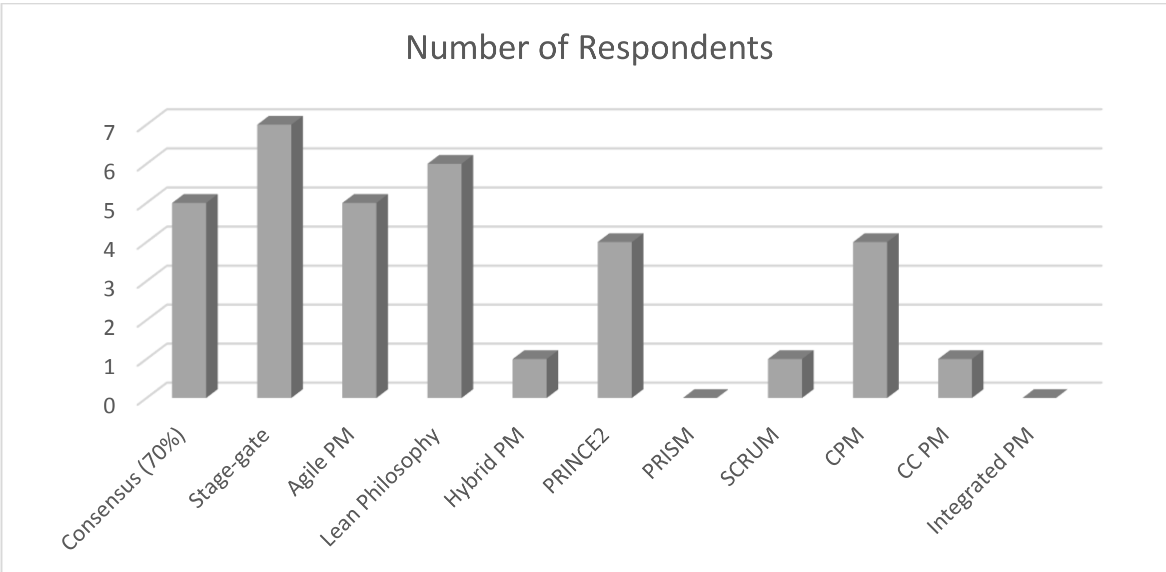


FIGURE 4.8 Research Questionnaire Number 13.

Describe how best revamp projects are managed in your organisation

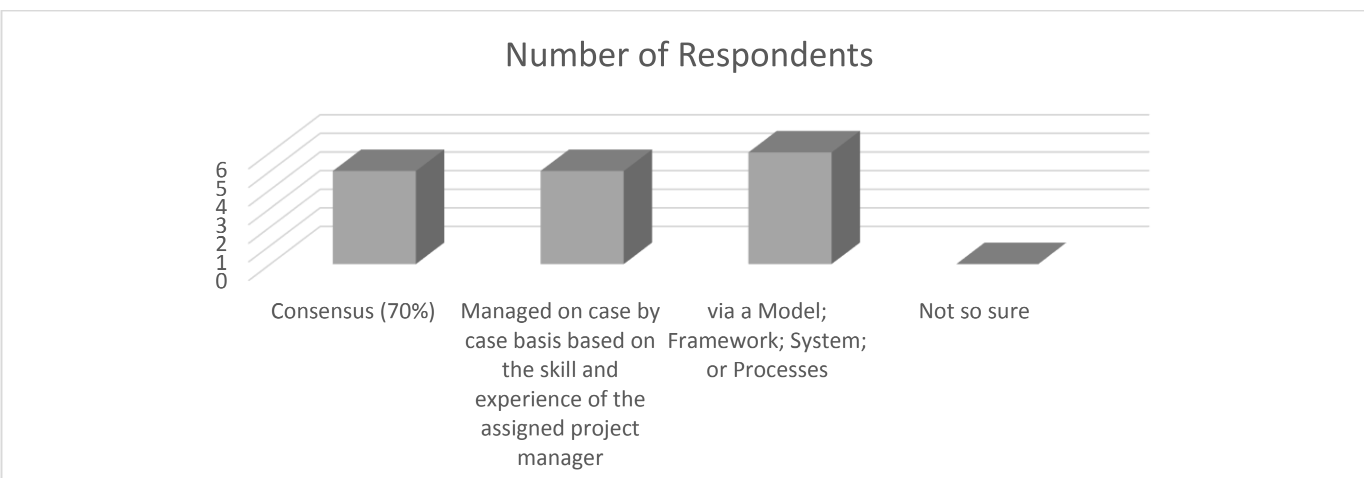


FIGURE 4.9 Research Questionnaire Number 14.

Select all applicable means below, as to how your project team or organisation can improve or overcome failures in some or any revamp project

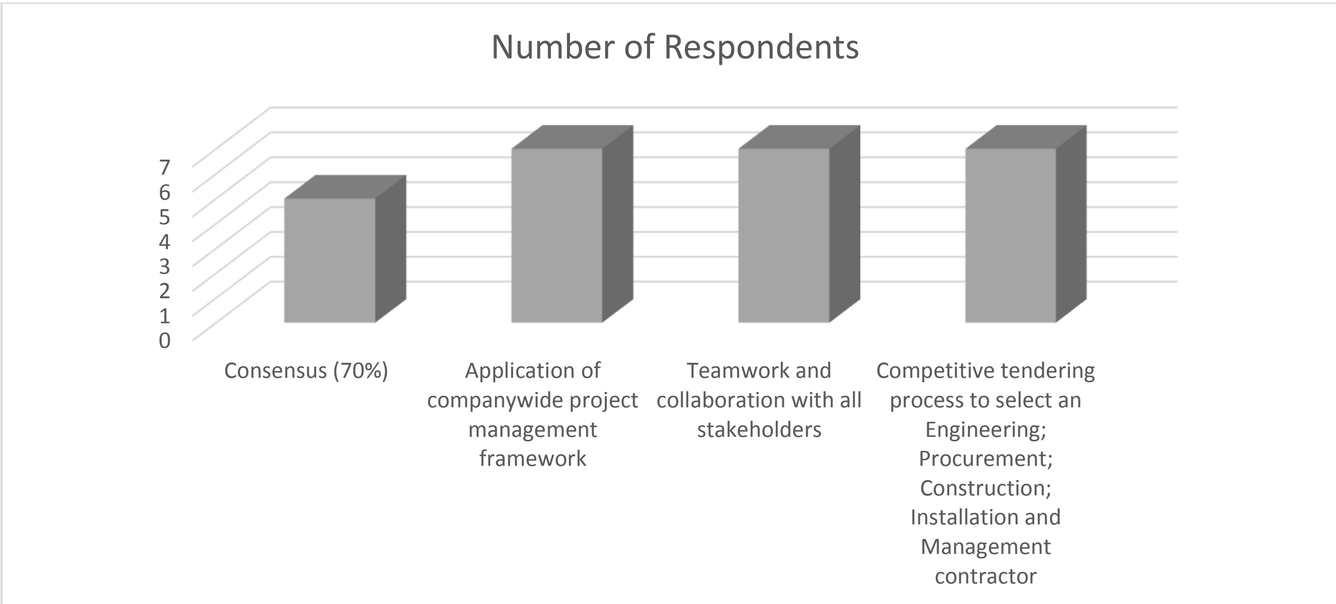


FIGURE 4.10 Research Questionnaire Number 15.

Select all from below and add if applicable that which your organisation can do to ensure implementation of standardised processes, frameworks, or models for managing revamp project execution?

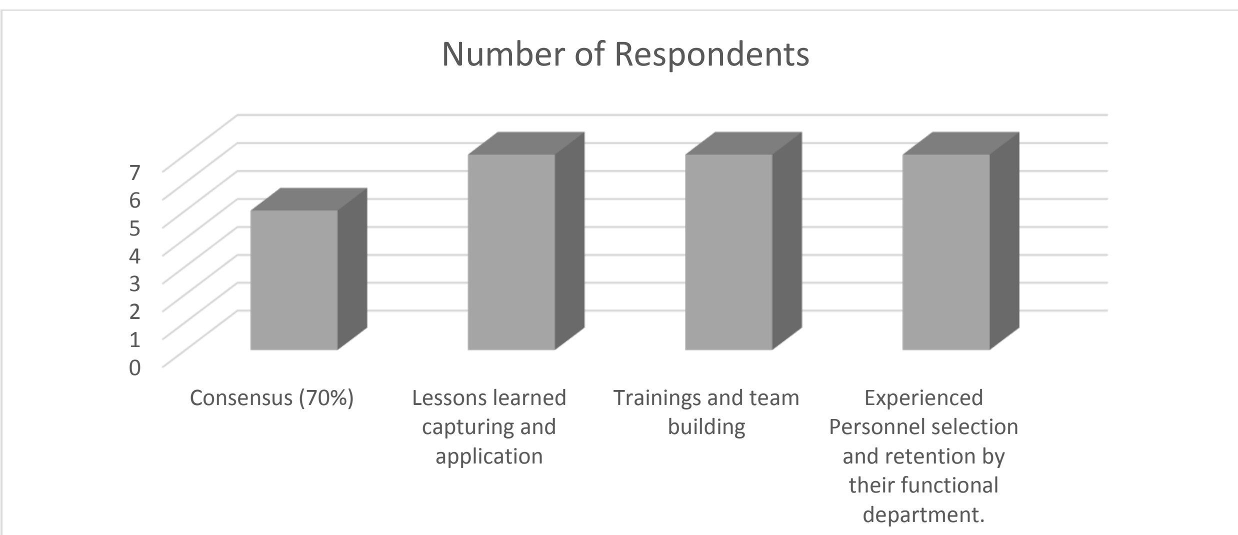


FIGURE 4.11 Research Questionnaire Number 16.

Analytical Hierarchy Process (AHP) is a globally acceptable multiple criteria (pairwise comparison) decision making approach of selecting majority expert opinion from competing alternatives. How knowledgeable are you about AHP?

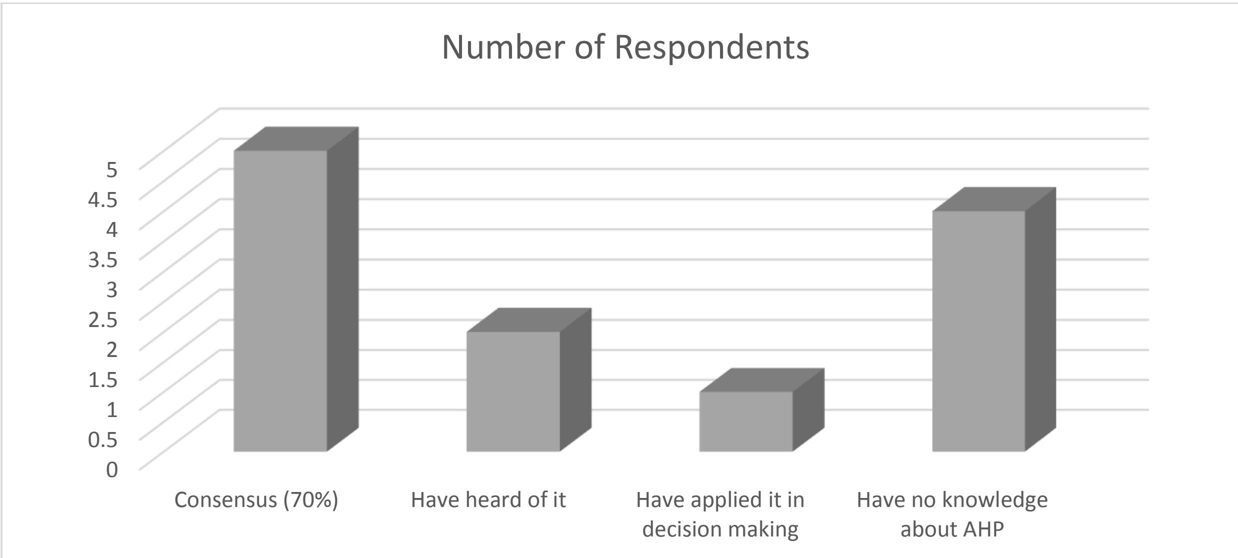


FIGURE 4.12 Research Questionnaire Number 17.

AHP Analysis Questionnaire: Worksheets are in Appendix A

FIGURE 4.13 Research Questionnaire Number 18

Compare the execution project activities, constraints, and project management approach that contributes most value to FFSD project performance using the AHP table attached.

Table 4.11 Research Questionnaire Number 18 (Worksheet Template)

AHP Comparison Scale

Numeric Value	Verbal Judgement
9	Extremely important
8	Very, very strong
7	Very strongly more important
6	Strong plus
5	Strongly more important
4	Moderate plus
3	Moderately more important
2	Weak or slight
1	Equally important

* Fill the upper/grey diagonal matrix.

Case study 1, Respondent 1: Execution Phase Activities

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1	9.00	9.00	6.00
Prefab/construction		1	6	6
Site Installation			1.00	8.00
Pre-comm/Comm				1

Case study 1, Respondent 2: Execution Phase Activities

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1	7.00	8.00	6.00

Prefab/construction		1	8	6
Site Installation			1.00	3.00
Pre-comm/Comm				1

Case study 1, Respondent 3: Execution Phase Activities

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1	9.00	9.00	3.00
Prefab/construction		1	7	4
Site Installation			1.00	3.00
Pre-comm/Comm				1

Case study 1, Respondent 4: Execution Phase Activities

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1	9.00	7.00	1.00
Prefab/construction		1	7	9
Site Installation			1.00	7.00
Pre-comm/Comm				1

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1	8.00	1.00	7.00
Prefab/construction		1	7	6
Site Installation			1.00	7.00
Pre-comm/Comm				1

Case study 1, Respondent 6: Execution Phase Activities

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1	6.00	2.00	1.00
Prefab/construction		1	2	1
Site Installation			1.00	5.00
Pre-comm/Comm				1

Case study 1, Respondent 7: Execution Phase Activities

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1	9.00	7.00	1.00
Prefab/construction		1	8	7
Site Installation			1.00	1.00
Pre-comm/Comm				1

On sub criteria of criterion Engineering:

Sub criteria	Scope	Procurement	Cost/Schedule
Scope	1.00	2.00	2.00
Procurement		1.00	2.00
Cost/Schedule			1.00

On Sub criteria of criterion Prefab/Construction:

Sub criteria	Risk	Human Resources
Risk	1.00	5.00
Human Resources		1.00

On Sub criteria of criterion Site Installation:

Sub criteria	HSEQ	Integration
HSEQ	1.00	8.00
Integration		1.00

On Sub criteria of criterion Pre-com/ Commissioning:

Sub criteria	Knowledge	Stakeholder
Knowledge	1.00	7.00
Stakeholder		1.00

Alternatives for Sub criterion Scope:

Alternatives	Lean	APM
Lean	1.00	7.00

Alternatives for Sub criterion Procurement:

Alternatives	Lean	APM
Lean	1.00	7.00

APM		1.00

APM		1.00

Alternatives for Sub criterion Cost/Schedule:

Alternatives	Lean	APM
Lean	1.00	7.00
APM		1.00

Alternatives for Sub criterion Risk:

Alternatives	Lean	APM
Lean	1.00	9.00
APM		1.00

Alternatives for Sub criterion Human Resources:

Alternatives	Lean	APM
Lean	1.00	8.00
APM		1.00

Alternatives for Sub criterion HSEQ:

Alternatives	Lean	APM
Lean	1.00	4.00
APM		1.00

Alternatives for Sub criterion Integration:

Alternatives	Lean	APM
Lean	1.00	8.00
APM		1.00

Alternatives for Sub criterion Knowledge:

Alternatives	Lean	APM
Lean	1.00	7.00
APM		1.00

Alternatives for Sub criterion Stakeholder:

Alternatives	Lean	APM
Lean	1.00	4.00
APM		1.00

Should the consensus opinion differ from yours in some instances, would you still subscribe to the proposed optimal FPSO revamp project management model from AHP approach?

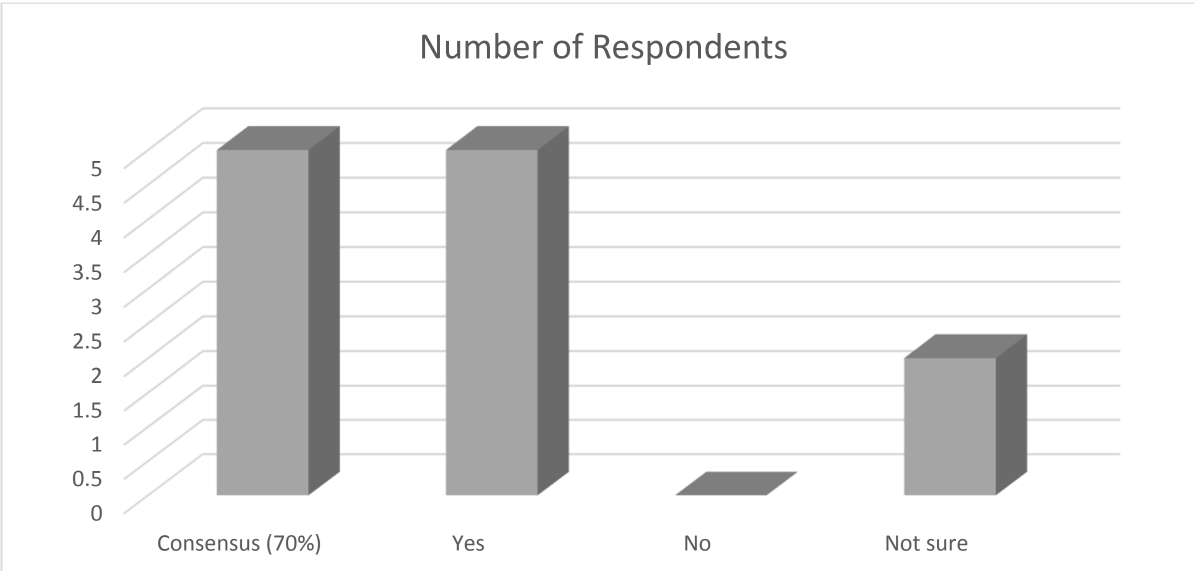


FIGURE 4.14 Research Questionnaire Number 19

SECTION 3 (Open question)

How would you convince your organisation to adopt a new optimised model for managing FPSO revamp project execution?

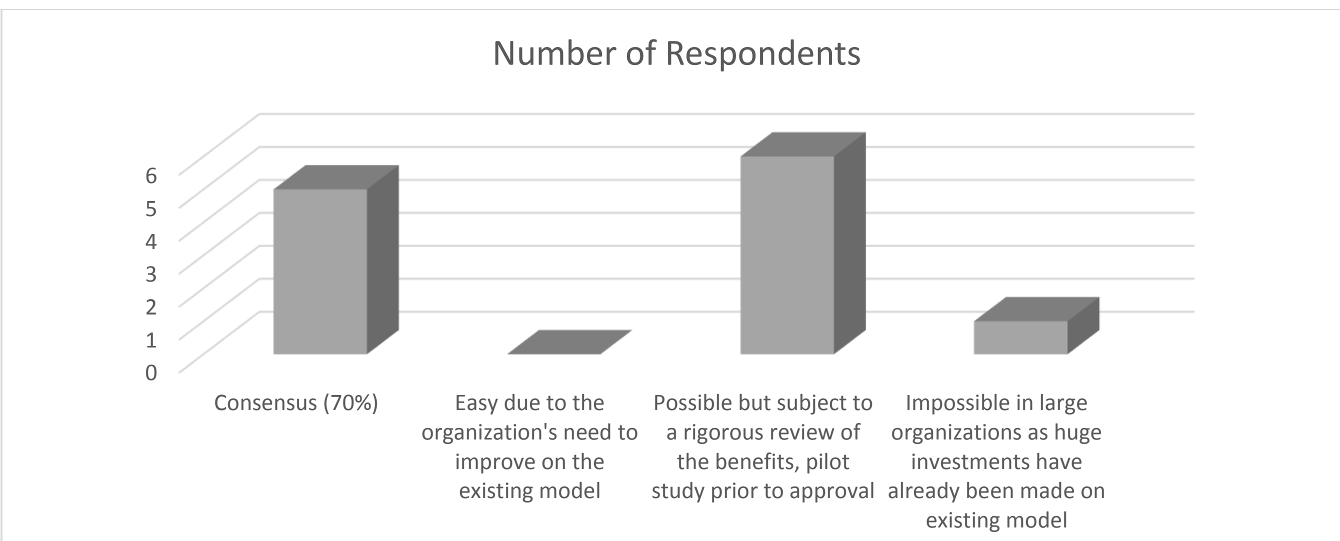


FIGURE 4.15 Research Questionnaire Number 20

Interview Survey (Open question)

How would you assess specifically the issues and discussions around wastage, re-work, inspection and acceptance of finished products, materials availability, storage, and handling during project execution?

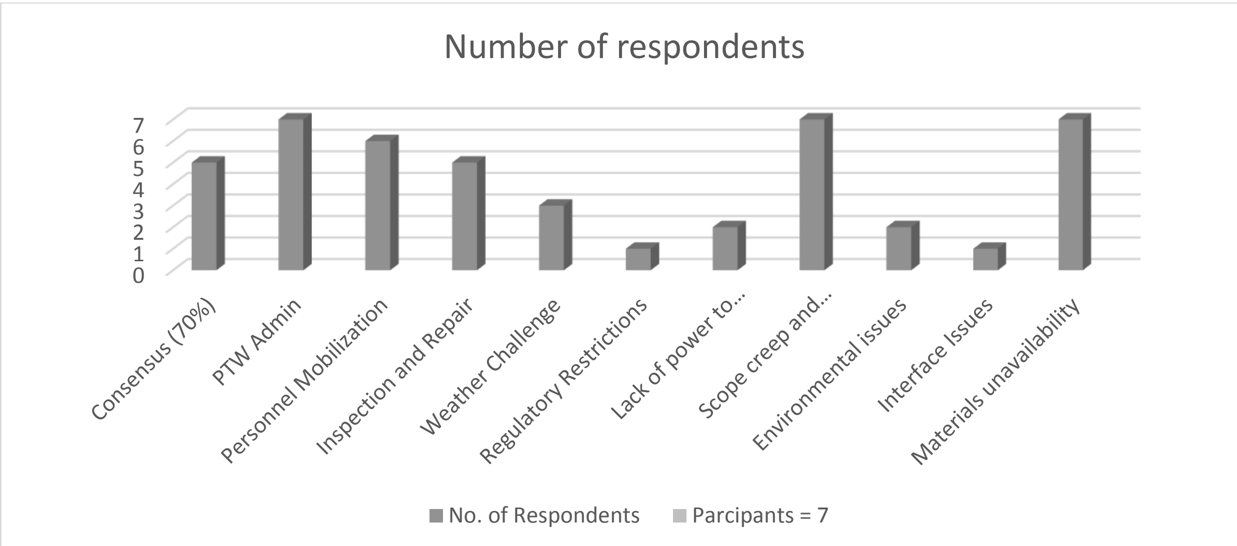


FIGURE 4.16 Research Questionnaire Number 6

4.5 Research Validation by Documentation

To further validate the research outcomes, the close out report document of an FPSO revamp project case was analysed and presented. This is consistent with the philosophy of triangulation in case study research where multiple sources of evidence converge into a corroborative line of inquiry and conclusions (Yin, 2009).

4.5.1 Case Study 1 Project Close Out Report Review

This sub-section gives an account of a close out report from case study 1. It relates to project successes factors, challenges and lesson learned. As expected, this scope of work focuses on topside revamp activities of an FPSO in operation in Nigeria and typically requires plant shutdown at some point in the execution stage of the project for tie-in of the new systems to the existing facility.

The aim of this report from the company's perspective was to document the events surrounding the revamp project activities from preparation through to execution, including lessons learned and recommendations based on feedback received from participants in the project, and close-out. The report also includes the challenges encountered and how they were resolved. These lessons learned, feedback and recommendations are useful for improving on similar projects in future.

The revamp project activity was performed as part of the corporation's long term integrity management plan and pressure vessels internal inspections requirement by company standards and regulations, as stipulated by the Department of Petroleum Resources (DPR), an agency of the Nigeria National Petroleum Corporation (NNPC).

Following months of preparation, the company gave the go-ahead to bring down the production loops for intervention. The entire shutdown lasted approximately one month from ramp down of the first well to completion of the shutdown work scope and plant start up.

Approximately 400,000-man hours were expended during the pre-shutdown and shutdown execution phases, with zero Lost Time Incident (LTI). At peak, POB of about 700 people spread across the FPSO, FLOTEL and support vessel was recorded and over 100 work permits were raised for work. These feats are in keeping with the company's policy of zero tolerance for HSE incidents in all its operations. The shutdown was considered a major milestone achievement both from an HSE point of view and the work scope completion perspective within the estimated time frame.

The overall scope of work was grouped into two broad groups for proper management:

A. Work Preparation

B. Offshore site intervention works

4.5.2 Work Preparation

Work preparation was further divided into onshore pre-fabrication and early desktop preparatory work. An onshore pre-fabrication activity coordinated by the company's construction team was launched in the major EPC contractor yard for all corroded piping replacement spools, tertiary supports, and structural installation members. In addition, an onshore team of preparators for the various packages were mobilized in the contractor offices to allow the commencement of the preparation phase of the packages.

A Master Document Register (MDR) matrix of about 150 documents and procedures was drawn up and agreed on with contractors for the scope of work review.

During the onshore preparation phase, a material tracker spreadsheet was developed to track and control all materials requested through the approved company procurement channel. It consists of MTO of all materials required to complete the intervention. The work steps below were developed to control all the materials, bag-tag integration, and mobilisation:

1. Develop MTO based on approved spading plan and engineering documents (isometric drawings were used as references).

2. Site visit performed to confirm the applicability of spading plan (to use spade or blind flange) and the condition of joints and spectacle blinds. During this period, heavy corrosion was found on

some spectacle blinds on some specific network was identified, therefore a temporary spade was fabricated and installed upstream of the spectacle without breaking the initial joints.

3. Various special fittings and long lead items required for final installation such as Seal Ring, Blind Hub, vessel internals and large bore blind flanges were monitored to ensure delivery tracking and timely arrival to site.

4. Work Pack and Permit to Work were developed internally to reduce cost and contracting scope. The document numbers then integrated on to Material Tracker to generate specific tag numbers for materials, designation, and location.

5. Materials arrangement for ease of identification, handling, and transportation, otherwise known as ‘Bagging and Tagging’, was performed at onshore materials base with supervision from the construction team to systematically ensure that all materials were bagged, tagged, and stored properly in containers dedicated for offshore installation campaign. After verification, materials and valves were then preserved to prevent contamination.

6. A dedicated bag was used to separate spading consumables (non-CAF gasket, seal ring, RTJ) used for spading activity to differentiate from reinstatement consumables. This was to ensure no shortage on the materials because of wrong application.

4.6 Offshore site intervention works subcategories:

4.6.1 Prior shutdown works

Site preparation was started earlier by the construction team when the first batch of FFSD materials (containers) were delivered offshore. Upon receipt, site checks and verification were performed to ensure all materials had been shipped as per the packing list and had experienced no damage during transport. Other materials were shipped subsequently, including a specific container of machining equipment. After verification Is were completed, the materials were distributed to their designated locations, including valves and Double Block and Bleed (DBB) valves. Specific lifting tools for the Gas Export Compressor (GEC) Cooling unit and boxes of the unit spares were also relocated from their container and distributed to a designated lay down area deck.

Meanwhile, groups of scaffolding teams were distributed to erect temporary access platforms and load bearing scaffolds. Scaffolding was required for safe access and load bearing was required to assist lifting during spading/de-spading, valve replacement and machining equipment support. Additional scaffold materials were mobilised from onshore to ensure the quantity was enough to cover all areas. Another specific preparation was the installation and test loading of several winches. As part of the preparatory work, hot bolting activities were planned and carried out to ease the freeing of bolts during the FFSD.

In addition, the new replacement GEC Cooler unit trial lift to check the crane parameters on the designated vessel was performed during this time. The experience obtained from previous shut down interventions created good lessons learnt for shutdown management, information on equipment characteristics, and details on what to prepare and how to prepare it. This early preparation contributed to the success of the full field facility shutdown scope of work.

4.6.2 Shutdown works

The key scope of work carried out during the plant shutdown included the following:

I. Intrusive inspection of pressure vessels. About 30 pieces of equipment were fully inspected including heat exchangers, separators, drums, columns, scrubbers, and air receivers.
II. Replacement of over 100 defective valves with new ones of nominal sizes ranging from between three-quarter and 30 inches.
III. Replacement of Gas Export Compressor (GEC) Discharge Coolers
IV. Various piping sectional repair or replacement
V. Yearly preventive maintenance on all compressors in addition to some gas leak repairs.
VI. Intervention on the high voltage switchboards, POC for Schneider switchboards, switch gears and relay testing on the ABB switchboards. Overhauling of senior Daniel orifice, ICSS + Triconex activities request for modifications.
VII. Gas Export Compressor coolers balancing and partial discharge measurement checks.
VIII. Opportunity jobs on the turbine generators and recirculation pumps shaft installations

In a nutshell, more than 20 different contractors participated in the shutdown operations. Services provided ranged from vessels opening, cleaning, and boxing up to implementation of plant isolation, bolting and torqueing, modification of scaffolds, corroded piping replacements, valves installation, leak tests, OEM specialists support, etc.

Materials and equipment were procured and staged on work locations before commencement of the shutdown. Materials procured included HSE equipment, isolation materials, production materials, valves, lifting equipment, piping materials, maintenance spares for preventive maintenance and overhauls.

4.6.3 Post shutdown work

The post shutdown activities included the following: painting touch-up, scaffolding dismantling, demobilisation of personnel, materials and equipment and re-instatement of FOTEL gangway landing platform.

4.7 Key Project Performance Records

The below project performance records were captured during the execution project stage.

4.7.1 Cost Performance

The estimated project cost of the revamp scope of work was over US$40m. This estimate includes both capital expenditure (CAPEX) and operational expenditure (OPEX) compared with approximately US$55m spent at the project close-out within a project lifecycle of three years. Therefore, while not overlooking the time value of money relative to inflation, the project budget over performance was approximately 37% from reasons captured in the lessons learned in section 4.7.4.

4.7.2 Specific Health Safety and Environment (HSE) Performance

Approximately 700 personnel underwent HSE training, which was organised onshore, in addition to specific hands-on training provided on-site for personnel involved in specialised activities. Job risk assessment workshops were held on site with company and contractor personnel to ensure a shared understanding of tasks, associated risks and mitigation measures. The required supervision level was carefully assessed, and additional support personnel were mobilised where required. These efforts resulted in the HSE pyramid for the project indicated in Figure 4.17. There was a proactive and conscious effort at hazards identification at the base of the pyramid, resulting in zero LTI throughout the execution stage of the project.

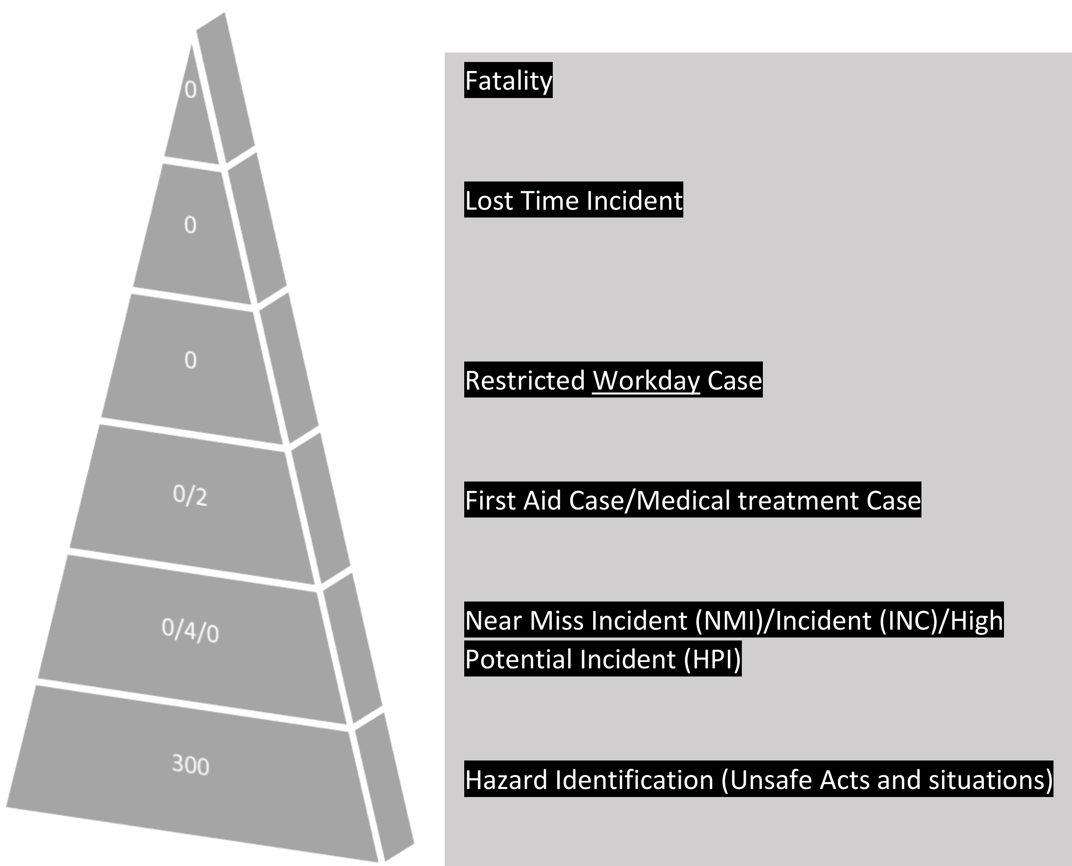


FIGURE 4.17 Site HSE Triangle for Specific Revamp Project Execution

4.7.3 Permit to Work (PTW)

A company approved PTW procedure was deployed during the FFSD. Approximately 1,200 PTWs were used during the FFSD. The plan to have all PTWs and supporting documents (including procedures, job cards, valve isolation and spading plans, lifting plans, etc) issued, reviewed, approved, and inputted to the e-permit software at least two months before the FFSD, could not be fully realised by all entities. One reason is the time taken by contractor personnel to understand company procedures. Several modifications had to be made to contractor deliverables during the early stages. Other plausible reasons include difficulties in visiting the site prior to the FLOTEL mobilisation due to POB constraints and contractor not allocating enough and quality resources to match the volume of documents generated.

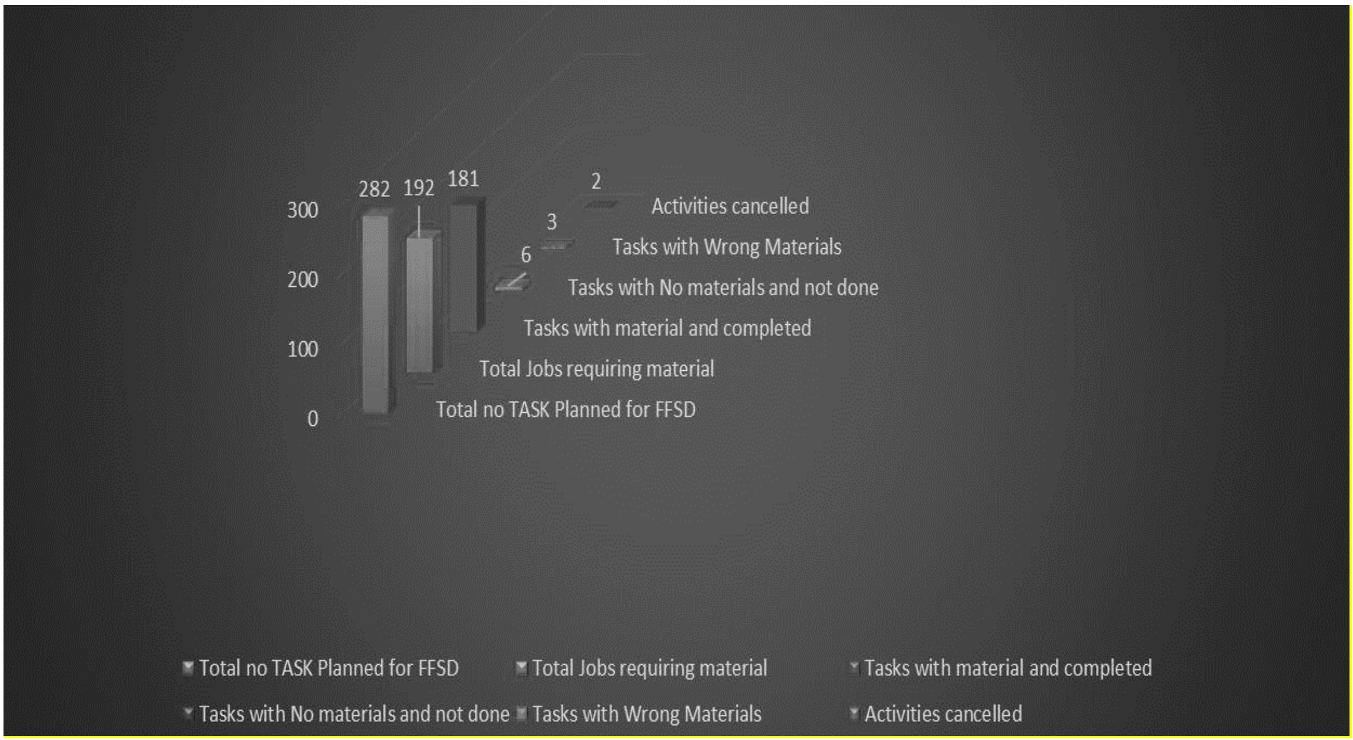


FIGURE 4.18 Status Report of Task at Revamp at Project Execution Completion

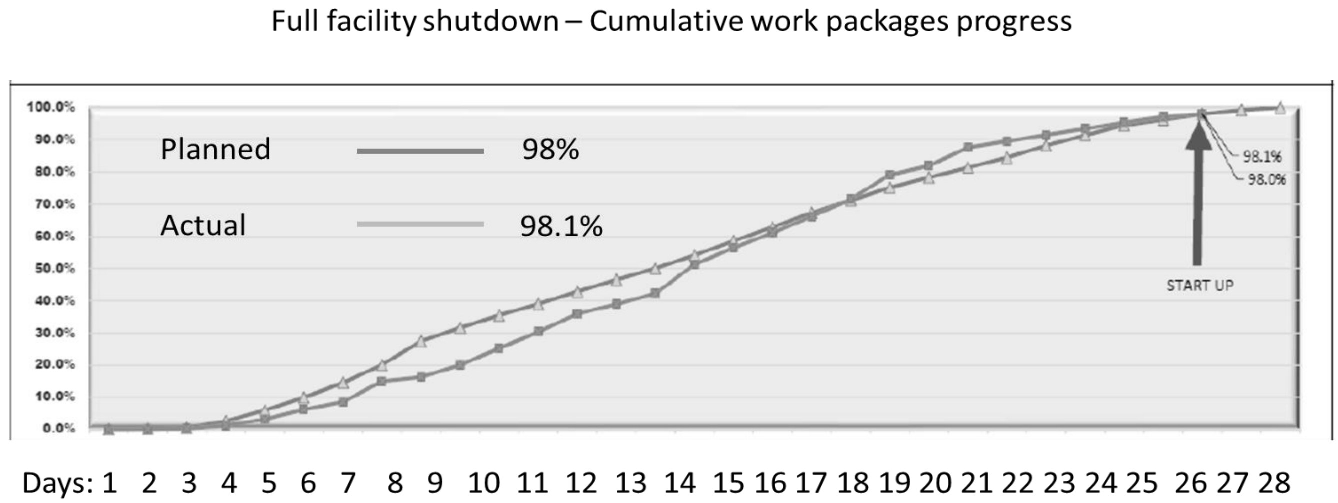


Figure 4.19 Progress Schedule of Revamp Project Execution during Full Facility Shutdown.

4.7.4 Lessons learned feedback and recommendations

All participating company project units, contractions and key players were invited to submit their feedback upon completion of the FFSD and re-start of the FPSO.

Responders were asked to categorise their feedback as follows:

Good practice to be replicated, Opportunity to be improved, Poor practice to be avoided

The outcome of the exercise has been as summarised in the following section as lessons learned.

Table 4.2 Project Lessons learned Capture

S/N	Event	Causes	Lesson Learned	Impacted Knowledge Area(s)
Onshore Fabrication/Preparation phase:				
1	Zero Lost Time Incident (LTI) recorded throughout the onshore fabrication	- Commitment by management and all project team members to sustain and continuously improve the safety culture. - Visible interest in safety walkthroughs and proper fabrication risk assessment	Management commitment to a clear safety roadmap should be encouraged in other to sustain excellent safety records and culture through all the project stages	- Scope of work management - Quality management - Risk Management - Communication management - Integration management
2	Challenges with sourcing of fabrication materials	- Initial scope of work wasn't very clear. - Lack of as-built documentation - Survey from manual dimensional checks was defective. - Late issuance and freezing of scope of work	- Mobilise competent personnel and freeze work scope as soon as possible. - Carry out scope of work verification survey early using laser scan technology.	- Scope of work management. - Quality management - Procurement management. - Time management - Human resources management
3	Completion of onshore fabrication scope of work was delayed	- Lack of as-built documentation. - Late fabrication work request - Challenges with sourcing fit-for purpose materials - Time requirements for quality checks and painting	- Freeze scope of work early. - Commence fabrication early using competent personnel. - Include contingency materials stock. - Incorporate in the planning ample time for quality checks - Joint	- Time management - Scope of work management - Cost management

			preparation and fit-up, Visual inspection, Radiography test, Hydrostatic pressure test and painting etc.	
4	Prefabricated spools had no clashes or dimensional errors during fit-up and installation	- Company deployed laser scan and pipe fit assurance services contractor during scope of work verification survey especially for piping network without as-built documentation	Engage dedicated service contractor for scope of work verification survey to avert potential delays with typical revamp modification work scope.	- Time management - Quality management - Cost management. - Communication management - Scope of work management
5	Lack of visibility during preparation phase	- Delays in identification and freezing of scope of work. - Delays in finalising both contracting and execution strategies - Delays in mobilisation of dedicated project team	- Respective entities should issue a weekly preparation report so that the management is aware of the exact preparation status of all the planned activities. - Maintenance scope of work should be frozen much earlier. Some changes occurred until commencement date - Production team should pre-check all required isolation valves to ensure no hold ups during actual intervention (2 weeks before) - Procedures should be validated and better adapted to the activity to be done. - Torqueing procedure with glass reinforcement plastic (GRP)	- Communication management - Integration management - Cost management - Quality management

			materials, Vessel cleaning procedure, Welding procedure, Vessel internal leak test procedures etc. should be clarified and approved before site intervention.	
6	A clear procedure was prepared for the ramp-down and ramp-up.	- Work preparation was carried out early by competent personnel	- This procedure should be updated according to operational constraints	- Scope of work management. - Human resources management
7	Contracting and Contractors inefficiency	- Late involvement of the main contractor. - So many teams under one supervisor making job supervision almost cumbersome - Some supervisors' roles were not clearly defined - Some contractor personnel complained of no pre-information on their roles on the FFSD e.g., tank cleaning personnel. - Other contractor personnel arrived site without knowing what they are to do and who is their supervisor	- Experienced main contractor should be awarded earlier, and detailed preparation should start well in advance before commencement date. - Professional supervisory competencies to be identified and deployed accordingly	- Human resources management. - Time management - Cost management
8	Good practices and challenges recorded with procurement and materials availability.	- A stock of FFSD spares was created, 60% of spading materials were from previous FFSD. - For the FFSD, some critical fast track procurements were identified and solved	- A central storekeeper should be nominated to survey and compute offshore and onshore tools and spares (flanges, valves, hoses, gaskets). This would forestall the disappearance of work materials	- Procurement management - Time management - Cost management

		- Some wrong materials were procured (T-cards, scaffold tags). - Standard premobilization inspection report on some equipment e.g., mobile air compressors were not sent to site - Some ordered materials were not delivered to site (oxygen kits, slings for confined space rescue). Site HSE had to make use of site stock. - Late arrival of materials (including life rafts, portable radios, spare batteries, etc), spare parts and tools, leading to a last-minute postponement of the FFSD by 2 days - Some expired HSE materials were delivered on site (chemical cartridges, tubes for breathing air analysis).	- Critical equipment (air compressors, batteries, nitrogen, forklift, hoses etc.) should be verified onshore by Company staff before shipment. - All spare parts should be available and confirmed correct by each trade prior to commencement date - Bag and tag packing lists to be improved. Identification of materials arriving on site was sometimes very difficult - Third party equipment to be used during FFSD to be properly pre-mobbed and function tested. - Installation of external battery charging system for mobile air compressor to improve its availability during shutdown - Early procurement should be launched to facilitate on-time site delivery especially for long-lead materials - Materials must be checked onshore before delivery to Site - HSE to be in the loop for validation of order during procurement.	- Integration management - Communication management

Offshore Installation:				
9	- Offshore campaign was executed with zero LTI	- Daily coordination meetings - Workshop sessions - Finger saver tool was very useful to avoid hand incidents - Competent and experienced fire watch personnel were deployed at dedicated areas for hot work monitoring. - Several hot works could be done simultaneously	- Futuristic planning meetings helped to foster excellent team building through the installation stage - Contractor HSE supervisor training should be more detailed than worker's general awareness HSE training and with specific reference to requirements for FFSD activities. - Site should be involved in designing the training program - Increase awareness for hazard reporting of contractors' personnel onshore prior to site mobilisation. - A dedicated team for housekeeping is recommended to improve housekeeping. - Recommend, control, and ensure usage of appropriate Personal Protective Equipment (PPEs) by all personnel.	- Communication management - Integration management - Scope of work management
10	Integrity of Welding habitat deployed at some hot work locations was compromised.	- Inadequate supply of fire-retardant tarpaulin supplied to site. - Personnel complacency - Inadequate awareness on requirements for hot-work	- Launch procurement of materials early. - Deploy experienced personnel for work offshore	- Risk management - Quality management. - Scope of work management. - Procurement management

11	Challenges with processing and approval of PTWs	- Some procedures in the PTW pack were not approved making it very difficult to ascertain the viability and review of such procedures. - On many occasions, hand signing of such procedures by any site available hierarchy became the only available option - Wrong and non-applicable Piping and Instrument Drawings and other documents were found in many PTW packs. - Late submission of JRA to Site.	- Develop Document Review and Approval (DRAM) matrix early. - Commence document review early and track progress to closure. - A review workshop is recommended to expedite document review and approval. - Deadline for completion of all PTWs should be one week before FFSD start-date	- Quality management - Integration management. - Communication management - Time management
12	Slippages were observed in completion of some work packages	- Due to the lateness of preparation of some PTWs	- Mobilise competent personnel early during the planning stages of the project	- Time management - Integration management. - Risk management. - Human resources management - Scope of work management
13	Good PTW coordination after initial approval challenges	- Use of the General Coordination Permit: very useful tool for management of PTWs - PTW authority was available during night and day to deliver	- Having PTW coordinator per shift should be mandatory. - Fast track permits should be approved and allowed for urgent, and opportunity works.	- Integration management. - Human resources management.

		daily PTWs, and track work coordination on site - A waiver was granted by company to allow use of light PTW procedure during Hydrocarbon free phase	- Performing authorities should be identified early enough before the FFSD to enable specific training on their roles and responsibilities in PTW management and to familiarise themselves with the site. - Need to improve Night PTW coordination by ensuring that PTW is handed over on site rather than in the office. - PTWs should stay with the production operator at site once they leave the central PTW office. - Ensure that people taking PTW coordinator position are trained to use e-permit software and have a good knowledge of FFSD scope and are familiar with the site - Ensure the improvement of communication network and availability for e-permit processing and tracking. - All permits should be prepared, reviewed, and sorted correctly prior to commencement to avoid overload of work for the permit office.	- Communication management

14	- Daily report for management was very clear and simple to understand the FFSD progress		- Internal presentations with daily priorities for supervisors and performing authorities should be issued from coordination meetings. - Integrated planning is a great tool to prevent arbitrary decisions and to boost cross-functional teamwork. - Performing entities should be involved in its elaboration and review. Each entity preferred to work with their own planning during the preparation phase. - A shared location/network should be created to ensure one master version of critical files (spading, procedures, planning) - Provide A0 size print-out of the general execution schedule for site (visual display). - Endeavour to avoid delays resulting from production issues of process isolation, inhibition and handing over of equipment for intervention.	- Time management. - Communication management - Integration management - Stakeholder management

15	Additional unplanned co-activities were executed	- Some interface activities were not captured in the general execution schedule - (example is standard component exchange on Heat Exchanger.)	- Integrated planning should be reviewed by site personnel well in advance before FFSD. - Consider some maintenance activities for night shifts to avoid overcrowding. - During the FFSD, a visual planning should be presented and updated the day shift.	- Time management. - Integration management
16	Offshore Site coordination was generally good.	- Reduction of personnel rotation change and overlap during handovers gave continuity during the FFSD. - The central information centre was important to collate and streamline all the information and to decide priorities on the way forward. - A follower for each sector was defined to report on global progress during the coordination meeting - Regular Steering Committee meetings were held among the stakeholders and chaired by the operations executive. The frequency of the meetings increased as the shutdown drew closer. It started quarterly then increased to monthly about one year to the shutdown and then to	- All activities should pass by the central information Centre - FFSD preparation team should arrive on site well ahead of the FFSD. - Consider having one ICSS engineer/support per shift instead of one working all through day and night (on call). - A multi-disciplinary team dedicated to the FFSD preparation is mandatory at least one year before.	- Integration management

		weekly about 3 months to the start of the shutdown.		
17	Great team work regardless of the department (Production, Projects, Maintenance, Inspection, Logistics, Project controls) ensured a successful FFSD.	- Daily and weekly coordination meeting assisted in identifying grey areas, issues, and challenges ahead for early mitigation and resolution	- Personnel demobilisation planning should be improved	- Communication management - Integration management
18	An ad-hoc instrument team was defined for the restart	- Previous experience on similar scope of work. - Definition of critical tasks register for commissioning and start-up	- Ensure the deployment of competent and experienced personnel	- Scope of work management - Time management - Human resources management
19	Time was saved during internal inspection of vessel.	- Baroscopic inspection allowed to gain time and to realise quick analysis. - Previous experience on the efficiency of Baroscopic inspection tools	- Deploy competent and experienced personnel for the right job. - Take advantage of improvements in technology	- Time management. - Quality management - Scope of work management. - Human resources management - Cost management
20	FFSD tasks were very clear to all team members	- The use of I-VIEW for the FFSD tasks ensured an integrated database of activities.	- This software should be used for identification of opportunity jobs (work in campaign mode).	- Time management. - Cost management.

			- Take advantage of improvements in technology	- Quality management. - Scope of work management
21	Emergency Shut Down test was performed successfully with hitches recorded.	- Method statement for maintenance scope was unclear	- Restart procedure should be reviewed to ensure it's flawless. - Critical chemical stock level to be reconfirmed and should be available two weeks before start-up - Negative impacts of maintenance could have been averted with a validated procedure and anticipation of control card failure (proper preparation)	- Time management - Scope of work management. - Quality management - Procurement management
22	Delays in implementation of some lifting plans on site	- Late mobilisation of integrated project team - Document review as per approved DRAM was not followed	- Lifting plans should be generated with the discipline supervisors and not only by the lifting superintendent, to avoid changes on the go during activity - Contractors must respect Safe Working Load (SWL) of lifting gears and should be mobilised with own lifting gears	- Communication management. - Integration management. - Cost management - Scope of work management
23	No cleaning was done on instrument cavities for some separators.		Cavities should be verified after cleaning	- Quality management - Scope of work management

24	Challenges with torqueing operations efficiency	- Competency of the torqueing team - Limitation in the number of torqueing crew.	- Plan to have a standalone torqueing contractor with QA/QC torqueing personnel. - To assure quality, torqueing should be engaged by CPY aside from the main contractor and should liaise directly with CPY rep	- Quality management - Human resources management. - Cost management - Scope of work management
25	Damage of dry gas seals on Compressor following leak test.	- Maintenance procedures and method statements not reviewed early by competent personnel	- Leak test plans must be reviewed by maintenance team early	- Quality management - Scope of work management - Human resources management
26	FLOTEL and POB Field trials and on-site inspection including connection to the FPSO was achieved in just a day.	- The team leveraged on previous experience on similar scope of work	- Ensure the deployment of competent personnel and contractors for delivery scope of work	- Scope of work management. - Human resources management - Time management
27	Good POB control between FPSO and FLOTEL.	- Two gangway watchers (one on FPSO side and one on FLOTEL side), use of different T-card colours (for night, day, and off-shifts). - Close pax transfer monitoring, quick overview of movements especially during mustering	- Ensure the deployment of competent personnel and contractors for scope of work	- Time management - Human resources management - Integration management

		- Accommodation very comfortable with enough space		
28	Late mobilisation of Flotel (4 days prior personnel mobilization). Also, poor catering and other services	- Bureaucracies with Flotel documentation validation and clearance by marine authorities	- Ensure the provision/availability of quality meals and services on the Flotel. - Certifications (Helideck, gangway) should be verified prior to the FFSD. - Ensure the improvement of medical facilities on the Flotel and ensure that inspection is carried out by onshore medical department before Flotel's arrival on site for adequacy of facility and medications.	- Time management - Procurement management - Cost management - Quality management
29	Personnel mobilisation not completed before FFSD start-up.	- Limitation in helicopter capacity against large number of personnel to be air lifted. - Inadequate logistics planning - Anomalies spotted during verification of personnel travel documentation.	- Use of fast boats should be considered for personnel mobilisation.	- Time management - Communication management. - Integration management
30	A lot of rework and reduced productivity was recorded.	- Too many inexperienced ad hoc contractors' personnel were mobilised.	- Contractors should improve their process of recruitment (selection)	- Human resources management. - Integration management. - Time management - Risk management

31	Pre-shutdown work scope wasn't completed as scheduled	- Scaffold erection could not be fully completed during pre-SD phase due to late mobilisation and scope growth - Installation of lifting equipment could not be fully completed during pre-SD phase due to unavailability of materials and scope growth	- Endeavour to freeze scope and mobilise early to site for pre-shut down works with competent personnel	- Time management. - Scope of work management - Communication management - Intégration management - Procure ment management
32	Shortage of liquid nitrogen during inerting/pre-commissioning phase	- Adequate contingency stock to compensate for depletion quantity may not have been factored into the required volume estimation. - Liquid nitrogen became unusually scarce within the country within the period - Unanticipated leak tightness test failure rate on flanges and closures.	- Deploy competent personnel for pre-commissioning activities. - Ensure the inclusion of adequate contingency stock quantities in the procurement plan. - Commence procurement for consumables early directly with the manufacturers instead of using vendors - N2 tanks, supports and equipment should arrive at the same time and early enough to ensure a good layout from the start.	- Time management - Procurement management - Scope of work management - Quality management - Communication management - Integration management

			- For subsequent FFSD, do consider the opportunity of using N2 generators instead of N2 tanks	
33	Many opportunity works were coordinated and executed e.g., production loop preservation and intelligent pigging was carried out with produced water	- Extra contingency material was available for use - Leverage on previous experience	- Ensure deployment of competent personnel for completing scope of work	- Scope of work management - Human resources management - Integration management
34	Successes and challenges recorded with logistics and marine coordination	- Open containers of 10 and 20 feet were used for better demobilisation - Provision of dedicated PSV to remove the surplus of materials /scaffolding provided post-FFSD. - Daily morning meetings with logistics and SITE to manage material transfer - Flotel had adequate deck space (700 m2) - Flotel deck crew was available 24 h/d - Lists of names were sent very late for booking	- Adequate number and reliable forklifts should be available. - Cranes should be inspected and reliable 2 months prior to the FFSD	- Scope of work management - Communication management -Integration management - Procurement management - Cost management - Quality management - Risk management

		- No additional vessels and helicopter means were used. - Standby surfer boat for personnel transfer/emergency evacuation was of small capacity (25 pax). - During Flotel disconnection, a lot of man-hours was used to transfer personnel (230-day crew) from Flotel to the FPSO and vice versa - Mud skip tagging, and coordination assured reliable sand weighing from separators		
35	Several issues to maintain the air supply from the utility network.	- Very low reliability of the temporary air compressors provided by contractor. - Challenges with sourcing fit for purpose mobile compressors locally - Air supply from FPSO is grossly inadequate to support additional equipment mobilised for the revamp scope of work	- Contractor to be self-sustaining regarding utility air supply. - Ensure the early launch of procurement and carry out the inspection of the pre-mobilised equipment as required.	- Procurement management. - Scope of work management - Quality management - Cost management

Some 16 out of the 35 lessons learned captured during the real-life revamp project intervention were positive and are presented in Figure 4.20 and 4.21

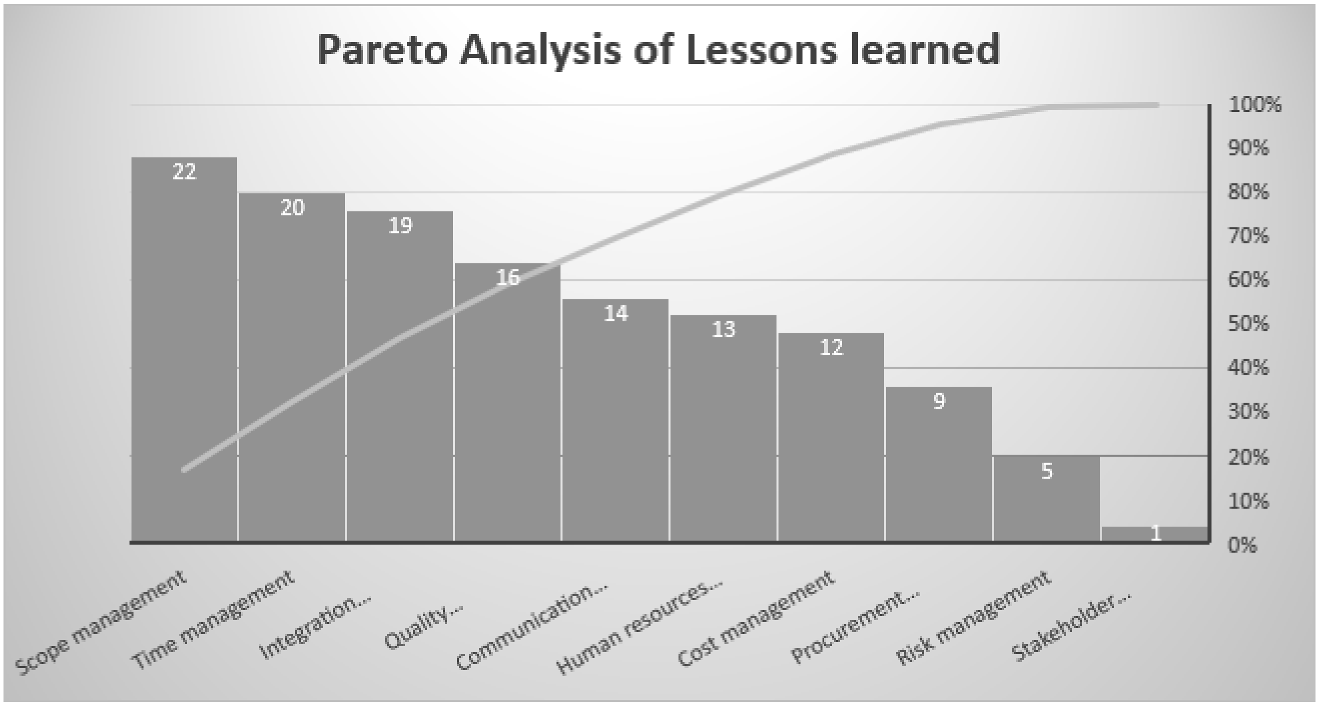


FIGURE 4.20 Pareto Analysis of Project Lessons Learned Capture

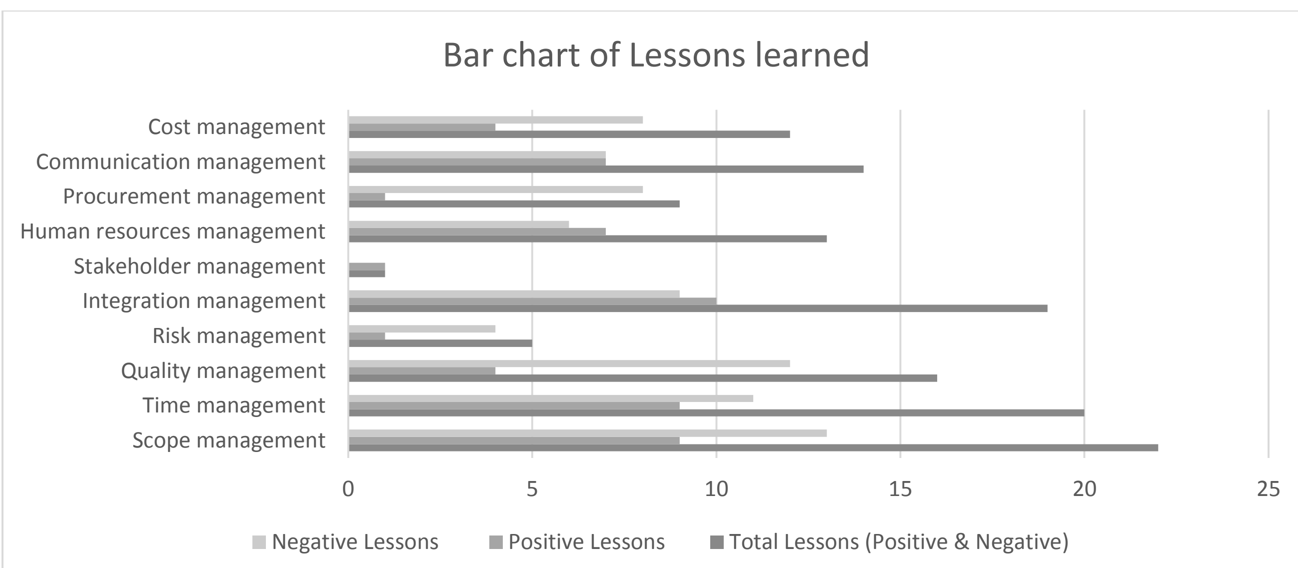


FIGURE 4.21 Bar Chart of Project Lessons Learned Capture

4.8 Case Study 2

Case study 2 is a major multinational oil and gas operating company in Nigeria. This company was approached for the purpose of research validation due to their operatorship of at least an FPSO in Nigeria and the availability of experienced personnel among their staff to share lessons learned and provide feedback to the adopted research instrument of questionnaire and interview survey. This multinational company is in active operation in at least five continents and has employed over one million personnel. The contractual relationship is both a Joint Venture (JV) and Production Sharing Contract (PSC) with the Nigerian government represented by Nigeria National Petroleum Corporation (NNPC).

For the purposes of this research, and with reference to Table 4.1, a total of nine participants comprising three project coordinators, four project managers and two project executives responded as required. The results are presented in the level 1 and level 2 Analytic Hierarchy Process (AHP) tables and charts attached. The participant's experience levels ranged from 13 to 32 years. Questionnaire responses and interview surveys of the expert panellists indicated that the operation of the company's facilities utilised a standardised proprietary project management system or framework leveraging on the stage-gate project management model, irrespective of the locality of operations.

4.9 Case Study 2 Project Close Out Report Review

The close out report is the approved detailed account or dossier of project information developed by this multinational oil and gas organisation under focus following project completion. This document is stored in archives, both electronically and in hard copies for reference purposes. The prominent contents of this dossier include the project name, organisation involved and physical location, detailed records of the scope of work, the key performance indicators, the overall project performance, success factors and challenges, health, safety and environmental statistics, customer satisfaction and lessons learned as captured throughout the project lifecycle.

4.10 Case Study 2 Project Scope of Work

The scope of work under study is specific to the topsides of an FPSO revamp project during the execution stage and covers ten oil and gas process systems: production manifold, production flowline, GAS lift, water injection, air instrument, methanol injection, flare header, fuel gas, pigging liquid supply and return and open drain.

To effectively manage the project at execution stage, the project activities were divided into three broad segments as listed below:

A. Onshore fabrication comprises the pre-fabrication of piping and structural members in the fabrication workshop based on the Issued for Construction (IFC) drawing developed as a deliverable of the detailed engineering design. The estimated weight of the FPSO topsides modification fabrication, including all packages, is over 200 tonnes of steel broken down into various sized components as listed below:

B. Carbon steel piping - 180 Tonnes
C. Stainless steel piping - 10 Tonnes
D. Topside structure, deck - 20 Tonnes
E. A pig launcher/receiver known as pig traps - 20 Tonnes

Main offshore campaign: The concept of the main offshore campaign and the pre-shutdown was to install and commission all equipment and systems prior to shut down. The main offshore campaign consists of planning through to the actual activities carried out on the FPSO. This is further broken down into the early preparatory work and pre-shutdown work, prior to the shutdown tie-in activities. The associated construction activities work scope per discipline is indicated below:

1. Mechanical - 50 Tonnes
2. Structures - 100 Tonnes
3. Piping - 250 Tonnes
4. Instrumentation - 80 Tonnes
5. Electrical - 20 Tonnes
6. Pipe spools - 600 Tonnes
7. Loop checks – 300
8. Mechanical completion "A" check sheets - 1,800
9. Mechanical completion "B" check sheets - 700

The purpose of the early preparatory and execution work using the FPSO-based crew was to allow a smooth start to the construction works once the accommodation vessel was mobilised. The scope includes hot-bolting, erection of access and load bearing scaffolds, permit to work preparation, installation of static rigging equipment, staging of pre-assembled valve trains, delivery of tools and equipment offshore, pre-mobilisation inspection of equipment and finalisation of offshore execution personnel spread, offshore mobilisation documentation readiness and travel schedule. It also entailed preparation for the accommodation vessel gangway installation and associated gangway connection steelwork at aft of FPSO, moving of existing life rafts and raft recovery davit also at FPSO aft. Also, during this period, offshore execution job cards preparation is updated and progressed, an installation engineering dossier developed and procedures and method statements including offshore work execution planning are continued onshore.

The pre-shutdown scope includes brownfield modification work scope covering hot work that was carried out on the accommodation vessel to reduce to as low as reasonably practicable the interface issues of construction versus producing facility work requirements. In addition, the installation of new subsea and chemical injection packages, the mobilisation and positioning of the accommodation vessel at the aft of the FPSO, execution of scaffolding, installation of instruments and interconnecting lines and cables, as well as installation of equipment skids and associated structural works. This work also included installation of deck extension, installation, and static commissioning of interconnecting piping to reach readiness for shutdown tie-ins, installation and static commissioning of electrical equipment, installation of process autoclave tubing, subsea flowlines and umbilical interface scope (installation of pull-in winch, pull-in of steel catenary risers and Umbilical, hydrotest of subsea flowlines, installation of intelligent pigging, installation of riser protector), The shutdown scope of work essentially constitutes the final tie-in or connection of the new or modified units or sections after pre-commissioning activities to the existing facility. This requires the full facility outage as per approved procedures to avert any potential incidents from stored or residual hydrocarbon inventory in the process circuit. Key activities included the need to perform shut down tie-ins and upgrade the control system, perform commissioning, start-up to achieve first oil and demobilise the accommodation vessel.

The post-main offshore campaign was essentially made up of the reinstatement of the accommodation vessel gangway landing platform following the demobilisation of the vessel, and the punch list close out scope of work carried out after the plant restart for normal oil and gas production; It also includes scaffold dismantling and touch-painting. The scope covered five oil and gas process systems comprising the pigging liquid supply and return; water injection; cable tray installation; production flowline and subsea chemical injection.

4.11 Case study 2 Project Key Performance Records

Onshore Piping Fabrication Man-hours:

With reference to the budgeted and actual onshore fabrication man-hours records in Appendix E, the project recorded approximately a 150% increase in man-hours. The reasons for the increase in budgeted man-hours are as captured under the project success factors, challenges and lessons learned documentation in the project close out report under review in this chapter. This increase resulted from scope creep, reworks and quality issues, procurement including health safety and environmental challenges, which took a negative toll on the project onshore fabrication performance. This indicates process inefficiency compared to the constraints or the knowledge areas theory.

4.12 Offshore Construction/Installation Man-hours

Also recorded during the FPSO revamp project under review was the construction and installation man-hours for offshore works, as well as the site query log. Here, the records showed an escalation of man-hours up to 40%. The reasons for the man-hour increase are provided in Appendix F.

4.13 Site Query Log

Additionally, the details of the site query log show approximately 200 line-items in Appendix F. The site query log was useful for the research verification exercise as it provided an opportunity for qualitative analysis of the clarification request impacts into the knowledge areas criteria. Therefore, the actual real life FPSO revamp project provided the needed opportunity to examine practice against theory and literature, as indicated in the discussions in Chapter 7.

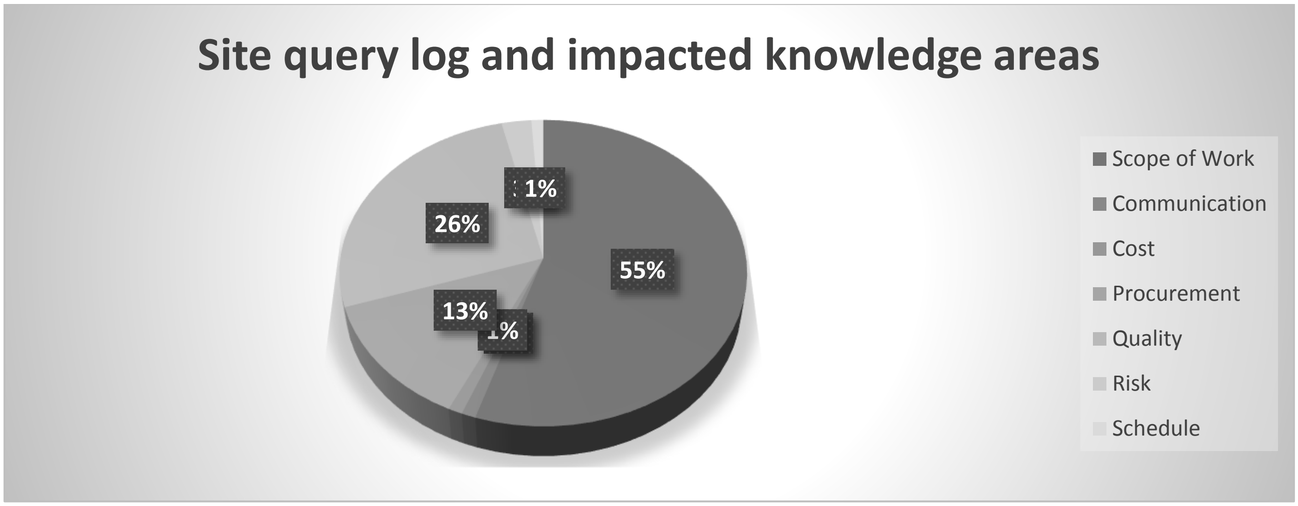


FIGURE 4.22 Site Query Log and Impact

4.14 Pre-shutdown Scope Summary Analysis

The schedule of the various work systems was analysed against the initial planned timeline and was recorded as key project documentation and indications of the project performance. About 40 work packages, comprising piping and structures, electrical and instrumentation scope of work in various process systems of the FPSO, were analysed. Only the electrical works on the production manifold were completed on schedule because intervention on the system was started over 50 days ahead of the initial planned start date.

4.15 Project Successes Factors, Challenges and Lessons Learned

This section documents the key events during the execution of the case study project under review, the causative factors for the events, the unanticipated challenges, the lessons learned from such occurrences that could be applied to subsequent future projects and the potential knowledge areas impacted by the events. As a standard practice in the case study organization under review, during project implementation the project lessons learned are captured individually by the project team, reviewed at respective entities level, and finally collated across all entities, reviewed at formal lesson learned workshop on completion of the project. Subsequently, the lessons learned are documented in a project close-out report and archived for use in subsequent similar projects. The essence of reviewing the lessons learned section, Table 4.3 in this research was to understand the revamp project management events of value to the organisation, the challenges and ascertain the knowledge area that was impacted during the realisation of the completed project, this was a means of triangulating the expert consensus of the questionnaire and interview survey findings.

Table 4.3 specific project lessons learned capture

S/N	Event	Causes	Lesson Learned	Impacted Knowledge Area(s)
Onshore Fabrication:				
1	Zero Lost Time Incident (LTI) recorded throughout the onshore fabrication	- Commitment by management and all project team members to sustain and continuously improve the safety culture. - Visible interest in safety walkthroughs and proper fabrication risk assessment.	- Management commitment to a clear safety roadmap should be encouraged to sustain excellent safety records and culture through all the project stages	- Scope of work management - Quality management - Risk Management - Communication management - Integration management
2	Fabricator increased fabrication pace to meet set target dates	- Determination to deliver and maintain good reputation regardless of their relative inexperience from previous projects - Dedicated and experienced staff were engaged to manage given specific scope of work. - Regular meetings were held to discuss issues, proffer mitigations and to communicate changing priorities	- Engage dedicated and experienced personnel early in the project to manage specific work scope on the critical path.	- Schedule management - Cost management. - Communication management
3	Good office space and catering facilities for contractor and company	- Existing facilities were used for similar purposes in the past for previous client. - Good maintenance culture on the part of the facilities owners.	- Ensure good office space and catering facilities in the project plan to enhance collaborative and efficient work execution.	- Integration management -Scope of work management
4	Inability of Contractor to provide adequate fabrication	- Competing operator scope within the fabrication yard.	Engage experienced experts early for proper planning and	- Risk management - Procurement management

	manpower and dedicated fabrication shop for both stainless steel and Duplex stainless-steel fabrication	- Poor definition of fabrication timeline, forecast and manpower requirements - Poor prioritisation of project scope compared to contract milestones - Misalignment between sub-contractor project management team and the fabrication team due to matrix organisation	to forestall schedule and cost escalation	- Cost management - Time management
5	Fabrication key equipment and plant unavailability for use	- Lack of readily available maintenance spares to fix faulty equipment.	Provide for key equipment spares availability in the project plan. Target should be to deliver them at location prior to start of project.	- Time management - Cost management - Scope of work management - Procurement management - Communication management
6	Several spools were returned from offshore for fabrication repair or modification	- Mismatch and clashes during fit-up at site. - Poor workmanship	Engage experienced personnel to carry out proper site survey and to deliver fit-for purpose pre-fabrication	- Scope of work management - Quality management - Time management - Cost management
7	Subcontractor schedule and project controls were at variance with approved project schedule and commitment during project kick-off meeting	- Poor definition of fabrication timeline, forecast and manpower allocation. - Contractor was not accustomed to providing required level of details on lump sum contract. - Contractor was not adequately staffed to manage the level of information development required on large projects	Project controls data requirements for milestones payment would have ensured that contractor respected agreed project schedule.	- Integration management - Time management - Scope of work management - Communication management

Offshore Installation:				
8	Good collaboration between offshore site management, FPSO operations and maintenance, fabric maintenance and the shutdown team	- Daily coordination meetings - Workshop sessions - Colocation within one office space	- Colocation of site management team a platform for interaction, visual displays of progress, futuristic planning meetings helped to foster excellent team building through the installation stage	- Communication management - Integration management
9	No incidence of critical installation equipment (crane) breakdown	- Good preventive maintenance plan in place - Mobilisation of equipment OEM representative on board	- Ensure that critical FPSO lifting equipment are included in the plan. - Carry out functionality test of the critical lifting equipment prior to site mobilization	- Scope of work management - Time management - Cost management - Integration management
10	Permit to work (PTW) processing was optimised	- Work methods management advisors were mobilised to function as Operating Authorities (OA)	- Plan to mobilise additional work management advisors to function as OAs. Dedicated FPSO OAs are usually inadequate to manage the huge PTW requirements during project execution	- Time management - Stakeholder management - Communication management
11	Scope growth recorded was extensive	- Inadequate scope of work survey during the planning stages - Inadequate planning for contingencies and scope creep in a typical revamp project	- Engage experienced personnel early to prepare job cards for offshore job execution - Plan a cycle of site surveys to address potential changes in work scope	- Scope of work management - Quality management - Time management - Cost management

12	Electrical and Instrumentation (E and I) scope had a lot of reworks	- Inexperienced personnel in E and I work execution. - Poor supervision - Unclear scope of work	- Engage experienced personnel early to prepare job cards for E and I scope of work - Carry out detailed site survey to define the work scope	- Scope of work management - Quality management - Time management - Cost management - Communication management
13	Mobilisation of night shift crew was delayed	- Temporary power lighting (non-armoured cable) supplied by contractor was not fit-for purpose (area safety classification rating)	- Ensure that a competent contractor with prior experience in executing similar offshore projects is engaged.	- Time management - Scope of work management - procure ment management - Quality management - Communication management
14	Mobilisation of required personnel on board the FPSO for work execution was delayed	- Delivery of safety critical equipment for emergency evacuation was delayed. - Customs clearance of safety equipment was delayed	- Identify Long Lead Equipment and launch procurement early. - Allocate period for clearing customs in the project plan	- Time management - Cost management - Scope of work management - Procurement management -Integration management - Communication management
15	Delivery of fittings and installation materials was delayed	- There was no global view and sharing of the progressive plans with stakeholders on the part of the Engineering Procurement and Construction (EPC) Contractor - Company representative was unable to detect schedule issues timely	- Prepare Materials Take Off (MTO) from site survey and drawings and account for contingencies in the procurement plan. - Launch procurement early.	- Procurement management - Time management - Stakeholder management - Communication management - Scope of work management
16	All onshore fabricated spools with quality issues and rework	- Absence of radiographic test and hydrostatic test equipment at offshore site	- Offshore installation campaign to incorporate plans for Radiographic Test and	- Time management - Cost management - Quality management

	were shipped back onshore for modification		Hydrostatic test on board the FPSO for quick modification work turnaround	- Scope of work management
17	EPC contractor was unable to sustain continuous productive work campaign	- Relatively late and staggered delivery of procured topsides materials. - Contractor was eager to pre-maturely earn milestones related to offshore mobilisation. - Delays in completing topsides fabrication - Lack of visible integrated schedule between procurement and topsides execution	- Engage experienced personnel to start pre-fabrication to coincide with required on site (ROS) schedule. Materials delivery against installation planning should be tied to milestone payment	- Risk management - Scope of work management - Time management - Cost management - Human resources management
18	Topsides budget manhours increased from 125,000 to 175,000 approximately	- Unforeseen brownfields work not adequately captured in the planning stages. - Contractor refusal to include brownfield or scope growth allowance in early execution budget quantities. - Late mobilisation for brownfield survey and very early demobilisation of the personnel. - Inexperience of the contractor in understanding requirement for both brownfield and fabrication modification scope growth.	- Provide for revamp project contingency peculiarities in the early planning stages. - Plan for Agile responses to scope growth and modification requirements - Engage experienced EPC contractor to work on offshore execution campaign.	- Scope of work management - Time management - Cost management

19	FPSO management and project team continually had bed space challenges	- Specific positions and number of personnel allocations against mobilisation timeline in the contract was in adequate to manage brownfield project. - Contract terms for personnel on board (POB) management was too restrictive relative to timelines	- Contract exhibit to be flexible and allow for scalability in POB until closer to execution or to remain flexible throughout the offshore installation campaign.	- Communication management. - Integration management. - Stakeholder management. - Time management. - Cost management
20	Potential manhours claim by contractor was prevented by company	- A two hours per shift company interference period (CIP) was provided in the contract to carter for brownfield simultaneous operations (SIMOPS) issues.	- Incorporate CIP clause in the contract to prevent unnecessary downtime claims from contractor - Company and contractor to align on initiatives to minimise actual CIP hours and its impact	- Cost management. - Scope of work management - Integration management - Human resources management
21	The topsides team actively participated in safety leadership training program under lump sum contract	- Managements commitment to Health Safety and Environment throughout the offshore installation campaign. - Commitment to the weekly tier 3 safety meeting and general safety meeting on site.	- Provide for safety awareness workshops and trainings in the project plan. - Lead by example and encourage contractor to key into company's safety programs and procedures.	- Integration management. - Risk management - Communication management - Human resources management

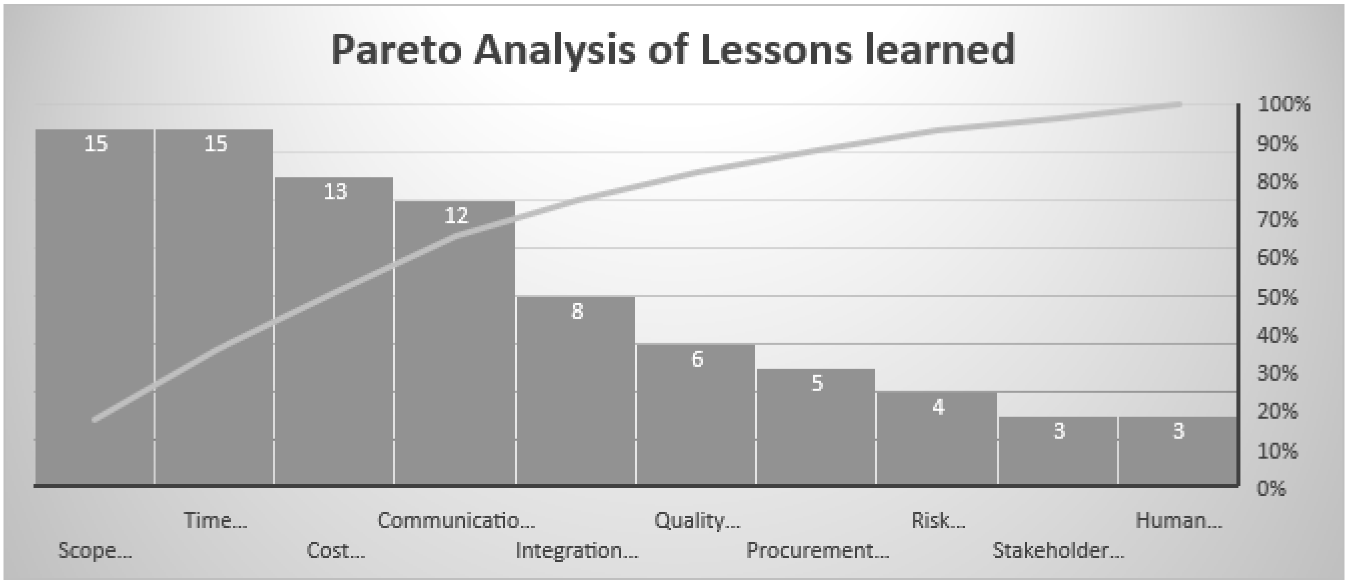


FIGURE 4.23 Case Study 2 Pareto Analysis of Lessons Learned.

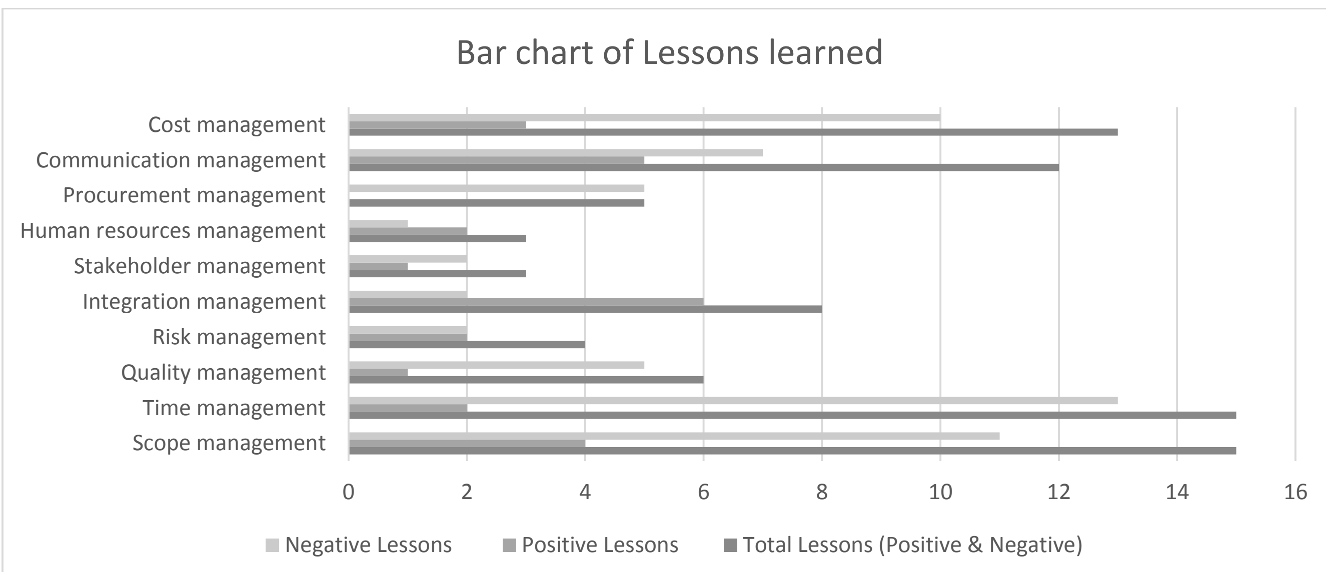


FIGURE 4.24 Bar Chart View of Lessons Learned Capture.

Eight out of the 21 lessons learned captured during the real-life revamp project intervention were positive. This will encourage personnel to keep maintaining their good work ethics, safety, and project management excellence. The classification into knowledge areas is for proper focus and ownership for the responsible department, easy reference, archiving and future application. This initiative therefore promotes continuous improvement and enhances communication, which leads to effective knowledge management, overall project management efficiency, growth, and competitive advantage of the organisation.

4.16 Case Study 3

Case study 3 is a major multinational oil and gas company operating in Nigeria. This company was approached for the purposes of research validation due to their operatorship of at least one FPSO in Nigeria and the readily available experienced personnel to share lessons learned and provide feedback on the adopted research instrument of questionnaire and interview survey. This multinational company is in active operation in at least five continents and has over one million personnel in its employ. The contractual relationship is both a Joint Venture (JV) and Production Sharing Contract (PSC) with the Nigerian government, represented by Nigeria National Petroleum Corporation (NNPC).

For this research, and referencing Table 4.1, a total of eight participants comprising one project coordinator, four senior project managers and three project executives responded as required. The results are presented in level 1 and level 2 of the Analytic Hierarchy Process (AHP) tables and charts attached. The participant experience levels ranged from 23 to 36 years. Questionnaire responses and interview surveys of expert panellists indicated that the operation of the company's facilities utilised a standardised proprietary project management system or framework leveraging on the stage-gate project management model, irrespective of the locality of operations.

4.17 Case Study 4

Case study 4 is a major multinational oil and gas company operating in Nigeria. This company was approached for the purposes of research validation due to their operatorship of at least one FPSO in Nigeria and the readily available experienced personnel to share lessons learned and provide feedback on the adopted research instrument of questionnaire and interview survey. This multinational company is in active operations in at least five continents with over one million personnel in their employ. The contractual relationship is both a Joint Venture (JV) and Production Sharing Contract (PSC) with the Nigerian government represented, by Nigeria National Petroleum Corporation (NNPC).

For the purposes of this research, and referencing Table 4.1, a total of seven participants comprising two project coordinators and five senior project managers responded as required. The results are presented in level 1 and level 2 of the Analytic Hierarchy Process (AHP) tables and charts attached. The participant experience levels ranged from 15 to 36 years. Questionnaire responses and interview surveys of the expert panellists indicated the company's utilisation of a standardised proprietary project management system or framework leveraging on the stage-gate project management model, irrespective of the locality of operations.

4.18 Case Study 5

Case study 5 is neither an organisational nor a specific oil and gas company operating in Nigeria but is made up of expert participants identified from professional contacts in LinkedIn. This case study is complementary to the above four company case studies for the purpose of research validation and was therefore used for the purpose of testing the model. The unprecedented COVID-19 pandemic ushered this additional case study that was not originally considered for the study. This initiative, therefore, helped to actualise the targeted number of expert panellists for the research. The participants' LinkedIn profiles reflected the wealth of experience required for the research and raises the quality of responses. The experienced personnel shared previous lessons learned on FPSO revamp project management and provided feedback to the adopted research instrument of questionnaire and interview survey from a global perspective. This lent further credence to the validity of the research outcomes.

For the purposes of this research, and referencing Table 4.1, a total of eight participants comprising four project coordinators, three senior project managers and one project executive responded as required. The results are presented in the level 1 to 3 of the Analytic Hierarchy Process (AHP) tables and charts attached. The participant experience levels ranged from 14 to 42 years. Questionnaire responses and interview surveys of the experts experienced in the management of revamp projects outside of Nigeria indicated similar results as that of the specific oil and gas operating organizations in Nigeria, the details have been covered Chapter 6 of this thesis.

4.19 Researcher's Perspective of close out reports review

The review of the two project close-out reports using the case study covered key learning points and critical success factors during the execution stage of the project development. This has further validated the findings of this research, especially the optimisation of FPSO revamp project model development. Evaluating the critical factors for the executed project management success demonstrates the importance of project success analysis as a knowledge management-based approach to continuous improvements in project delivery.

Furthermore, quality data and performance-oriented information in the project close out reports have been used as reference factors in the assessment of project success. This is consistent with the argument by researchers that performance indicators are requirements for continuous improvements. This good practice therefore has indicated high project management maturity of the case study organisation for the research; however, the poor maturity of project management is a major reason for the under-performance of projects (Takagi & Varajao, 2019; Todorovic et al., 2015).

Simplifying this assertion further, the standard of project management is a function of cost and schedule performance of the project (Frankhouser, 1981) but it equally includes other critical performance indicators as perceived by the organisation. Therefore, case study 1 is appropriate for realising the objectives of this research.

4.20 Summary

Chapter four accounted for the choice of the Delphi method from the literature as the adopted instrument for this research. It outlined the research activities at both the first and second rounds of both questionnaire and interview surveys for data collection. Data have been collected from experts affiliated to five different case studies. Four out of the five case studies are multinational oil and gas operating organisations in Nigeria and, the fifth is made up of experts from the oil and gas operating companies from different parts of the world. The demography of the expert is including those with between 12 to 42 years of experience, and the experts provided feedback and greater insights for the study.

This chapter also reviewed two revamp projects close out reports from case study 1 and 2. The additional sources of evidence include lessons learned records, progress curves for the revamp scope of work, the issues log for the project, the cost performance, and the technical queries log. These have been used to further validate the research findings and model development. The research findings converged to a common conclusion, which is consistent with the requirement for triangulation in case studies research. Discussions on the research findings will be carried out in Chapter Seven.

CHAPTER FIVE

Modelling Development

5.1 Introduction

Chapter five introduces the sequence of model development and the Analytic Hierarchy Process (AHP) as being the process model adopted for this study, after the attributes and advantages had been considered. The steps for the proposed model development, validation, testing, and AHP working formula are explained in detail. In addition, the overview of both the as-is and proposed optimised to-be process models, as well as the proposed revamp project management performance measurement tool and control framework, are covered.

5.2 Process Modelling

The modelling technique for this research is consistent with the generic modelling process indicated in Figure 5.1. The five stage-gate project management model is an existing model under focus for this study. However, there is a need to review the model for improvement opportunities. Hence, the need for new data to be collected from experts, who are knowledgeable in executing revamp projects on FPSO assets. Model validation is an important aspect of process modelling and it is best to have a self-sufficient process modelling tool capable of validating data for adequacy. Once the data inputted represents the model developed, the development process comes to an end.

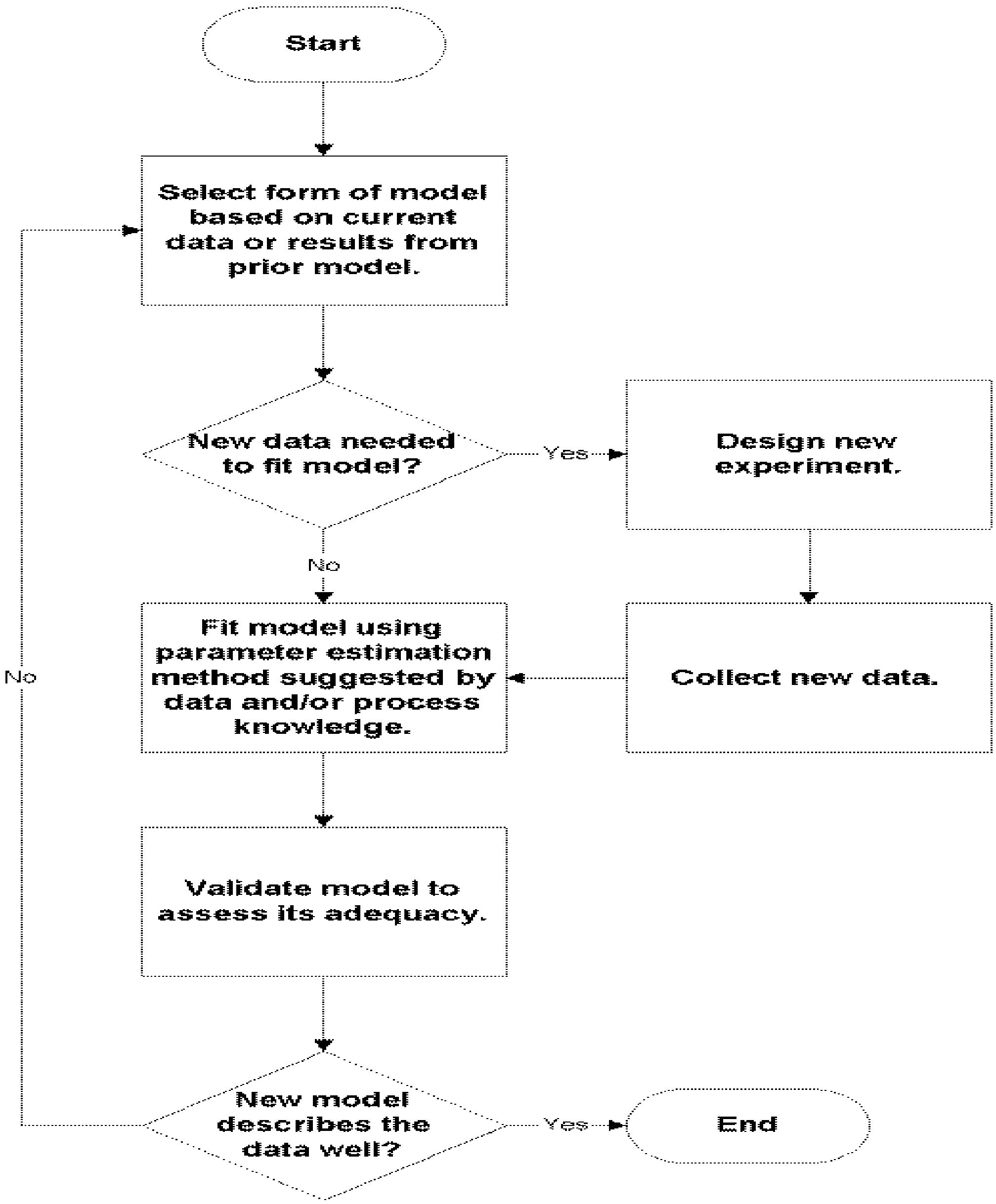


FIGURE 5.1 Model Building Sequence

Source: Extracted from NIST/SEMATECH (2012)

5.3 Overview of Analytic Hierarchy Process

The AHP has the attributes of process modelling features and sequence as described in Figure 5.1. However, to achieve stronger and more reliable outcomes from research endeavours, researchers have recommended the combination of the Delphi method with other advanced modelling methods. Common among them are fuzzy sets, the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) (Ameyaw et al., 2016).

The above three processes are better described as multiple-attribute decision methods (MADM) and they all have their strengths and preferred areas of application. The fuzzy process is known to deal with complex issues associated with procurement. It has also been utilised in project risk management for the railways sector with great improvements, including the proposal to utilise the modified Fuzzy Analytic Hierarchy Process (FAHP) to yield a higher level of confidence in the analysed risk of a railway system (An et al., 2016), while the ANP has been utilised in supplier selection for a diesel manufacturing firm with success having considered Benefits, Opportunities, Costs and Risks (BOCR) in the hierarchical model.

According to Ameyaw et al. (2016), Kim (2013), Neves and Camando (2015), and De Steiguer et al. (2016) the AHP was developed by Thomas L. Saaty between the 1970s and 1980s and is arguably the most popular among the MADM (Multiple Attributes Decision Making) methods. The AHP is a simple structured and practical qualitative and quantitative approach for reviewing competing alternatives to arrive at an optimal decision in complex situations (Saaty 2008; Kim 2013; De steiguer 2016; Neves & Camando 2015; Mu & Pereyra-Rojas 2017; Gaikwad, 2016). It encompasses multi-objective environments, limited resources allocation and forecasting, and has the homogeneity axiom that prescribes comparing both alternatives and criteria to only one order of magnitude, beyond which judgements or decisions generally result in less accurate and greater inconsistency in priorities (Kim, 2013).

According to Mu and Pereya-Rojas (2017), the AHP process is broad based and deals with decisions covering four different standpoints of Benefits, Opportunities, Costs and Risks (BOCR), also known as Strengths, Weaknesses, Opportunities and Threats (SWOT) from a strategic planning perspective. Making individual decisions about competing priorities is a lot easier than situations involving group decisions, and therefore requires a structured approach in relevant information gathering and processing to capture the true representation of individual perspectives, beliefs, values, and compromises. Unlike science that measures objects objectively and allows for subjective interpretation of the measurement, the opposite is true in decision making, where the priority scales are obtained from objective measurement, following subjective judgements (Saaty, 2008).

The AHP has been used to support the development of multiple criteria decision-making tools for resolving economic, technical, and social issues. In addition, the American Society of Civil Engineers (ASCE,2013, cited in Ameyaw et al. 2016) has pointed out that AHP has been deployed by researchers in various complex challenging decisions covering organisational, contracting, project planning and design, labour and personnel management and IT issues. There are lots of applications of the AHP. The International Symposium on the Analytic Hierarchy Process (ISAHP) meets every two years to report on the research and applications of this subject.

It is important to note that the application of the AHP is not new in the oil and gas industry. In Brazil, the AHP has been deployed in making critical decisions. It was adopted by a major oil and gas company for its information technology project selection process. It was also used in 1987 for deciding the best type of platform to drill after the consideration of the cost of new build and end-of-life solutions – a segment of brownfield or revamp services (Neves & Camando, 2015; Saaty, 2008). Nevertheless, it is surprising to note that no oil and gas research utilised the AHP between 2013 and 2016 compared to between 2001 and 2012, even though there has been significant growth in the popularity and interest in the use of AHP in the industry (Khaira & Dwivedi, 2017).

Yavuz, (2015) cited in Khaira and Dwivedi, (2017) posited that AHP can be applied for not more than nine criteria and recommends additional sub-criteria to achieve four hierarchical orders covering goal, criteria, sub-criteria, and alternatives, as against the basic three layers. However, Devarun et al. (2009), cited in Khaira and Dwivedi (2017) suggested to consider only the main criteria involving the two-stage AHP (Criteria – Alternatives), mainly for simplicity, clarity, and time (one of the main criticisms of AHP) Today, there are several software applications such as Expert choice, Super Decisions and Decision Lens, which reduces the time implications.

Why AHP for Revamp Project Management Research

There are several reasons why AHP can be used for project management research. Firstly, one advantage of the AHP is its systematic approach of translating or converting intangible and difficult to quantify or subjective measurements, such as satisfaction, feelings, and preferences, into tangible figures such as price, weight, and length. In real world conditions, what we know how to measure is far less than what we do not know how to measure, and we can deal with intangible attributes which have no scales of measurement by pairwise comparison (Saaty, 2008).

Secondly, AHP can evaluate relative importance and trade-offs amongst competing priorities to make informed decisions. Criteria with far lesser priority value could therefore be either discarded or merged with others to simplify the computation process.

Thirdly, the AHP is suitable for expert group decision making synthesis. Especially for experts, combining their individual choices, selections, or priorities with others to form a group decision may not be welcome. In addition, how much of the group decision represents the individual decisions is usually challenging, However, AHP does the harmonisation simply with the computation of geometric mean to the choices.

Fourthly, AHP allows for minor inconsistencies in judgements because humans are not always consistent. Most of our ideas, feelings, behaviour, and actions are not fixed and can consistently change with time and perspective.

According to Saaty, (2000, cited in De Steinguer, 2017) the nine-point scale is the standard rating for the AHP. This standard scale, known as Saaty's comparison scale, was adopted based on the psychologist George Miller's research that suggested decision makers were unable to consistently maintain their gradations of preference better than seven plus or minus two. However, Kardi

(2006) posited that the scaling is not necessarily one to nine but for qualitative data involving subjective opinions, preferences, and rankings it is better to maintain this scale. He equally suggested that lessons learned from simple MCDM in quantifying subjective opinions for decision making are not to use rank aggregation but score aggregation to eliminate the concept of rank reversal.

In AHP, the ratio scales are obtained from the principal Eigen vectors and the inconsistency index is derived from the principal Eigen value. It is recommended that the result for group decision aggregation be computed using geometric as against arithmetic mean of values obtained from the expert participants (Saaty, 2008). Thus, following priority matrix computation for each survey response, the geometric mean was computed to obtain the final group result.

Table 5.1 AHP - Saaty's Comparison Scale (2000)

Numeric Value	Verbal Judgement
9	Extremely important
8	Very, very strong
7	Very strongly more important
6	Strong plus
5	Strongly more important
4	Moderate plus
3	Moderately more important
2	Weak or slight
1	Equally important
Reciprocals of above	If element i has a non-zero value relative to another j, then j has the reciprocal value relative to i

Given the number of attributes, whether criteria or alternatives, the number of comparisons is given by the computation in the table for all number n, where n is an integer.

Table 5.2 Scale of Attributes versus number of comparison and Random Consistency Index

Number of Attributes	n	1	2	3	4	5	6	7	8	9
Number of Comparison	n(n-1)/2	0	1	3	6	10	15	21	28	36
Random consistency index	RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Source: Saaty (2008); Taherdoost (2020).

Table 5.2 indicates the number of comparisons for n number of attributes and the random consistency index RI. Taherdoost (2020) posited the steps for AHP decision making process summarised below:

a) Develop a model for the decision – break down the decision into a hierarchy, consisting of goal, criteria, and alternatives.

b) Derive priorities for the criteria and carry out consistency checks.

c) Derive localised preferences or priorities for the alternatives.

d) Derive finalised priorities – the derived model

e) Carry out sensitivity analysis.

f) Finalised decision.

There are several criticisms of AHP, including the lack of a theoretical basis for the formulation of hierarchies, therefore no standardisation; arbitrary rankings from subjective opinions using a ration scale; summation of individual weights into composite weights; and absence of robust foundational statistical theory (Teehankee, 2009). Despite this, decision makers still find AHP very attractive, and it is used in both the public and private sectors, including in the oil and gas industry.

From the above discussion, we can observe a great correlation between the attributes of the AHP and that of revamp project management in terms of managing complex issues at different phases of a process requiring decisions to be made. In addition, there are critical factors for successful FPSO revamp project management executions expected from a group of experts experienced in the oil and gas industry. These are the criteria and sub-criteria and AHP can synthesis expert group decision making (Saaty, 2008). Therefore, the combination of AHP and the Delphi method is an appropriately selected mix for this research.

AHP Working Formulas:

Reciprocal Matrix (***RM)*** $a_{ji} = 1/ a_{ij}$

Normalized Matrix $NM = \sum a_{ij = 1 \text{ to } n}$

Priority Vector $PV = \sum a_{ij / n}$

Where a_{ij} ***= Elements of a Normalized matrix***

Principal Eigen Value $\lambda_{max} = \sum a_{ij} (PV)_{ij}$

Consistency Index $CI = \frac{\lambda_{max} - n}{n - 1}$

Consistency Ratio, $CR = \frac{CI}{RI}$

Where ***RI*** = Consistency index for average 500 randomly entered judgement matrices

A matrix is acceptable if CR $\leq$ **0.1**

Consistency Ratio is given by the Consistency Index (CI) divided by Random consistency index (RI).

5.4 The As-is and Proposed Model Development using the AHP process

The schematics of the AHP as-is and proposed model development are shown in Figures 5.2 and 5.3 respectively. They both have basic features as per AHP requirements; however, the steps, level, alternatives, and number of criteria vary. While the as-is has three levels and two steps, the proposed model has four levels from zero to three. It also has three steps to get a better understanding of the challenges associated with revamp execution. Level zero is the goal which represents the objective function of the optimisation exercise. This is followed by the knowledge areas in the case of the as-is case and by the major revamp execution phase activities before the knowledge areas in the case of the proposed model. These attributes or criteria and sub-criteria are the variables to be subjected to pairwise comparisons and sit at levels 1 and 2 of the AHP hierarchy. There is no alternative in the as-is case, however at level 3 is the proposed modern project management approaches to be subjected to pairwise comparisons for process improvement opportunities. Activities on each of the levels are linked by straight lines called relationship lines. Going by the above description, the proposed AHP model development has four levels, with a three-step improvement process.

FIGURE 5.2 The As-is FPSO Revamp Project Management Model

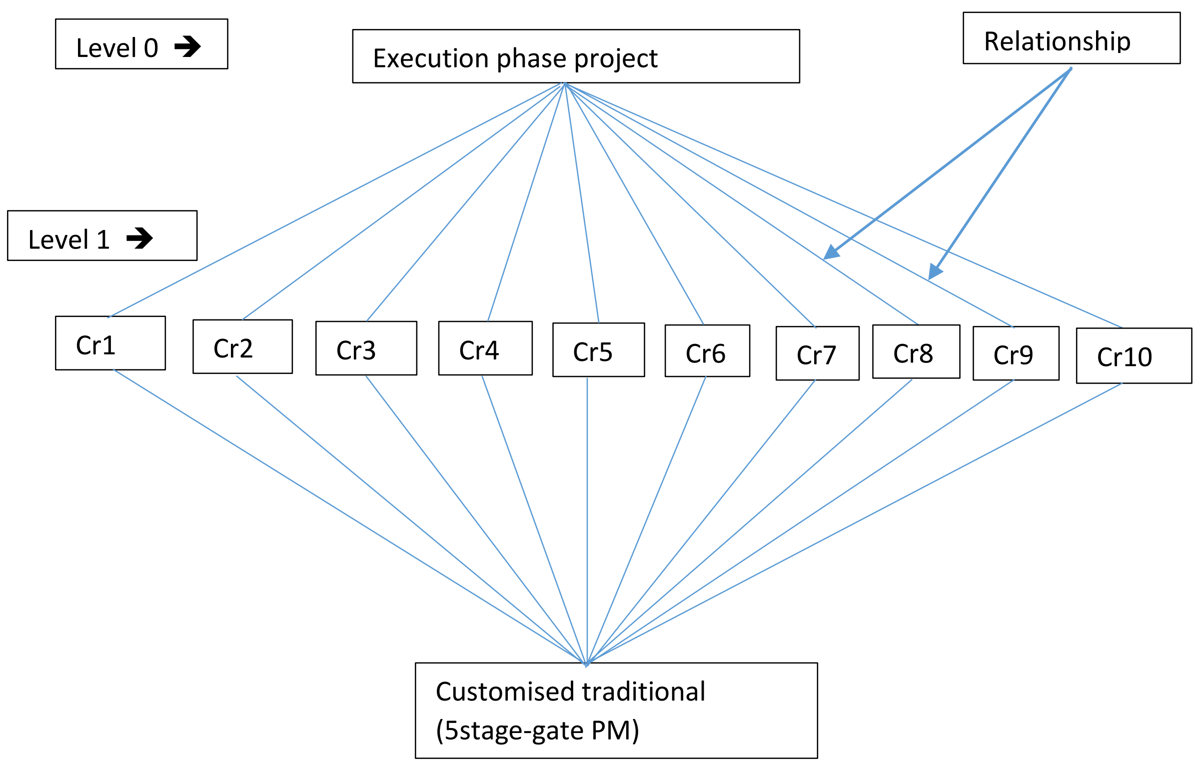


FIGURE 5.3 Proposed Optimal FPSO Revamp Project Management Model

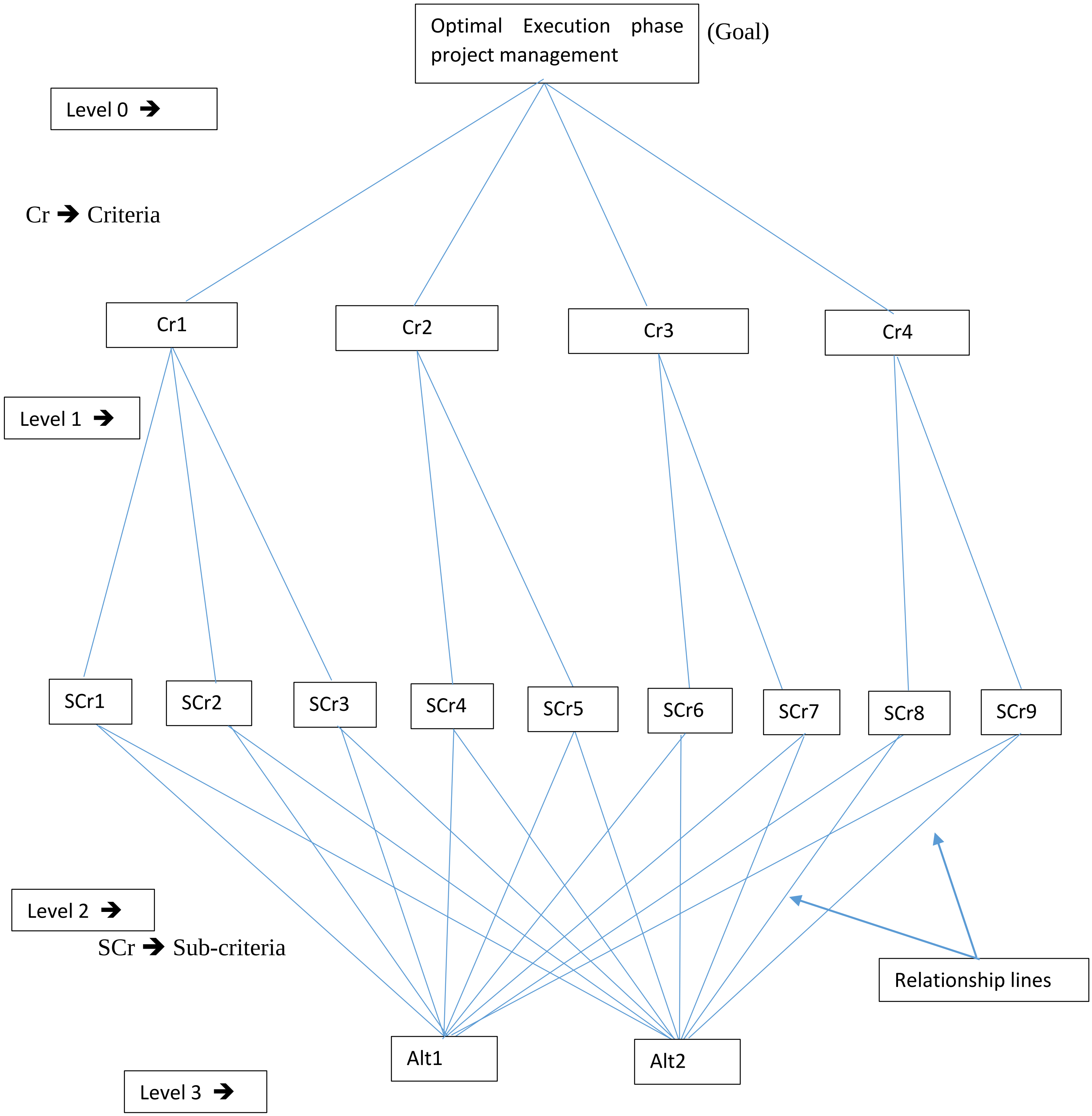


FIGURE 5.4 The As-is and proposed to-be Engineering activities Model

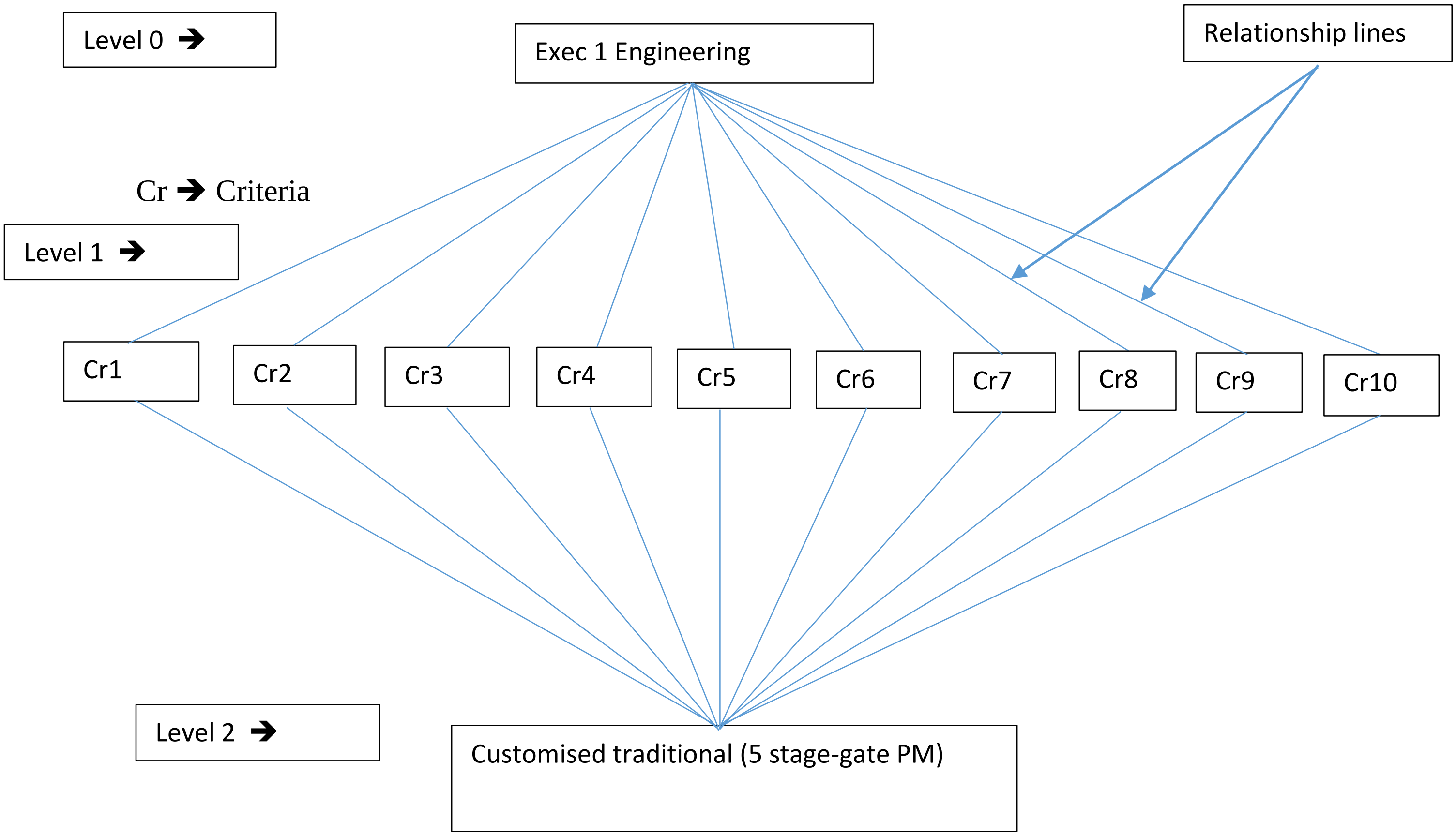


FIGURE 5.5 Proposed To-be Engineering Model

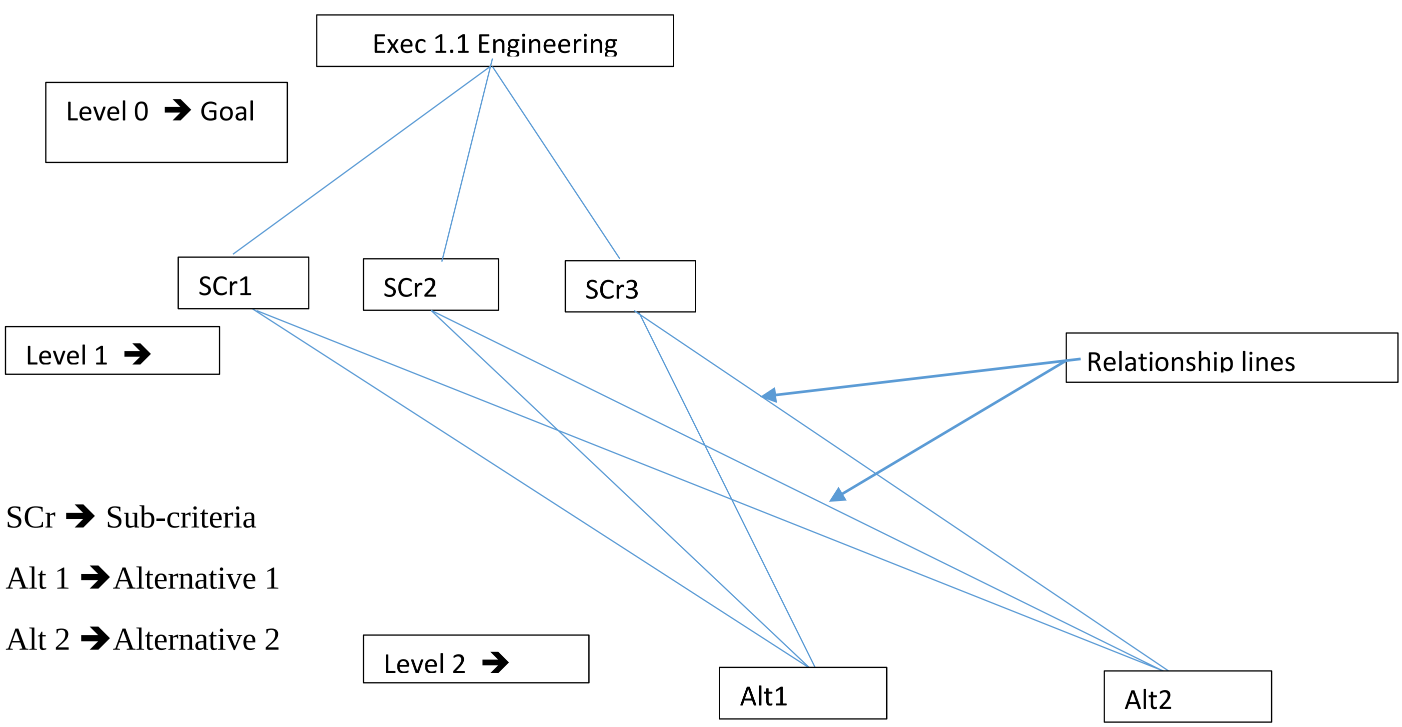


Figure 5.5 is indicative of the as-is detailed engineering model during the execution stage of FPSO revamp project realisation. The model has a typical three level, two step Analytic Hierarchy Process (AHP). Exec 1 Engineering means execution stage 1 under the engineering purview with a goal or objective function of detailed engineering optimisation at level zero (0).

Cr1 to Cr10 represent the 10 knowledge areas comprising scope of work, time, cost, quality, procurement, stakeholder and communication, human resources, risk, and integration management. The solid lines linking the different levels from 0 to 2 are called relationship lines that give pairwise comparison of the criteria with respect to the engineering function.

At level 2, the customised traditional (five stage-gate project management) is utilised as the sole project management model for FPSO revamp project execution.

Also, Figure 5.5 is the proposed to-be engineering FPSO revamp project management model. This is like Figure 5.4 but differs with the criteria reviewed and has been abridged from expert panellist feedback from ten to three consisting of the critical success criteria (E. Cr1 to E. Cr3)

Also, the customised traditional (five stage-gate project management) has been replaced by two alternative project management approaches of Lean and Agile project management (APM). Thus, at level 2, there is provision for pairwise comparison of project management alternatives with respect to the three identified criteria for FPSO revamp project management improvement.

FIGURE 5.6 The As-is Pre-fabrication and Construction Activities Model

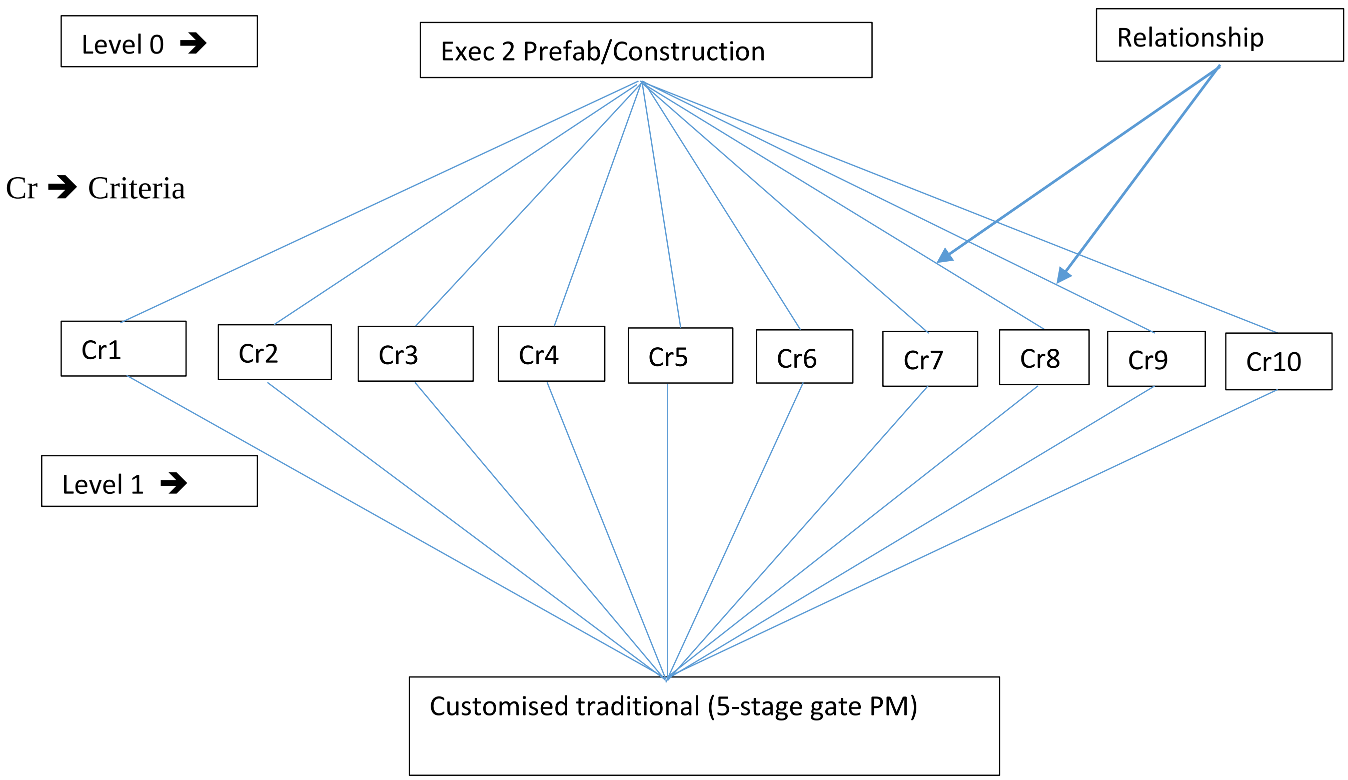


FIGURE 5.7 Proposed to-be Pre-fabrication and Construction Model

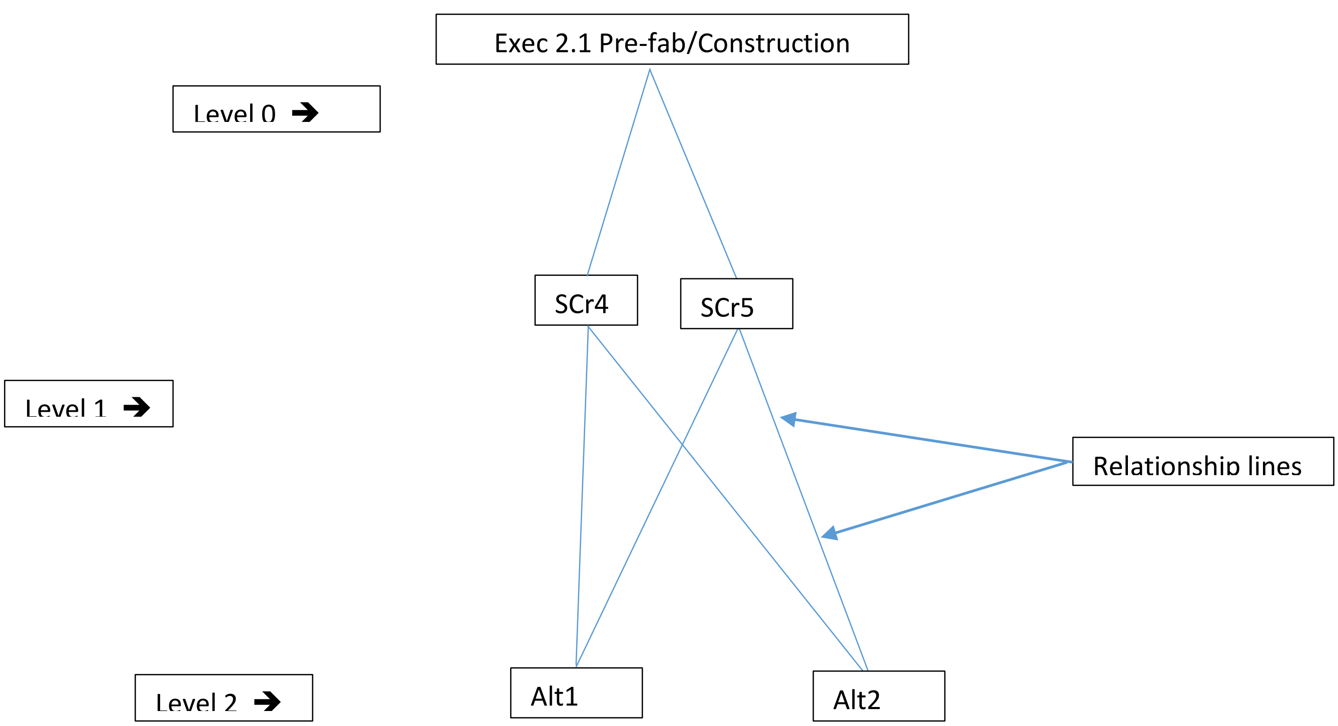


Figure 5.7 is indicative of the as-is prefab and construction model during the execution stage of FPSO revamp project realisation. The model is a typical three level, two step Analytic Hierarchy Process (AHP). Exec 2 Prefab/Construction means execution stage 1 under the engineering purview with a goal or objective function of detailed engineering optimization at level zero (0).
Cr1 to Cr10 represents the 10 knowledge areas comprising scope of work, time, cost, quality, procurement, stakeholder, and communication, human resources, risk, and integration management. The solid lines linking the different levels from 0 to 2 are called relationship lines that gives pairwise comparison of the criteria with respect to the engineering function.
At level 2, the customised traditional (five stage-gate project management) is utilised as the sole project management model for FPSO revamp project execution.
Also, Figure 5.7 is the proposed to-be FPSO revamp project management model. This is like Figure 5.6 but differs with the criteria reviewed and has been optimised from expert panellist feedback from ten to two critical factors (SCr4 and SCr5).
Also, the customised traditional (five stage-gate project management) has been replaced with two alternative project management approaches of Lean and Agile project management (APM). Thus, at level 2, there is provision for pairwise comparison of project management alternatives with respect to the two identified criteria for FPSO revamp project management improvement.

FIGURE 5.8 The As-is Installation Model

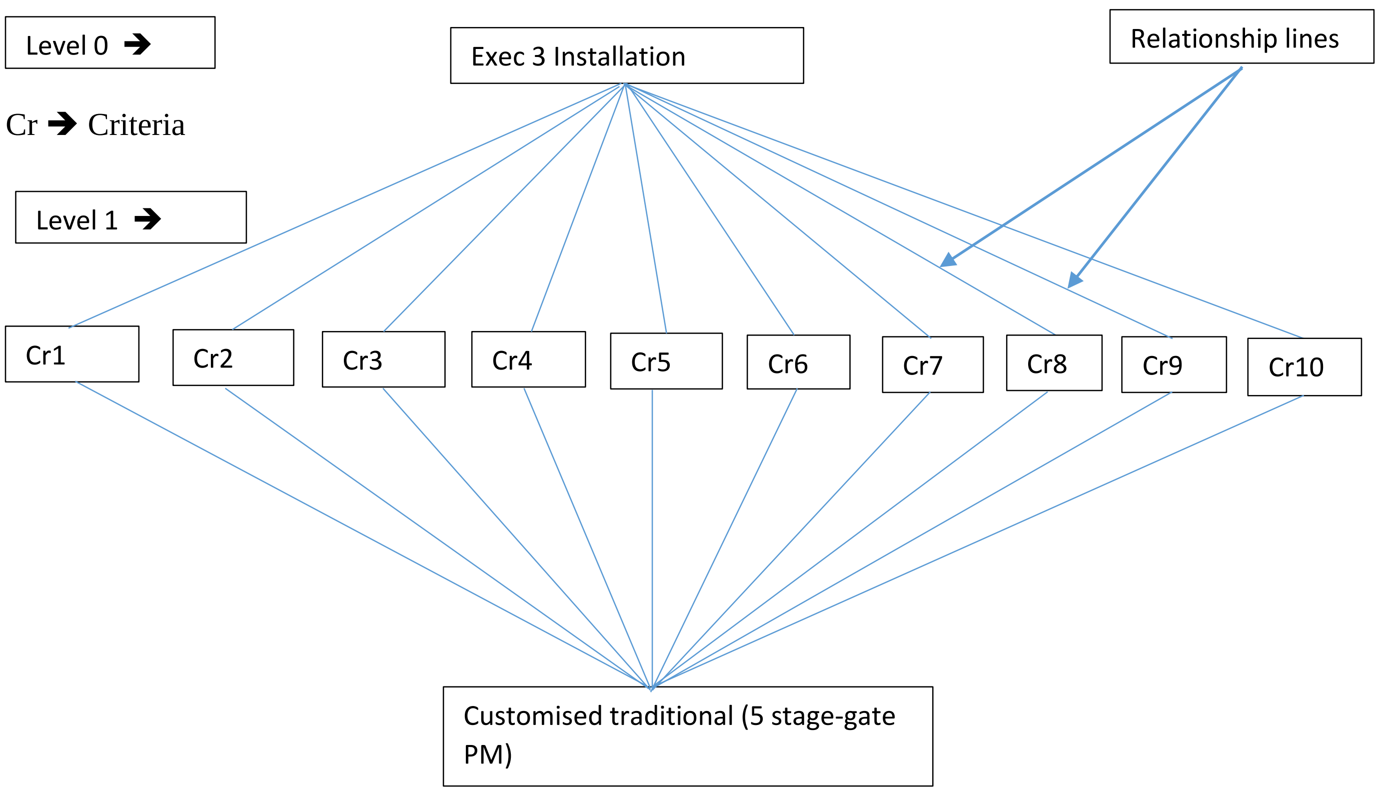
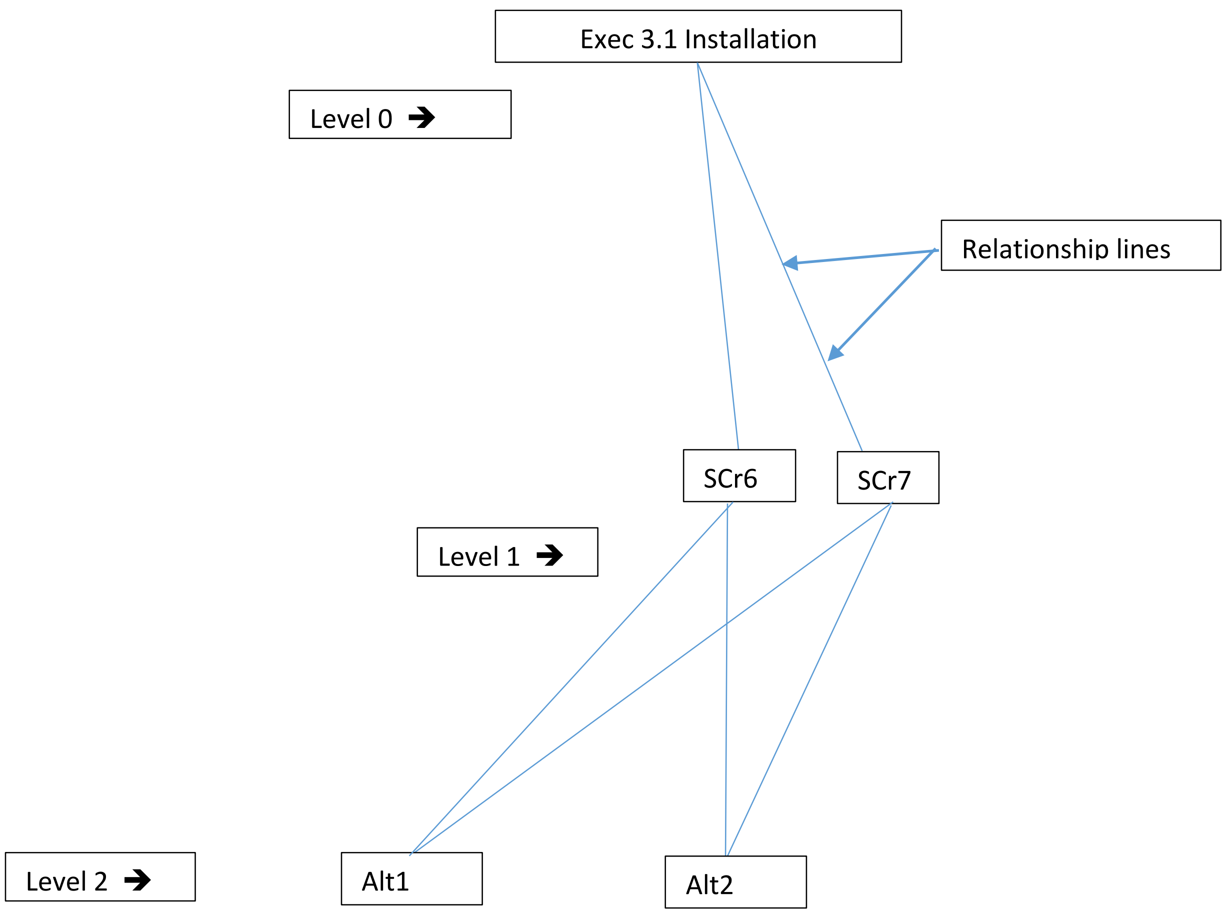


Figure 5.8 is indicative of the as-is installation model during the execution stage of FPSO revamp project realisation. The model is a typical three level, two step Analytic Hierarchy Process (AHP).

Exec 3 Installation means execution stage 1 under the installation purview with a goal or objective function of detailed engineering optimisation at level zero (0).

Cr1 to Cr10 represents knowledge areas comprising scope of work, time, cost, quality, procurement, stakeholder, and communication, human resources, risk, and integration management. The solid lines linking the different levels from 0 to 2 are called relationship lines that gives pairwise comparison of the criteria with respect to the installation function.

FIGURE 5.9 The To-be Installation Model



At level 2, the customised traditional (five stage-gate project management) is utilised as the sole project management model for FPSO revamp project execution.

Also, Figure 5.9 is the proposed to-be FPSO revamp project management model. This is like Figure 5.8 but differs with the criteria reviewed and has been optimised from expert panellist feedback from ten to two critical success factors (SCr6 to SCr7).

Also, the customised traditional (five stage-gate project management) has been replaced with two alternative project management approaches of Lean and Agile project management (APM). Thus, at level 2, there is provision for pairwise comparison of project management alternatives with respect to the seven identified criteria for FPSO revamp project management success.

FIGURE 5.10 As-is Pre-com/Commissioning Model

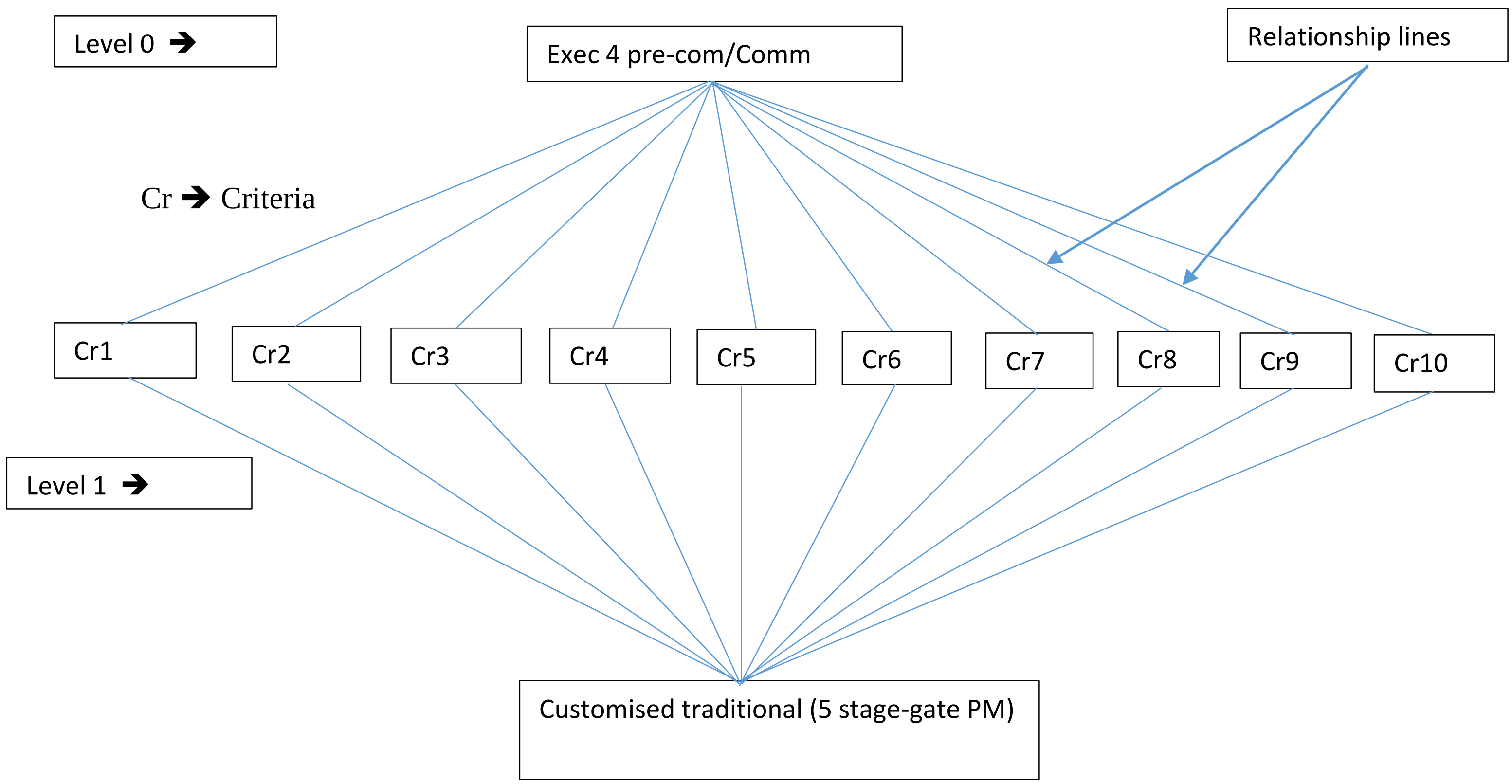


FIGURE 5.11 Proposed to-be Pre-com/Commissioning Model

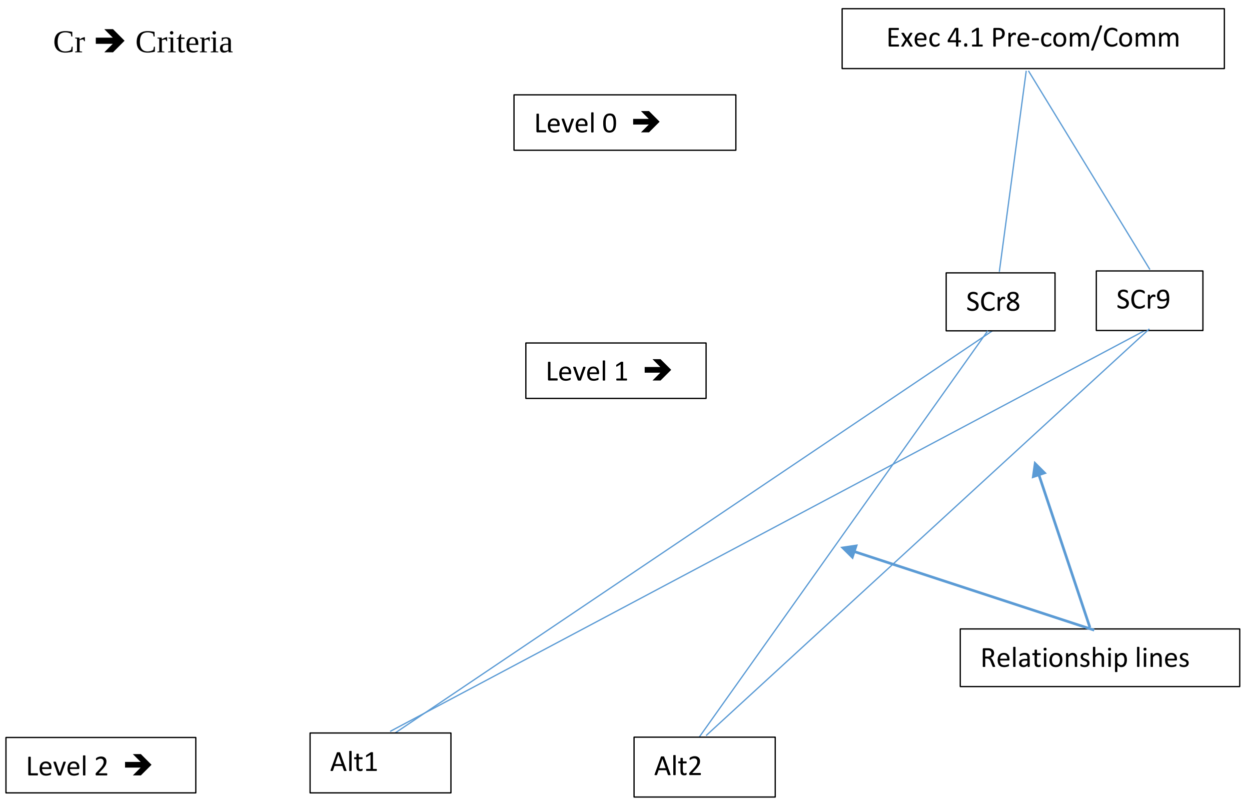


Figure 5.11 is indicative of the as-is Pre-com/Commissioning model during the execution stage of FPSO revamp project realisation. The model is a typical three level, two step Analytic Hierarchy Process (AHP). Exec 4Pre-com/Commissioning means execution stage 1 under the pre-commissioning/commissioning purview with a goal or objective function of detailed engineering optimisation at level zero (0).

Cr1 to Cr10 represents the knowledge areas comprising scope of work, time, cost, quality, procurement, stakeholder, and communication, human resources, risk, and integration management. The solid lines linking the different levels from 0 to 2 are called relationship lines that gives pairwise comparison of the criteria with respect to the pre-commissioning/commissioning function.

At level 2, the customised traditional (five stage-gate project management) is utilised as the sole project management model for FPSO revamp project execution.

Also, Figure 5.11 is the proposed to-be FPSO revamp project management model. This is like Figure 5.10 but differs with the criteria reviewed and has been optimised from expert panellist feedback from ten to two critical success factors (SCr8 and SCr9).

Also, the customised traditional (five stage-gate project management) has been replaced with two alternative project management approaches of Lean and Agile project management (APM). Thus, at level 2, there is provision for pairwise comparison of project management alternatives with respect to the seven identified criteria for FPSO revamp project management improvement.

5.5 The Proposed FPSO Revamp Project Management Control Workflow

The Stage-gate management process, otherwise known as the traditional or waterfall management process, is from the foundation of the Project Management Body of Knowledge (PMBOK) and basically functions through a philosophy of planning and working to achieve the set plan management style. As robust and useful as this process is, it has over time not been adequate to support current realities. This has given rise to the introduction of several competing management approaches. Some relatively new methods include the Agile Project management (APM) and the Lean philosophy, Integrated Project Delivery (IPD), and Building Information Modelling (BIM). All have been deployed by organisations to yield significant project improvements.

Other researchers and academics have attempted to combine one or two of these new approaches with the waterfall project management to form a hybrid project management system, believing that they would make a powerful conceptual strategy or process based on the project type for optimisation purposes. In this research, the AHP has been used to develop a new project management model specific to revamp project execution. The proposed new model has seven steps for implementation, starting with step 1 which is selection of execution stage component activities – an extract from the original five stage-gate lifecycle and confirmed by the literature. As highlighted earlier in this study, oil and gas project development passes through a sequential process and for this reason the new proposed optimised revamp project model as presented retains most attributes of the traditional five stage-gate process.

Step 2, an important consideration in the development of this proposed model, is the task of identifying the critical knowledge areas going by experiences and lessons learned in similar past projects during the execution phase for each stage of the execution activities. However, the step 2 challenge has been considered by utilising the literature review highlighted earlier in this report and was also confirmed via questionnaire and interview survey responses by the experts.

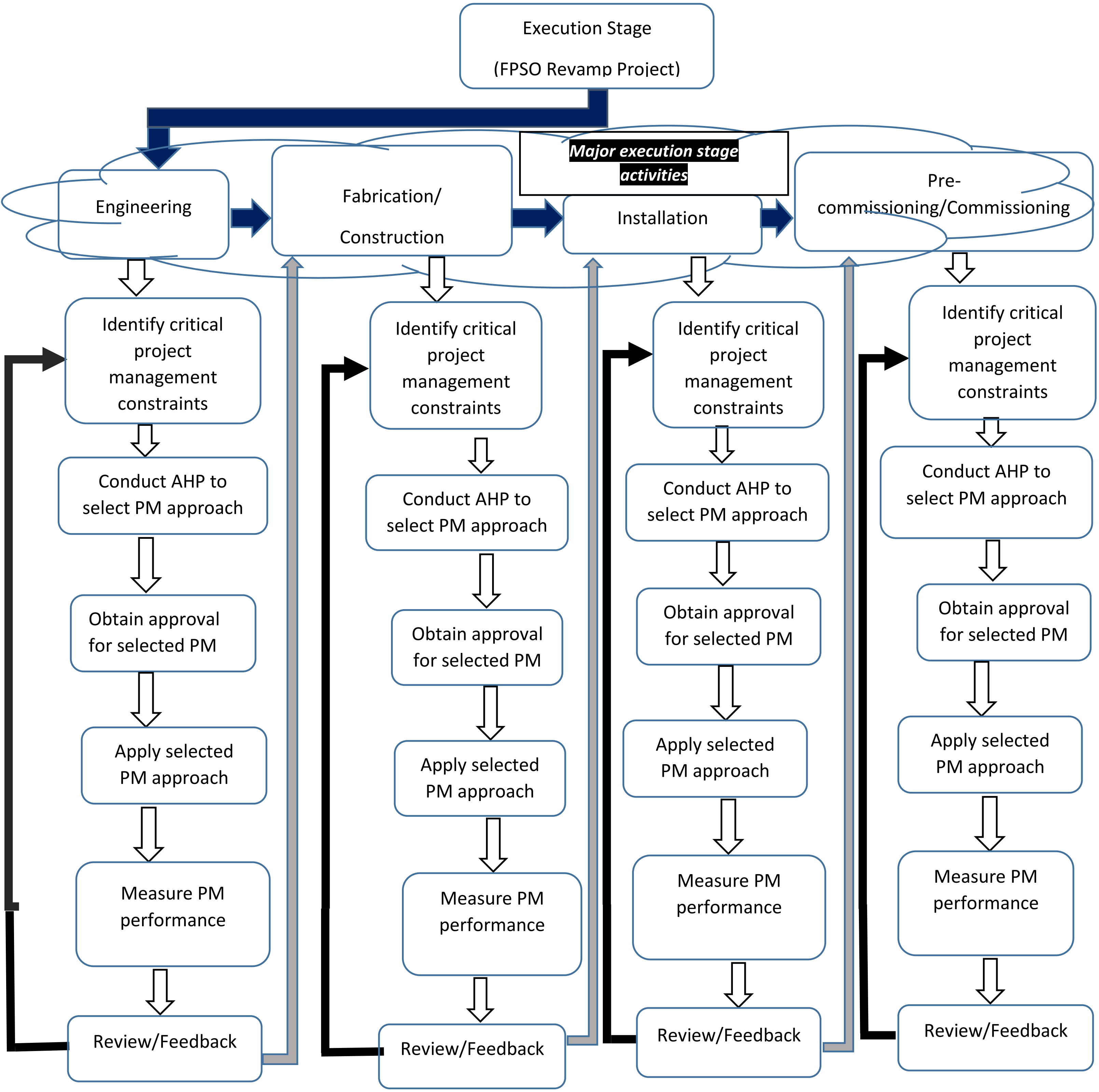
Step 3. Nevertheless, the implementation of the work processes by the process groups has been either modified by the Lean or replaced with the APM mindset. This was subject to the measurement criteria from an AHP analysis of the critical knowledge areas by the researcher. While a pilot study is highly recommended in step 4 for the obvious reasons of acceptance and validation by the stakeholders, the PM approach from the AHP exercise is eventually selected in step 5; monitoring and control of the selected option in step 5 is reassessed for continuous deployment on the project or for subsequent projects as required in step 6.

It is pertinent to note that the detailed attributes of both the Lean philosophy and the APM were reviewed and factored into both the questionnaire and interview surveys. The monitoring and controlling of the project management option in step 6 is very important to assure continuous improvement in the use of the new model. The anticipated review and feedback from the review of execution activities (engineering through construction to pre-commissioning and commissioning) performances will assist in re-evaluating the new model implementation cycle. In addition, is the fact that the final selected approach for each stage of the execution activities was subjected to consistency assessment as part of the AHP process in step 3. How the new proposed model works is that, should the selection phase of a revamp project be judged as Lean inclined for instance, the traditional work processes during the selection phase will be modified by the introduction of Lean philosophy. Following the completion of the execution stage, the project management team (PMT) will complete the requisite deliverables and make a presentation to the gatekeeper for approval, before moving to the next project phase in accordance with the standard stage-gate requirement.

While most major oil and gas companies have existing project management systems leveraging on the traditional stage-gate management process, some indigenous operators in Nigeria and other countries may not have developed or adopted a standard project management system. Therefore, this proposed new revamp project management model could be deployed by all operators wishing to either improve their processes or in the quest for an optimised revamp project management process for adoption.

In addition, Figures 5.4 to 5.11 are schematics of the AHP modelling approach and captures the feedback from both questionnaire and interview surveys with respect to the research. The figures indicate both the as-is industry practice and the to-be being a true reflection of the research outcome. Briefly stated, the traditional practice has 10 knowledge areas as criteria required to satisfy the optimal project management performance objective function or goal of FPSO revamp project. However, through the AHP modelling approach, a three level, two step model could be utilised in the bid to achieve optimal project performance with criteria and alternative choices to make.

FIGURE 5.12 Proposed FPSO Revamp Project Monitoring/control workflow (Execution Phase)



5.4 FPSO Revamp project – Execution Stage Activities Performance Measurement Tool

Table 5.3 represents the proposed execution stage activities performance measurement tool obtained from the questionnaire and interview surveys. The Key Performance Indicators (KPIs) range from the more critical factors, including Health Safety and Environment (HSE), cost, time, quality, and scope of work, to the less critical indicators grouped under “others”. While the total weight for every specific execution stage activity equals the percentage priority from the AHP survey analysis, the aggregate percentage priority for the respective KPI for example in Table 7.1 is the product of the percentage weight and the rating score used for the evaluation, thus the individual KPI weightings are different for the specific sequential execution stage activities.

The decision remark is such that a score of 80% and above indicates an optimal performance and is a signal to continue with the existing project management approach. A score from 70% to 79% signals you to continue with the selected project management approach with caution and to carry out an AHP update based on the performance feedback and lessons learned from previous projects executed. A score of less than 70% signals a discontinuation with the selected project management approach and a requirement to conduct a fresh AHP analysis prior to the start of the next new project. However, this tool could be customised to suit the needs of project teams and organisations, depending on the criticality rating, weight or priority assigned to each KPI.

FPSO Revamp project – Execution Stage Performance Measurement Tool												
KPIs\Activities	Engineering			Prefab/Construction			Installation			Pre-commissioning/ Commissioning		
	Weight %	Rating	Aggregate weight	Weight %	Rating	Aggregate weight	Weight %	Rating	Aggregate weight	Weight %	Rating	Aggregate weight
HSEQ	-		0%	-		0%	10		0%	-		0%
Cost and Schedule	11	Enter value	0%	-		0%	-	Enter value	0%	-	Enter value	0%
Procurement	16		0%	-	Enter value	0%	-		0%	-		0%
Risk	-		0%	16		0%			0%	-		0%
Scope of work	27		0%			0%			0%	-		0%
Others	-		0%	8		0%	2		0%	10		0%
Total	54		0%	24		0%	12		0%	10		0%
Decision - Remark	**80% and above Continue with selected PM approach; 70% - 79% Continue with selected PM and revisit AHP based on performance feedback Less than 70% Discontinue with selected PM approach and conduct fresh AHP analysis**											

Table 5.3 FPSO Revamp project – Execution Stage Performance Measurement Tool

5.5 Summary

This chapter accounted for the efforts of the research work in identifying the nine critical success criteria in the eyes of experts in FPSO revamp project execution from the project management constraints, and explored a three step, four AHP level multi-criteria decision-making methodology for developing an optimised FPSO revamp project management model. This involved a selection from alternative project management approaches. Details of the AHP research data collection and analysis is covered Chapter Six of this thesis.

CHAPTER SIX

Case Studies – AHP Data Analysis

6.1 Introduction

This chapter presents the Analytic Hierarchy Process (AHP) analysis for the development, validation, and testing of the optimised model. A total of five case studies have been collected and analysed. Case study 1 was used for the model development, case studies 2 and 3 for validation, with case studies 4 and 5 for testing. While case studies 1 to 4 are specific multinational oil and gas producing companies, case study 5 are group of experts from various oil and gas operating companies around the world.

Although four case studies were initially envisaged for this research project, there was a need to re-strategize on the research instrument in the face of the widespread lockdown occasioned by the unprecedented COVID-19 pandemic that introduced a new normal way of life in early 2020.

To actualise the targeted number of experts for the research, the networking opportunities presented by the internet was used to reach out to experienced professionals on LinkedIn, thereby increasing the number of case studies for the model testing from one to two. This development is of interest as it further enhanced the validity of the research outcomes from experienced professional contacts all over the world.

The focus of the study was to improve FPSO revamp project management that is not performing optimally, by recommending two alternative revamping methods, namely the Lean method and Agile Project Management (APM). To select the best method from the alternatives, the Analytical Hierarchy Process (AHP) was employed. To acquire data for the AHP analysis, the Delphi method comprising questionnaires and an interview-based survey for data acquisition was used.

The basic criteria considered includes engineering, prefab/construction, site installation and pre-com/commissioning. The sub-criterions for engineering include project scope, procurement, and cost/schedule management. The sub-criterion for prefab/construction includes project risk and human resources management. The sub-criterions for site installation include project HSEQ and integration management, while the sub-criterions for pre-com/commissioning includes knowledge and stakeholder management. The data are grouped in a tabular form as presented in Table 6.1

Steps for AHP Analysis

FIGURE 6.1 Sequence for AHP Data Analysis

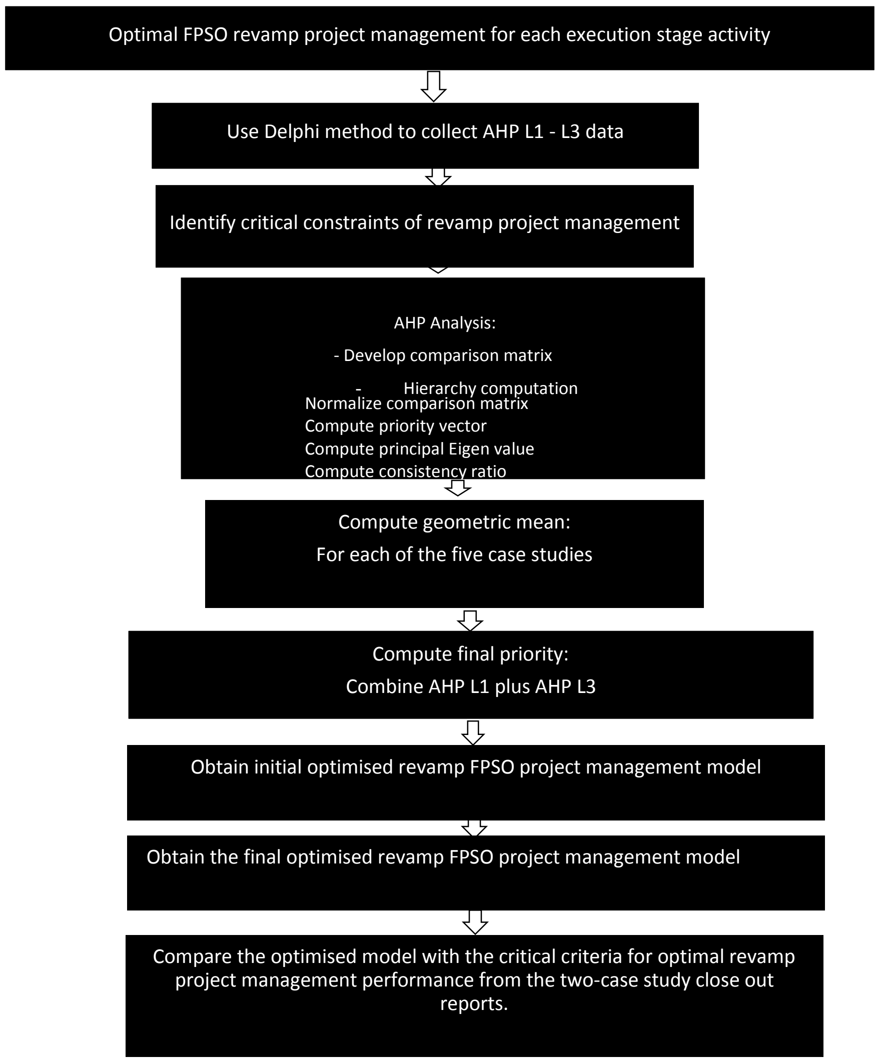


Figure 6.1 indicates the steps that were utilised in the AHP model development, validation and testing for the five case studies shown in this section.

Step 1:

For each case study, obtain from both questionnaire and interview surveys issued to the experts (Delphi, round 1), the four critical activities (called the criteria) and the nine project management constraints (called the sub-criteria) for optimal revamp project development during execution stage.

Step 2 (Comparison matrix computation):

Enter values from step 1 into the prepared comparison four by four matrix table, AHP level 1. The values from the experts have been indicated in the upper half of the diagonal matrix.

Step 3 (Comparison matrix computation):

Complete the one number three by three and three number, two by two matrix tables AHP L2, by reciprocal matrix computation. This is obtained by dividing the number 1 by any value (1 to 9) provided by the experts in step 1 and entering values into the corresponding vertical to horizontal vector in the lower half of the diagonal matrix. Sum up the vertical columns thereafter.

Step 4 (Hierarchy computation):

Normalise the four-by-four matrix, AHP L1 and the four sets of matrices for the nine sub-criteria, AHP L2 in step 3 by entering the corresponding value obtained by dividing each vector component in the comparison matrix by the summation of their vertical columns.

Step 5 (Hierarchy computation):

Compute each priority vector column by calculating the average value of the horizontal vectors of the rationalised matrix in step 5.

Step 6 (Hierarchy computation):

Compute each principal Eigen value for each column by multiplying the corresponding priority vector in step 5 by the summation of their vertical columns in step 3.

Step 7 (Hierarchy computation):

Compute the consistency index (CI) for the rationalised seven by seven matrix by subtracting the number n equals seven representing the number of the knowledge areas being compared from the summation of the principal Eigen value and then dividing the value obtained by n minus one, equals six knowledge areas as required.

Step 8 (Hierarchy computation):

Complete the hierarchy computation exercise by calculating the consistency ratio (CR). This is obtained by dividing the Consistency Index (CI) from step 7 by the random consistency Index (RI) for number (n) equal seven which is the number of attributes being compared.

Step 9:

Repeat steps 2 to 8 for AHP level 3 computation involving just two competing attributes of Lean and Agile Project Management (APM).

Step 10:

Compute the geometric mean of all the seven attributes and two alternatives from the data obtained from the expert participants for the five case studies.

Step 11:

Compute final priority by combining the values obtained in both AHP L1 to L3 matrices in step 10. For all computations above, use MS Excel as the base calculation tool or recognised AHP software if required.

Step 12:

Report the initial optimised revamp FPSO project management model from step 11 as required.

Step 13:

Compare the optimised model in step 12 with the critical criteria for optimal revamp project management performance analysed from the two different case study close out reports in this research.

Step 14:

Report the final optimised revamp FPSO project management model as concluded.

Analytical Hierarchy Process (AHP)

Table 6.1 AHP criteria and sub-criterions for Case study 1

Criteria	Engineering	Prefab/ Construction	Site Installation	Pre-com/ Commissioning	Alternatives	Respondents
Engineering	Scope	Risk	HSEQ	Knowledge	Lean	Respondent 1
Prefab/ Construction	Procurement	Human Resources	Integration	Stakeholder	APM	Respondent 2
Site Installation	Cost/Schedule					Respondent 3
Pre-com/ Commissioning						Respondent 4
						Respondent 5
						Respondent 6
						Respondent 7

The first step was to generate the design of experiment which was administered to skilled professionals in five different case study companies for the final data that was employed for the modelling. The outcome of the design of experiment including the data is presented in Appendix D.

To run the analysis, experiment data from case study 1 was employed to develop the AHP model. The data from case studies 2 and 3 were employed for model validation while the data from case studies 4 and 5 were used for testing the AHP model to select the final alternative method.

6.2 AHP Model Development

The priorities for the four basic selected criterions were calculated based on AHP and the results are presented in Table 6.2

Table 6.2 Geometric Mean Priorities by criterion:

Criteria	%
Engineering	50.42
Prefab/Construction	25.56
Site Installation	14.40
Pre-com/ Commissioning	9.62

Based on the results of Table 6.2, it was observed that engineering is the criterion that mostly impacts the decision-making processes of all the respondents in case study 1, with a percentage score of 50.42%, followed by prefab/construction with 25.56% and site installation with 14.40%. Pre-com/commissioning had 9.62% influence on the overall decision-making process. The pictorial representation of the calculated priorities by criterion is presented in Figure 6.2.

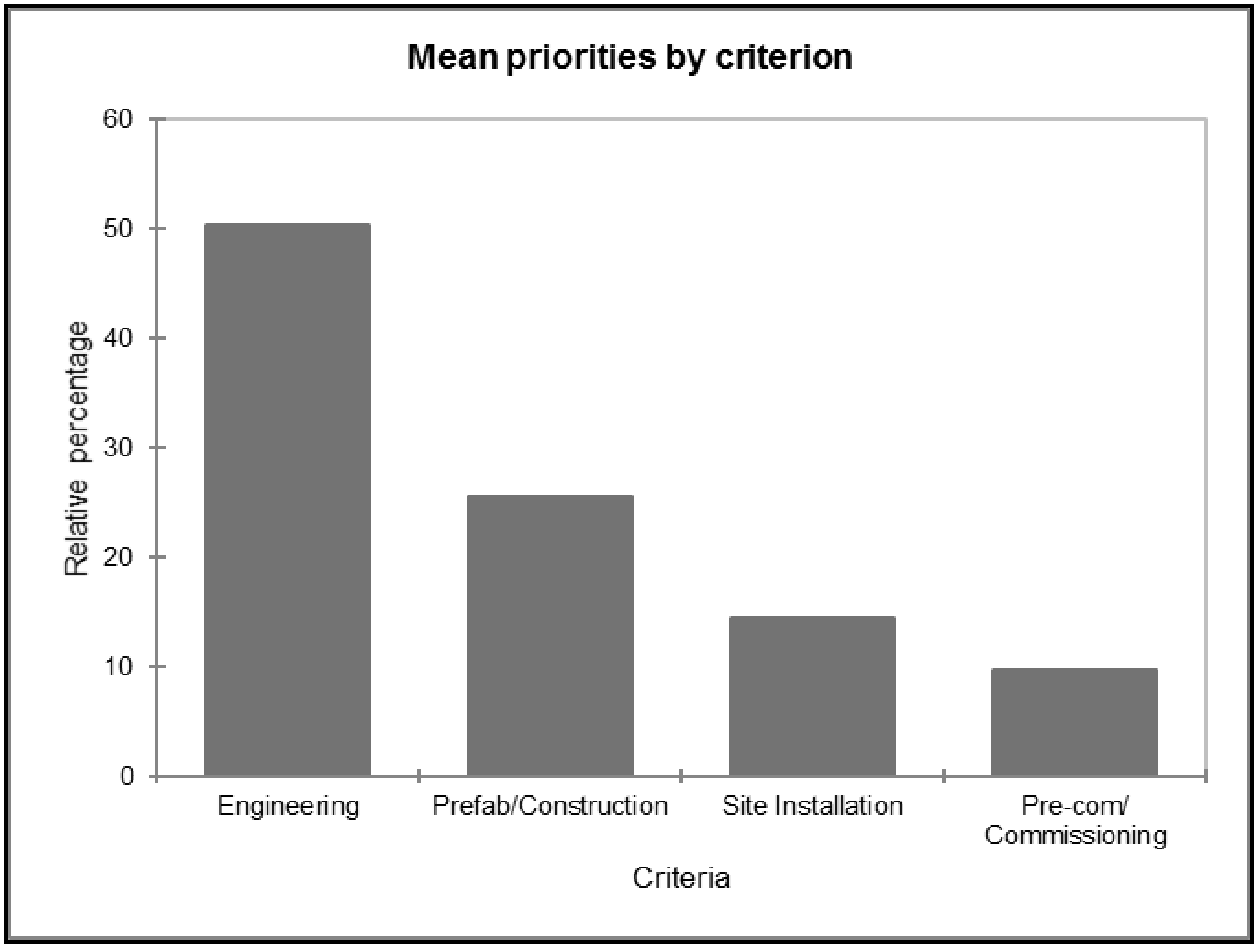


FIGURE 6.2 Geometric Mean Priorities by criterion:

To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated and are presented in Table 6.3 and Figure 6.3

Table 6.3 Geometric Mean Priorities by sub-criterion of Engineering:

Engineering	%
Scope	26.90
Procurement	14.53
Cost/Schedule	8.99

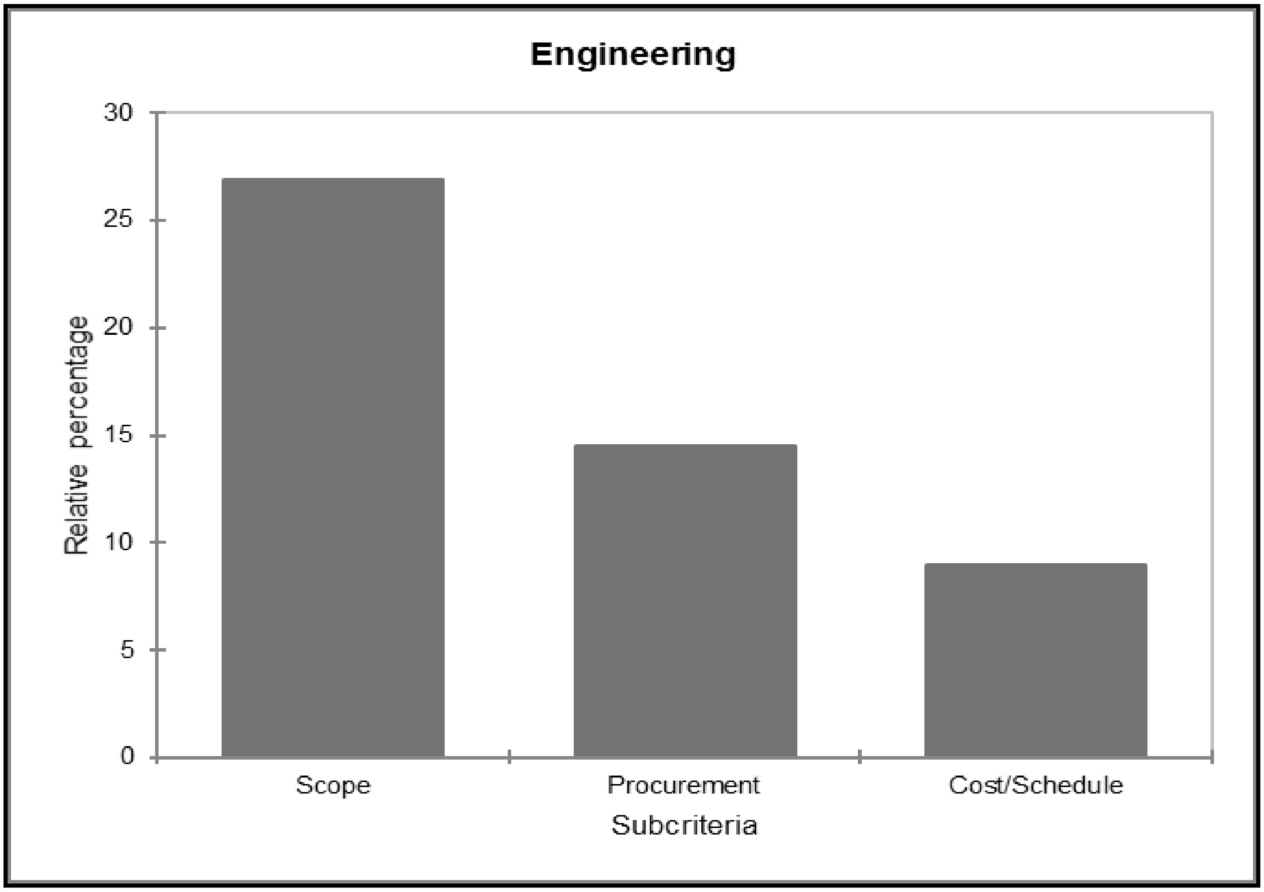


FIGURE 6.3 Geometric Mean Priorities by sub-criterion of Engineering:

From the results of Table 6.3 and Figure 6.3, it was observed that scope is the sub-criterion of engineering that mostly impacts the decision-making process, with a calculated mean priority of 26.90% followed by procurement with 14.53% and lastly cost/schedule with 8.99%.

Based on the overall perspective of the seven respondents from case study 1, the priorities by alternatives were calculated for selecting the most suitable revamping method and are presented in Table 6.4 and Figure 6.4

Table 6.4 Geometric Mean Priorities by alternative:

Crit./Alt.	Lean	APM
Engineering	40.38	10.04
Scope	20.82	6.08
Procurement	12.38	2.15
Cost/Schedule	7.19	1.81
Prefab/Construction	20.57	4.99
Risk	15.53	4.04
Human Resources	5.03	0.95
Site Installation	11.65	2.75
HSEQ	10.39	2.51
Integration	1.26	0.24
Pre-com/ Commissioning	7.45	2.17
Knowledge	6.45	1.98
Stakeholder	1.01	0.19

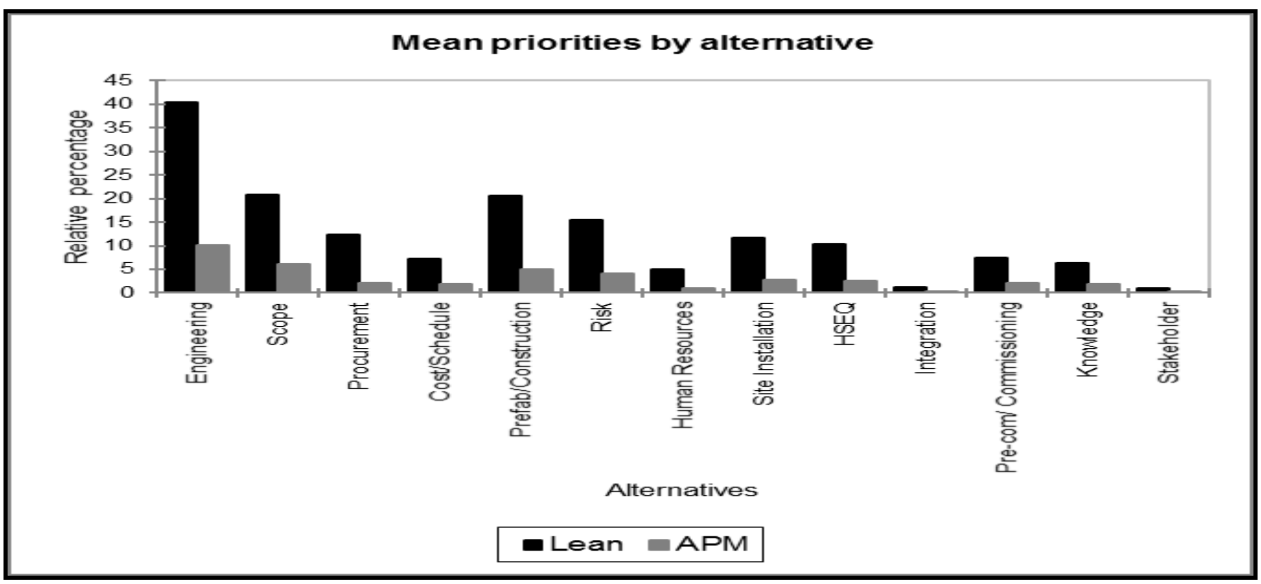


FIGURE 6.4 Geometric Mean Priorities by alternative:

The results of Table 6.4 and Figure 6.4 further support the claim that engineering is the criterion that mostly impacts the decision-making process of all the respondents in case study 1. To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained and the alternative with the highest mean sum was judged the best alternative. From the computation, the Lean method had a total score of 160.09 against the APM method with a total score of 39.91. Hence, the Lean method was selected as the best revamping method. To further support the selection of the Lean method ahead of the APM method, a critical analysis of the view of each of the respondents in Case study 1 was conducted and the results obtained from each rating is presented as follows.

6.3 Results Obtained from the Rating of Respondent 1

The priorities of criterion based on the rating of respondent 1 are presented in Table 6.5

Table 6.5 Priorities by criterion based on Respondent 1

Criteria	%
Engineering	60.87
Prefab/Construction	20.86
Site Installation	13.48
Pre-com/ Commissioning	4.79

CR = 0.494; CI = 54.86%

With a consistency ratio (CR) of 0.494, which is less than 10%, it was concluded that the comparison table generated by respondent 1 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 1. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 1 and are presented in Table 6.6

Table 6.6 Priorities by sub-criterion of Engineering based on Respondent 1

Engineering	%
Scope	29.86
Procurement	18.99

Cost/Schedule	12.03

CR = 0.027; CI =6.63%

With a consistency ratio (CR) of 0.027, which is less than 10%, it was concluded that the comparison table generated by respondent 1 is also valid. It is again observed based on the rating of respondent 1 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 29.86%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 1 and the alternative with the highest mean sum was judged to be the best alternative by respondent 1. The priorities by alternatives according to respondent 1 are presented in Table 6.7 and Figure 6.5

Table 6.7 Priorities by alternative based on Respondent 1

Crit./Alt.	Lean	APM	CR	CI
Engineering	53.26	7.61	0.00	0.00
Scope	26.12	3.73	0.00	0.00
Procurement	16.61	2.37	0.00	0.00
Cost/Schedule	10.53	1.50	0.00	0.00
Prefab/Construction	18.74	2.13	0.00	0.00
Risk	15.65	1.74	0.00	0.00
Human Resources	3.09	0.39	0.00	0.00
Site Installation	10.92	2.56	0.00	0.00
HSEQ	9.58	2.40	0.00	0.00
Integration	1.33	0.17	0.00	0.00
Pre-com/ Commissioning	6.14	0.64	0.00	0.00
Knowledge	3.67	0.52	0.00	0.00
Stakeholder	0.48	0.12	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 1 is also valid. From the computation, the Lean method had a total score of 176.1208 as against the APM method with a total score of 25.8792. Hence, the Lean method was selected as the best revamping method according to respondent 1.

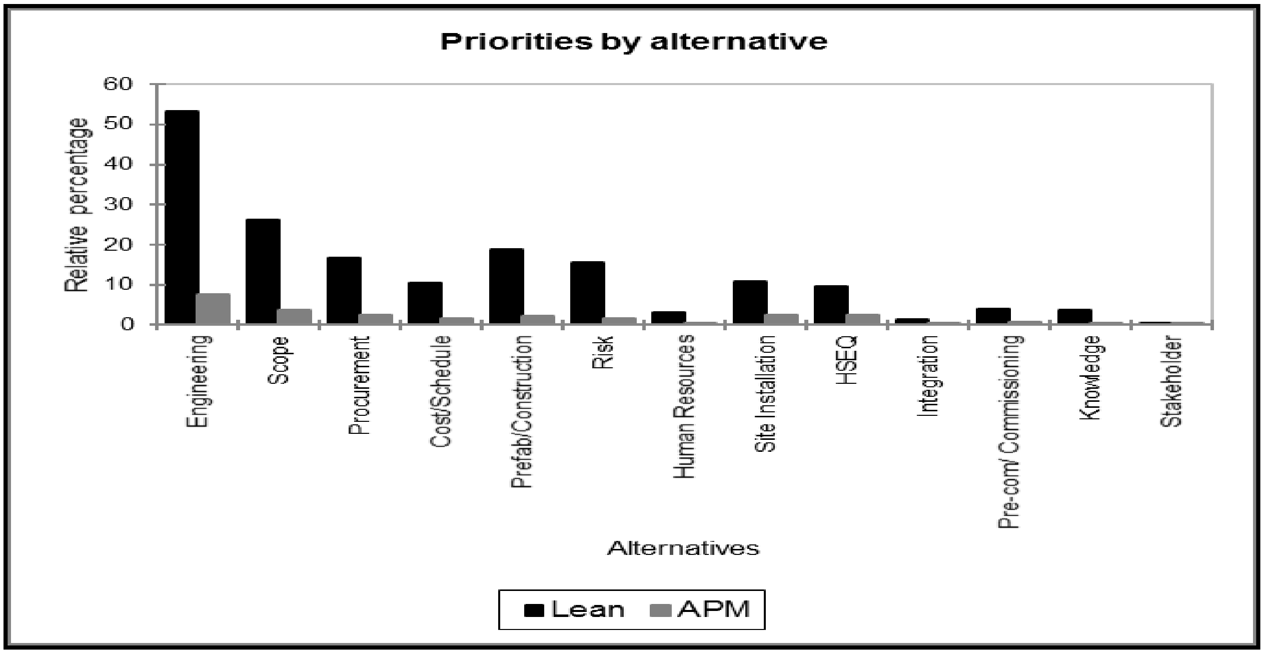


FIGURE 6.5 Priorities by alternative according to respondent 1

6.4 Results Obtained from the Rating of Respondent 2

The priorities of criterion based on the rating of respondent 2 are presented in Table 6.8

Table 6.8 Priorities by criterion based on Respondent 2

Criteria	%
Engineering	59.45
Prefab/Construction	26.42
Site Installation	8.69
Pre-com/ Commissioning	5.45

CR = 0.275; CI = 30.5%

With a consistency ratio (CR) of 0.275, which is less than 10%, it was concluded that the comparison table generated by respondent 2 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 2. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 2 and are presented in Table 6.9

Table 6.9 Priorities by sub-criterion of Engineering based on Respondent 2

Engineering	%
Scope	32.04
Procurement	17.67
Cost/Schedule	9.74

CR = 0.005; CI = 0.79%

With a consistency ratio (CR) of 0.005, which is less than 10%, it was concluded that the comparison table generated by respondent 2 is also valid. It was again observed based on the rating of respondent 2 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 32.04%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 2 and the alternative with the highest mean sum was judged to be the best alternative by respondent 2. The priorities by alternatives according to respondent 2 are presented in Table 6.10 and Figure 6.6.

Table 6.10 Priorities by alternative based on Respondent 2

Crit./Alt.	Lean	APM	CR	CI
Engineering	43.29	16.16	0.00	0.00
Scope	21.36	10.68	0.00	0.00
Procurement	16.14	3.53	0.00	0.00
Cost/Schedule	7.79	1.95	0.00	0.00
Prefab/Construction	17.61	8.81	0.00	0.00
Risk	13.21	6.60	0.00	0.00
Human Resources	4.40	2.20	0.00	0.00
Site Installation	7.61	1.07	0.00	0.00
HSEQ	7.03	0.78	0.00	0.00
Integration	0.58	0.29	0.00	0.00
Pre-com/ Commissioning	4.03	1.42	0.00	0.00
Knowledge	3.58	1.19	0.00	0.00
Stakeholder	0.45	0.23	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 2 is also valid. From the computation, the Lean method had a total score of 145.0845 as against the APM method with a total score of 54.9155. Hence, the Lean method was selected as the best revamping method according to respondent 2.

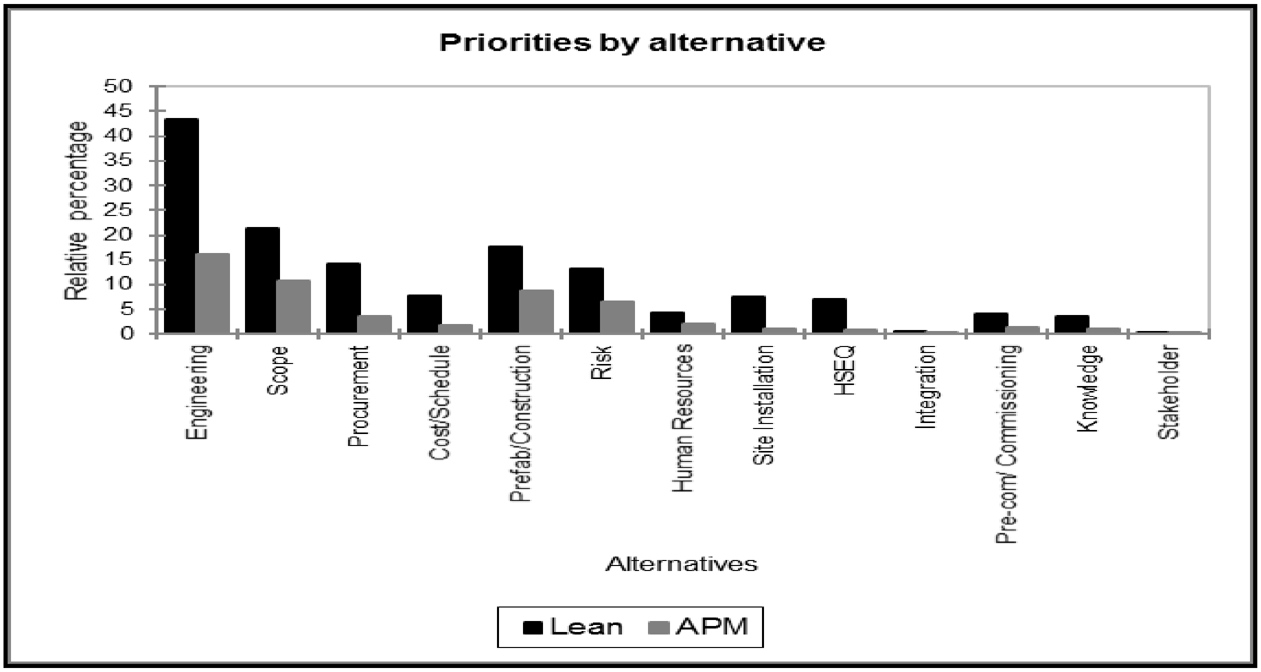


FIGURE 6.6 Priorities by alternative according to respondent 2

6.5 Results Obtained from the Rating of Respondent 3

The priorities of criterion based on the rating of respondent 3 are presented in Table 6.11

Table 6.11 Priorities by criterion based on Respondent 3

Criteria	%
Engineering	57.52
Prefab/Construction	23.38
Site Installation	10.39
Pre-com/ Commissioning	8.71

CR = 0.445; CI = 49.39%

With a consistency ratio (CR) of 0.445, which is less than 10%, it was concluded that the comparison table generated by respondent 3 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 3. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 3 and are presented in Table 6.12

Table 6. 12 Priorities by sub-criterion of Engineering based on Respondent 3

Engineering	%
Scope	28.21
Procurement	17.94
Cost/Schedule	11.37

CR = 0.027; CI =6.63%

With a consistency ratio (CR) of 0.027, which is less than 10%, it was concluded that the comparison table generated by respondent 3 is also valid. It was again observed based on the rating of respondent 3 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 28.21%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 3 and the alternative with the highest mean sum was judged to be the best alternative by respondent 3. The priorities by alternatives according to respondent 3 are presented in Table 6.13 and Figure 6.7

Table 6.13 Priorities by alternative based on Respondent 3

Crit./Alt.	Lean	APM	CR	CI
Engineering	50.33	7.19	0.00	0.00
Scope	24.69	3.53	0.00	0.00
Procurement	15.70	2.24	0.00	0.00
Cost/Schedule	9.95	1.42	0.00	0.00
Prefab/Construction	20.56	2.81	0.00	0.00
Risk	13.64	1.95	0.00	0.00
Human Resources	6.93	0.87	0.00	0.00
Site Installation	9.34	1.05	0.00	0.00
HSEQ	8.42	0.94	0.00	0.00
Integration	0.92	0.12	0.00	0.00
Pre-com/ Commissioning	7.33	1.38	0.00	0.00
Knowledge	6.22	1.24	0.00	0.00

Stakeholder	1.11	0.14	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 3 is also valid. From the computation, the Lean method had a total score of 175.1252 as against the APM method with a total score of 24.8749. Hence, the Lean method was selected as the best revamping method according to respondent 3.

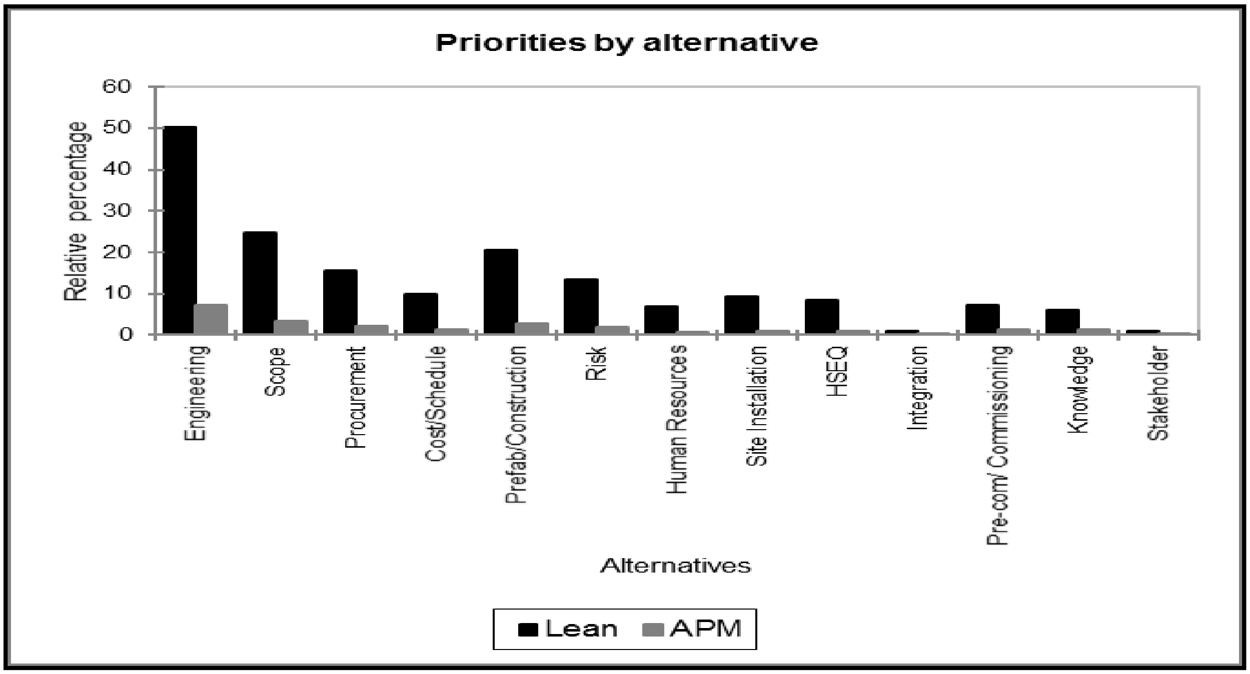


FIGURE 6.7 Priorities by alternative according to respondent 3

6.6 Results Obtained from the Rating of Respondent 4

The priorities of criterion based on the rating of respondent 4 are presented in Table 6.14

Table 6.14 Priorities by criterion based on Respondent 4

Criteria	%
Engineering	45.98
Prefab/Construction	27.73
Site Installation	13.31
Pre-com/ Commissioning	12.99

CR = 1.254; CI = 139.28%

With a consistency ratio (CR) of 1.254, which is less than 10%, it was concluded that the comparison table generated by respondent 4 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 4. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 4 and are presented in Table 6.15

Table 6.15 Priorities by sub-criterion of Engineering based on Respondent 4

Engineering	%
Scope	24.08
Procurement	13.99
Cost/Schedule	7.91

CR = 0.130; CI = 22.46%

With a consistency ratio (CR) of 0.130, which is less than 10%, it was concluded that the comparison table generated by respondent 4 is also valid. It was again observed based on the rating of respondent 4 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 24.08%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 4 and the alternative with the highest mean sum was judged to be the best alternative by respondent 4. The priorities by alternatives according to respondent 4 are presented in Table 6.16 and Figure 6.8.

Table 6.16 Priorities by alternative based on Respondent 4

Crit./Alt.	Lean	APM	CR	CI
Engineering	39.23	6.75	0.00	0.00
Scope	20.07	4.01	0.00	0.00
Procurement	12.24	1.75	0.00	0.00
Cost/Schedule	6.92	0.99	0.00	0.00
Prefab/Construction	23.39	4.33	0.00	0.00
Risk	17.33	3.47	0.00	0.00
Human Resources	6.07	0.87	0.00	0.00
Site Installation	11.64	1.66	0.00	0.00
HSEQ	10.48	1.50	0.00	0.00
Integration	1.16	0.17	0.00	0.00
Pre-com/ Commissioning	10.91	2.07	0.00	0.00
Knowledge	9.02	1.80	0.00	0.00
Stakeholder	1.89	0.27	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 4 is also valid. From the computation, the Lean method had a total score of 170.3585 as against the APM method with a total score of 29.6415. Hence, the Lean method was selected as the best revamping method according to respondent 4.

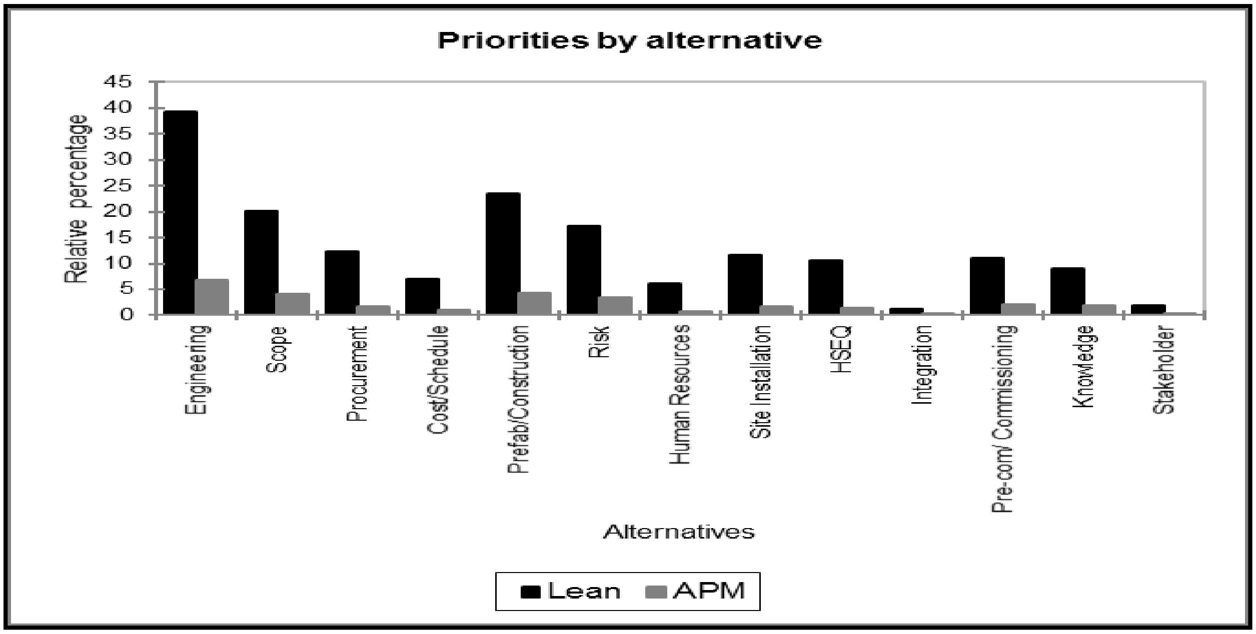


FIGURE 6.8 Priorities by alternative according to respondent 4

6.7 Results Obtained from the Rating of Respondent 5

The priorities of criterion based on the rating of respondent 5 are presented in Table 6.17

Table 6.17 Priorities by criterion based on Respondent 5

Criteria	%
Engineering	43.57
Prefab/Construction	30.35
Site Installation	22.47
Pre-com/ Commissioning	3.60

CR = 0.668; CI = 74.24%

With a consistency ratio (CR) of 0.668, which is less than 10%, it was concluded that the comparison table generated by respondent 5 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 5. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of Engineering were calculated based on the rating of respondent 5 and are presented in Table 6.18.

Table 6.18 Priorities by sub-criterion of Engineering based on Respondent 5

Engineering	%
Scope	25.00
Procurement	12.48
Cost/Schedule	6.10

CR = 0.069; CI = 11.83%

With a consistency ratio (CR) of 0.069, which is less than 10%, it was concluded that the comparison table generated by respondent 5 is also valid. It was again observed based on the rating of respondent 5 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 25.00%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 5 and the alternative with the highest mean sum was judged to be the best alternative by respondent 5. The priorities by alternatives according to respondent 5 are presented in Table 6.19 and Figure 6.9.

Table 6.19 Priorities by alternative based on Respondent 5

Crit./Alt.	Lean	APM	CR	CI
Engineering	34.55	9.02	0.00	0.00
Scope	18.75	6.25	0.00	0.00
Procurement	11.23	1.25	0.00	0.00
Cost/Schedule	4.57	1.52	0.00	0.00
Prefab/Construction	26.55	3.79	0.00	0.00
Risk	17.70	2.53	0.00	0.00
Human Resources	8.85	1.26	0.00	0.00
Site Installation	18.83	3.64	0.00	0.00
HSEQ	16.65	3.33	0.00	0.00
Integration	2.19	0.31	0.00	0.00

Pre-com/ Commissioning	2.77	0.84	0.00	0.00
Knowledge	2.32	0.77	0.00	0.00
Stakeholder	0.45	0.06	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 5 is also valid. From the computation, the Lean method had a total score of 165.4139 as against the APM method with a total score of 34.5861. Hence, the Lean method was selected as the best revamping method according to respondent 5.

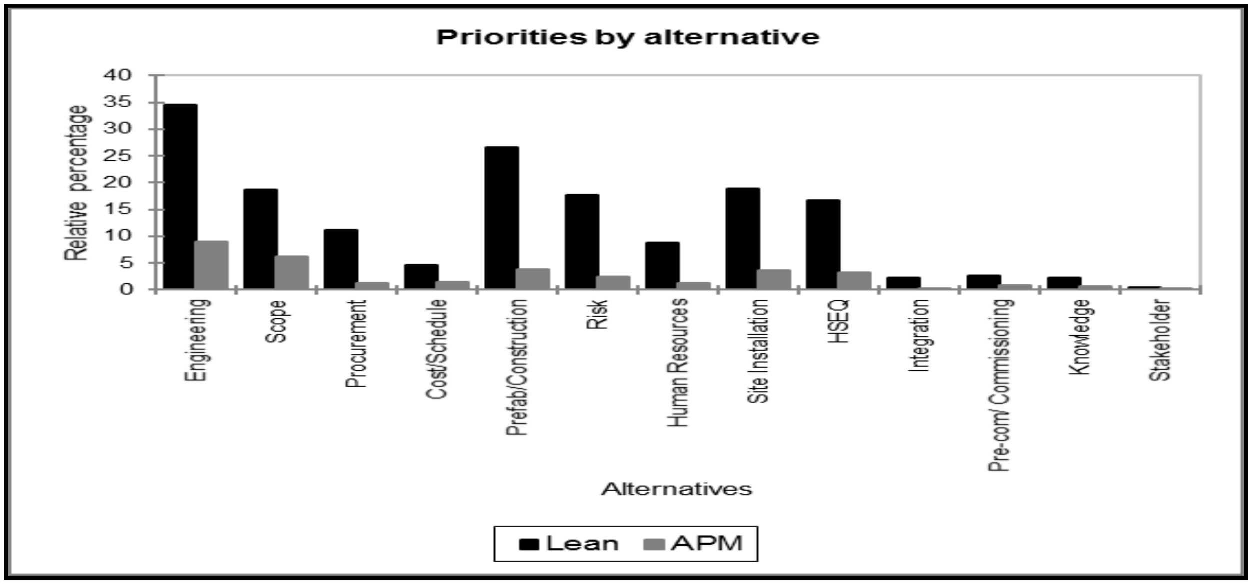


FIGURE 6.9 Priorities by alternative according to respondent 5

6.8 Results Obtained from the Rating of Respondent 6

The priorities of criterion based on the rating of respondent 6 are presented in Table 6.20

Table 6.20 Priorities by criterion based on Respondent 6

Criteria	%
Engineering	39.76
Prefab/Construction	17.24
Site Installation	26.59
Pre-com/ Commissioning	16.40

CR = 0.394; CI = 43.77%

With a consistency ratio (CR) of 0.394, which is less than 10%, it was concluded that the comparison table generated by respondent 6 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 6. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of Engineering were calculated based on the rating of respondent 6 and are presented in Table 6.21

Table 6.21 Priorities by sub-criterion of Engineering based on Respondent 6

Engineering	%
Scope	23.86
Procurement	7.95
Cost/Schedule	7.95

CR = 0; CI = 0%

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 6 is also valid. It was again observed based on the rating of respondent 6 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 23.86%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 6 and the alternative with the highest mean sum was judged to be the best alternative by respondent 6. The priorities by alternatives according to respondent 6 are presented in Table 6.22 and Figure 6.10.

Table 6.22 Priorities by alternative based on Respondent 6

Crit./Alt.	Lean	APM	CR	CI
Engineering	28.50	11.27	0.00	0.00
Scope	17.89	5.96	0.00	0.00
Procurement	5.30	2.65	0.00	0.00
Cost/Schedule	5.30	2.65	0.00	0.00
Prefab/Construction	11.88	5.36	0.00	0.00

Risk	9.58	4.79	0.00	0.00
Human Resources	2.30	0.57	0.00	0.00
Site Installation	18.08	8.51	0.00	0.00
HSEQ	15.95	7.98	0.00	0.00
Integration	2.13	0.53	0.00	0.00
Pre-com/ Commissioning	12.38	4.02	0.00	0.00
Knowledge	11.07	3.69	0.00	0.00
Stakeholder	1.31	0.33	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 6 is also valid. From the computation, the Lean method had a total score of 141.6829 as against the APM method with a total score of 58.3171. Hence, the Lean method was selected as the best revamping method according to respondent 6.

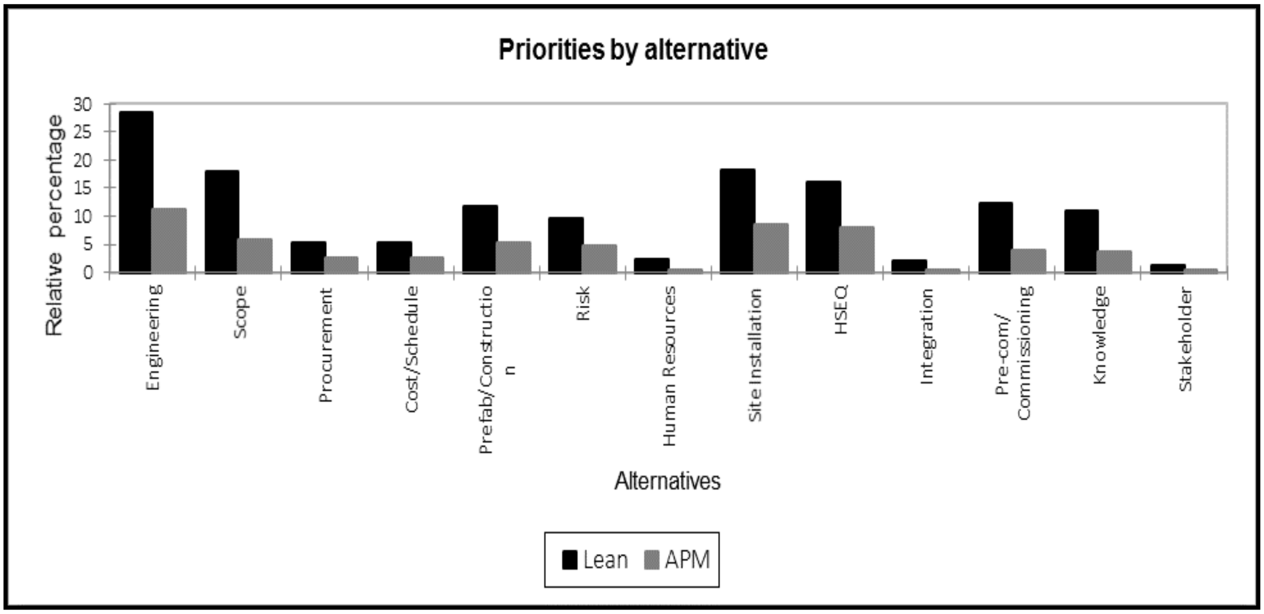


FIGURE 6.10 Priorities by alternative according to respondent 6

6.9 Results Obtained from the Rating of Respondent 7

The priorities of criterion based on the rating of respondent 7 are presented in Table 6.23

Table 6.23 Priorities by criterion based on Respondent 7

Criteria	%
Engineering	45.80
Prefab/Construction	32.93
Site Installation	5.86
Pre-com/ Commissioning	15.41

CR = 0.722; CI = 80.22%

With a consistency ratio (CR) of 0.722, which is less than 10%, it was concluded that the comparison table generated by respondent 7 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 7. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of Engineering were calculated based on the rating of respondent 7 and are presented in Table 6.24

Table 6.24 Priorities by sub-criterion of Engineering based on Respondent 7

Engineering	%
Scope	25.26
Procurement	12.68
Cost/Schedule	7.86

CR = 0.189; CI = 32.54%

With a consistency ratio (CR) of 0.189, which is less than 10%, it was concluded that the comparison table generated by respondent 7 is also valid. It was again observed based on the rating of respondent 7 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priority of 25.26%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 7 and the alternative with the highest mean sum was judged to be the best alternative by respondent 7. The priorities by alternatives according to respondent 7 are presented in Table 6.25 and Figure 6.11.

Table 6.25 Priorities by alternative based on Respondent 7

Crit./Alt.	Lean	APM	CR	CI
Engineering	33.49	12.31	0.00	0.00
Scope	16.84	8.42	0.00	0.00
Procurement	11.41	1.27	0.00	0.00
Cost/Schedule	5.24	2.62	0.00	0.00
Prefab/Construction	25.21	7.72	0.00	0.00
Risk	21.61	7.20	0.00	0.00
Human Resources	3.60	0.51	0.00	0.00
Site Installation	5.13	0.73	0.00	0.00
HSEQ	4.61	0.66	0.00	0.00
Integration	0.51	0.07	0.00	0.00
Pre-com/ Commissioning	10.59	4.82	0.00	0.00
Knowledge	9.25	4.62	0.00	0.00
Stakeholder	1.35	0.19	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 7 is also valid. From the computation, the Lean method had a total score of 148.8503 as against the APM method with a total score of 51.1497. Hence, the Lean method was selected as the best revamping method according to respondent 7.

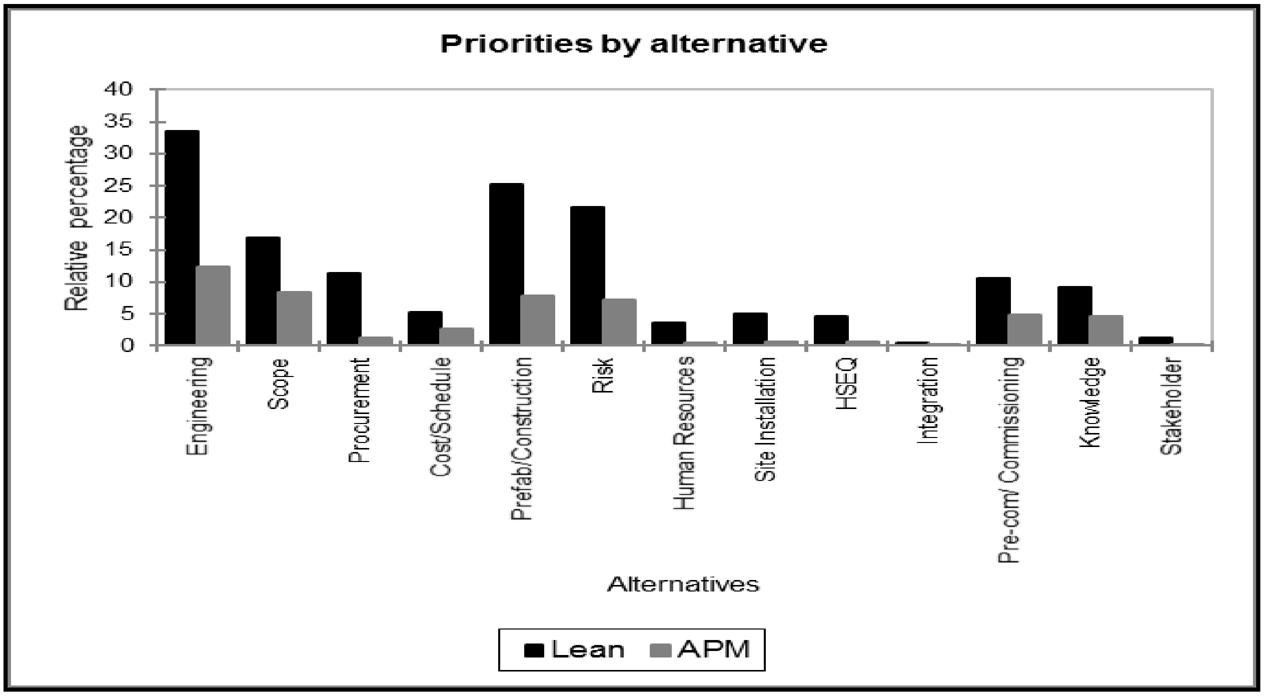


FIGURE 6.11 Priorities by alternative according to respondent 7

6.10 Model Validation

To validate the outcomes of the AHP model and further justify the selection of the Lean method ahead of the APM method, data from case studies 2 and 3 were employed as validation data and the results of the validation process are presented as follows.

The priorities for the four basic selected criterions were calculated based on AHP using the validation data and results are presented in Table 6.26 and 6.27.

Table 6.26 Priorities by criterion based on Case study 2

Criteria	%
Engineering	50.93
Prefab/Construction	23.43
Site Installation	17.11
Pre-com/ Commissioning	8.52

Table 6.27 Priorities by criterion based on Case study 3

Criteria	%
Engineering	53.82
Prefab/Construction	20.98
Site Installation	15.20
Pre-com/ Commissioning	10.00

Based on the results of Tables 6.26 and6.27, it can be observed that engineering is the criterion that mostly impacts the decision-making process of all the respondents in case studies 2 and 3, with a percentage score of 50.93% and 53.82% respectively. This is followed by prefab/construction with 23.43% and 20.98% and site installation with 17.11% and 15.20% respectively. Pre-com/commissioning had the least influence on the overall decision-making process with 8.52% and 10.00% respectively. A comparison of the model's results and the validation results based on the priorities by criterion are presented in Table 6.28

Table 6.28 Comparison of model and validation result base on geometric Mean Priorities by criterion

Computed Priorities	**Model Result**	**Validation Results**	
	Case study 1	**Case study 2**	**Case study 3**
Engineering	50.42%	50.93%	53.82%
Prefab/Construction	25.56%	23.43%	20.98%
Site Installation	14.40%	17.11%	15.20%
Pre-com/ Commissioning	9.62%	8.52%	10.00%

The results of Table 6.28 show a reasonable agreement between the model results and the validation results, thus justifying the adequacy of the AHP model. A pictorial representation of the calculated priorities by criterion using the validated data is presented in Figures 6.12 and 6.13 respectively.

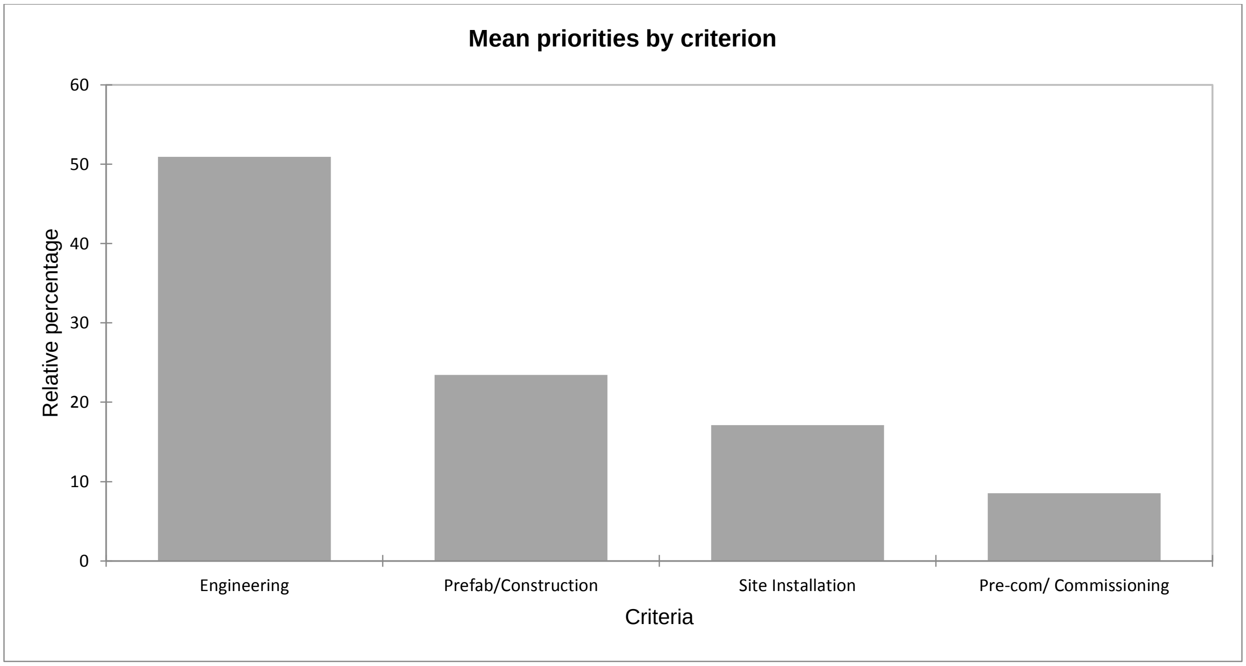


FIGURE 6.12 Geometric Mean Priorities by criterion based on validated data from

Case study 2

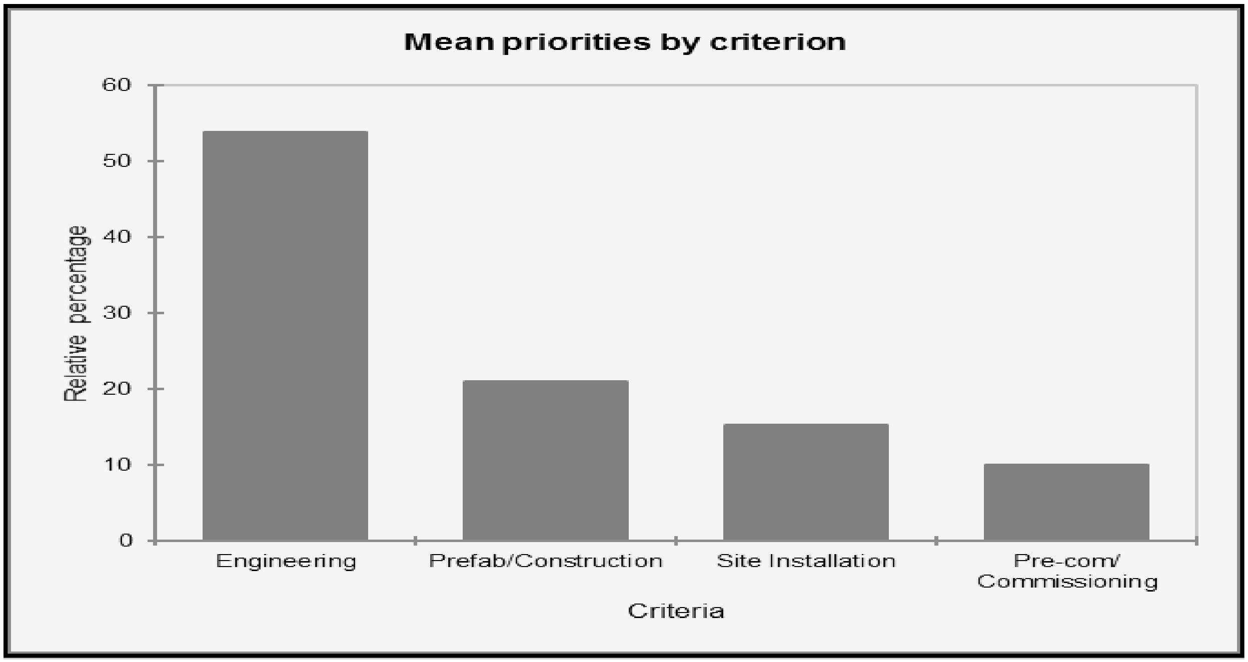


FIGURE 6.13 Geometric Mean Priorities by criterion based on validated data from **Case study 3**

To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated using the validated data from case studies 2 and 3. The results obtained are presented in Tables 6.29 and Figures 6.14 and 6.15

Table 6.29 Geometric Mean Priorities by sub-criterion of Engineering based on Case study 2

Engineering	%
Scope	25.69
Procurement	15.88
Cost/Schedule	9.36

Table 6.30 Geometric Mean Priorities by sub-criterion of Engineering based on Case study 3

Engineering	%
Scope	25.82
Procurement	17.08
Cost/Schedule	10.92

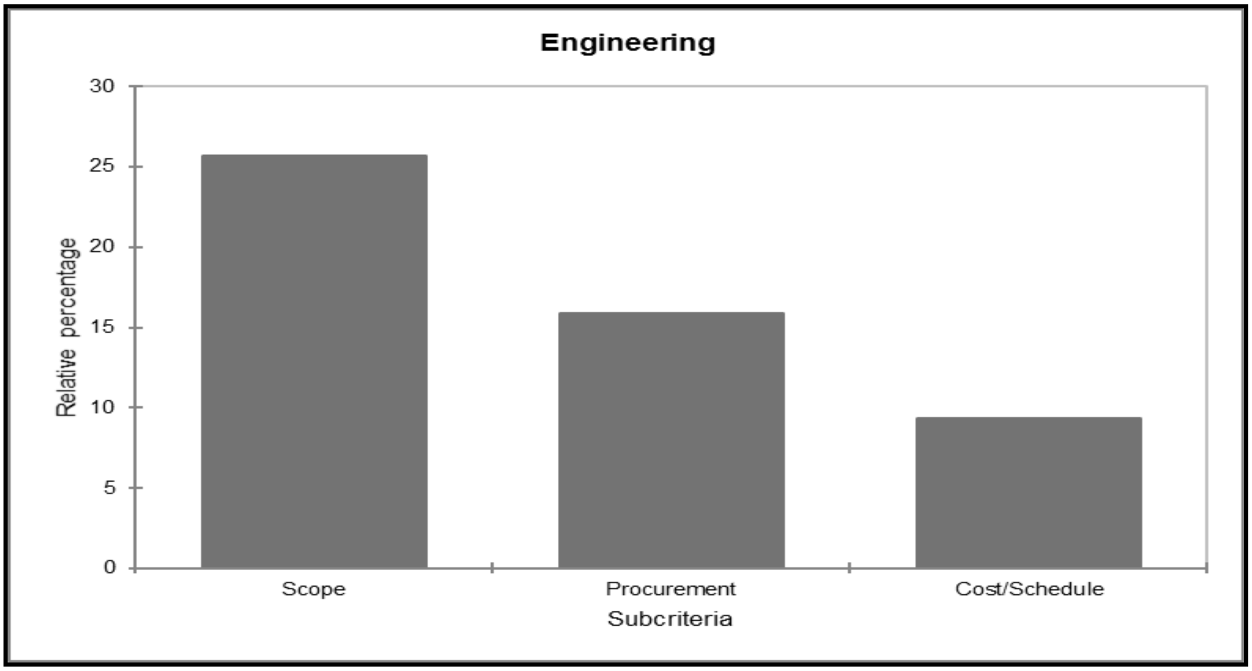


FIGURE 6.14 Geometric Mean Priorities by sub-criterion of Engineering for Case study 2

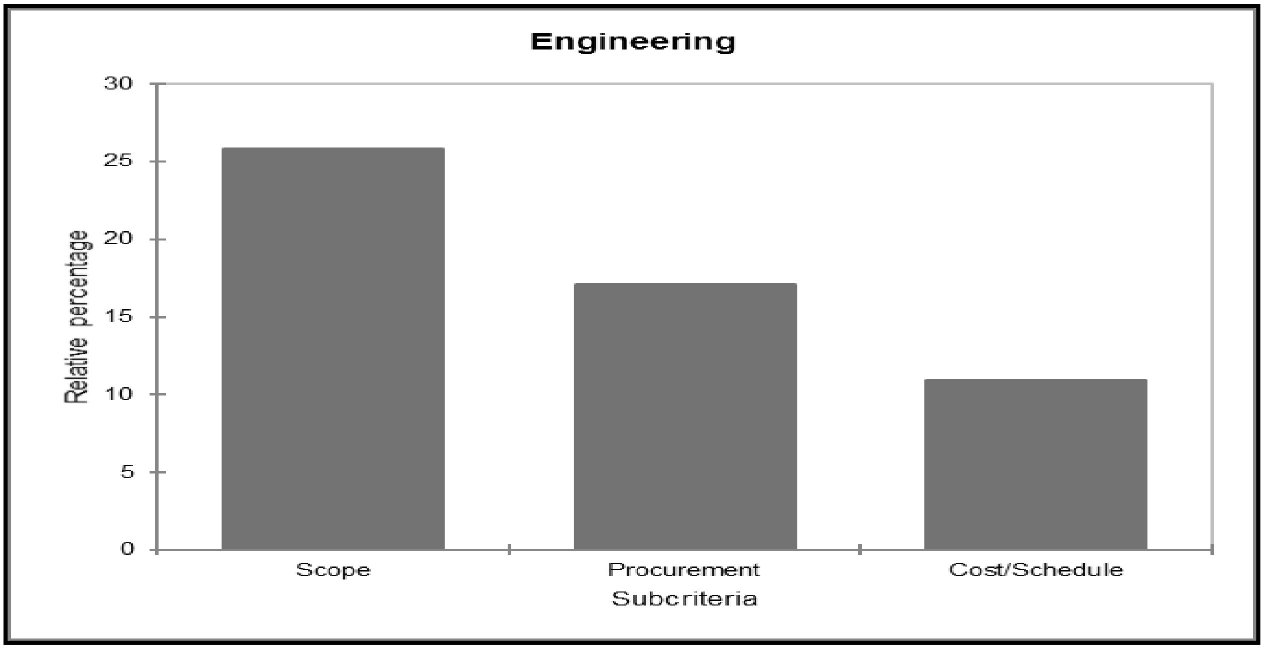


FIGURE 6.15 Geometric Mean Priorities by sub-criterion of Engineering for Case study 3

From the results of Table 6.28 and Figures 6.14 and 6.15, it can be observed that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 25.69% and 25.82%, followed by procurement with 15.88% and 17.08%, and then cost/schedule with 9.36% and 10.92%. A comparison of the model's results and the validation results based on the priorities by sub-criterion of engineering are presented in Table 6.31.

Table 6.31 Comparison of model and validation result base on Geometric Mean Priorities by sub-criterion of Engineering

Computed Priorities	**Model Result**	**Validation Results**	
	Case study 1	**Case study 2**	**Case study 3**
Scope	26.90%	25.69%	25.82%
Procurement	14.53%	15.88%	17.08%
Cost/Schedule	8.990%	9.360%	10.92%

Again, the results of Table 6.31 show a reasonable agreement between the model results and the validation results, thus justifying the adequacy of the AHP model.

Based on the overall perspective of the respondents from case studies 2 and 3 which were employed for validation, the priorities by alternatives were calculated for selecting the most suitable revamping method. The results obtained are presented in Tables 6.32 and 6.33 and Figures 6.16 and 6.17.

Table 6.32 Geometric Mean Priorities by alternative using validation data from Case study 2

Crit./Alt.	Lean	APM
Engineering	38.72	12.22
Scope	19.87	5.83
Procurement	11.74	6.13
Cost/Schedule	7.11	2.26
Prefab/Construction	18.25	5.18
Risk	12.91	3.52
Human Resources	5.34	1.66
Site Installation	12.66	4.45
HSEQ	9.70	3.47
Integration	2.96	0.99
Pre-com/ Commissioning	6.08	2.44
Knowledge	4.67	2.03
Stakeholder	1.41	0.41

Table 6.33 Geometric Mean Priorities by alternative using validation data from Case study 3

Crit./Alt.	Lean	APM
Engineering	43.62	10.20
Scope	21.55	4.27
Procurement	13.47	3.61
Cost/Schedule	8.60	2.33
Prefab/Construction	16.09	4.89
Risk	11.20	3.67
Human Resources	4.90	1.21
Site Installation	12.23	2.98
HSEQ	9.17	2.25
Integration	3.05	0.73
Pre-com/ Commissioning	8.06	1.94
Knowledge	5.23	1.31
Stakeholder	2.83	0.63

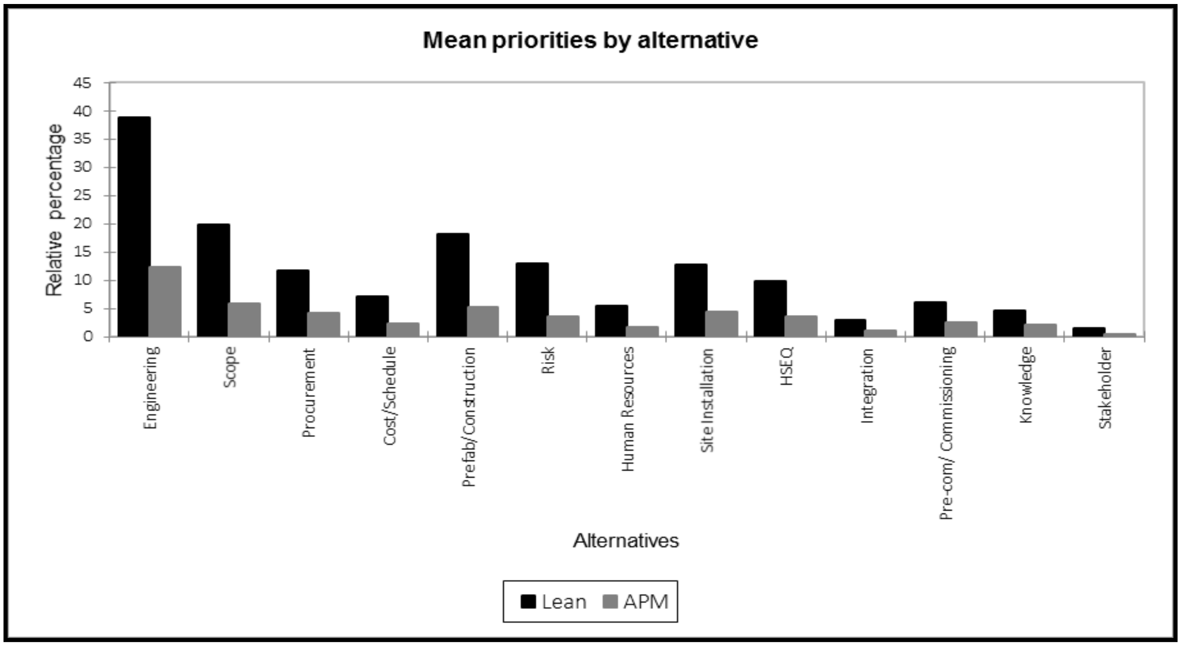


FIGURE 6.16 Geometric Mean Priorities by alternative using validation data from Case study 2

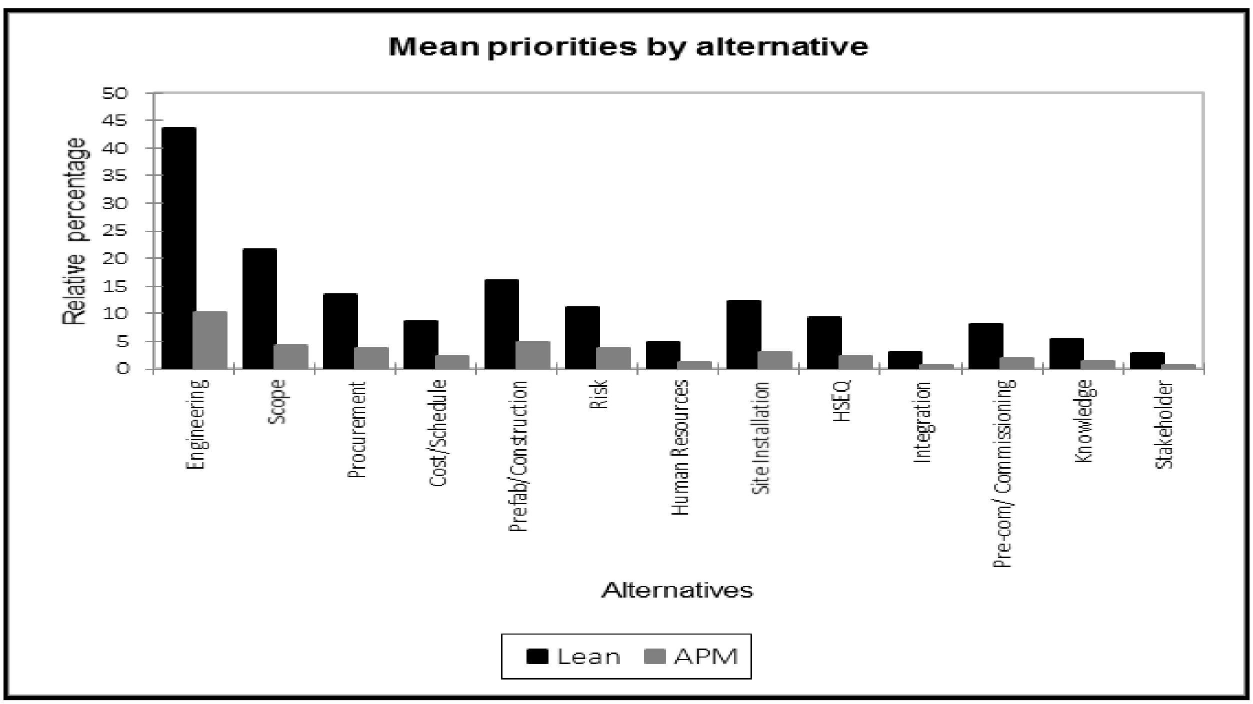


FIGURE 6.17 Geometric Mean Priorities by alternative using validation data from Case study 3

To select the most suitable alternative method amongst the two methods, the sum of the calculated priorities by alternative was obtained using the validation data and the alternative with the highest mean sum was judged to be the best alternative.

From the computation, the Lean method had a total score of 151.4127 as against the APM method with a total score of 48.5873. Hence, the Lean method was selected as the best revamping method based on the validation data from case study 2. Using the validation data from case study 3, the Lean method had a total score of 159.9935 as against the APM method with a total score of 40.00647. Hence, the Lean method was selected as the best revamping method based on the validation data from case study 3. A comparison of the model results and the validation result are presented in Table 6.34.

Table 6.34 Comparison of model and validation result base on the selection of best alternative method

Alternatives	**Model Result**	**Validation Results**	
	Case study 1	**Case study 2**	**Case study 3**
Lean Method	160.090%	151.4127%	159.9935%
APM	39.910%	48.5873%	40.00647%

To further support the selection of the Lean method over of the APM method, a critical analysis of the view of some of the respondents in case studies 2 and 3 was conducted and the results obtained from each rating are presented as follows.

6.11 Results Obtained from the Rating of Respondent 1: from Case studies 2 and 3

The priorities of criterion based on the rating of respondent 1 are presented in Tables 6.35 and 6.36

Table 6.35 Priorities by criterion based on Respondent 1 (Case study 2)

Criteria	%
Engineering	57.23
Prefab/Construction	21.71
Site Installation	15.94
Pre-com/ Commissioning	5.12

CR = 0.424; CI = 47.1%

Table 6.36 Priorities by criterion based on Respondent 1 (Case study 3)

Criteria	%
Engineering	37.06
Prefab/Construction	16.59
Site Installation	23.17
Pre-com/ Commissioning	23.17

CR = 0.144; CI = 16.05%

With consistency ratios (CR) of 0.424 and 0.144, which are less than 10%, it was concluded that the comparison table generated by respondent 1 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 1. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of Engineering were calculated based on the rating of respondent 1 and are presented in Tables 6.37 and 6.38

Table 6.37 Priorities by sub-criterion of Engineering based on Respondent 1 (Case study 2)

Engineering	%
Scope	32.83
Procurement	16.39
Cost/Schedule	8.01

CR = 0.069; CI = 11.83%

Table 6.38 Priorities by sub-criterion of Engineering based on Respondent 1 (Case study 3)

Engineering	%
Scope	18.18
Procurement	11.56
Cost/Schedule	7.32

CR = 0.027; CI =6.63%

With consistency ratios (CR) of 0.069 and 0.027, which are less than 10%, it was concluded that the comparison table generated by respondent 1 is also valid. It was again observed based on the rating of respondent 1 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 32.83% and 18.18%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 1 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 1 are presented in Table 6.39 and Figures 6.18 and 6.19.

Table 6.39 Priorities by alternative based on Respondent 1 (Case study 2)

Crit./Alt.	Lean	APM	CR	CI
Engineering	41.56	15.67	0.00	0.00
Scope	24.62	8.21	0.00	0.00
Procurement	10.93	5.46	0.00	0.00
Cost/Schedule	6.01	2.00	0.00	0.00
Prefab/Construction	15.38	6.33	0.00	0.00
Risk	8.14	2.71	0.00	0.00
Human Resources	7.24	3.62	0.00	0.00
Site Installation	8.85	7.08	0.00	0.00
HSEQ	5.31	5.31	0.00	0.00
Integration	3.54	1.77	0.00	0.00
Pre-com/ Commissioning	2.67	2.45	0.00	0.00
Knowledge	2.24	2.24	0.00	0.00
Stakeholder	0.43	0.21	0.00	0.00

Table 6.40 Priorities by alternative based on Respondent 1 (Case study 3)

Crit./Alt.	Lean	APM	CR	CI
Engineering	31.90	5.16	0.00	0.00
Scope	15.58	2.60	0.00	0.00
Procurement	9.91	1.65	0.00	0.00
Cost/Schedule	6.41	0.92	0.00	0.00
Prefab/Construction	14.37	2.22	0.00	0.00
Risk	7.26	1.04	0.00	0.00
Human Resources	7.11	1.19	0.00	0.00
Site Installation	20.23	2.94	0.00	0.00
HSEQ	18.25	2.61	0.00	0.00
Integration	1.99	0.33	0.00	0.00
Pre-com/ Commissioning	19.86	3.31	0.00	0.00
Knowledge	13.24	2.21	0.00	0.00
Stakeholder	6.62	1.10	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 1 is valid. From the computation, the Lean method had a total score of 136.9150 and 172.7313 as against the APM method with a total score of 63.0850 and 27.2687 for case studies 2 and 3. Hence, the Lean method was selected as the best revamping method according to respondent 1.

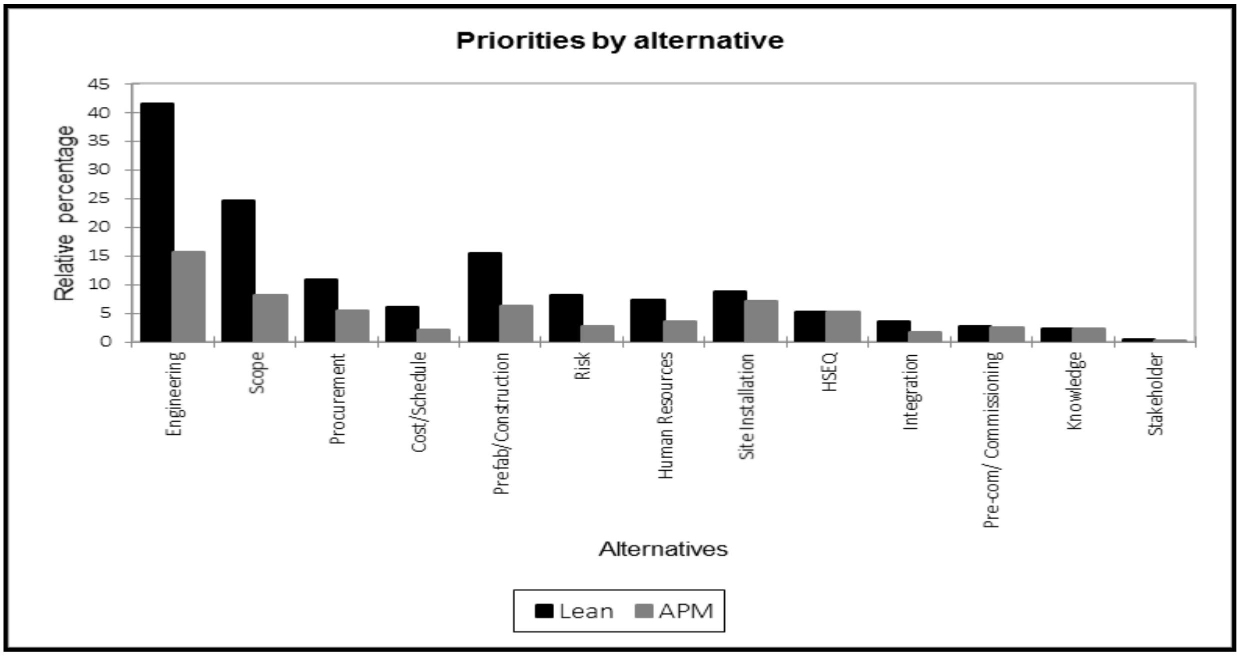


FIGURE 6.18 Priorities by alternative according to respondent 1 (Case study 2)

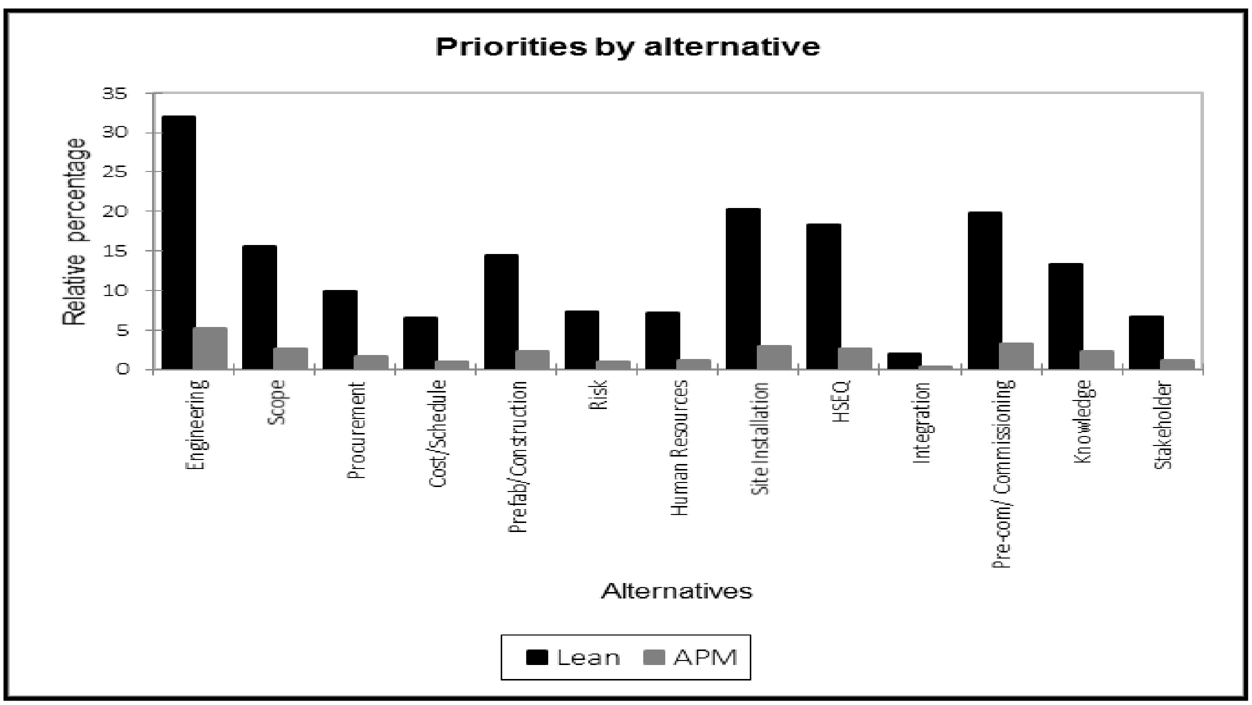


FIGURE 6.19 Priorities by alternative according to respondent 1 (Case study 3)

6.12 Results Obtained from the Rating of Respondent 2: from Case study 2 and 3

The priorities of criterion based on the rating of respondent 2 are presented in Table 6.41 and 6.42

Table 6.41 Priorities by criterion based on Respondent 2 (Case study 2)

Criteria	%
Engineering	55.60
Prefab/Construction	23.64
Site Installation	15.65
Pre-com/ Commissioning	5.11

CR = 0.441; CI = 49.01%

Table 6.42 Priorities by criterion based on Respondent 2 (Case study 3)

Criteria	%
Engineering	38.86
Prefab/Construction	31.11
Site Installation	15.31
Pre-com/ Commissioning	14.73

CR = 0.393; CI = 43.65%

With consistency ratios (CR) of 0.441 and 0.393, which are less than 10%, it was concluded that the comparison table generated by respondent 2 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 2. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 2 and are presented in Table 6.43 and 6.44.

Table 6.43 Priorities by sub-criterion of Engineering based on Respondent 2 (Case study 2)

Engineering	%
Scope	28.63
Procurement	17.05

Cost/Schedule	9.92

CR = 0.189; CI = 32.62%

Table 6.44 Priorities by sub-criterion of Engineering based on Respondent 1 (Case study 3)

Engineering	%
Scope	19.06
Procurement	12.12
Cost/Schedule	7.68

CR = 0.027; CI =6.63%

With consistency ratios (CR) of 0.189 and 0.027, which are less than 10%, it was concluded that the comparison table generated by respondent 2 is also valid. It was again observed based on the rating of respondent 2 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with a calculated mean priority of 28.63% and 19.06%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 2 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 2 are presented in Tables 6.45, 6.46 and Figure 6.20

Table 6.45 Priorities by alternative based on Respondent 2 (Case study 2)

Crit./Alt.	Lean	APM	CR	CI
Engineering	48.52	7.09	0.00	0.00
Scope	24.54	4.09	0.00	0.00
Procurement	15.16	1.89	0.00	0.00
Cost/Schedule	8.82	1.10	0.00	0.00
Prefab/Construction	20.26	3.38	0.00	0.00
Risk	13.51	2.25	0.00	0.00
Human Resources	6.75	1.13	0.00	0.00
Site Installation	13.60	2.05	0.00	0.00
HSEQ	9.13	1.30	0.00	0.00

Integration	4.47	0.75	0.00	0.00
Pre-com/ Commissioning	4.38	0.73	0.00	0.00
Knowledge	3.28	0.55	0.00	0.00
Stakeholder	1.09	0.18	0.00	0.00

Table 6.46 Priorities by alternative based on Respondent 2 (Case study 3)

Crit./Alt.	Lean	APM	CR	CI
Engineering	28.66	10.20	0.00	0.00
Scope	15.88	3.18	0.00	0.00
Procurement	6.06	6.06	0.00	0.00
Cost/Schedule	6.72	0.96	0.00	0.00
Prefab/Construction	21.60	9.50	0.00	0.00
Risk	17.28	8.64	0.00	0.00
Human Resources	4.32	0.86	0.00	0.00
Site Installation	11.05	4.25	0.00	0.00
HSEQ	6.80	3.40	0.00	0.00
Integration	4.25	0.85	0.00	0.00
Pre-com/ Commissioning	9.82	4.91	0.00	0.00
Knowledge	3.68	3.68	0.00	0.00
Stakeholder	6.14	1.23	0.00	0.00

With a consistency ratio (CR) of 0.00, which are less than 10%, it was concluded that the comparison table generated by respondent 2 is valid. From the computation, the Lean method had a total score of 173.5136 and 142.2754 as against the APM method with a total score of 26.4864 and 57.7247 for case studies 2 and 3. Hence, the Lean method was selected as the best revamping method according to respondent 2.

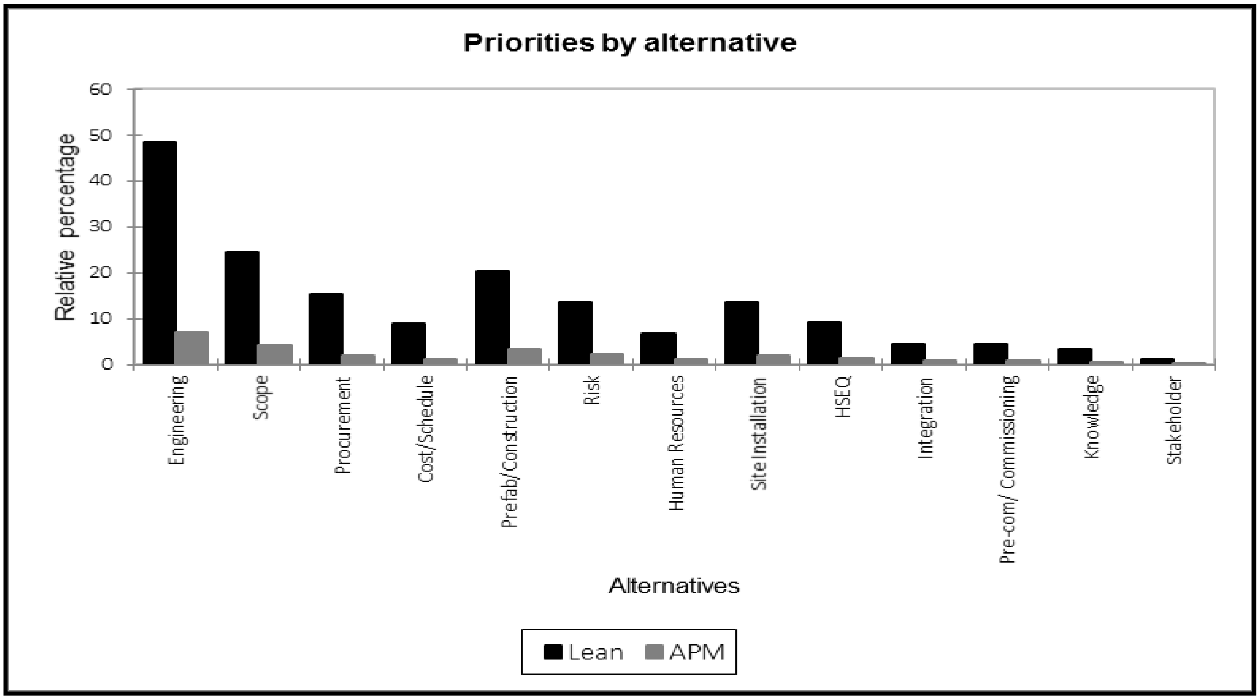


FIGURE 6.20 Priorities by alternative according to respondent 2 (Case study 2)

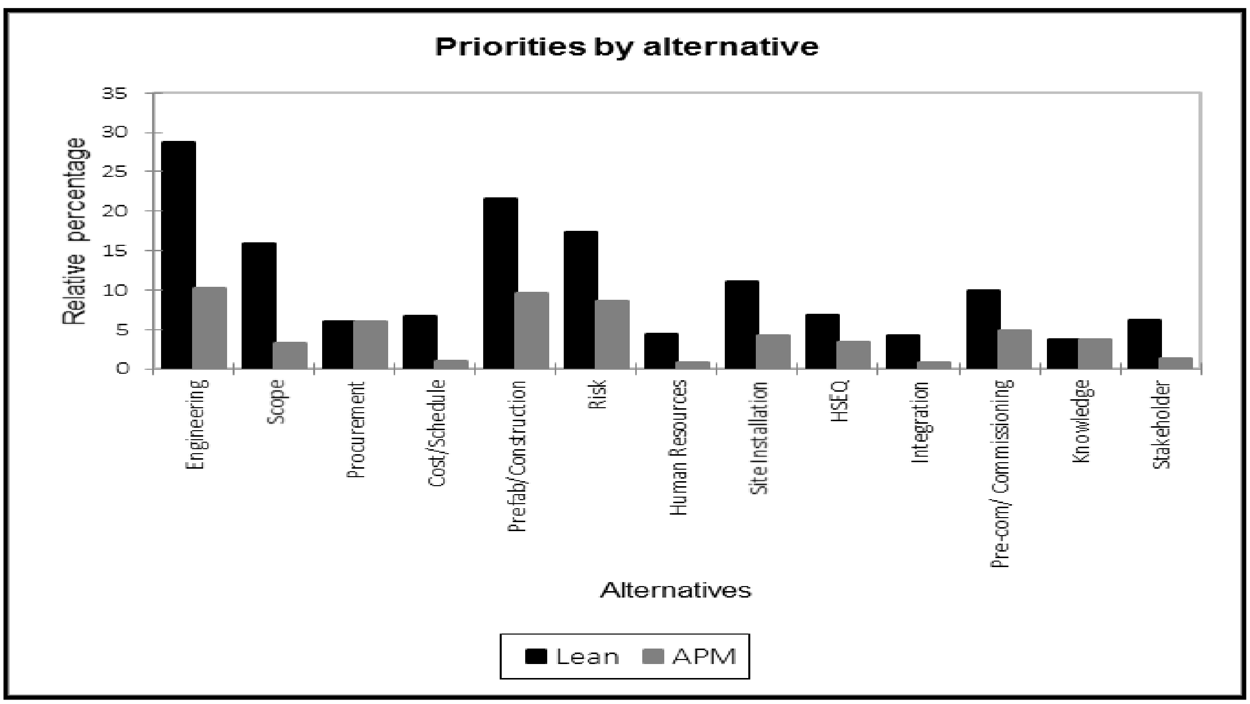


FIGURE 6.21 Priorities by alternative according to respondent 2 (Case study 3)

6.13 Results Obtained from the Rating of Respondent 3: from Case study 2 and 3

The priorities of criterion based on the rating of respondent 3 are presented in Tables 6.47 and 6.48

Table 6.47 Priorities by criterion based on Respondent 3 (Case study 2)

Criteria	%
Engineering	57.83
Prefab/Construction	23.10
Site Installation	14.49
Pre-com/ Commissioning	4.57

CR = 0.479; CI = 53.18%

Table 6.48 Priorities by criterion based on Respondent 3 (Case study 3)

Criteria	%
Engineering	67.12
Prefab/Construction	15.29
Site Installation	13.98
Pre-com/ Commissioning	3.61

CR = 0.240; CI = 26.7%

With consistency ratios (CR) of 0.479 and 0.290, which are less than 10%, it was concluded that the comparison table generated by respondent 3 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 3. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 3 and are presented in Tables 6.49 and 6.50

Table 6.49 Priorities by sub-criterion of Engineering based on Respondent 3 (Case study 2)

Engineering	%
Scope	28.37
Procurement	18.04
Cost/Schedule	11.43

CR = 0.027; CI =6.63%

Table 6.50 Priorities by sub-criterion of Engineering based on Respondent 3 (Case study 3)

Engineering	%
Scope	38.36
Procurement	19.18
Cost/Schedule	9.59

CR = 0; CI = 0%

With consistency ratios (CR) of 0.027 and 0.00, which are less than 10%, it was concluded that the comparison table generated by respondent 3 is also valid. It was again observed based on the rating of respondent 3 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 28.37% and 38.36%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 3 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 3 are presented in Tables 6.51 and 6.52 and Figure 6.22

Table 6.51 Priorities by alternative based on Respondent 3 (Case study 2)

Crit./Alt.	Lean	APM	CR	CI
Engineering	48.58	9.25	0.00	0.00
Scope	25.53	2.84	0.00	0.00
Procurement	13.53	4.51	0.00	0.00
Cost/Schedule	9.52	1.90	0.00	0.00
Prefab/Construction	14.44	8.66	0.00	0.00
Risk	5.78	5.78	0.00	0.00
Human Resources	8.66	2.89	0.00	0.00
Site Installation	12.66	1.83	0.00	0.00
HSEQ	11.45	1.43	0.00	0.00
Integration	1.21	0.40	0.00	0.00
Pre-com/ Commissioning	3.18	1.40	0.00	0.00
Knowledge	2.03	1.02	0.00	0.00
Stakeholder	1.14	0.38	0.00	0.00

Table 6.52 Priorities by alternative based on Respondent 3 (Case study 3)

Crit./Alt.	Lean	APM	CR	CI
Engineering	57.61	9.51	0.00	0.00
Scope	31.96	6.39	0.00	0.00
Procurement	17.26	1.92	0.00	0.00
Cost/Schedule	8.39	1.20	0.00	0.00
Prefab/Construction	13.52	1.77	0.00	0.00
Risk	9.06	1.13	0.00	0.00
Human Resources	4.46	0.64	0.00	0.00
Site Installation	12.52	1.46	0.00	0.00
HSEQ	10.48	1.16	0.00	0.00
Integration	2.04	0.29	0.00	0.00
Pre-com/ Commissioning	3.16	0.45	0.00	0.00
Knowledge	2.63	0.38	0.00	0.00
Stakeholder	0.53	0.08	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 3 is valid. From the computation, the Lean method had a total score of 157.7092 and 173.6300 as against the APM method with a total score of 42.2908 and 26.3700 for case studies 2 and 3. Hence, the Lean method was selected as the best revamping method according to respondent 3.

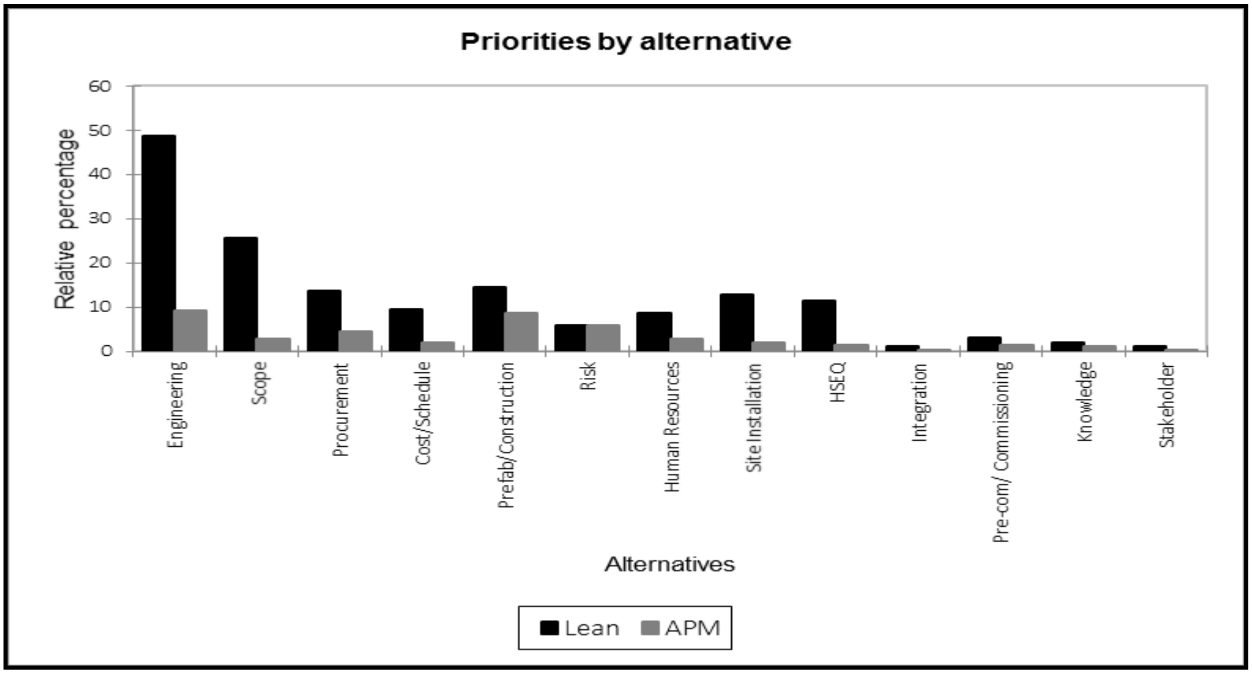


FIGURE 6.22 Priorities by alternative according to respondent 3 (Case study 2)

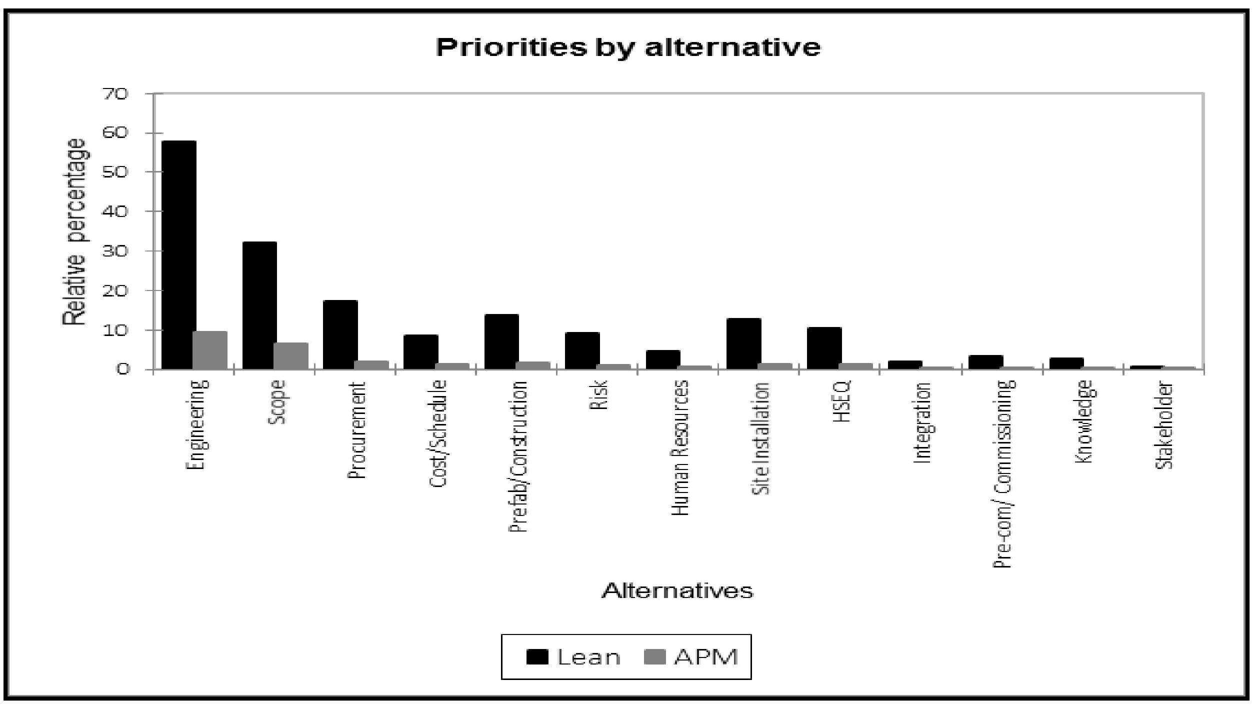


FIGURE 6.23 Priorities by alternative according to respondent 3 (Case study 3)

6.14 Results Obtained from the Rating of Respondent 4: from Case study 2 and 3

The priorities of criterion based on the rating of respondent 4 are presented in Table 6.53 and 6.54.

Table 6.53 Priorities by criterion based on Respondent 4 (Case study 2)

Criteria	%
Engineering	56.45
Prefab/Construction	22.23
Site Installation	16.11
Pre-com/ Commissioning	5.22

CR = 0.472; CI = 52.46%

Table 6.54 Priorities by criterion based on Respondent 4 (Case study 3)

Criteria	%
Engineering	56.59
Prefab/Construction	22.30
Site Installation	15.98
Pre-com/ Commissioning	5.12

CR = 0.395; CI = 43.93%

With consistency ratios (CR) of 0.472 and 0.395, which are less than 10%, it was concluded that the comparison table generated by respondent 4 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 4. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 4 and are presented in Tables 6.55 and 6.56

Table 6.55 Priorities by sub-criterion of Engineering based on Respondent 4 (Case study 2)

Engineering	%
Scope	26.97
Procurement	19.76
Cost/Schedule	9.72

CR = 0.068; CI = 11.76%

Table 6.56 Priorities by sub-criterion of Engineering based on Respondent 4 (Case study 3)

Engineering	%
Scope	27.76
Procurement	17.65
Cost/Schedule	11.18

CR = 0.027; CI =6.63%

With consistency ratios (CR) of 0.068 and 0.027, which are less than 10%, it was concluded that the comparison table generated by respondent 4 is also valid. It was again observed based on the rating of respondent 4 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 26.97% and 27.76%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 4 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 4 are presented in Tables 6.57, 6.58 and Figures 6.24 and 6.35.

Table 6.57 Priorities by alternative based on Respondent 4 (Case study 2)

Crit./Alt.	Lean	APM	CR	CI
Engineering	41.26	15.19	0.00	0.00
Scope	21.58	5.39	0.00	0.00
Procurement	14.82	4.94	0.00	0.00
Cost/Schedule	4.86	4.86	0.00	0.00
Prefab/Construction	18.52	3.70	0.00	0.00
Risk	13.89	2.78	0.00	0.00
Human Resources	4.63	0.93	0.00	0.00
Site Installation	8.65	7.46	0.00	0.00
HSEQ	7.16	7.16	0.00	0.00
Integration	1.49	0.30	0.00	0.00
Pre-com/ Commissioning	4.02	1.20	0.00	0.00

Knowledge	2.93	0.98	0.00	0.00
Stakeholder	1.09	0.22	0.00	0.00

Table 6.58 Priorities by alternative based on Respondent 4 (Case study 3)

Crit./Alt.	Lean	APM	CR	CI
Engineering	49.77	6.83	0.00	0.00
Scope	24.29	3.47	0.00	0.00
Procurement	15.69	1.96	0.00	0.00
Cost/Schedule	9.79	1.40	0.00	0.00
Prefab/Construction	19.51	2.79	0.00	0.00
Risk	13.01	1.86	0.00	0.00
Human Resources	6.50	0.93	0.00	0.00
Site Installation	13.98	2.00	0.00	0.00
HSEQ	9.32	1.33	0.00	0.00
Integration	4.66	0.67	0.00	0.00
Pre-com/ Commissioning	4.48	0.64	0.00	0.00
Knowledge	2.99	0.43	0.00	0.00
Stakeholder	1.49	0.21	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 4 is valid. From the computation, the Lean method had a total score of 144.900 and 175.49 as against the APM method with a total score of 55.10 and 24.510 for case studies 2 and 3. Hence, the Lean method was selected as the best revamping method according to respondent 4.

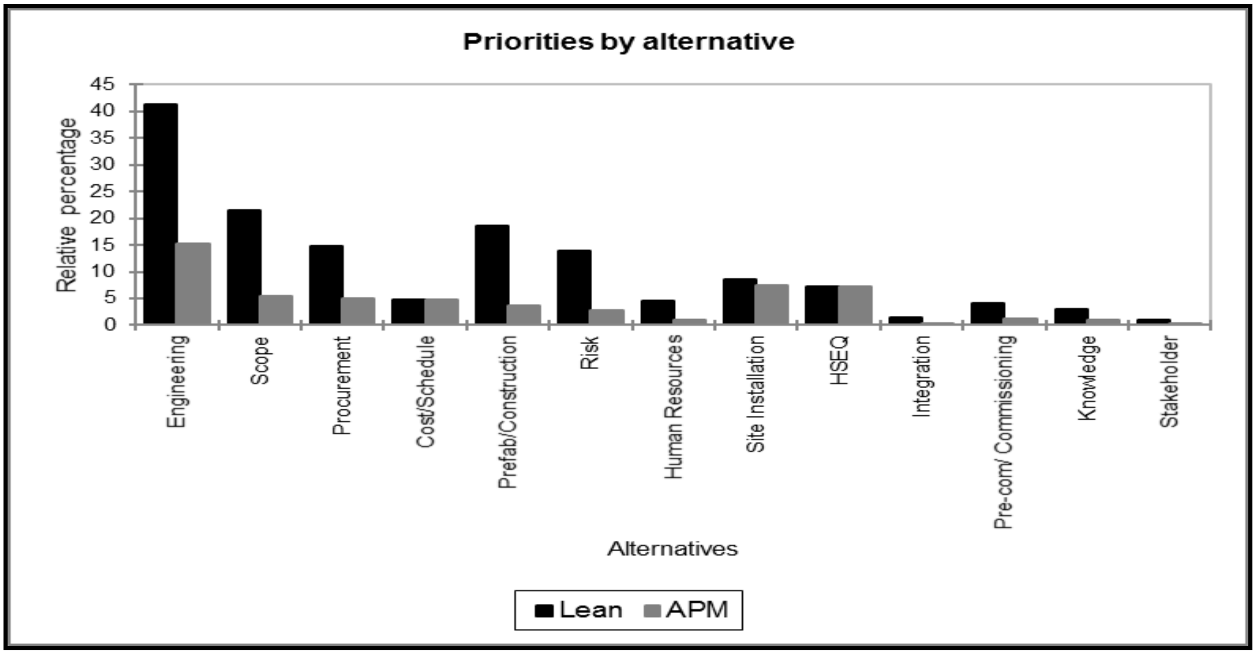


FIGURE 6.24 Priorities by alternative according to respondent 4 (Case study 2)

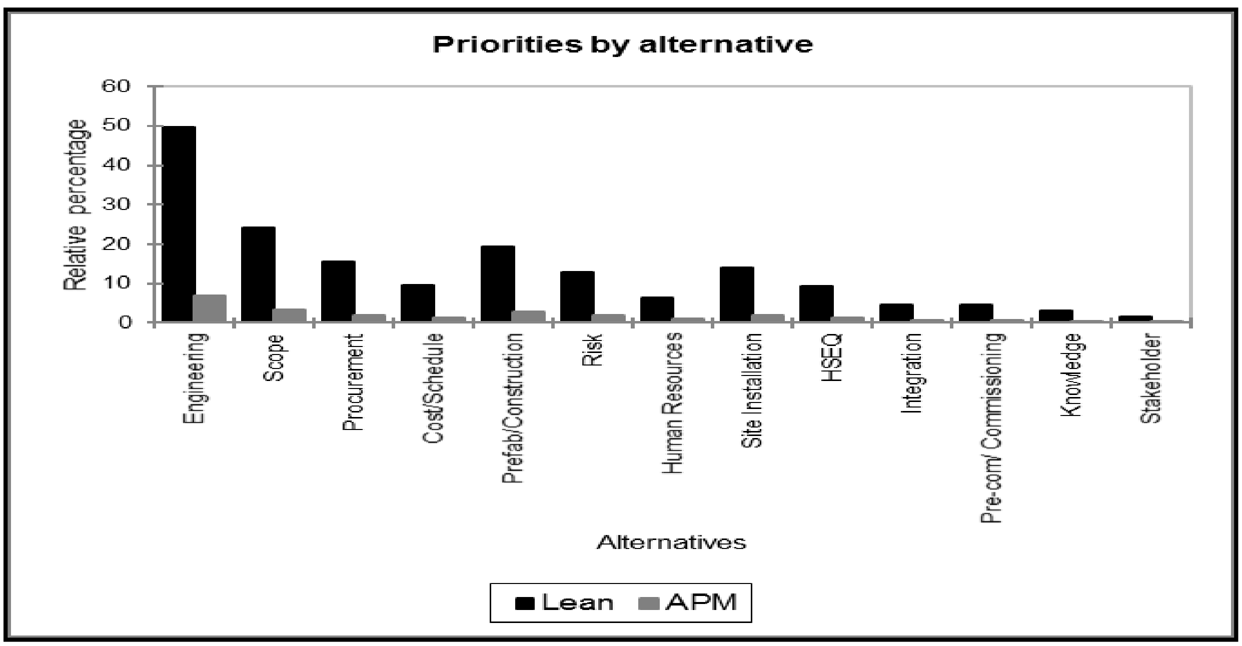


FIGURE 6.25 Priorities by alternative according to respondent 4 (Case study 3)

6.15 Results Obtained from the Rating of Respondent 5: from Case study 2 and 3

The priorities of criterion based on the rating of respondent 5 are presented in Tables 6.59 and 6.60

Table 6.59 Priorities by criterion based on Respondent 5 (Case study 2)

Criteria	%
Engineering	55.60
Prefab/Construction	23.64
Site Installation	15.65
Pre-com/ Commissioning	5.11

CR = 0.441; CI = 49.01%

Table 6.60 Priorities by criterion based on Respondent 4 (Case study 3)

Criteria	%
Engineering	58.70
Prefab/Construction	22.00
Site Installation	14.71
Pre-com/ Commissioning	4.59

CR = 0.434; CI = 48.22%

With consistency ratios (CR) of 0.441 and 0.434, which are less than 10%, it was concluded that the comparison table generated by respondent 5 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 5. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of Engineering were calculated based on the rating of respondent 5 and are presented in Tables 6.61 and 6.62.

Table 6.61 Priorities by sub-criterion of Engineering based on Respondent 5 (Case study 2)

Engineering	%
Scope	26.57
Procurement	19.46
Cost/Schedule	9.58

CR = 0.068; CI = 11.76%

Table 6.62 Priorities by sub-criterion of Engineering based on Respondent 5 (Case study 3)

Engineering	%
Scope	19.57
Procurement	19.57
Cost/Schedule	19.57

CR = 0; CI = 0%

With consistency ratios (CR) of 0.068 and 0.00, which are less than 10%, it was concluded that the comparison table generated by respondent 5 is also valid. It was again observed based on the rating of respondent 5 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 26.57% and 19.57%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 5 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 5 are presented in Tables 6.63 and 6.64, and Figures 6.26 and 6.27.

Table 6.63 Priorities by alternative based on Respondent 5 (Case study 2)

Crit./Alt.	Lean	APM	CR	CI
Engineering	48.81	6.80	0.00	0.00
Scope	23.61	2.95	0.00	0.00
Procurement	16.68	2.78	0.00	0.00
Cost/Schedule	8.51	1.06	0.00	0.00
Prefab/Construction	19.75	3.88	0.00	0.00
Risk	17.73	3.55	0.00	0.00
Human Resources	2.03	0.34	0.00	0.00
Site Installation	13.67	1.98	0.00	0.00
HSEQ	12.33	1.76	0.00	0.00
Integration	1.34	0.22	0.00	0.00

Pre-com/ Commissioning	4.57	0.53	0.00	0.00
Knowledge	6.14	0.46	0.00	0.00
Stakeholder	0.44	0.07	0.00	0.00

Table 6.64 Priorities by alternative based on Respondent 5 (Case study 3)

Crit./Alt.	Lean	APM	CR	CI
Engineering	29.35	29.35	0.00	0.00
Scope	9.78	9.78	0.00	0.00
Procurement	9.78	9.78	0.00	0.00
Cost/Schedule	9.78	9.78	0.00	0.00
Prefab/Construction	11.00	11.00	0.00	0.00
Risk	7.33	7.33	0.00	0.00
Human Resources	3.67	3.67	0.00	0.00
Site Installation	7.36	7.36	0.00	0.00
HSEQ	5.52	5.52	0.00	0.00
Integration	1.84	1.84	0.00	0.00
Pre-com/ Commissioning	2.29	2.29	0.00	0.00
Knowledge	1.72	1.72	0.00	0.00
Stakeholder	0.57	0.57	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 5 is valid. From the computation, the Lean method had a total score of 173.61 and 100.00 as against the APM method with a total score of 26.39 and 100.00 for case studies 2 and 3. Hence, the Lean method was selected as the best revamping method according to respondent 5.

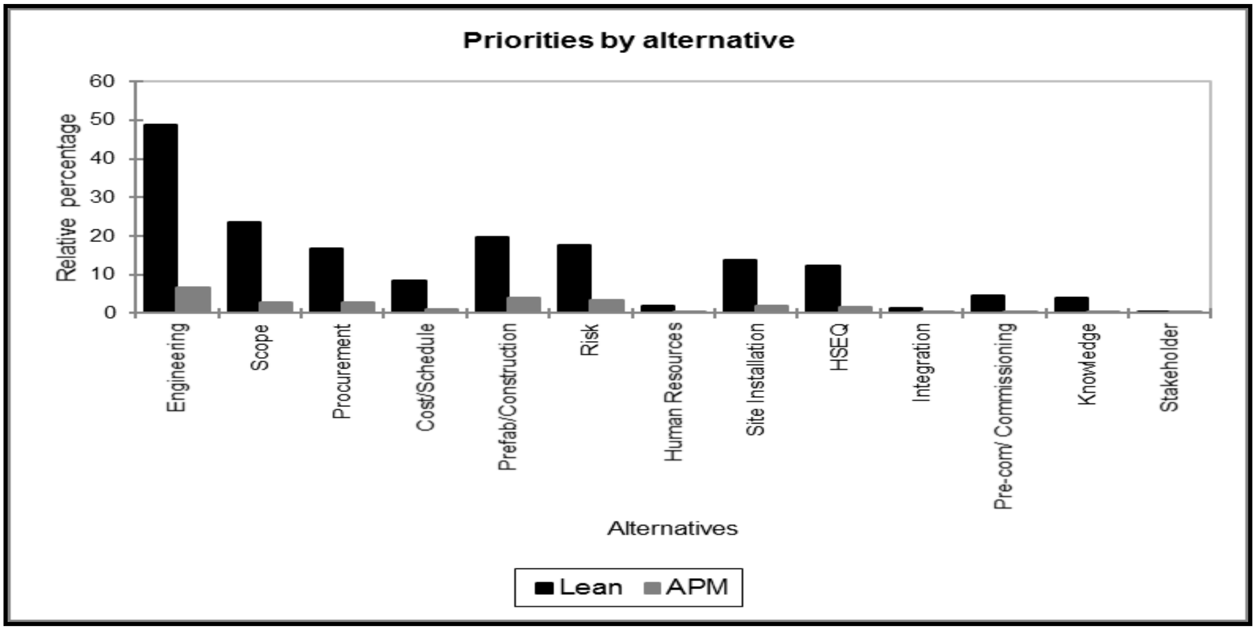


FIGURE 6.26 Priorities by alternative according to respondent 5 (Case study 2)

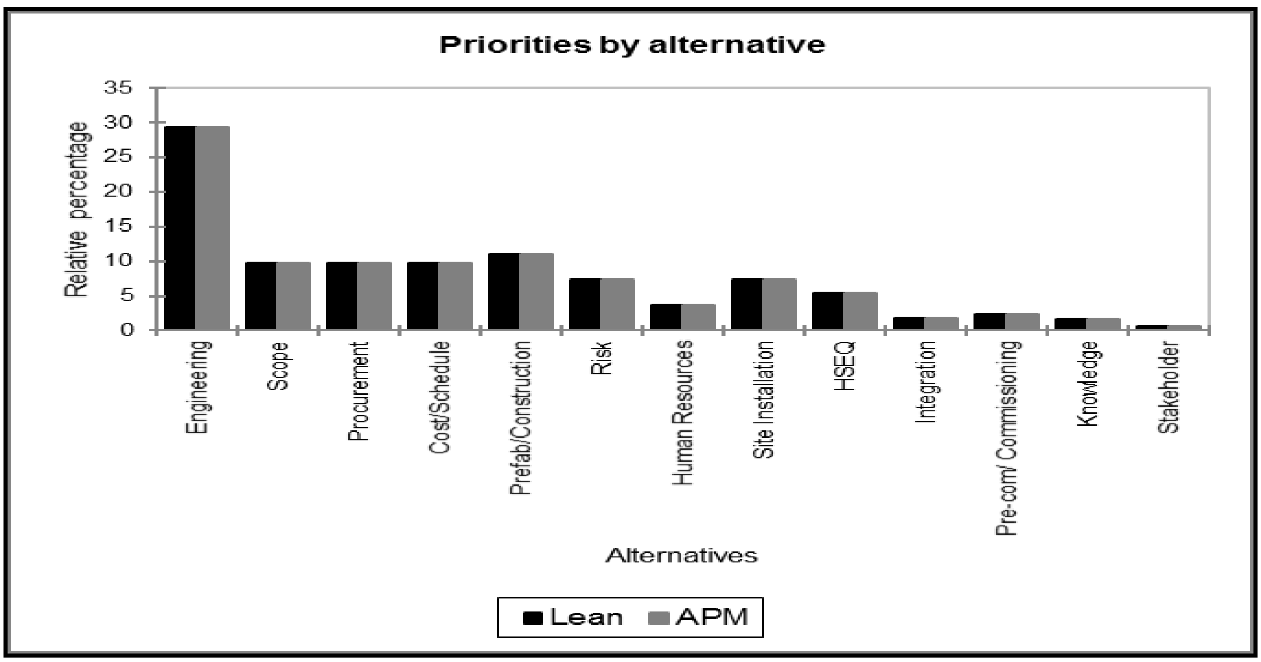


FIGURE 6.27 Priorities by alternative according to respondent 5 (Case study 3)

6.16 Model Testing

To test the outcome of the validated AHP model and further justify the selection of the Lean method ahead of the APM method, data from case studies 4 and 5 were employed as testing data and the results obtained are presented as follows.

The priorities for the four basic selected criterions were calculated based on AHP using the testing data and the results are presented in Tables 6.65 and 6.66 respectively

Table 6.65 Priorities by criterion using the testing data from Case study 4

Criteria	%
Engineering	59.93
Prefab/Construction	27.99
Site Installation	6.15
Pre-com/ Commissioning	5.93

Table 6.66 Priorities by criterion using the testing data from Case study 5

Criteria	%
Engineering	60.11
Prefab/Construction	24.86
Site Installation	9.10
Pre-com/ Commissioning	5.93

Based on the result of Tables 6.65 and6.66, it was observed that engineering is the criterion that mostly impacts the decision-making process of all the respondents in case studies 4 and 5 with a percentage score of 59.93% and 60.11% respectively. This is followed by prefab/construction with 27.99% and 24.86%, and site installation with 6.15% and 9.10% respectively. Pre-com/commissioning had the least influence on the overall decision-making process with 5.93% and 5.93% respectively. A comparison of the model's results, the validation results and the testing results based on the priorities by criterion is presented in Table 6.67

Table 6.67 Comparison of model, validation, and testing results based on Priorities by criterion

Computed Geometric Mean Priorities	Model Result	Validation Results		Testing Results	
	Case study 1	Case study 2	Case study 3	Case study 4	Case study 5
Engineering	50.42%	50.93%	53.82%	59.93%	60.11%
Prefab/Construction	25.56%	23.43%	20.98%	27.99	24.86
Site Installation	14.40%	17.11%	15.20%	6.15	9.10
Pre-com/ Commissioning	9.62%	8.52%	10.00%	5.93	5.93

The results of Table 6.67 show a reasonable agreement between the model results, the validation results, and the testing results, thus justifying the adequacy of the AHP model. A pictorial representation of the calculated priorities by criterion using the testing data is presented in Figures 6.28 and 6.29.

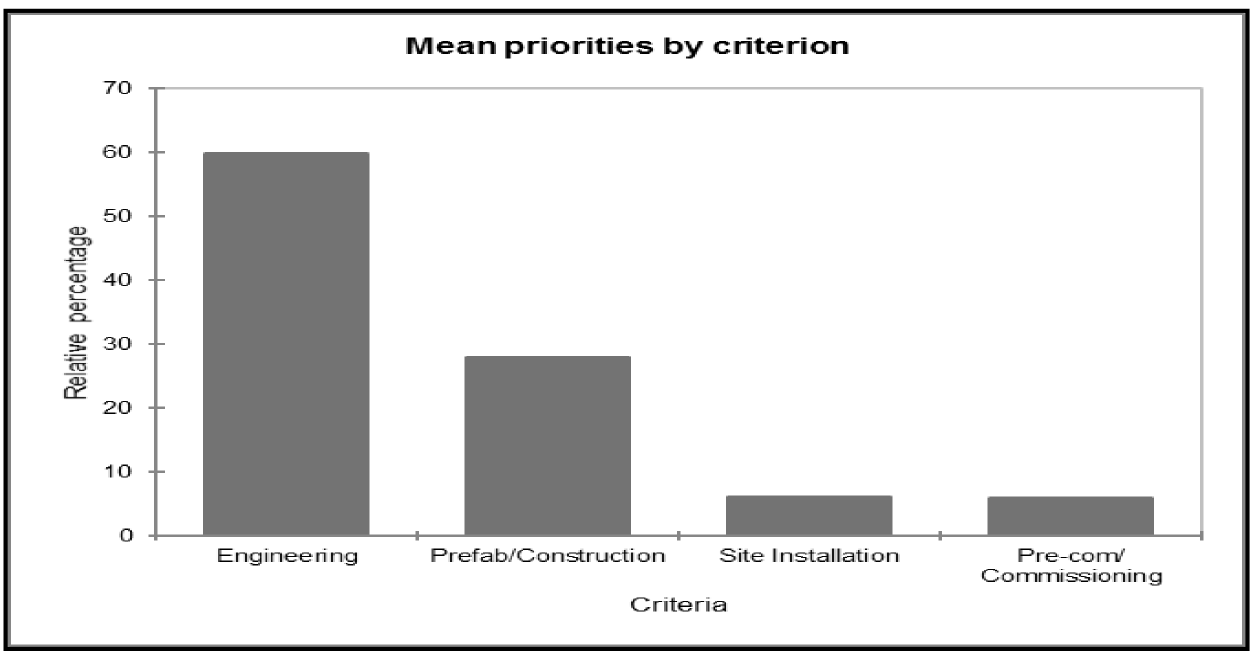


FIGURE 6.28 Geometric Mean Priorities by criterion based on testing data from Case study 4

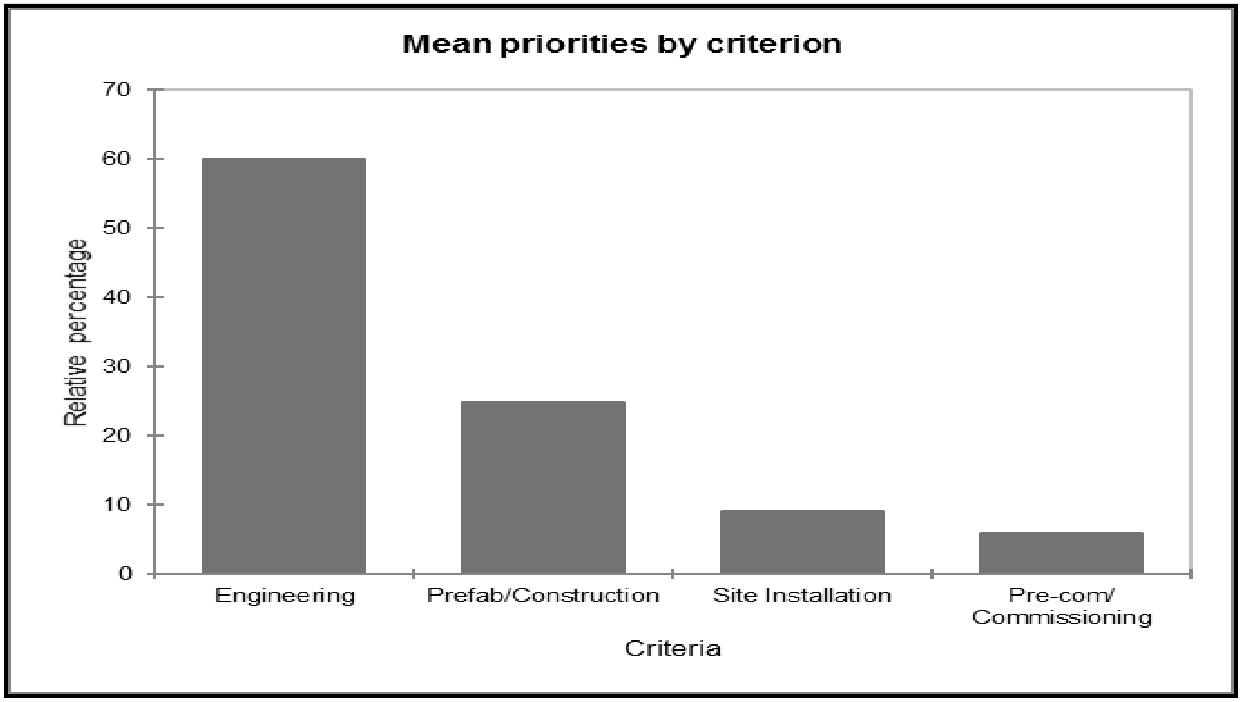


FIGURE 6.29 Geometric mean Priorities by criterion based on testing data from Case study 5

To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated using the testing data from case studies 4 and 5. The results obtained are presented in Tables 6.68 and 6.69, and Figures 6.30 and 6.31

Table 6.68 Geometric Mean Priorities by sub-criterion of Engineering using the testing data from Case study 4

Engineering	%
Scope	29.78
Procurement	17.19
Cost/Schedule	12.95

Table 6.69 Geometric Mean Priorities by sub-criterion of Engineering using the testing data from Case study 5

Engineering		%
Scope	30.09	
Procurement	17.76	
Cost/Schedule	12.26	

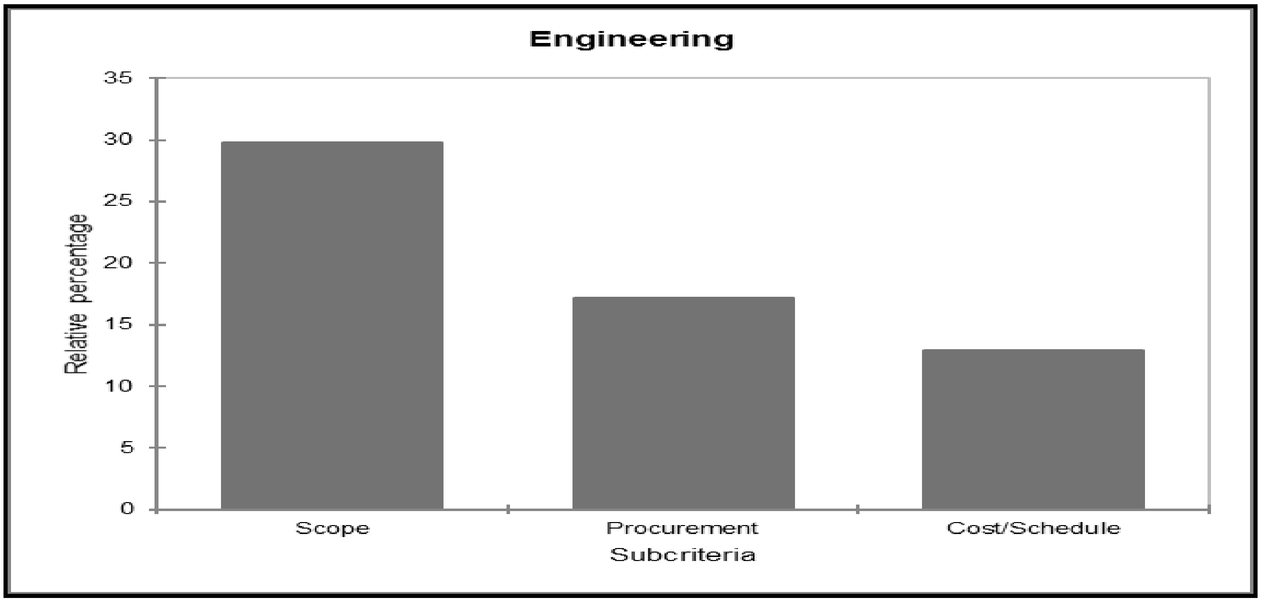


FIGURE 6.30 geometric Mean Priorities by sub-criterion of Engineering using the testing data from Case study 4

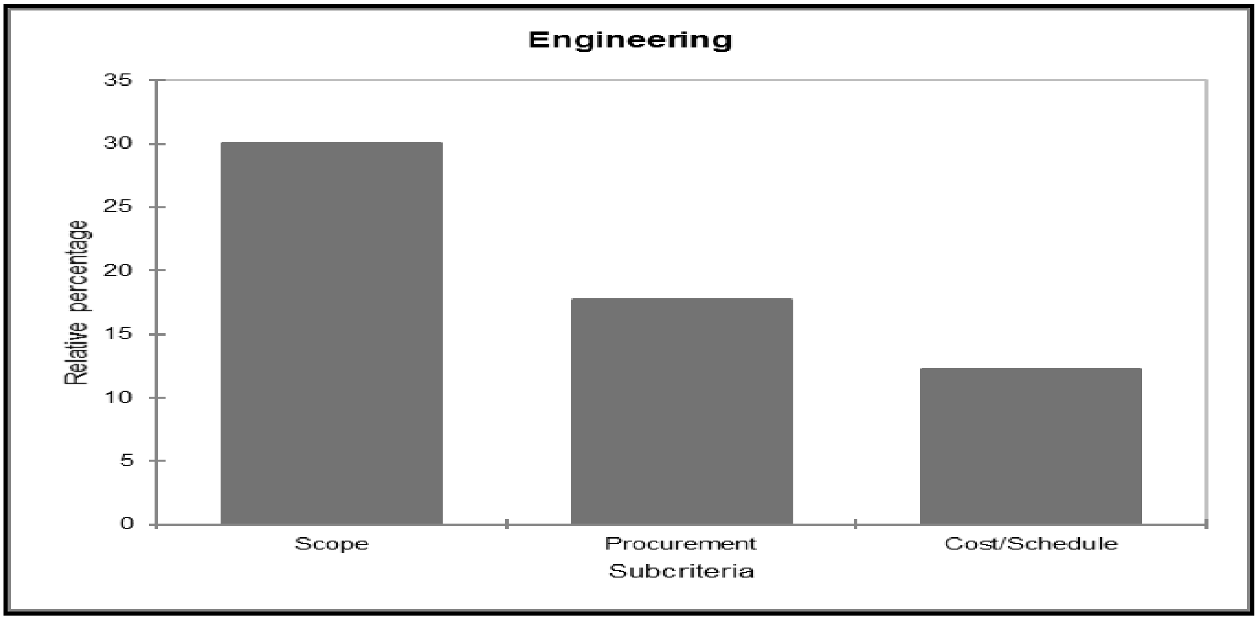


FIGURE 6.31 Geometric Mean Priorities by sub-criterion of Engineering using the testing data from Case study 5

From the results of Tables 6.70 and Figures 6.32 and 6.33, it can be observed that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 29.78% and 30.09%, followed by procurement with 17.19% and 17.16%, followed by cost/schedule with 12.95% and 12.26%. A comparison of the model's results, the validation results and the testing results based on the priorities by sub-criterion of engineering is presented in Table 6.70

Table 6.70 Comparison of model, validation, and testing results based on Priorities by sub-criterion of Engineering

Computed Geometric Mean Priorities	**Model Result**	**Validation Results**		**Testing Results**	
	Company A	**Case study 2**	**Case study 3**	**Case study 4**	**Case study 5**
Scope	26.90%	25.69%	25.82%	29.78%	30.09%
Procurement	14.53%	15.88%	17.08%	17.19%	17.16%
Cost/Schedule	8.990%	9.360%	10.92%	12.95%	12.26%

Again, the results of Table 6.70 show a reasonable agreement between the model results, validation results and testing results, thus justifying the adequacy of the AHP model. Based on the overall perspective of the respondents from case studies 4 and 5, which were employed for testing the AHP model, the priorities by alternatives were calculated for selecting the most suitable revamping method. The results are presented in Tables 6.71 and 6.72, and Figures 6.32 and 6.33

Table 6.71 Geometric Mean Priorities by alternative using testing data from Case study 4

Crit./Alt.	Lean	APM
Engineering	46.99	12.94
Scope	21.75	8.03
Procurement	14.21	2.98
Cost/Schedule	11.03	1.93
Prefab/Construction	22.37	5.62
Risk	15.34	4.05
Human Resources	7.03	1.57
Site Installation	4.86	1.29
HSEQ	3.26	0.93
Integration	1.60	0.36
Pre-com/ Commissioning	4.60	1.34
Knowledge	2.93	0.98
Stakeholder	1.67	0.36

Table 6.72 Geometric Mean Priorities by alternative using testing data from Case study 5

Crit./Alt.	Lean	APM
Engineering	50.93	9.18
Scope	25.71	4.39
Procurement	14.86	2.90
Cost/Schedule	10.36	1.89
Prefab/Construction	19.74	5.12
Risk	13.74	3.83
Human Resources	6.00	1.29
Site Installation	7.86	1.24
HSEQ	5.69	0.83
Integration	2.17	0.41
Pre-com/ Commissioning	4.81	1.12
Knowledge	3.22	0.81
Stakeholder	1.59	0.31

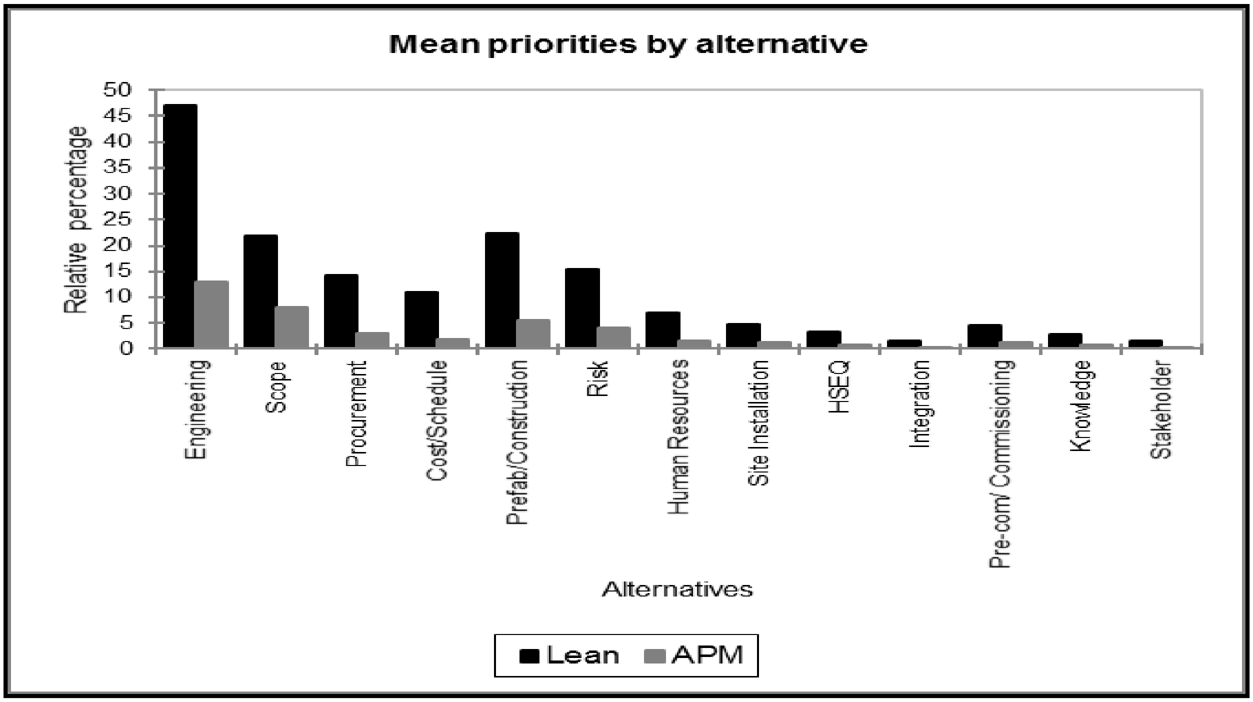


FIGURE 6.32 Geometric Mean Priorities by alternative using testing data from Case study 4

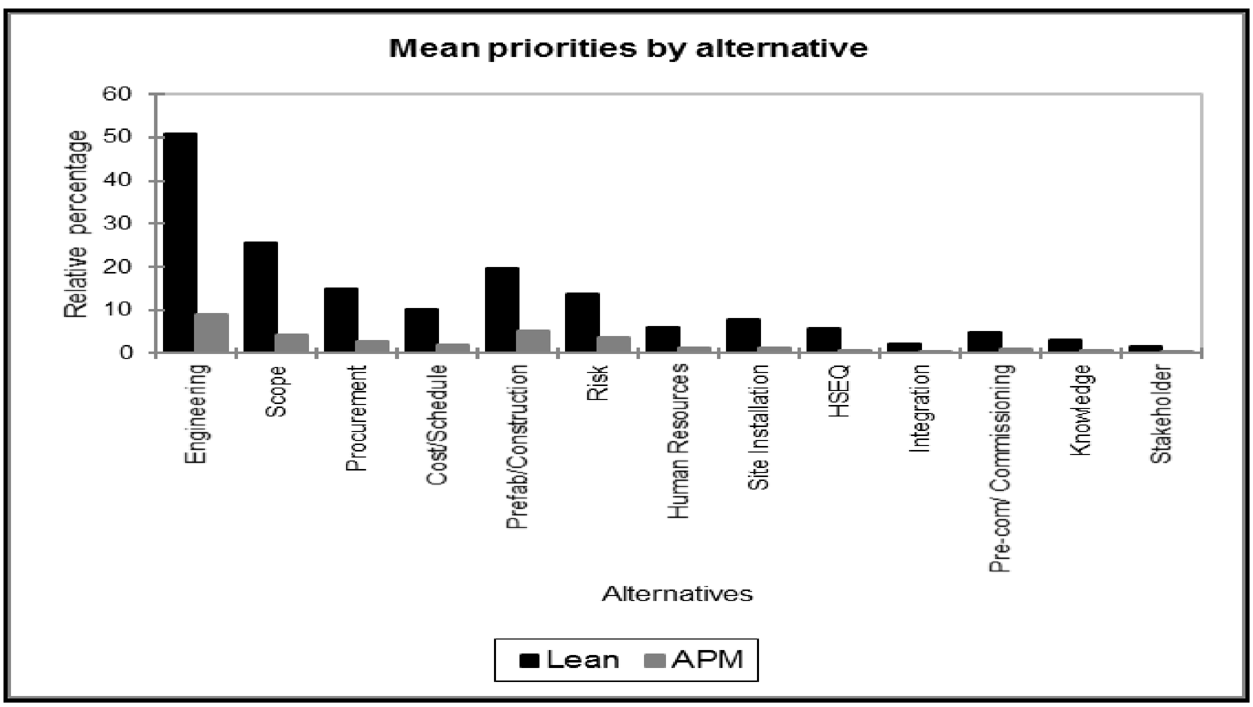


FIGURE 6.33 Geometric Mean Priorities by alternative using testing data from Case study 5

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained using the testing data and the alternative with the highest mean sum was judged to be the best alternative.

From the computation, the Lean method had a total score of 157.64 as against the APM method with a total score of 42.360. Hence, the Lean method was selected as the best revamping method based on the testing data from case study 5. Using the validation data from case study 5, the Lean method had a total score of 166.680 as against the APM method with a total score of 33.320. Hence, the Lean method was selected as the best revamping method based on the testing data from case study 5. A comparison of the model's results, the validation results and the testing results is presented in Table 6.73.

Table 6.73 Comparison of model, validation, and testing results based on the selection of best alternative method

Alternatives	**Model Result**	**Validation Results**		**Testing Results**	
	Case study 1	**Case study 2**	**Case study 3**	**Case study 4**	**Case study 5**
Lean Method	160.090%	151.4127%	159.9935%	157.640%	166.680%
APM	39.910%	48.5873%	40.00647%	42.360%	33.320%

The comparison results presented in Table 6.74 show that the Lean method is a better method for revamping compared to the APM method. To further support the selection of the Lean method ahead of the APM method, a critical analysis of the view of some of the respondents in case studies 4 and 5 was conducted and results obtained from each rating are presented as follows.

6.17 Results Obtained from the Rating of Respondent 1: from Case studies 4 and 5

The priorities of criterion based on the rating of respondent 1 are presented in Tables 6.74a and 6.75

Table 6.74 Priorities by criterion based on Respondent 1 (Case study 4)

Criteria	%
Engineering	63.08
Prefab/Construction	25.69
Site Installation	7.22

Pre-com/ Commissioning	4.01

CR = 0.292; CI = 32.4%

Table 6.75 Priorities by criterion based on Respondent 1 (Case study 5)

Criteria	%
Engineering	62.66
Prefab/Construction	25.35
Site Installation	7.57
Pre-com/ Commissioning	4.41

CR = 0.307; CI = 34.08%

With consistency ratios (CR) of 0.292 and 0.307, which are less than 10%, it was concluded that the comparison table generated by respondent 1 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 1. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 1 and are presented in Tables 6.76 and 6.77.

Table 6.76 Priorities by sub-criterion of Engineering based on Respondent 1 (Case study 4)

Engineering	%
Scope	30.94
Procurement	19.68
Cost/Schedule	12.47

CR = 0.027; CI =6.63%

Table 6.77 Priorities by sub-criterion of Engineering based on Respondent 1 (Case study 5)

Engineering	%
Scope	30.74
Procurement	19.55

Cost/Schedule	12.38
CR = 0.027; CI =6.63%	

With consistency ratios (CR) of 0.027 and 0.027, which are less than 10%, it was concluded that the comparison table generated by respondent 1 is also valid. It was again observed based on the rating of respondent 1 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 30.94% and 30.74%.

To select the most suitable alternative method amongst the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 1 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 1 are presented in Tables 6.78 and 6.79, and Figures 6.34 and 6.35

Table 6.78 Priorities by alternative based on Respondent 1 (Case study 4)

Crit./Alt.	Lean	APM	CR	CI
Engineering	53.60	9.48	0.00	0.00
Scope	26.52	4.42	0.00	0.00
Procurement	16.40	3.28	0.00	0.00
Cost/Schedule	10.69	1.78	0.00	0.00
Prefab/Construction	21.04	4.65	0.00	0.00
Risk	13.70	3.42	0.00	0.00
Human Resources	7.34	1.22	0.00	0.00
Site Installation	6.39	0.83	0.00	0.00
HSEQ	4.33	0.48	0.00	0.00
Integration	2.06	0.34	0.00	0.00
Pre-com/ Commissioning	3.37	0.64	0.00	0.00
Knowledge	2.23	0.45	0.00	0.00
Stakeholder	1.15	0.19	0.00	0.00

Table 6.79 Priorities by alternative based on Respondent 1 (Case study 5)

Crit./Alt.	Lean	APM	CR	CI
Engineering	43.84	18.82	0.00	0.00
Scope	20.49	10.25	0.00	0.00
Procurement	13.03	6.52	0.00	0.00
Cost/Schedule	10.32	2.06	0.00	0.00
Prefab/Construction	16.90	8.45	0.00	0.00
Risk	11.27	5.63	0.00	0.00
Human Resources	5.63	2.82	0.00	0.00
Site Installation	6.23	1.35	0.00	0.00
HSEQ	4.54	0.50	0.00	0.00
Integration	1.68	0.84	0.00	0.00
Pre-com/ Commissioning	2.94	1.47	0.00	0.00
Knowledge	1.96	0.98	0.00	0.00
Stakeholder	0.98	0.49	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 1 is valid. From the computation, the Lean method had a total score of 168.82 and 139.82 as against the APM method with a total score of 31.180 and 60.180 for case studies 4 and 5. Hence, the Lean method was selected as the best revamping method according to respondent 1.

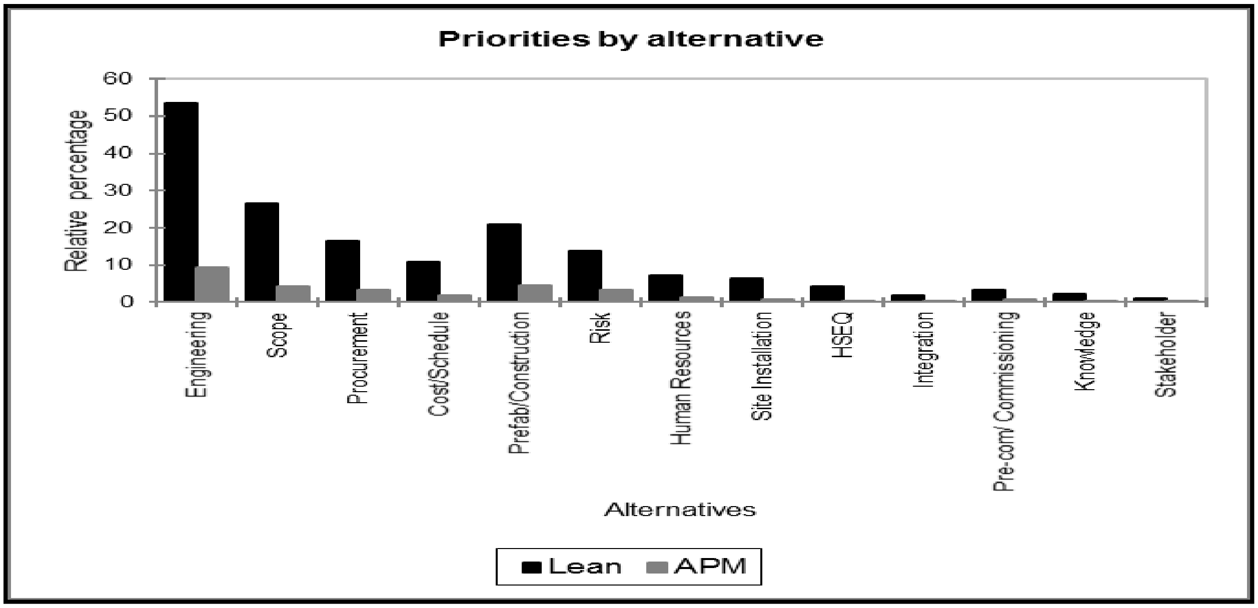


FIGURE 6.34 Priorities by alternative according to respondent 1 (Case study 4)

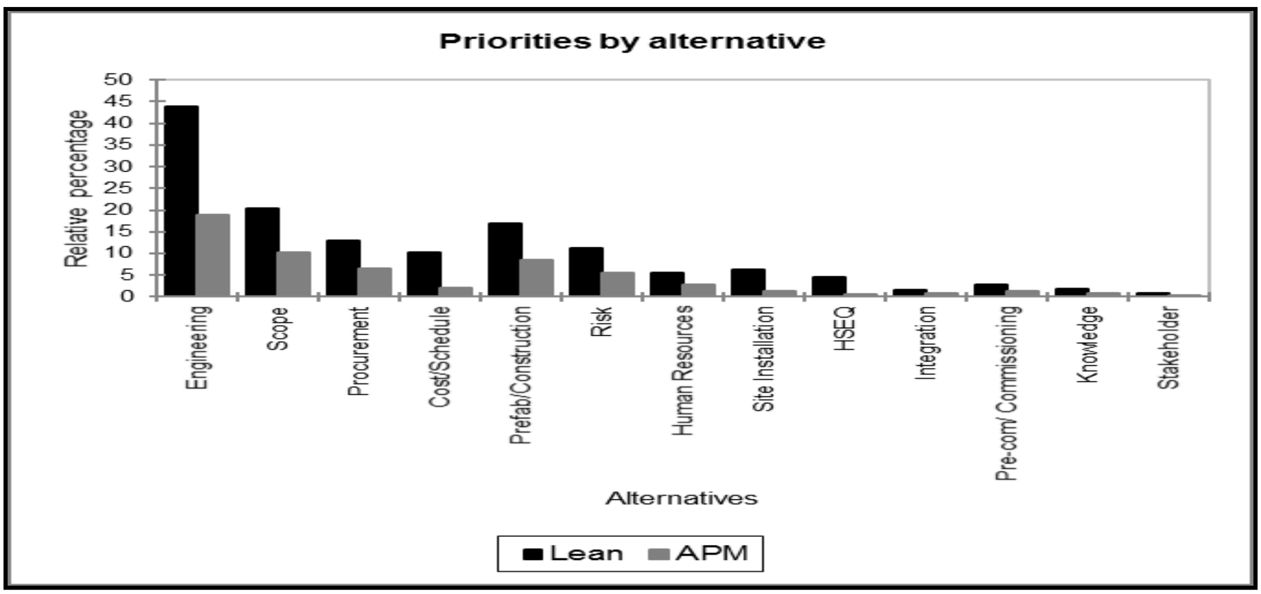


FIGURE 6.35 Priorities by alternative according to respondent 1 (Case study 5)

6.18 Results Obtained from the Rating of Respondent 2: from Case studies 4 and 5

The priorities of criterion based on the rating of respondent 2 are presented in Tables 6.80 and 6.81.

Table 6.80 Priorities by criterion based on Respondent 2 (Case study 4)

Criteria	%
Engineering	61.83
Prefab/Construction	28.10
Site Installation	4.91
Pre-com/ Commissioning	5.16

CR = 0.222; CI = 24.62%

Table 6.81 Priorities by criterion based on Respondent 2 (Case study 5)

Criteria	%
Engineering	63.89
Prefab/Construction	24.64
Site Installation	5.34
Pre-com/ Commissioning	6.14

CR = 0.211; CI = 23.44%

With consistency ratios (CR) of 0.222 and 0.211, which are less than 10%, it was concluded that the comparison table generated by respondent 2 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 2. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 2 and are presented in Tables 6.82 and 6.83.

Table 6.82 Priorities by sub-criterion of Engineering based on Respondent 2 (Case study 4)

Engineering	%
Scope	49.46
Procurement	6.18

Cost/Schedule	6.18

CR = 0; CI = 0%

Table 6.83 Priorities by sub-criterion of Engineering based on Respondent 2 (Case study 5)

Engineering	%
Scope	31.33
Procurement	19.93
Cost/Schedule	12.62

CR = 0.027; CI =6.63%

With consistency ratios (CR) of 0.00 and 0.027, which are less than 10%, it was concluded that the comparison table generated by respondent 2 is also valid. It was again observed based on the rating of respondent 2 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 49.46% and 31.33%.

To select the most suitable alternative method amongst the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 2 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 2 are presented in Tables 6.84 and 6.85, and Figures 6.36 and 6.37

Table 6.84 Priorities by alternative based on Respondent 2 (Case study 4)

Crit./Alt.	Lean	APM	CR	CI
Engineering	30.92	30.92	0.00	0.00
Scope	24.73	24.73	0.00	0.00
Procurement	3.09	3.09	0.00	0.00
Cost/Schedule	3.09	3.09	0.00	0.00
Prefab/Construction	14.05	14.05	0.00	0.00
Risk	10.54	10.54	0.00	0.00
Human Resources	3.51	3.51	0.00	0.00
Site Installation	2.45	2.45	0.00	0.00
HSEQ	1.64	1.64	0.00	0.00

Integration	0.82	0.82	0.00	0.00
Pre-com/ Commissioning	2.58	2.58	0.00	0.00
Knowledge	1.72	1.72	0.00	0.00
Stakeholder	0.86	0.86	0.00	0.00

Table 6.85 Priorities by alternative based on Respondent 2 (Case study 5)

Crit./Alt.	Lean	APM	CR	CI
Engineering	57.01	6.88	0.00	0.00
Scope	27.85	3.48	0.00	0.00
Procurement	17.93	1.99	0.00	0.00
Cost/Schedule	11.22	1.40	0.00	0.00
Prefab/Construction	22.14	2.49	0.00	0.00
Risk	19.71	2.19	0.00	0.00
Human Resources	2.43	0.30	0.00	0.00
Site Installation	4.75	0.59	0.00	0.00
HSEQ	4.22	0.53	0.00	0.00
Integration	0.53	0.07	0.00	0.00
Pre-com/ Commissioning	5.46	0.68	0.00	0.00
Knowledge	4.85	0.61	0.00	0.00
Stakeholder	0.61	0.08	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 2 is valid. From the computation, the Lean method had a total score of 100.00 and 178.71 as against the APM method with a total score of 100.00 and 21.290 for case studies 4 and 5. Hence, the Lean method was selected as the best revamping method according to respondent 2.

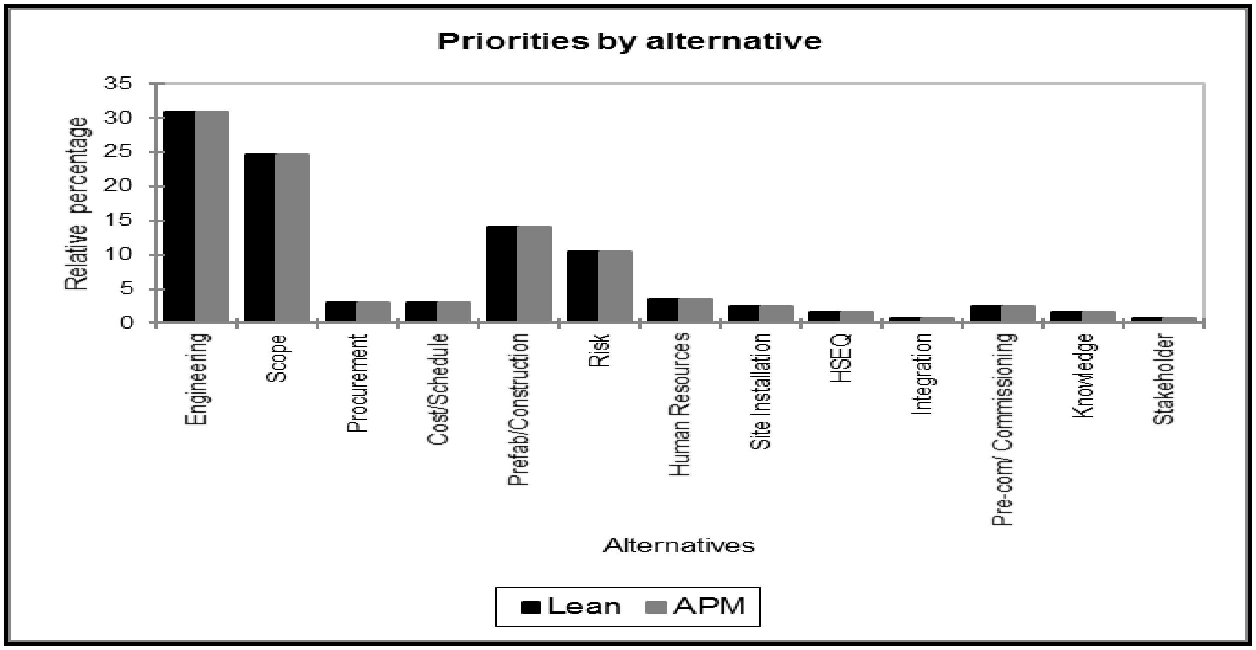


FIGURE 6.36 Priorities by alternative according to respondent 2 (Case study 4)

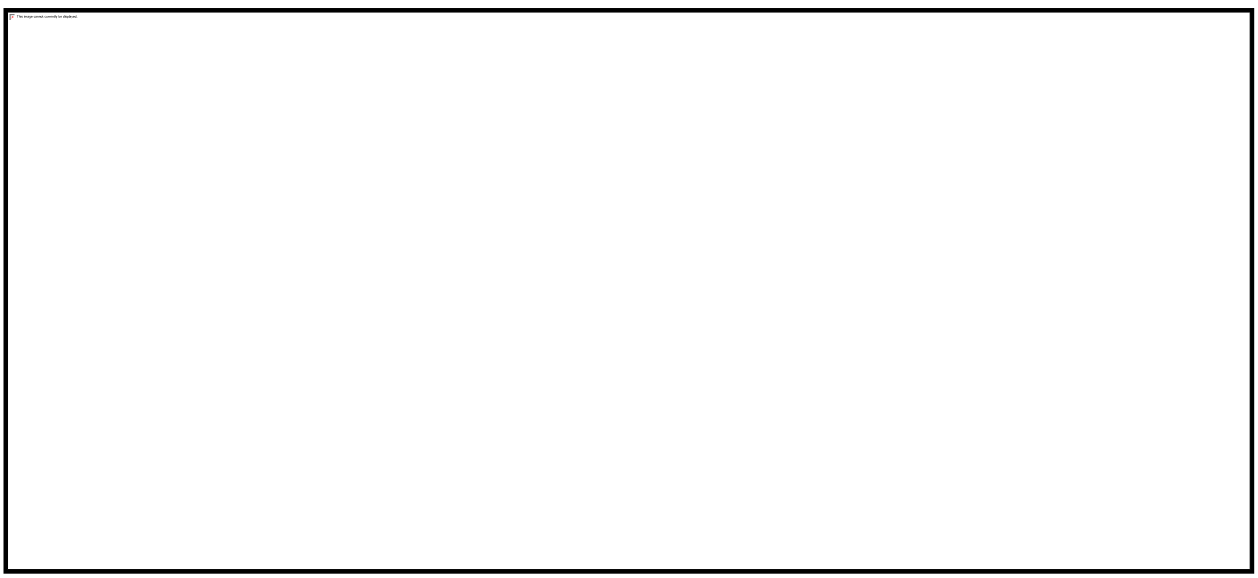


FIGURE 6.37 Priorities by alternative according to respondent 2 (Case study 5)

6.19 Results Obtained from the Rating of Respondent 3: from Case studies 4 and 5

The priorities of criterion based on the rating of respondent 3 are presented in Tables 6.86 and 6.87

Table 6.86 Priorities by criterion based on Respondent 3 (Case study 4)

Criteria	%
Engineering	70.19
Prefab/Construction	16.13
Site Installation	5.88
Pre-com/ Commissioning	7.80

CR = 0.184; CI = 20.44%

Table 6.87 Priorities by criterion based on Respondent 3 (Case study 5)

Criteria	%
Engineering	52.17
Prefab/Construction	27.26
Site Installation	15.99
Pre-com/ Commissioning	4.58

CR = 0.320; CI = 35.54%

With consistency ratios (CR) of 0.184 and 0.320, which are less than 10%, it was concluded that the comparison table generated by respondent 3 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 3. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering were calculated based on the rating of respondent 3 and are presented in Tables 6.88 and 6.89.

Table 6.88 Priorities by sub-criterion of Engineering based on Respondent 3 (Case study 4)

Engineering	%
Scope	28.58
Procurement	23.06
Cost/Schedule	18.55

CR = 0.109; CI = 18.78%

Table 6.89 Priorities by sub-criterion of Engineering based on Respondent 3 (Case study 5)

Engineering	%
Scope	40.11
Procurement	7.03
Cost/Schedule	5.03

CR = 0.070; CI = 12.15%

With consistency ratios (CR) of 0.109 and 0.070, which are less than 10%, it was concluded that the comparison table generated by respondent 3 is also valid. It was again observed based on the rating of respondent 3 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 28.58% and 40.11%.

To select the most suitable alternative method amongst the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 3 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 3 are presented in Tables 6.90, 6.91 and Figures 6.38 and 6.39.

Table 6.90 Priorities by alternative based on Respondent 3 (Case study 4)

Crit./Alt.	Lean	APM	CR	CI
Engineering	58.01	12.18	0.00	0.00
Scope	22.86	5.72	0.00	0.00
Procurement	18.45	4.61	0.00	0.00
Cost/Schedule	16.70	1.86	0.00	0.00
Prefab/Construction	14.43	1.70	0.00	0.00
Risk	7.26	0.81	0.00	0.00
Human Resources	7.17	0.90	0.00	0.00
Site Installation	5.17	0.71	0.00	0.00
HSEQ	3.43	0.49	0.00	0.00
Integration	1.74	0.22	0.00	0.00
Pre-com/ Commissioning	6.47	1.33	0.00	0.00
Knowledge	6.16	1.04	0.00	0.00

Stakeholder	2.31	0.29	0.00	0.00

Table 6.91 Priorities by alternative based on Respondent 3 (Case study 5)

Crit./Alt.	Lean	APM	CR	CI
Engineering	46.27	5.90	0.00	0.00
Scope	36.10	4.01	0.00	0.00
Procurement	5.86	1.17	0.00	0.00
Cost/Schedule	4.31	0.72	0.00	0.00
Prefab/Construction	26.11	3.16	0.00	0.00
Risk	16.16	2.02	0.00	0.00
Human Resources	7.95	1.14	0.00	0.00
Site Installation	14.26	1.73	0.00	0.00
HSEQ	9.60	1.07	0.00	0.00
Integration	4.66	0.67	0.00	0.00
Pre-com/ Commissioning	6.11	0.47	0.00	0.00
Knowledge	3.66	0.41	0.00	0.00
Stakeholder	0.45	0.06	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 3 is valid. From the computation, the Lean method had a total score of 168.16 and 177.48 as against the APM method with a total score of 31.84 and 22.52 for Case study 4 and 5. Hence, the Lean method was selected as the best revamping method according to respondent 3.

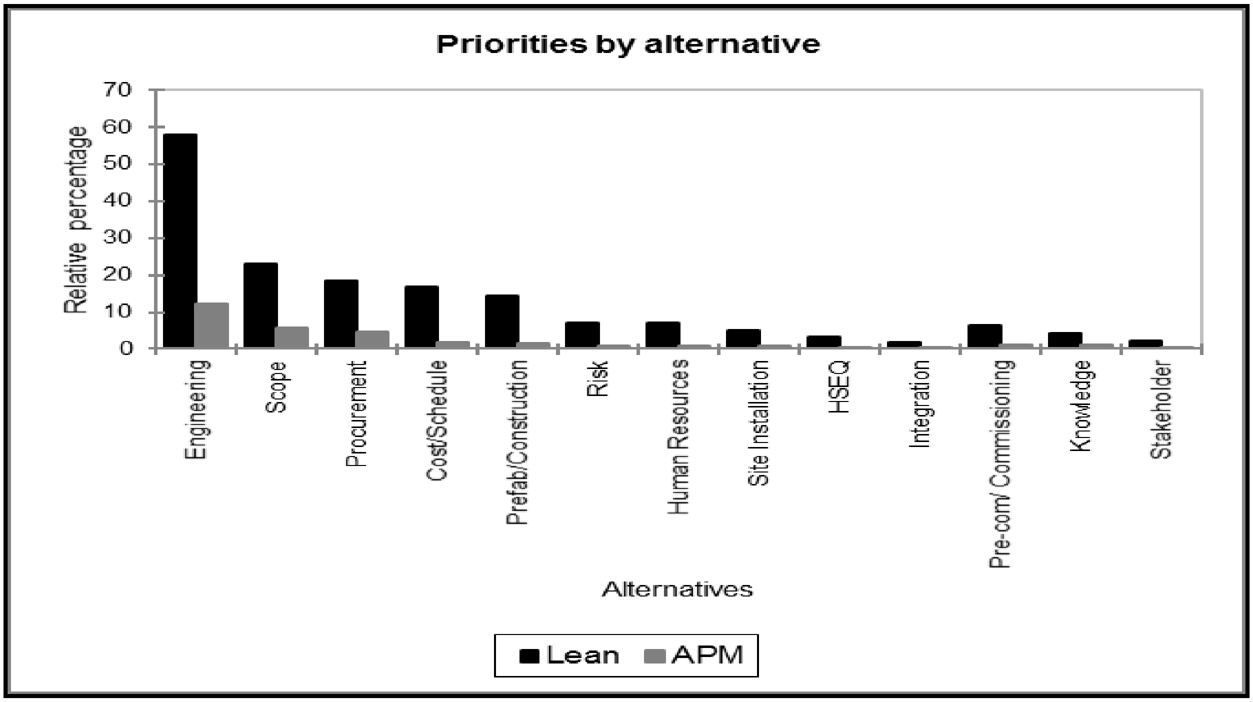


FIGURE 6.38 Priorities by alternative according to respondent 3 (Case study 4)

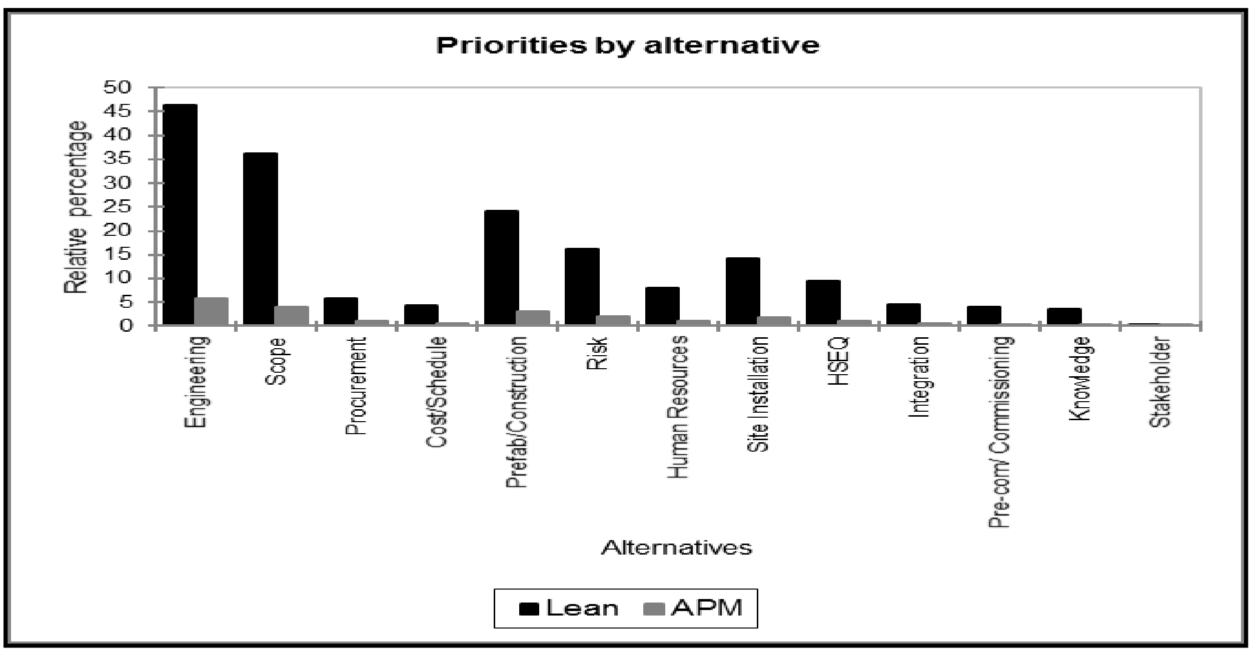


FIGURE 6.39 Priorities by alternative according to respondent 3 (Case study 5)

6.20 Results Obtained from the Rating of Respondent 4: from Case studies 4 and 5

The priorities of criterion based on the rating of respondent 4 are presented in Tables 6.92 and 6.93

Table 6.92 Priorities by criterion based on Respondent 4 (Case study 4)

Criteria	%
Engineering	67.33
Prefab/Construction	18.41
Site Installation	6.13
Pre-com/ Commissioning	8.13

CR = 0.257; CI = 28.58%

Table 6.93 Priorities by criterion based on Respondent 4 (Case study 5)

Criteria	%
Engineering	60.57
Prefab/Construction	24.34
Site Installation	11.70
Pre-com/ Commissioning	3.39

CR = 0.525; CI = 58.3%

With consistency ratios (CR) of 0.257 and 0.525, which are less than 10%, it was concluded that the comparison table generated by respondent 4 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 4. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of engineering was calculated based on the rating of respondent 4 and are presented in Table 6.94 and 6.95.

Table 6.94 Priorities by sub-criterion of Engineering based on Respondent 4 (Case study 4)

Engineering	%
Scope	22.44
Procurement	22.44
Cost/Schedule	22.44

CR = 0; CI = 0%

Table 6.95 Priorities by sub-criterion of Engineering based on Respondent 4 (Case study 5)

Engineering	%
Scope	29.71
Procurement	18.89
Cost/Schedule	11.97

CR = 0.027; CI =6.63%

With consistency ratios (CR) of 0.00 and 0.027, which are less than 10%, it was concluded that the comparison table generated by respondent 4 is also valid. It was again observed based on the rating of respondent 4 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 22.44% and 29.71%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 4 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 4 are presented in Tables 6.96 and 6.97, and Figures 6.40 and 6.41.

Table 6.96 Priorities by alternative based on Respondent 4 (Case study 4)

Crit./Alt.	Lean	APM	CR	CI
Engineering	59.53	7.79	0.00	0.00
Scope	19.95	2.49	0.00	0.00
Procurement	19.64	2.81	0.00	0.00
Cost/Schedule	19.95	2.49	0.00	0.00
Prefab/Construction	16.36	2.05	0.00	0.00
Risk	10.91	1.36	0.00	0.00
Human Resources	5.45	0.68	0.00	0.00
Site Installation	5.32	0.81	0.00	0.00
HSEQ	3.51	0.58	0.00	0.00
Integration	1.82	0.23	0.00	0.00

Pre-com/ Commissioning	7.00	1.13	0.00	0.00
Knowledge	3.39	0.68	0.00	0.00
Stakeholder	3.62	0.45	0.00	0.00

Table 6.97 Priorities by alternative based on Respondent 4 (Case study 5)

Crit./Alt.	Lean	APM	CR	CI
Engineering	53.67	6.90	0.00	0.00
Scope	26.41	3.30	0.00	0.00
Procurement	16.79	2.10	0.00	0.00
Cost/Schedule	10.47	1.50	0.00	0.00
Prefab/Construction	21.63	2.70	0.00	0.00
Risk	14.42	1.80	0.00	0.00
Human Resources	7.21	0.90	0.00	0.00
Site Installation	10.29	1.41	0.00	0.00
HSEQ	6.82	0.97	0.00	0.00
Integration	3.47	0.43	0.00	0.00
Pre-com/ Commissioning	3.04	0.35	0.00	0.00
Knowledge	2.04	0.23	0.00	0.00
Stakeholder	1.01	0.13	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 4 is valid. From the computation, the Lean method had a total score of 176.44 and 177.28 as against the APM method with a total score of 23.56 and 22.72 for case studies 4 and 5. Hence, the Lean method was selected as the best revamping method according to respondent 4.

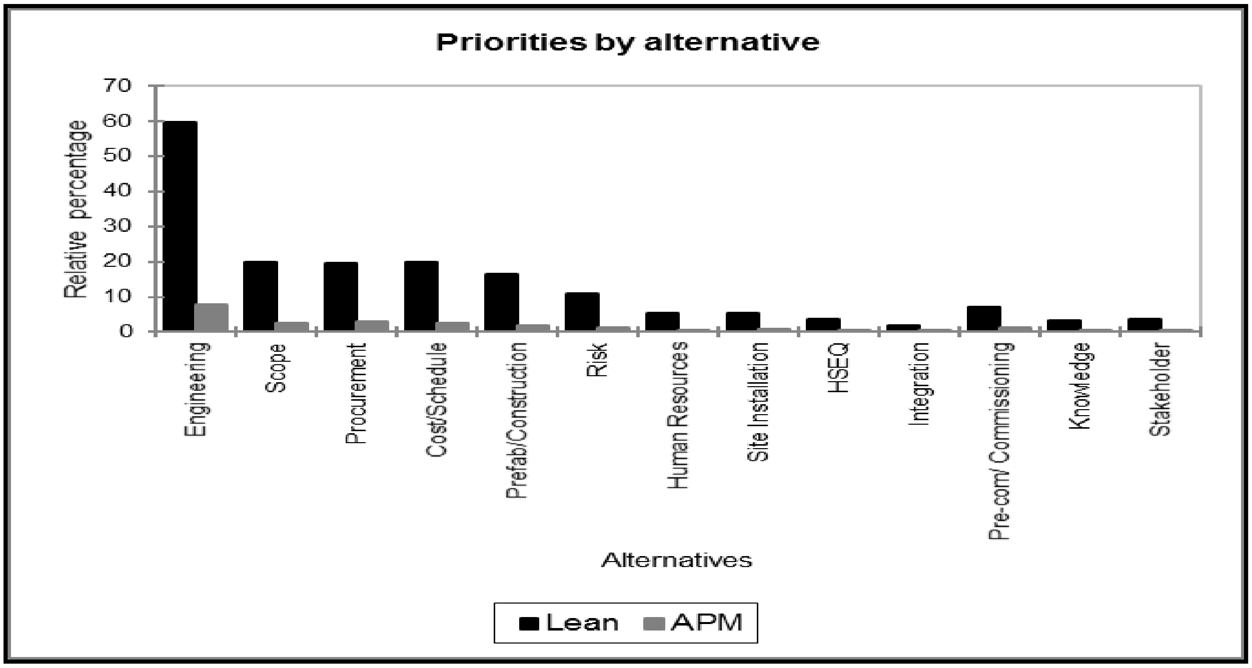


FIGURE 6.40 Priorities by alternative according to respondent 4 (Case study 4)

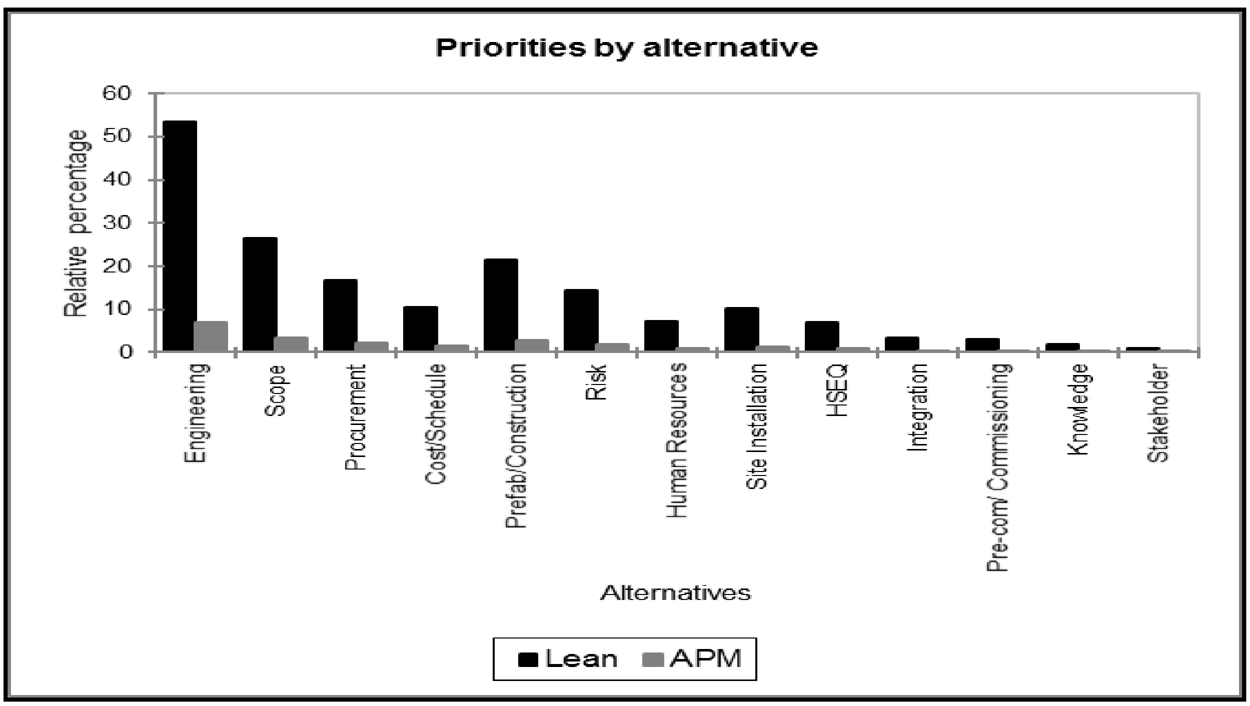


FIGURE 6.41 Priorities by alternative according to respondent 4 (Case study 5)

6.21 Results Obtained from the Rating of Respondent 5: from Case studies 4 and 5

The priorities of criterion based on the rating of respondent 5 are presented in Tables 6.98 and 6.99.

Table 6.98 Priorities by criterion based on Respondent 5 (Case study 4)

Criteria	%
Engineering	63.06
Prefab/Construction	25.41
Site Installation	7.41
Pre-com/ Commissioning	6.13

CR = 0.260; CI = 28.84%

Table 6.99 Priorities by criterion based on Respondent 5 (Case study 5)

Criteria	%
Engineering	57.70
Prefab/Construction	25.88
Site Installation	9.11
Pre-com/ Commissioning	7.31

CR = 0.265; CI = 29.43%

With consistency ratios (CR) of 0.260 and 0.265, which are less than 10%, it was concluded that the comparison table generated by respondent 5 is valid. Based on the outcome, engineering was again rated as the best criterion that impacts the decision-making process according to the rating of respondent 5. To understand the sub-criterion of engineering that mostly influenced the decision-making process, the priorities by sub-criterion of Engineering were calculated based on the rating of respondent 5 and are presented in Table 6.100 and 6.101.

Table 6.100 Priorities by sub-criterion of Engineering based on Respondent 5 (Case study 4)

Engineering	%
Scope	30.93
Procurement	19.67

Cost/Schedule	12.46

CR = 0.027; CI =6.63%

Table 6.101 Priorities by sub-criterion of Engineering based on Respondent 5 (Case study 5)

Engineering	%
Scope	28.30
Procurement	18.00
Cost/Schedule	11.40

CR = 0.027; CI =6.63%

With consistency ratios (CR) of 0.027 and 0.027, which are less than 10%, it was concluded that the comparison table generated by respondent 5 is also valid. It was again observed based on the rating of respondent 5 that scope is the sub-criterion of engineering that mostly impacts the decision-making process with calculated mean priorities of 30.93% and 28.30%.

To select the most suitable alternative method among the two methods, the sum of the calculated priorities by alternative was obtained according to the rating of respondent 5 and the alternative with the highest mean sum was judged to be the best. The priorities by alternatives according to respondent 5 are presented in Tables 6.102, 6.103 and Figures 6.42 and 6.3.

Table 6.102 Priorities by alternative based on Respondent 5 (Case study 4)

Crit./Alt.	Lean	APM	CR	CI
Engineering	54.27	8.79	0.00	0.00
Scope	26.51	4.42	0.00	0.00
Procurement	16.86	2.81	0.00	0.00
Cost/Schedule	10.90	1.56	0.00	0.00
Prefab/Construction	21.53	3.88	0.00	0.00
Risk	16.12	2.82	0.00	0.00
Human Resources	7.41	1.06	0.00	0.00
Site Installation	6.25	1.16	0.00	0.00
HSEQ	4.63	0.93	0.00	0.00
Integration	1.62	0.23	0.00	0.00

Pre-com/ Commissioning	3.61	0.52	0.00	0.00
Knowledge	2.41	0.34	0.00	0.00
Stakeholder	1.20	0.17	0.00	0.00

Table 6.103 Priorities by alternative based on Respondent 5 (Case study 5)

Crit./Alt.	Lean	APM	CR	CI
Engineering	49.70	7.99	0.00	0.00
Scope	25.15	3.14	0.00	0.00
Procurement	16.00	2.00	0.00	0.00
Cost/Schedule	8.55	2.85	0.00	0.00
Prefab/Construction	21.78	6.11	0.00	0.00
Risk	14.38	2.88	0.00	0.00
Human Resources	7.40	1.23	0.00	0.00
Site Installation	7.81	1.30	0.00	0.00
HSEQ	5.21	0.87	0.00	0.00
Integration	2.60	0.43	0.00	0.00
Pre-com/ Commissioning	5.34	1.97	0.00	0.00
Knowledge	3.25	1.62	0.00	0.00
Stakeholder	2.09	0.35	0.00	0.00

With a consistency ratio (CR) of 0.00, which is less than 10%, it was concluded that the comparison table generated by respondent 5 is valid. From the computation, the Lean method had a total score of 171.32 and 169.25 as against the APM method with a total score of 28.68 and 30.75 for case studies 4 and 5. Hence, the Lean method was selected as the best revamping method according to respondent 5.

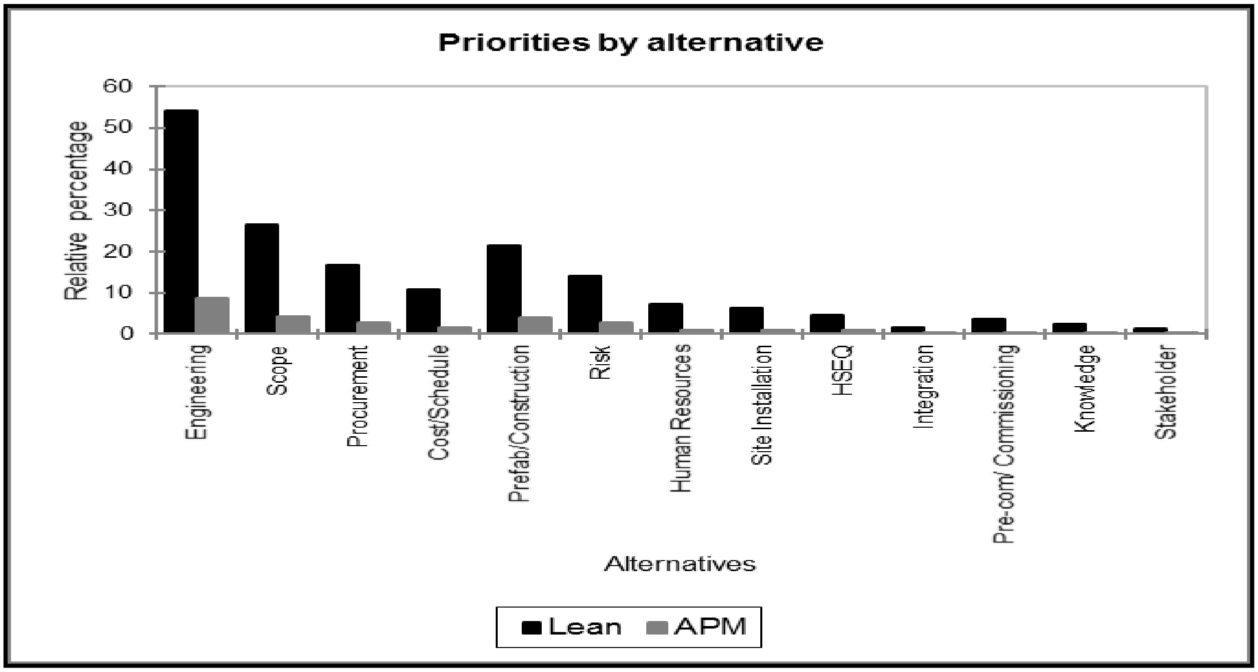


FIGURE 6.42 Priorities by alternative according to respondent 5 (Case study 4)

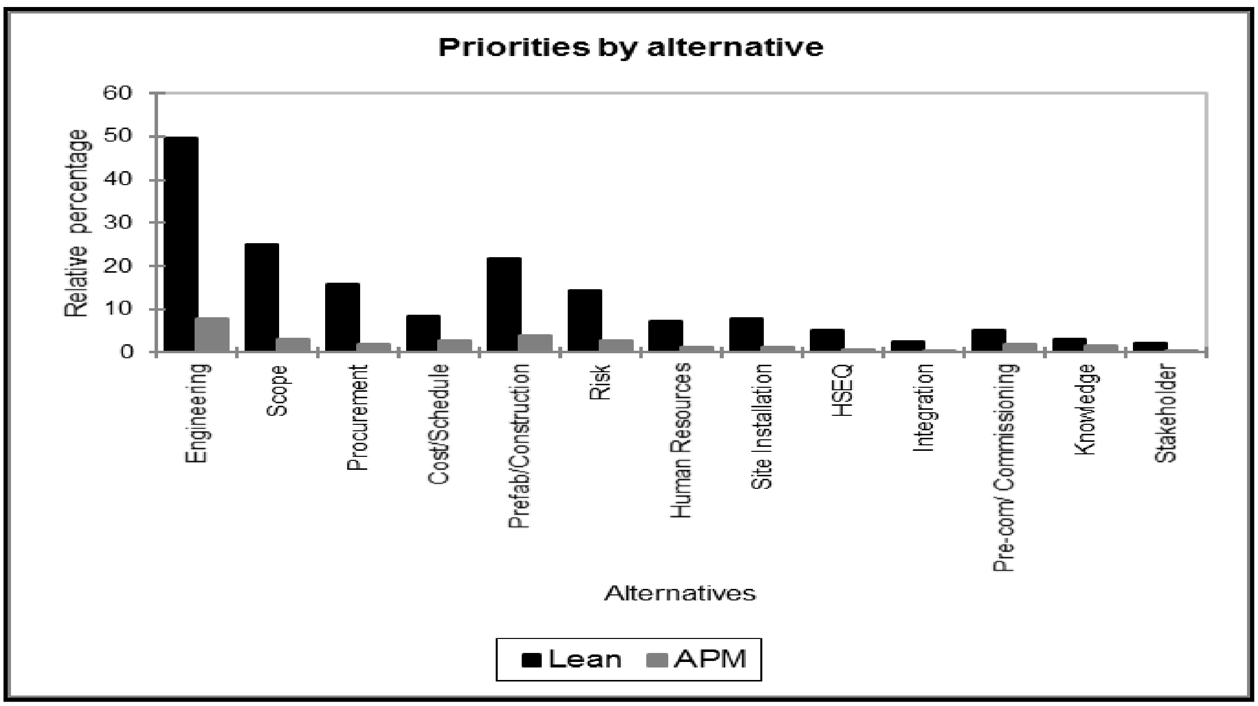


FIGURE 6.43 Priorities by alternative according to respondent 5 (Case study 5)

6.22 Summary

Chapter six discusses the results of the expert respondents' data collected through the questionnaires and the interview survey, to outline for the optimal revamp project model development, validation, and testing. This chapter has offered insights pertaining to the specific case study utilised for model development, validation, and testing. A detailed step by step approach in the analysis of all 39 respondents in the five case studies was presented. The expert feedback indicated that engineering activities and the three sub-criteria of project cost and schedule, scope, and procurement, play the most significant role for efficient project management during the execution phase. It has also been revealed that the Lean philosophy is the most appropriate project management approach for striving optimality in FPSO revamp project management. Discussions on the research findings is covered in Chapter 7.

CHAPTER SEVEN

Discussions

7.1 Introduction

This chapter highlights that most major oil and gas operating companies have deployed their individual customised project management systems to align with the traditional (also called stage-gate or waterfall project management) model to FPSO revamp projects to sustain continuous production and assurance of returns on investment to shareholders. This is due to the rigid incremental process-driven constraints that hamper the realisation of oil and gas projects. However, this development has lingered without attaining optimal performance. This research has developed an optimal revamp oil and gas project management model from an AHP modelling approach based on informed decisions from experts around the world, who are experienced in FPSO revamp project execution. This new proposed model is limited to FPSO revamp project management at the execution phase but could be structured to other project phases, other type of projects, and to other industries outside of oil and gas production. This is, however, subject to future research.

7.2 Findings, Opportunities, Challenges and Surprises

Contemporary Project Management Approaches and Performance

In this research, experts in revamp projects in the oil and gas sector reached a consensus that revamp projects are complex projects to manage, and that there is a need to improve on the current project management performance by major oil and gas producing corporations who deploy the stage-gate or traditional project management approach for the management of projects. They also concluded that, there would be an overall gain for individual project teams and wider groups of stakeholders if the quest for change is effectively pursued and supported by company management. In terms of the contemporary project management approaches, the academic literature was utilised to identify four potential project management approaches: Lean, Agile Project Management, BIM, and Hybrid project management. These could then be deployed to project processes for improvements, indicated in Table 2.1, which contains a comparison with the traditional, stage-gate or the waterfall project management models. It should be noted that these approaches were not robust enough to support the revamp project processes throughout the project lifecycle. It is also the case that some are still in the conceptual stage of development and there is no clear evidence of full deployment on a project. However, there is the likelihood for them to be partially applied to aspects of the stage-gate process to achieve great improvement.

The experts indicated Lean and APM as potential improvement options to the stage-gate approach but however preferred the Lean philosophy when compared to Agile project management, as indicated in Table 7.1. This includes considerations as to the fact that the characteristics of FPSO revamp projects are more complex but have relatively lower budgets than the capital project. This development was a surprise to the researcher, because APM is seemingly popular and known to have features that enable it to respond favourably to rapid changes and uncertainties during the execution phase of a typical revamp project.

The responses of the experts on how they would convince their management to consider changes to the existing stage-gate or waterfall approaches in revamp project management were quite interesting. Most respondents agreed with the fact that a change of approach is possible but it requires rigour, a Strength, Weakness, Opportunity, and Threat (SWOT) analysis, as well as an ample time to secure management approval. A direct quote from one expert regarding this question is as captured below:

> "*Not very straight forward as brownfield projects require a unique approach, requiring a specialised and experienced team to address the bespoke requirements for a pre-existing production facility that requires a significantly different approach to traditional greenfield projects*"

A few experts however believed this is impossible, considering the already huge investments on existing project management approaches, with a reference below:

> "*...It is not possible to change in large organisations due to huge investment on existing project management model, most project managers just wing it*".

Reviewing the responses further, the researcher opined that the majority of experts' opinions are in consistence with the theory of small incremental changes for continuous improvement, which the Lean philosophy offers compared to APM, which feels like a radical change or innovation. Even if a change was to yield better results, it will still be resisted because humans are naturally averse to change. In addition, company management will be confronted with the risk of failure changing from a predictive to an adaptive project management approach, which is an entirely new approach to take.

Underlying Challenge of FPSO revamp Project Underperformance at the Execution Phase.

By and large, from the feedback and analysis presented in the discussion, the underlying reason for revamp project management underperformance is linked to poor or uninformed decision making on the critical criteria required for optimal project gains. This realisation also came as a surprise to the researcher, as the thoughts in the public domain is linked to the non-adherence to the processes, procedures, and techniques of project management, which is recommended by the five stage-gate project management approach. Therefore, the root cause of the challenge is not expressly the holistic deployment of the five stage-gate project management approach but the lack of informed decision-making by the project practitioners and sponsors in selecting the appropriate knowledge areas to suit the specific project type and requirements. Another issue is the reluctance of project teams and organisations to seek process improvement outside of the traditional project management approaches, especially the one that tend towards innovation. The discussion on decision making is perceived by the project team as the duty of the project manager and the company's senior management.

Additionally, the project integration management from theory that better describes the efficient harmonisation of all other project management constraints, interfacing, and alignment with the strategic corporate business plans of the organisation is not well demonstrated amongst the project team being a top-down management approach. This makes the organisation miss the opportunities of the project team offering productive input and obtaining feedback from the experts, which could have enabled informed decisions at the project leadership or corporate level.

The project manager, on the other hand, who subsequently relies on previous experience and personal judgement, may either be too busy and, sometimes, shy or egoistic. This can also lead to loss of opportunity to engage both the project and functional support team in making informed decisions on important project objects and focus. Although, the timing may generally be considered wrong during the execution phase, but it should be discussed and documented as part of the company's knowledge management process for continuous improvement and subsequent application to future project development.

There is, therefore, a need to identify the actual critical project management constraints in the executing process group instead of it being wrapped up under integration management for clarity, responsibility and ownership of the respective processes, by either the project or the functional support team for improved project management. In addition, it is important to engage the construction project team, who are the active parties responsible for the execution project phase, early in the project development in order to take advantage in fast-tracking or overlapping activities to avert rework, omission, over design or a design that may not be feasible to install on site due to constructability issues. This can all lead to assurance of optimal project management performance.

Execution Phase Activities and Revamp Project Management Constraints

Experts have validated engineering, prefabrication and construction, site installation, pre-commissioning and commissioning as the major activities that would result in project management improvement during the execution phase. To achieve the desired goal of the project, nine project management constraints have been identified and linked to specific revamp project activities. This implies that the project team could trace the root cause of underperformance to a particular project activity and implement a corrective action on time instead of focussing on all the components that will potentially be more expensive and will realize little or no result. This scenario highlights the essence of identifying value-adding and removing nonvalue-adding activities, eliminating waste and assurance of customer satisfaction being the attributes of Lean philosophy.

Although all project constraints are important, scope, cost and schedule as well as procurement management are closely tied to engineering project activities. Human resources and risk management are considered most critical during pre-fabrication and construction activities as that affords the opportunity to plan to the next major activity. In addition, the next major activity and site installation performance are impacted by integration and HSEQ management. Lastly, the pre-commissioning and commissioning activity are closely linked with knowledge and stakeholder management.

Though the experts expressed their technical and project management challenges in dealing with revamping projects execution in the course of the study, there was no enthusiasm in discussions around project performance from cost and schedule perspective during construction, site installation, pre-commissioning and commissioning activities despite the two knowledge areas being part of the 'iron triangle' and the discourse in the literature on cost and schedule escalation in project development. This equally poses a surprise to the researcher.

This indication has been displayed in the consensus of the constraints indicated in Table 7.4 during the site activities. Asked whether it is an industry wide phenomenon, the researcher could not conclusively fathom the reasons for this development but opines that it could either be coincidental- a mindset that it ought to have been addressed during the FEL and Engineering activity, or human factor which is outside the scope of the study. Therefore, efforts to unravel this development would be an interesting area for future research.

Developing the Revamp Project Management Model

Since the research is geared towards optimising the existing FPSO revamp project management model by identifying the key success criteria during the execution project phase, proffering the most feasible alternative approach to the current practice and striving for optimal performance requires an in-depth validation of the research data. The research philosophy of pragmatism using mixed research method under multiple case study approach and the Delphi research instrument made the research methodology unique, focussed, simple and smart, thus supported the realisation of the research objectives. This, however, did not come without some inherent challenges.

Obtaining data from the experts, especially for five case study organisations, was challenging, yet interesting. Most of the experts are not co-located - many are either on vacation or on time-off as offshore rotation workers, and the personnel on duty ran a very tight schedule between the FPSO that is berthed offshore and the base office, which is on land.

However, obtaining the data from the questionnaire survey was all about resilience, patience and determination of the researcher, thanks to the internet and technology that have made the world a global village This, however, was not without some pockets of issues as connectivity always was not assured and the cost was very high. Another challenge encountered during data collection was the COVID-19 pandemic in 2020 that introduced a new normal to living. The initially planned face-to-face interview survey for this study was impacted, and instead, the researcher used the internet and telephone to complete all outstanding data collection from the experts. Interestingly, the researcher also hinged on the opportunity of the COVID-19 pandemic to re-strategize on the number of case studies, which increased from four to five, the fifth being the additional case obtained from professionals whose profiles on LinkedIn were outstanding in FPSO projects execution. This initiative represented a global oil and gas producing community, thus creating further validity to the research findings.

The first iteration of the Delphi method involving the questionnaire was utilised for streamlining the research criteria, sub-criteria and the alternative framework for model development using the Analytic Hierarchy Process (AHP) and focussed on the FPSO revamp project management improvement. The second iteration was the interview survey by telephone to complement the earlier questionnaire administered in the first iteration and the completion of the Analytic Hierarchy Process (AHP) levels 1 to 3 worksheets.

Although the AHP is relatively unpopular amongst the experts as a tool for making decisions in a complex real-life problem, it was utilised effectively by the researcher to align all the thoughts and feedback. For instance, it was utilised for setting priorities amongst competing attributes, to identify relatively weak criteria or factors that do not significantly contribute to a decision, supported the harmonisation of individual expert opinion into a common group decision while avoiding bias, allowed some level of inconsistency as humans, and enabled the conversion of subjective attributes like preferences, likes, and choices from intangible to tangible units of measurement.

AHP has all the attributes from theory as a model development approach and was carefully selected because of its features and processes that enable researchers to validate data and information. It also supports cycles of enquiry, which the pragmatism research philosophy portends. Although the AHP analysis could be completed using MS Excel due to the volume of pairwise comparison and computations for a total of 39 respondents and to avoid errors and clarity, AHP OS Software was utilised in this research and yielded excellent results for the modelling development. It therefore met an objective of the research.

7.3 Comparison between Theory and Management Methods with Current Practice

A standard, as defined by the International Organization for Standardization (ISO) and researchers, is a document approved by a recognised body for general consistent use as a guide, rule, or features for products, services and processes, in which compliance are not mandatory (PMI, 2013). This definition suggests that the PMBOK guide, which provided a standard for project management, is customisable. The literature also points out that most oil and gas operating corporations leverage on the stage-gate process for the development of customised project management models or systems. There is a chance, therefore, that these customised project management models could be further reviewed in line with current realities in practice and in the quest for continuous improvements in project systems and contribution to the body of knowledge.

Although the stage-gate process appears to have been developed with greenfield, major, mega or capital project management in mind, it has a caveat for 'tailoring' (PMBOK, 2013).Therefore, it is erroneous to see the guide as the 'one cap that fits all project types' as perceived in most oil and gas operating organisations. It is expected that project managers and practitioners tailor or apply scalability to the capital project-aligned guidelines for other project categories or types. This allows revamp projects, for example, to thrive without explicit standards and therefore makes it vulnerable to failure or underperformance due to lack of standardisation. Although mega projects have been defined as projects with capital expenditure (CAPEX) more than US$1bn, in practice, especially in smaller oil and gas operating companies, a project could attract lesser cost than this capital project threshold and still be regarded as a major project because it is critical to the realisation of the strategic corporate plans. Hence the assumption of similarities in project types and structures is the reason why the same project management processes and approaches are adopted by most oil and gas operating organisations for all projects (Mishar & Syahrilyan, 2012 cited in Rahim et al., 2017).

The FPSO revamp project is a culprit of the similarity assumption in the project classification based on CAPEX versus classification based on complexity and criticality to the immediate and long-term plan of the organisation. The objective of the research has been realised by being able to tailor the project management processes to suit the revamp project requirements, which results in optimum project management of projects in the oil and gas industry.

In addition, the framework for the stage-gate assumed that the project, the project manager, and the project team are assigned to the performing organisation. This implies that the framework has been developed from the perspective of the engineering, procurement, construction, installation (EPCI) contractor or the contracting community. Therefore, as far as the oil and gas operating organisations keep applying the stage-gate model without tailoring, the performance record is unlikely to improve. It is for this reason that this research study has infused elements of modern project management practices from the operator perspective to strive optimality.

From theory, the executing process group has no opportunity based on the stage-gate approach to input into four key knowledge areas, namely project scope management, project time management, project cost management and project risk management. These four knowledge areas have provisions for development reviews and approval of the associated processes only in the planning process group at the early stages of the project development, thereby creating a disconnect between the stage-gate approach and elements of the 'iron triangle' which were regarded traditionally as key project management performance criteria. The executing process group and, by extension, the project construction team, should play active roles in practice from the planning stages through to the execution phase for optimal project management performance. It is vital to understand the synergy of activities during the interface of the various phases (Rahim et al., 2017). For example, moving from the defining to the executing phase suggests early mobilisation of the construction team and fast-tracking in project management in order to avert potential cost and schedule impacts from poor quality, wrong project specifications relative to scope of work, repairs and reworks.

However, to meet the objectives of this research, project management processes that were hitherto under executing process group have been sanctioned for revamp project management improvements at the execution stage. This consensus by experts is consistent with the argument that, although the project management processes have been uniquely categorised, and interfaces within defined knowledge areas and process groups identified, in practice, they are iterative, can overlap and interact in ways to suit the project's needs (PMI, 2013).

7.4 Proposed PM Approach for Optimal FPSO Revamp Project at Execution Phase

Table 7.1 contains a summary of the research findings pertaining FPSO revamp project management during the execution phase. It describes the key activities, knowledge areas or project management constraints, and the preferred project management approach for optimal project management performance. The values in the respective boxes represent the priority levels expressed in percentages.

Table 7. 1. Proposed PM Approach for Optimal FPSO Revamp Project at Execution Phase

Serial Number	Knowledge Areas	Execution Phase Activities/Priority Values			
		Engineering	Construction	Installation	Pre-commission/Commissioning
		54%	24%	12%	10%
1	Project cost & schedule management	11%			
2	Project procurement management	16.0%			
3	Project scope management	27.0%			
4	Project risk management		16%		
5	Project Human Resources management		8%		
6	Project HSEQ management			10%	
7	Project Integration management			2%	
8	Project Knowledge management				7%
9	Project Stakeholder				3%
Complementary project management for optimal performance					
A. preference (Lean principles)	80%				
B. Alternative (Agile PM)	20%				

7.5. Summary

Chapter 7 has discussed the relationships between theory, literature, and practice about FPSO revamp project management at the execution phase and pointed to the facts and actions that have led to achieving the objectives of the research. First, the research methodology which integrated questionnaires and an interview survey with a Delphi method of data collection, together with AHP for model development when challenged with multi criteria decision making, required that the researcher reach out to participants through a purposive selection of experts in this field of endeavour, where experienced personnel are difficult to come by. Secondly, with the strategy and resolve for continuous enquiry and engagement with the experts, the root cause of the revamp project management challenge, which is uninformed decision making, was identified. In addition, solutions, and recommendations to solve the real-life problem of poor performance in FPSO revamp project management was achieved through expert consensus.

To conclude therefore, the researcher's choices, which have remained consistent with the theory of a multiple case study research strategy and pragmatism research philosophy, has been successfully deployed for realising the aim of the study.

CHAPTER EIGHT

Conclusions

Below summarises how the research objectives have been realised:

To investigate the current approaches used by oil and gas companies to manage FPSO revamp projects globally from the literature:

From literature, at least eight major oil and gas producing organisations around the world, comprising six multinational and two national companies, indicated conformance to the traditional waterfall otherwise called the stage-gate project management framework for all projects development irrespective of the local environment where the project is situated. This management framework is exemplified in the PMBOK guide and was confirmed in all the five case studies for this study being that oil and gas projects development are process driven with sequential and incremental progression from initiation through execution and handover to Operations.

To identify the major work activities and attributes of revamp projects with significant influence on project management performance:

The research findings demonstrated consensus of the participants in all five case studies for both the questionnaire and interview survey relating to four critical revamp project activities for optimal performance during execution phase. The activities include engineering, shop fabrication and construction works, offshore site installation and pre-commissioning and commissioning, while others are supportive and administrative in nature.

What is unique about this study is the venture undertaken into the execution project phase in a harsh offshore environment with limited interest and knowledge.

This opinion is informed because of limited access to the facility for survey or fieldwork and this was a challenge during the research. In addition, the difficulty encountered in the field trip from onshore to offshore through helicopter: the cost which includes visiting a hydrocarbon-laden asset offshore is a major challenge for any potential researcher. Also, availability of information and data poses an issue as they are lacking in the public domain. This is because, the experts are few and they are usually very busy and constrained by the strict information and data management regulations of their respective organisations. Therefore, the environment and the offshore work rigour reported by the experts as challenging made the research journey a complex venture. Nevertheless, the researcher was convinced that the findings and contributions to the body of knowledge on successful completion of the project would be phenomenal.

To critically analyse and evaluate other project management theories and approaches for application to revamp projects and develop a theoretical basis for new model development at the execution phase:

The comparison of four contemporary approaches and the traditional or stage-gate against five attributes for project management approach sustainability was showed in Table 2.1. They are industry application, robustness or independence through project lifecycle, ability to deal with project complexity, technology requirement and project management constraints or knowledge areas. In this research, which has focussed on FPSO revamp project execution, there are nine critical project management constraints identified for revamp project management. These knowledge areas form the sub-criteria for the FPSO revamp project execution in the AHP analysis. The knowledge areas from a review of the literature have not been ranked in order of priority to date, as all projects are unique and require tailoring to project management processes to suit their own peculiarities and specificities.

On the other hand, the contemporary project management approaches from literature are Lean philosophy, Agile project management (APM), Hybrid project management and Building Information Modelling. Each of these modern approaches had at least a flaw to support revamp project lifecycle, never been deployed on a project or still in conceptual stages of development, though they are very useful and complementary to the state-gate approach. However, the consensus of the experts in all five case studies for this research indicated Lean and Agile project management as most probable complementary approach.

Also, to support the quest for optimal project management approach sustainability, literature suggested the adoption of Analytic Hierarchy Process (AHP). The AHP framework is consistent with the process model development theory. It is complementary to the Delphi method as bias-free research instrument from literature for futuristic prediction. It was therefore appropriate for the multi-criteria decision making involving real life complex situation of the FPSO revamp project management improvement at the execution phase.

To develop, validate and test the proposed optimal FPSO revamp project management model based on the applicable theories and approaches:

The AHP model development has been validated and tested by all the multinational oil and gas case study organisations operating in Nigeria and in other parts of the world. The findings from this research reflect global perspective of the industry because the revamp project management experts operating in Nigeria and across the world have consensus opinion which is consistent with the literature that most major oil and gas operating companies all over the world are guided by same project management theory and practice covering ethics, standards and processes.

Again, consistent with theory and utilising the feedback of the experts through the research instrument of questionnaire and interview survey, the researcher has utilised the Analytic Hierarchy Process (AHP) to make informed project management decisions, establish priorities amongst project management constraints and has identified the Lean philosophy as a complementary alternative for the revamp type of project. This initiative will address the fundamental performance challenges and position project teams and practitioners on the trajectory of continuous improvement. Therefore, each of the major sub-department of the execution phase comprising engineering, prefabrication and construction, site installation, and pre-commissioning and commissioning functions, knows the constraints to focus on within the project plan to achieve optimal project management performance.

Also, Table 4.1 showed demography of experts for this study. A total of 24 participants out of 39 representing over 60% are expatriates working in Nigeria. This record is consistent with the fact that the dominant players in the oil and gas industry are multinational organisations (Ocheing et al., 2018) who are in active operations all around the world. However, this statistic is not surprising due to expatriation policy in most major oil and gas operating organisations globally. This indicates diversity, competitive edge and organisational performance sustainability. Although, each of these organisations has a unique corporate business and organisational structure, all are challenged with harmonising the socio-cultural diversity of the workforce into a common organisational culture and goal of operational excellence: all the organisations must align with standard operational procedures, guidelines, HSE standards, and the external constraint of deregulation (OGER, 2012, 2013; Bamanigopal, 2012 cited in Ocheing et al., 2018). Ocheing et al., (2018) posited that the oil and gas sector globally shares a common basic standard and practices. Therefore, the four multinational case studies in Nigeria used in this study are valid and a true reflection of the global community's position on moving the revamp project management to the status of optimal performance. Additionally, the group of oil and gas revamp project management experts all around the world that participated as the fifth case study, further proved the test result validity, reinforcing the fact that the objective of the research has been realised and that the case studies selected from major multinational oil and gas companies operating in Nigeria does not invalidate the outcomes of the research.

To develop a measurement tool, performance monitoring framework for the new model development and, recommendations based on the study:

This study has successfully developed an optimised model for FPSO revamp project management during the execution phase. The study approach is unique, and the findings are novel. The new proposed optimal FPSO revamp project management model has been developed using the Analytic Hierarchy Process (AHP) that complies with the features of a typical process modelling development framework. Based on the expert consensus from questionnaire and interview survey, this new model had bridged the gap between theory and practice by harmonising the stage-gate approach and the Lean philosophy. For the model to be sustainable, an implementation framework indicated in Figure 5.12 and a performance measurement tool was developed in this research. While the implementation framework is in line with Plan, Do, Check Act (PDCA) or Deming continuous improvement process, and has been used in describing the monitoring and control workflow, the performance measurement tool developed in Microsoft Excel, Table 5.3 is simple, user friendly and consistent with the UK KPI working group 2000.

8.1 Theoretical Contributions Emerging from Research

- There are several activities during the execution phase of project development, however, four, comprising engineering, shop fabrication and construction works, offshore site installation and pre-commissioning and commissioning are critical for optimal FPSO revamp project management.

- Nine theoretical knowledge areas comprising project scope, procurement, cost and schedule, risk, human resources, Health Safety Environment Quality (HSEQ), integration, knowledge, and stakeholder management have been identified as critical for optimal FPSO revamp project management at execution stage.

- The stage-gate project management approach is not yielding optimal performance. However, integration of either Lean principles or Agile Project Management with the Stage-gate management process for FPSO revamp at the execution stage improves project delivery. FPSO revamp project management have been optimised in this research by infusing the Lean philosophy into identified critical knowledge areas.

- A four level, three step Analytic Hierarchy Process (AHP) analysis of the current five stage-gate project management approach can be used to make group decisions concerning FPSO revamp project management for the execution project phase. A model utilizing Analytic Hierarchy Process (AHP) has been developed for optimal FPSO revamp during execution stage. The AHP used for the model development was an excellent methodology for harmonising the subjective, intangible expressions into tangible units of measurement by the experts. The approach to keep the developed model simple and smart enough to understand revealed the experts' inputs in getting to the basis of revamp project management optimisation.

- An implementation framework for monitoring and control workflow has been developed in line with Plan, Do, Check Act (PDCA) or Deming continuous improvement process. Also, the performance measurement tool is developed, consistent with the UK KPI working group 2000.

8.2 Contributions to Knowledge, implications for Theory and Practice

- FPSO asset revamp project management often fail because of uninformed decision making occasioned by its peculiarity and complexity rather than the hitherto suggested non-compliance with project management theory. The research validated the literature that most major oil and gas organisations rely on the stage-gate approach. This approach is result-oriented but requires informed multi-criteria decision- making for optimal performance.

- Project management improvement opportunities are not limited only to the Front-End Loading (FEL) stages of project development. Starting with the research focus on the execution project phase, most literature has hitherto focussed on the front-end loading (FEL) phases for improvement opportunities. This points to the tradition of assuming that most process improvement efforts should and are best discussed, planned and concluded ahead of the executing process group, and subsequent changes are managed through a change order process at the execution phase where the project components are realised.

There are lots of opportunities for further improvement during execution phase. The incentives in this phase include: huge budget allocation, activities are on the critical path which implies opportunity for schedule optimization, attracts huge workforce and therefore opportunities abound for sharing learning and continuous improvement. This research has shown that continuous improvement has no phase limitation especially with revamp projects with inherent challenges and uncertainties at play. Three project management constraints - project scope, cost and schedule and procurement are critical for optimal FPSO revamp project management at the execution phase and are best deployed for engineering activities. Streamlining specific activities to actual realisable needs like the engineering activity is an optimisation initiative, an attempt to eliminate waste and offers better decision-making for suitable deployment of resources.

- Lean philosophy had preference over Agile Project Management (APM). That, seemingly, is the most appropriate but has lesser acceptance in actual practice as the practical compensatory approach for optimal FPSO revamp project management.

- The research methodology (mixed research approach - combining the literature review, Delphi method and the AHP under case studies) is consistent with pragmatism philosophy which has proven to be an excellent approach for optimal decision- making in complex life problems of the FPSO revamp projects where the expertise required are not readily available. Due to the complex nature of the research topic, the researcher formulated a corresponding comprehensive research methodology with the pragmatism research philosophy to address the complex real-life problem of FPSO revamp project management.

To get to the root of the problem, it was important to iteratively engage experts through the Delphi method. In addition, the multiple case study approach provided an opportunity to focus on the issues and appropriate solutions in- depth, while ensuring the validity of the findings by having as many as five cases comprising four major multinational organisations. Validations and test results from the AHP data analysis is very close to the model development for all the case studies of multinational oil and gas organisations operating in Nigeria and in other parts of the world. Therefore, the findings from this research are reflections of a global perspective into the industry and the methodologies to acquire and analyse research data was ingenious and appropriate for achieving the research objectives.

8.3 Recommendations for future Research

Below are recommendations for future research based on the findings and limitations of the study:

a. Investigate why experts in the oil and gas industry seemingly shy away from discussing revamp project performance especially from cost and schedule perspective in the public domain.

b. Explore the usage of Analytic Hierarchy Process (AHP) modelling in deciding critical project management knowledge areas and compensatory project management approaches for optimising other project development phases.

c. Explore the application of the new FPSO revamp project management model from this study into other types of project including program and portfolio of projects and in other industries outside of oil and gas.

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APPENDICES

Appendix A: Questionnaire Survey and Cover Letter

10th April 2019

Dear Sir/Madam,

I am a PhD research student in the School of Science, Engineering and Environment (SEE), University of Salford Manchester, United kingdom and working on the research project entitled *" Optimal FPSO Revamp Project Management: The Execution Phase Model Development"* under the supervision of Prof Min An.

The aim of this research is to develop an optimal process model for managing oil and gas revamp projects during the execution phase, focusing on FPSO plants (Topside).

To achieve the research aim, the following objectives have been defined:

I. To investigate the current approaches used by oil and gas companies to manage FPSO revamp projects globally from the literature.

II. To identify the major work activities and attributes of revamp projects with significant influence on project management performance.

III. To critically analyse and evaluate other project management theories and approaches for application to revamp projects and develop a theoretical basis for new model development at the execution phase.

IV. To develop, validate and test the proposed optimal FPSO revamp project management model based on the applicable theories and approaches.

V. To develop a measurement tool, performance monitoring framework for the new model development and, recommendations based on the study.

As project practitioner or support personnel working for a major industry player in Nigeria oil and gas exploration and production industry, your expertise and experience would definitely provide me invaluable information, which I believe this will particularly help to complete my PhD study.

This questionnaire is an approved research instrument for the thesis and your participation will provide credibility to my research endeavour as well as improve overall body of knowledge especially to project practitioners.

However, do please note that your participation is entirely voluntary, and you are very free to withdraw at any time without any problem.

Responses from respondents would be used solely for the academic purpose of completing the titled thesis and I'm committed to maintaining anonymity and confidentiality of participants in accordance with the university's standard procedure and consistent with the approved Company's data management and protection of information guidelines.

The questionnaire is expected to take approximately thirty (30) minutes to complete. You are encouraged to answer all twenty (20) questions as there are no right or wrong answers to the questions asked.

Thank you for your participation.

Yours sincerely,

Name: Clement Isibor

@00275412, PhD Researcher, Construction and Project Management

E-mail: c.isibor@edu.salford.ac.uk, Tel: +2348064040611

Instruction: *Answer all twenty-eight (20) questions. There are no Right or Wrong answers. Do provide candid and precise answers.*

SECTION 1 (General questions)

1. What is the name of your company or organization to which it's affiliated?

…………………………………………………………………………………………………

2. What is the core business of your organization?

…………………………………………………………………………………………………

3. How many other continents other than Africa is your organization in active operations?

…………………………………………………………………………………………………

4. Does your organization have dedicated project department or global project entity?

…………………………………………………………………………………………………

5. What are your total years of experience working as either a project practitioner or project support?

…………………………………………………………………………………………………

6. What is your age/nationality/current job designation?

………………………………………………………………………………………………

SECTION 2 (Semi-structured) – Select only one answer appropriate for your organization or a brief narrative based on your experiences

7. Your organization utilizes the five stage-gate comprising initiation; selection; definition; execution and Operation framework or model for managing Capital or Major projects.
    a. Agree
    b. Disagree
    c. Unsure
8. Revamp 'brownfield' projects at execution phase major activities are Engineering, Prefabrication/Construction, Site installation, and pre-commissioning/commissioning attracts lesser budget estimate but are more complex to manage than capital/mega/major/ "greenfield" projects.
    a. Agree
    b. Disagree
    c. Unsure
9. How would you describe your organization's approach to manging revamp projects?
    a. Traditional (five stage-gate) model
    b. Agile Project Management
    c. Lean philosophy
    d. Hybrid Project Management (Traditional plus Agile Project Management) or other approaches.
10. How would you rate the overall FPSO revamp project performance in your organization judging by project management criteria like cost, schedule, quality, HSE, customer satisfaction etc.
    a. Excellent
    b. Calls for improvement
    c. Very poor
11. Indicate all the critical project management constraints from HSEQ, knowledge, cost & schedule, scope, procurement, risk, communication, human resources, integration,

stakeholder, Interface, Customer satisfaction management and others in your opinion for each of the under listed revamp project activities during execution phase.

Engineering…………………………………………………………….

Construction…………………………………………………….….

Installation…………………………………………………….……….

Pre-commissioning and Commissioning ………………………

12. Indicate area (s) or project function with brief reasons from where your organization should focus more to improve the overall revamp project performance.

    a. Initiation, Concept selection and Definition (FEL) Phases

    b. Execution Phase

    c. Operate Phase

13. Tick any or all the project management theory or model you have either applied totally or partially in executing previous revamp projects:

Traditional/ Stage gate/Waterfall; Agile PM; Lean philosophy; Hybrid (Traditional and Agile); PRINCE 2; PRISM; SCRUM; Critical Path Method (CPM); Critical Chain PM; Integrated PM, and Others - provide name

14. Describe how best revamp projects are managed in your organization

a. Managed on case by case basis based on the skill and experience of the assigned project manager

b. via a Model; Framework; System; or Processes

c. Not so sure

15. Select all applicable means below, how your project team or organization can improve or overcome failures in some or any revamp project

a. Application of companywide project management framework

b. Teamwork and collaboration with all stakeholders

c. Competitive tendering process to select an Engineering; Procurement; Construction; Installation and Management contractor

16. Select all from below and add if applicable that which your organization can do to ensure implementation of standardized process, framework, or model for managing revamp project execution?

a. Lessons learned capturing and application

b. Trainings and team building

c. Experienced Personnel selection and retention by their functional department.

17. Analytical Hierarchy Process (AHP) is a globally acceptable multiple criteria (pairwise comparison) decision making approach of selecting majority expert opinion from competing alternatives. How knowledgeable are you about AHP?

a. Have heard of it

b. Have applied it in decision making

c. Have no knowledge about AHP

18.

Compare the execution project activities, constraints, and project management approach that contributes most value to FFSD project performance using the AHP table attached.

AHP Comparison Scale

Numeric Value	Verbal Judgement
9	Extremely important
8	Very, very strong
7	Very strongly more important
6	Strong plus
5	Strongly more important
4	Moderate plus
3	Moderately more important
2	Weak or slight
1	Equally important

* Fill the upper/grey diagonal matrix.

Execution Phase Activities

Reciprocal Matrix

	Engineering	Prefab/construction	Site Installation	Pre-comm/Comm
Engineering	1.0			
Prefab/construction		1.0		
Site Installation			1.0	
Pre-comm/Comm				1.0

On sub criteria of criterion Engineering:

Sub criteria	Scope	Procurement	Cost/Schedule
Scope	1.00		
Procurement		1.00	
Cost/Schedule			1.00

On Sub criteria of criterion Prefab/Construction:

Sub criteria	Risk	Human Resources
Risk	1.00	
Human Resources		1.00

On Sub criteria of criterion Site Installation:

Sub criteria	HSEQ	Integration
HSEQ	1.00	
Integration		1.00

On Sub criteria of criterion Pre-com/ Commissioning:

Sub criteria	Knowledge	Stakeholder
Knowledge	1.00	
Stakeholder		1.00

Alternatives for Sub criterion Scope:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion Procurement:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion Cost/Schedule:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion Risk:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion Human Resources:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion HSEQ:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion Integration:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion Knowledge:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

Alternatives for Sub criterion Stakeholder:

Alternatives	Lean	APM
Lean	1.00	
APM		1.00

19. Should the consensus opinion differ from yours in some instances, would you still subscribe to the proposed optimal FPSO revamp project management model from AHP approach?

a. Yes

b. No

c. Not sure

SECTION 3 (Open question)

20. How would you convince your organization to adopt a new optimised model for managing FPSO revamp project execution?

Appendix B: Interview Survey Guide

Title of Thesis: Optimal FPSO Revamp Project Management:

The Execution Phase Model Development.

Key to Interview Guide: Q = Major Question; QP = Prompt Question

Q1. The position of (current job title of interviewee) comes with hard work, dedication, and experience. Could you share a little bit of you career profile up to your current job position?

Q1P1. How many years of your career have you majored as a project practitioner in the oil and gas industry?

Q2. How are typical projects (major and revamp) managed through its life cycle in your organization?

Q2P1. Could you share your project experiences working on live facility until shutdown for hook-up or tie-in?

Q2P2. What are the most challenging processes/phases?

Q2P3. Are the processes defined, formalized, and adopted by top management as guideline in your organization?

Q2P4. How do you classify jobs for project intervention in your organization?

Q3. Could you describe how your organization is structured to manage revamp projects involving Turn-Around-Maintenance or full facility shut down campaigns for optimal production shortfall?

Q3P1. How many Shut down or Turn around maintenance campaigns have you been involved in?

Q3P2. How does your organization assure proper planning and readiness for revamp project execution involving full field shutdown?

Q4. How would you assess the overall performance of one or more of the revamp projects that you were actively involved in?

Q4P1. What were your major performance indicators? – Safety concern, Schedule slippage and budget overrun etc.?

Q4P2. Looking back hindsight what could you have done differently to improve overall performance?

Q5. What are your organization's attitude towards improving revamp projects execution at all phases?

Q5P1. How do you assure continuous improvement in the performance of projects in your organization?

Q5P2. Does continuous improvement tools and applications adopted in your organization linked to any known theory or model?

Q5P3. Could you please throw some lights on the theory or model?

Q6. How would you assess specifically the issues and discussions around wastages, re-work, inspection and acceptance of finished products, materials availability, storage, and handling during project execution?

Q6P1. To what extent is the concept of Lean and/or Agile project management demonstrated in your organization?

Q6P2. How would you address the issues and concerns about wastages and customer satisfaction during project execution?

Q6P3. How do you ensure that experiences from completed projects are applied in subsequent similar projects?

Q6P4. How do you ensure that experienced personnel usage of company tools, applications and processes are preserved for sustained project performance and continuous improvement?

Q6P5. Why is it important for your organization to ensure implementation of standardized process, framework, or model for managing revamp project execution?

Q6P6. Mention major areas or project function with reasons where your organization should focus on to improve the overall revamp project performance.

Q6P7. How would you convince your organization to adopt a new optimised model for managing FPSO revamp project execution?

________________________ ___________________

Name of participant   Date   Signature

________________________ ___________________

(PhD Researcher)   Date

Appendix C: Ethical Application Approval Letter

University of Salford MANCHESTER

Research, Innovation and Academic Engagement Ethical Approval Panel

Doctoral & Research Support
Research and Knowledge Exchange,
Room 827, Maxwell Building
University of Salford
Manchester
M5 4WT

T +44(0)161 295 5278

www.salford.ac.uk/

6 November 2019

Clement Isibor

Dear Clement

RE: ETHICS APPLICATION STR1819-57 – Optimal FPSO Revamp Project Management: The Execution Phase Model Development

Based on the information you provided, I am pleased to inform you that your application STR1819-57 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

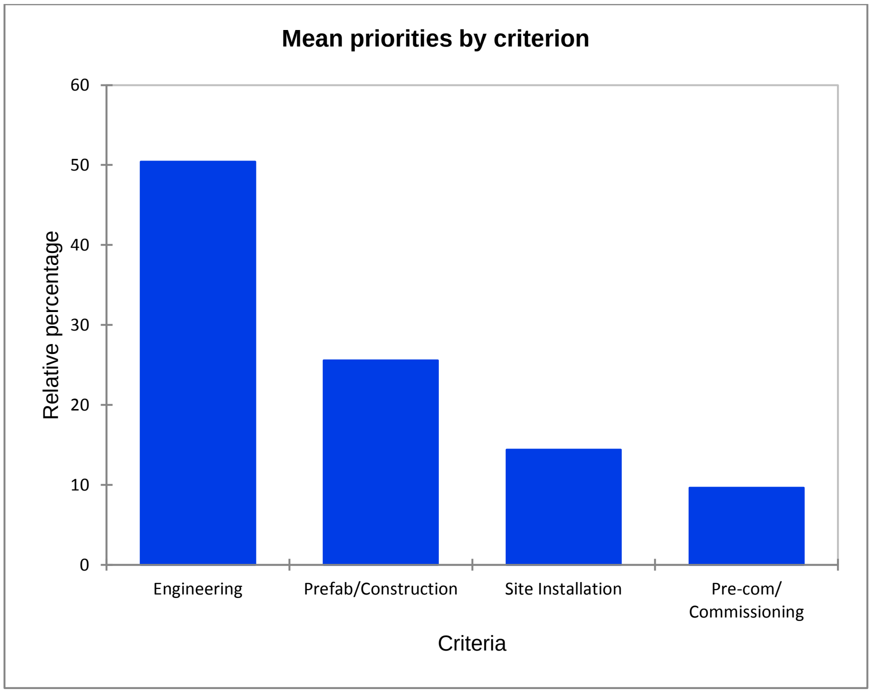
Dr Devi Prasad Tumula
Deputy Chair of the Science & Technology Research Ethics Panel

Appendix D: AHP Analysis

Mean priorities by criterion:

Criteria	%
Engineering	50.42
Prefab/Construction	25.56
Site Installation	14.40
Pre-com/ Commissioning	9.62

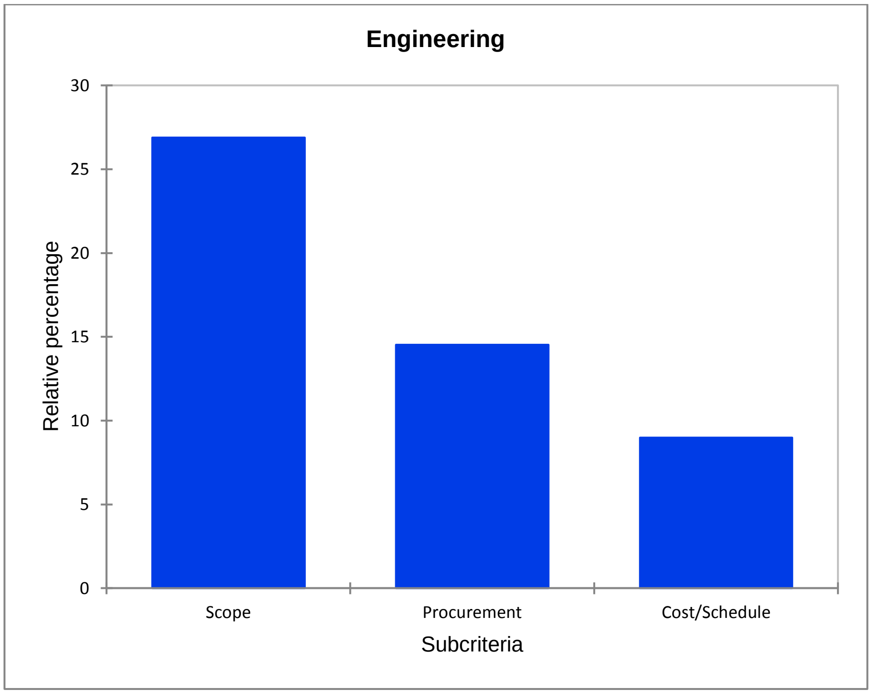
Figure: Mean priorities by criterion



Mean priorities by sub criterion of criterion:

Engineering	%
Scope	26.90
Procurement	14.53
Cost/Schedule	8.99

Figure: Engineering

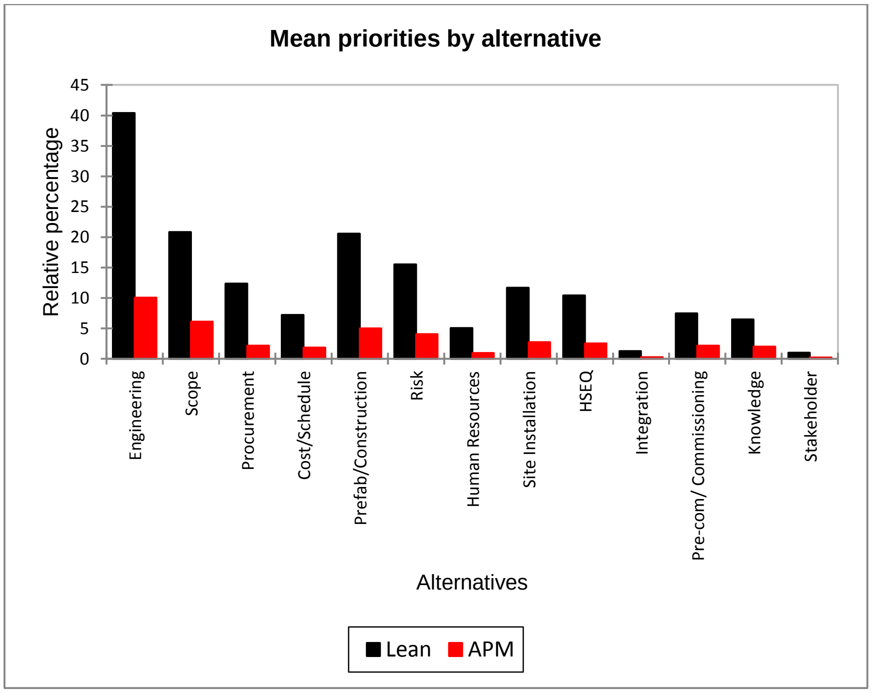


Mean priorities by alternative:

Crit./Alt.	Lean	APM
Engineering	40.38	10.04
Scope	20.82	6.08
Procurement	12.38	2.15
Cost/Schedule	7.19	1.81
Prefab/Construction	20.57	4.99
Risk	15.53	4.04
Human Resources	5.03	0.95
Site Installation	11.65	2.75
HSEQ	10.39	2.51
Integration	1.26	0.24
Pre-com/ Commissioning	7.45	2.17
Knowledge	6.45	1.98

Stakeholder	1.01	0.19

Figure: Mean priorities by alternative



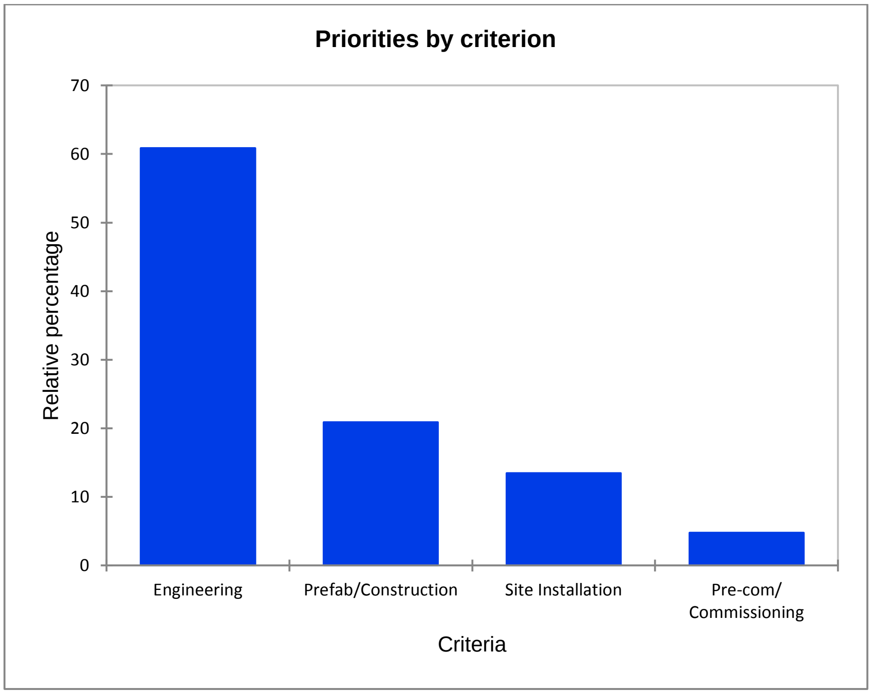
Results obtained from the ratings of evaluator EVA:

Priorities by criterion:

Criteria	%
Engineering	60.87
Prefab/Construction	20.86
Site Installation	13.48
Pre-com/ Commissioning	4.79

IC = 0.494; RC = 54.86%

Figure: Priorities by criterion

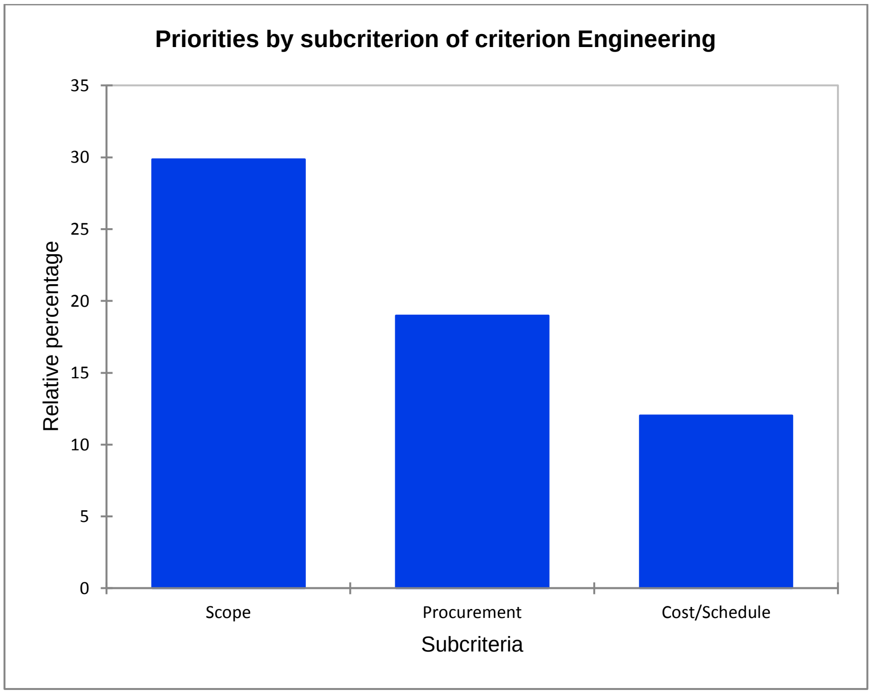


Priorities by sub criterion of the criterion:

Engineering	%
Scope	29.86
Procurement	18.99
Cost/Schedule	12.03

IC = 0.027; RC = 4.63%

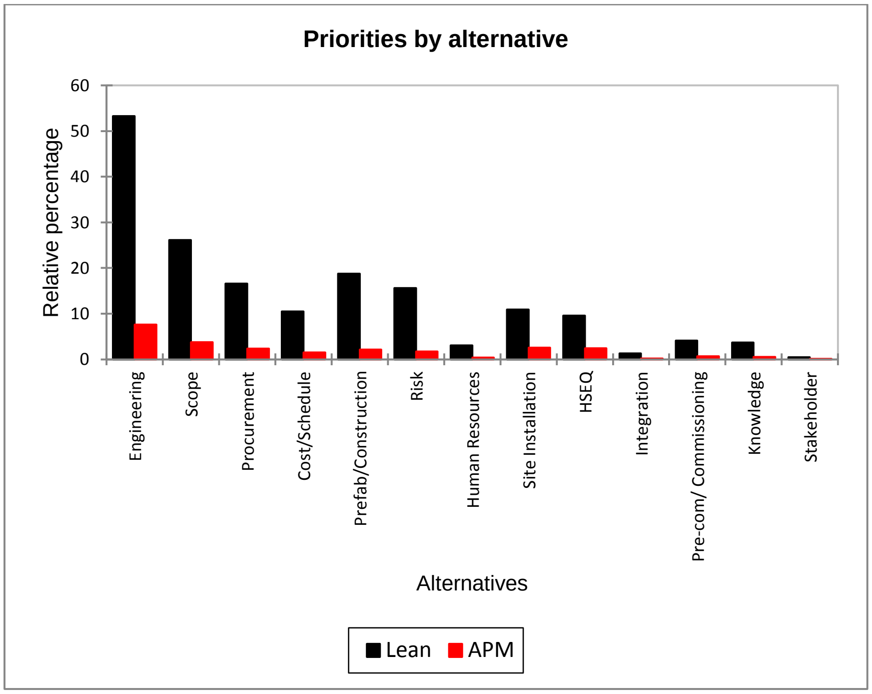
Figure: Priorities by sub criterion of criterion Engineering



Priorities by alternative:

Crit./Alt.	Lean	APM	IC	RC
Engineering	53.26	7.61	0.00	0.00
Scope	26.12	3.73	0.00	0.00
Procurement	16.61	2.37	0.00	0.00
Cost/Schedule	10.53	1.50	0.00	0.00
Prefab/Construction	18.74	2.13	0.00	0.00
Risk	15.65	1.74	0.00	0.00
Human Resources	3.09	0.39	0.00	0.00
Site Installation	10.92	2.56	0.00	0.00
HSEQ	9.58	2.40	0.00	0.00
Integration	1.33	0.17	0.00	0.00
Pre-com/ Commissioning	4.14	0.64	0.00	0.00
Knowledge	3.67	0.52	0.00	0.00
Stakeholder	0.48	0.12	0.00	0.00

Figure: Priorities by alternative



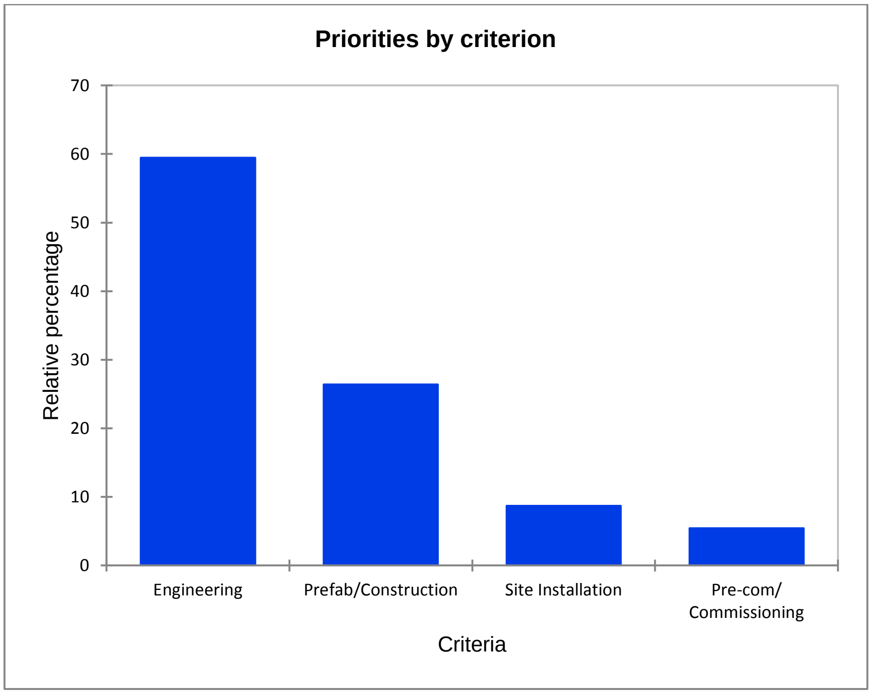
Results obtained from the ratings of evaluator EVB:

Priorities by criterion:

Criteria	%
Engineering	59.45
Prefab/Construction	26.42
Site Installation	8.69
Pre-com/ Commissioning	5.45

IC = 0.275; RC = 30.5%

Figure: Priorities by criterion

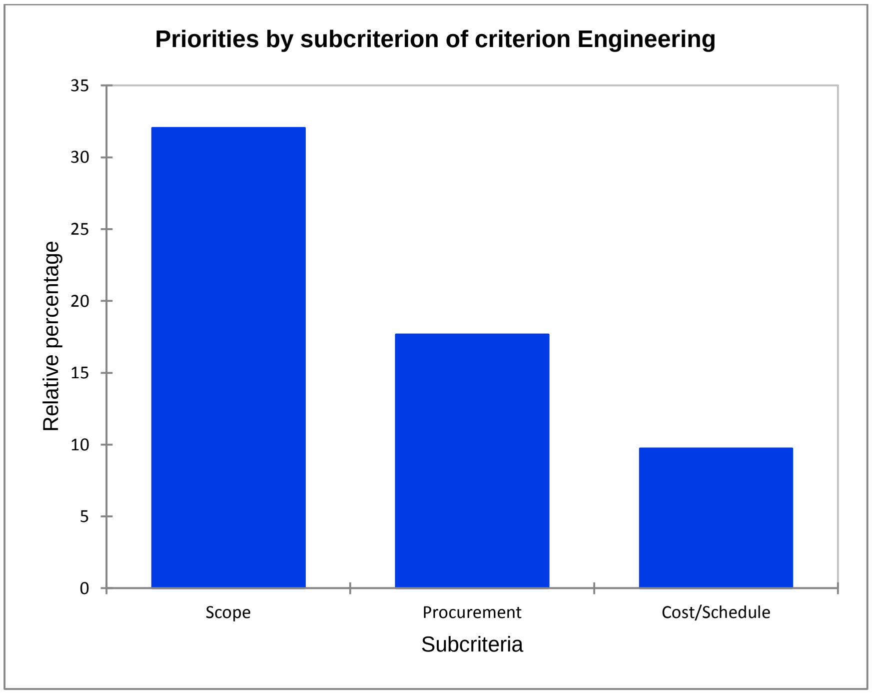


Priorities by sub criterion of the criterion:

Engineering	%
Scope	32.04
Procurement	17.67
Cost/Schedule	9.74

IC = 0.005; RC = 0.79%

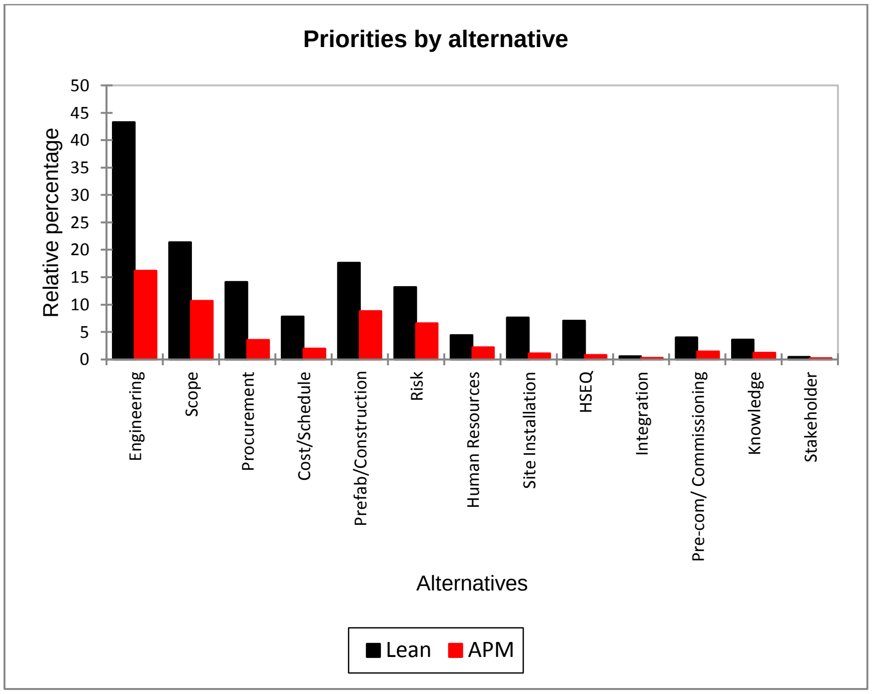
Figure: Priorities by sub criterion of criterion Engineering



Priorities by alternative:

Crit./Alt.	Lean	APM	IC	RC
Engineering	43.29	16.16	0.00	0.00
Scope	21.36	10.68	0.00	0.00
Procurement	14.14	3.53	0.00	0.00
Cost/Schedule	7.79	1.95	0.00	0.00
Prefab/Construction	17.61	8.81	0.00	0.00
Risk	13.21	6.60	0.00	0.00
Human Resources	4.40	2.20	0.00	0.00
Site Installation	7.61	1.07	0.00	0.00
HSEQ	7.03	0.78	0.00	0.00
Integration	0.58	0.29	0.00	0.00
Pre-com/ Commissioning	4.03	1.42	0.00	0.00
Knowledge	3.58	1.19	0.00	0.00
Stakeholder	0.45	0.23	0.00	0.00

Figure: Priorities by alternative



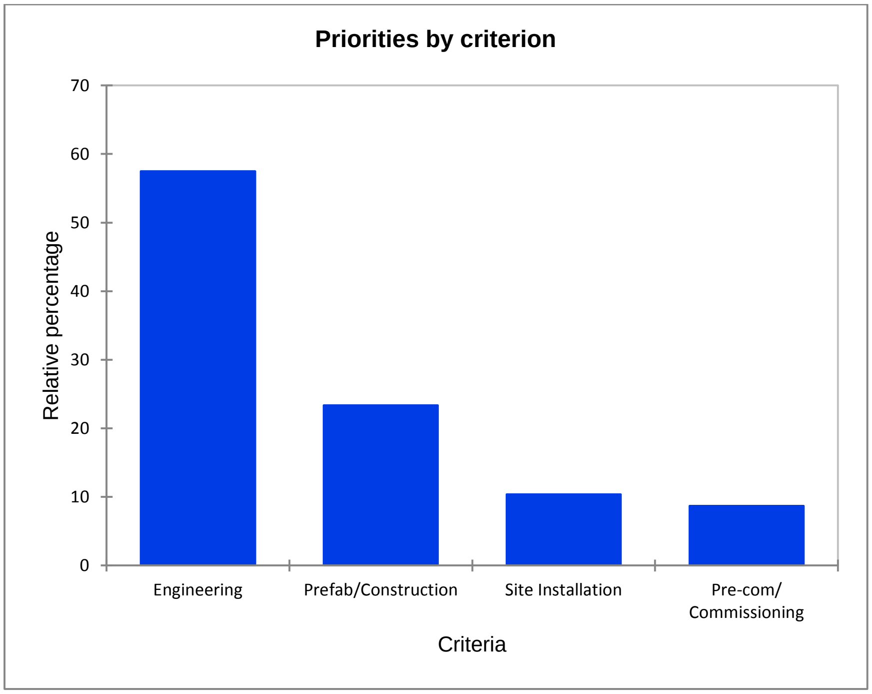
Results obtained from the ratings of evaluator EVC:

Priorities by criterion:

Criteria	%
Engineering	57.52
Prefab/Construction	23.38
Site Installation	10.39
Pre-com/ Commissioning	8.71

IC = 0.445; RC = 49.39%

Figure: Priorities by criterion

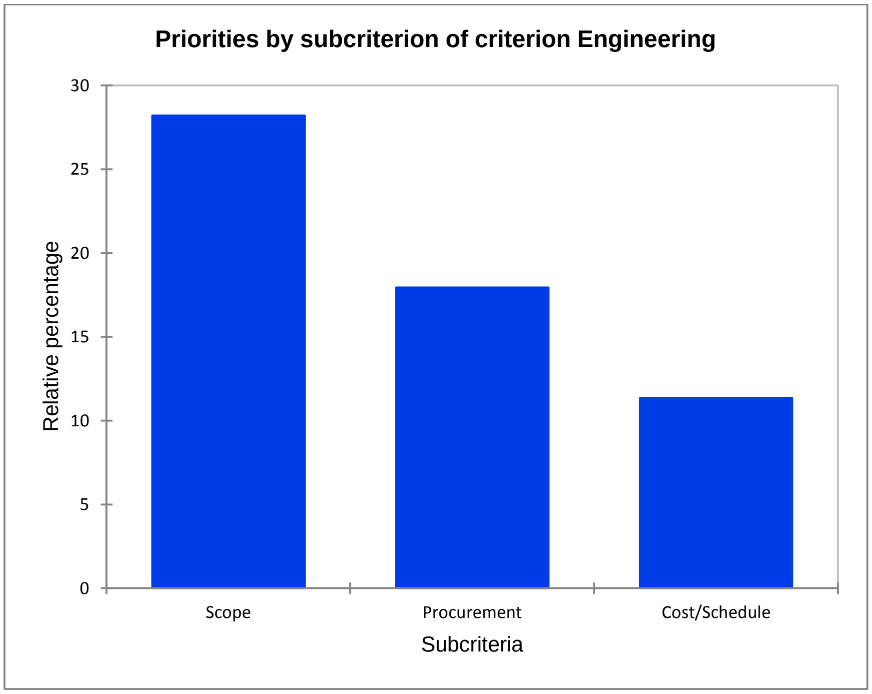


Priorities by sub criterion of the criterion:

Engineering	%
Scope	28.21
Procurement	17.94
Cost/Schedule	11.37

IC = 0.027; RC = 4.63%

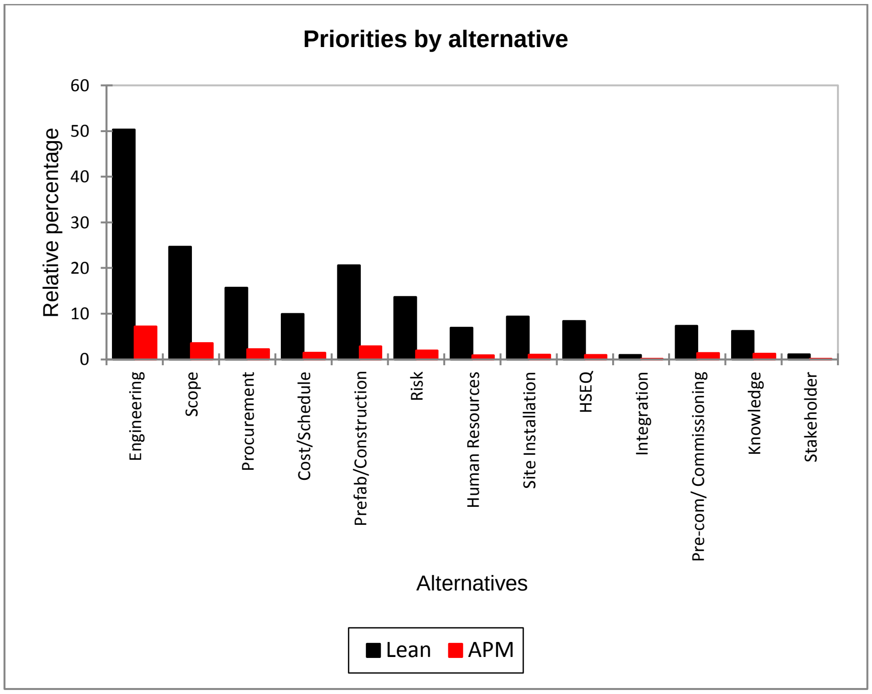
Figure: Priorities by sub criterion of criterion Engineering



Priorities by alternative:

Crit./Alt.	Lean	APM	IC	RC
Engineering	50.33	7.19	0.00	0.00
Scope	24.69	3.53	0.00	0.00
Procurement	15.70	2.24	0.00	0.00
Cost/Schedule	9.95	1.42	0.00	0.00
Prefab/Construction	20.56	2.81	0.00	0.00
Risk	13.64	1.95	0.00	0.00
Human Resources	6.93	0.87	0.00	0.00
Site Installation	9.34	1.05	0.00	0.00
HSEQ	8.42	0.94	0.00	0.00
Integration	0.92	0.12	0.00	0.00
Pre-com/ Commissioning	7.33	1.38	0.00	0.00
Knowledge	6.22	1.24	0.00	0.00
Stakeholder	1.11	0.14	0.00	0.00

Figure: Priorities by alternative



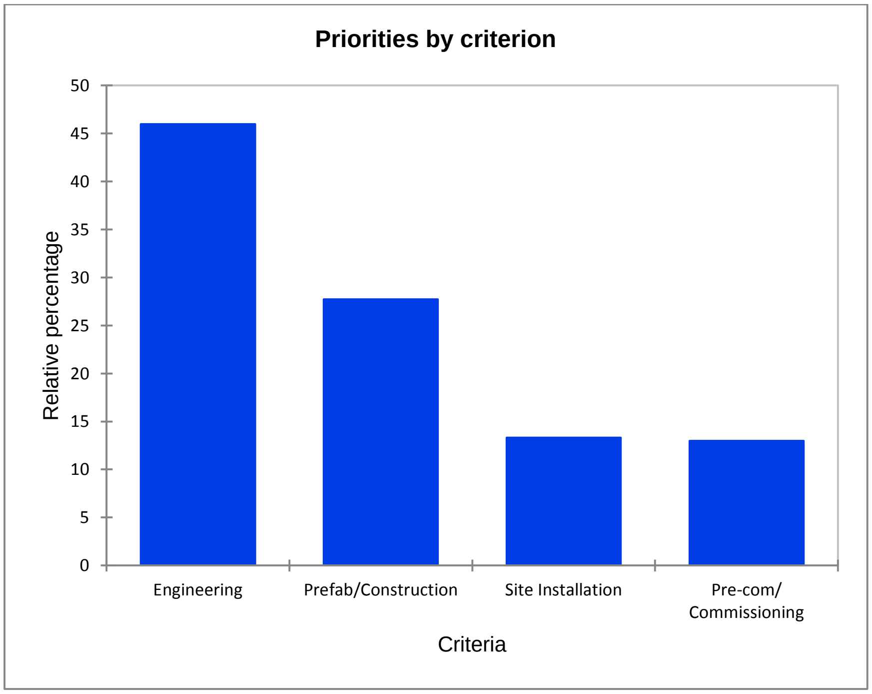
Results obtained from the ratings of evaluator EVD:

Priorities by criterion:

Criteria	%
Engineering	45.98
Prefab/Construction	27.73
Site Installation	13.31
Pre-com/ Commissioning	12.99

IC = 1.254; RC = 139.28%

Figure: Priorities by criterion

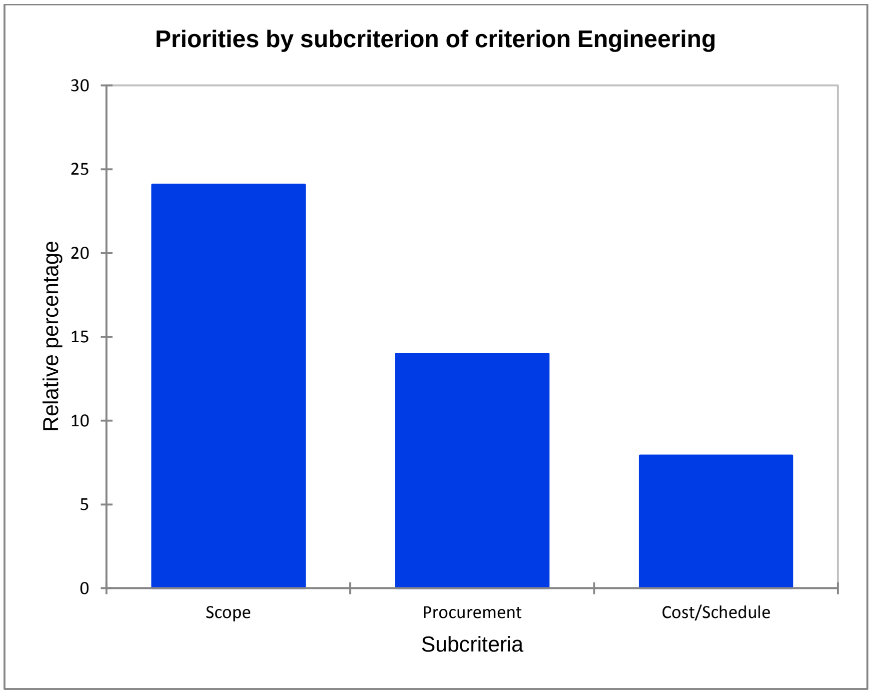


Priorities by sub criterion of the criterion:

Engineering	%
Scope	24.08
Procurement	13.99
Cost/Schedule	7.91

IC = 0.130; RC = 22.46%

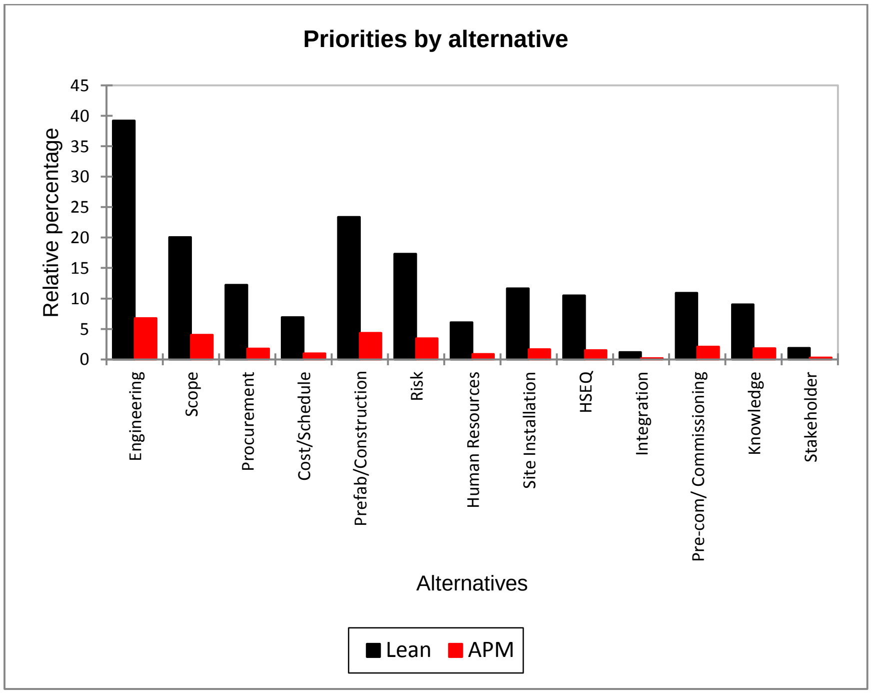
Figure: Priorities by sub criterion of criterion Engineering



Priorities by alternative:

Crit./Alt.	Lean	APM	IC	RC
Engineering	39.23	6.75	0.00	0.00
Scope	20.07	4.01	0.00	0.00
Procurement	12.24	1.75	0.00	0.00
Cost/Schedule	6.92	0.99	0.00	0.00
Prefab/Construction	23.39	4.33	0.00	0.00
Risk	17.33	3.47	0.00	0.00
Human Resources	6.07	0.87	0.00	0.00
Site Installation	11.64	1.66	0.00	0.00
HSEQ	10.48	1.50	0.00	0.00
Integration	1.16	0.17	0.00	0.00
Pre-com/ Commissioning	10.91	2.07	0.00	0.00
Knowledge	9.02	1.80	0.00	0.00
Stakeholder	1.89	0.27	0.00	0.00

Figure: Priorities by alternative



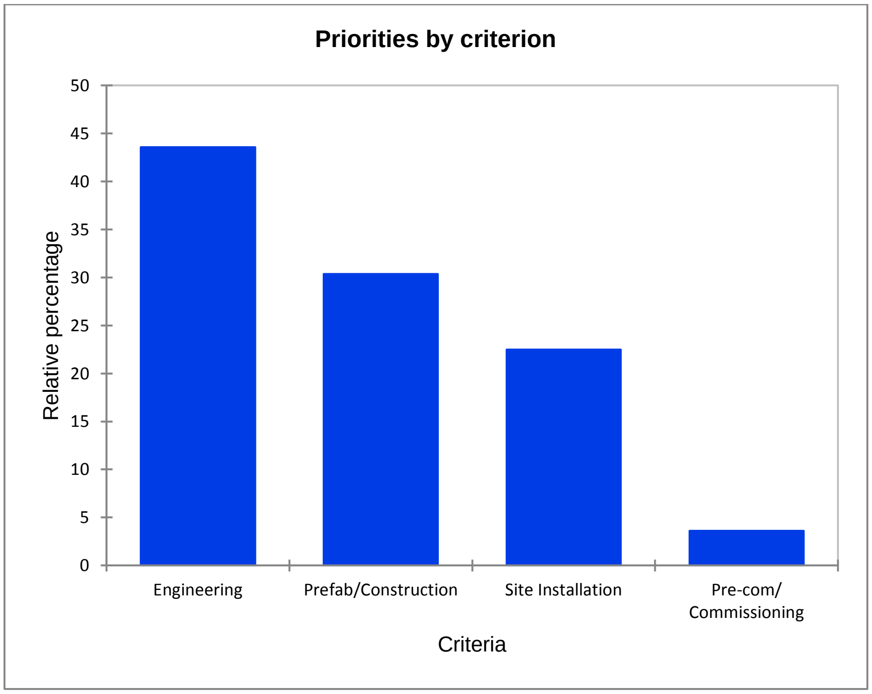
Results obtained from the ratings of evaluator EVE:

Priorities by criterion:

Criteria	%
Engineering	43.57
Prefab/Construction	30.35
Site Installation	22.47
Pre-com/ Commissioning	3.60

IC = 0.668; RC = 74.24%

Figure: Priorities by criterion

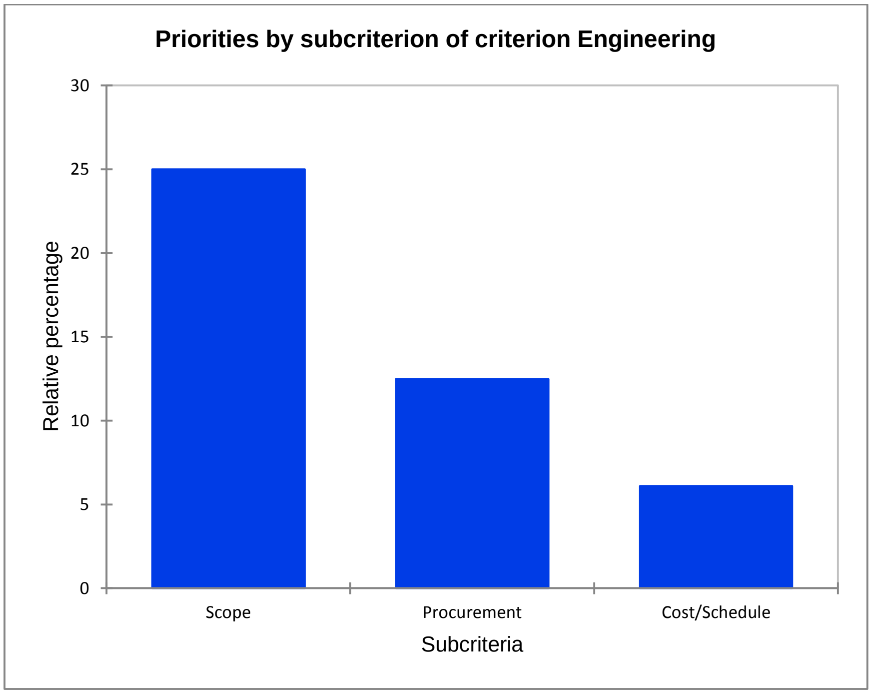


Priorities by sub criterion of the criterion:

Engineering	%
Scope	25.00
Procurement	12.48
Cost/Schedule	6.10

IC = 0.069; RC = 11.83%

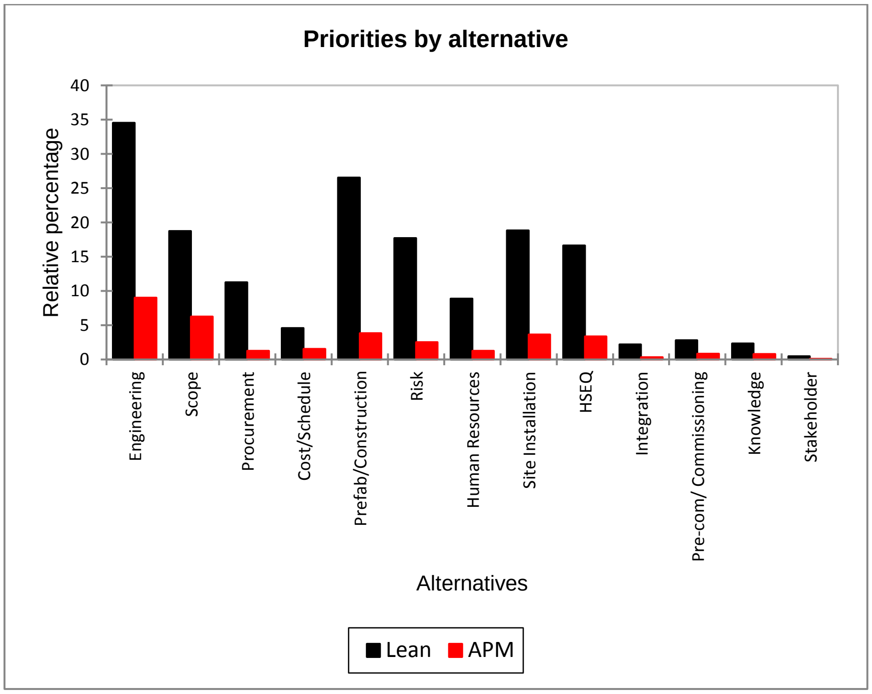
Figure: Priorities by sub criterion of criterion Engineering



Priorities by alternative:

Crit./Alt.	Lean	APM	IC	RC
Engineering	34.55	9.02	0.00	0.00
Scope	18.75	6.25	0.00	0.00
Procurement	11.23	1.25	0.00	0.00
Cost/Schedule	4.57	1.52	0.00	0.00
Prefab/Construction	26.55	3.79	0.00	0.00
Risk	17.70	2.53	0.00	0.00
Human Resources	8.85	1.26	0.00	0.00
Site Installation	18.83	3.64	0.00	0.00
HSEQ	16.65	3.33	0.00	0.00
Integration	2.19	0.31	0.00	0.00
Pre-com/ Commissioning	2.77	0.84	0.00	0.00
Knowledge	2.32	0.77	0.00	0.00
Stakeholder	0.45	0.06	0.00	0.00

Figure: Priorities by alternative



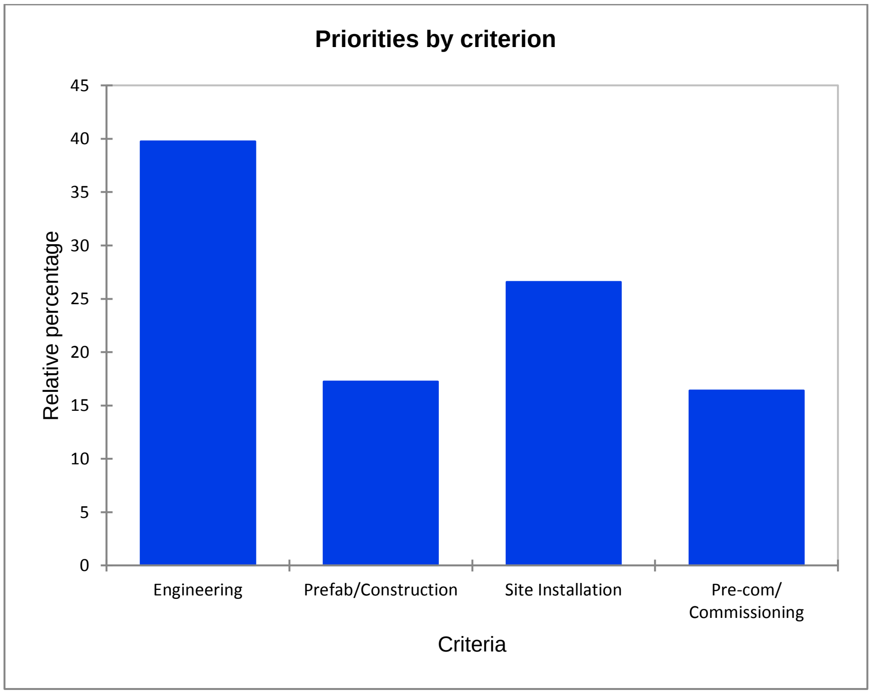
Results obtained from the ratings of evaluator EVF:

Priorities by criterion:

Criteria	%
Engineering	39.76
Prefab/Construction	17.24
Site Installation	26.59
Pre-com/ Commissioning	16.40

IC = 0.394; RC = 43.77%

Figure: Priorities by criterion

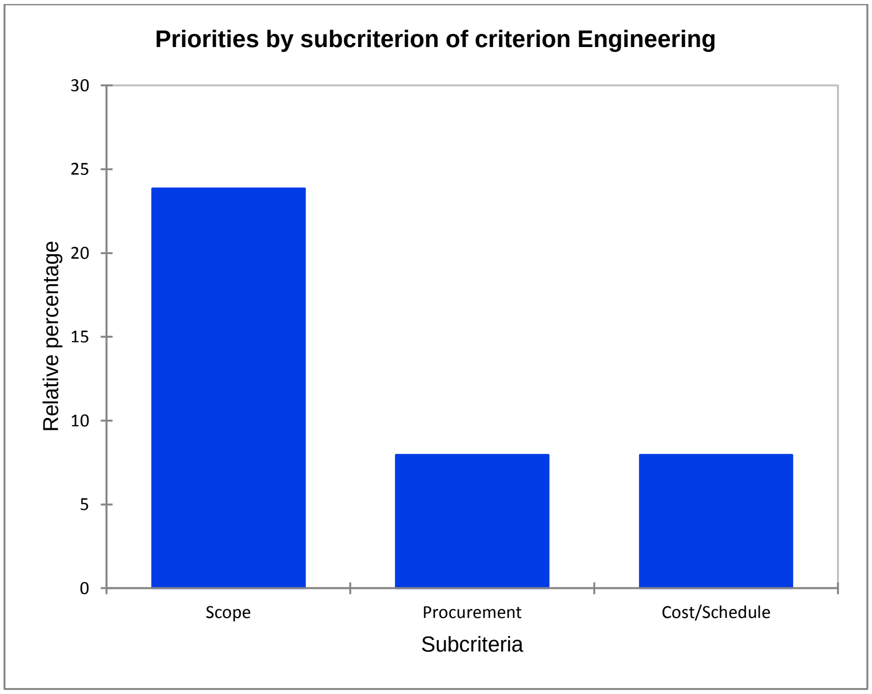


Priorities by sub criterion of the criterion:

Engineering	%
Scope	23.86
Procurement	7.95
Cost/Schedule	7.95

IC = 0; RC = 0%

Figure: Priorities by sub criterion of criterion Engineering



Priorities by alternative:

Crit./Alt.	Lean	APM	IC	RC
Engineering	28.50	11.27	0.00	0.00
Scope	17.89	5.96	0.00	0.00
Procurement	5.30	2.65	0.00	0.00
Cost/Schedule	5.30	2.65	0.00	0.00
Prefab/Construction	11.88	5.36	0.00	0.00
Risk	9.58	4.79	0.00	0.00
Human Resources	2.30	0.57	0.00	0.00
Site Installation	18.08	8.51	0.00	0.00
HSEQ	15.95	7.98	0.00	0.00
Integration	2.13	0.53	0.00	0.00
Pre-com/ Commissioning	12.38	4.02	0.00	0.00
Knowledge	11.07	3.69	0.00	0.00
Stakeholder	1.31	0.33	0.00	0.00

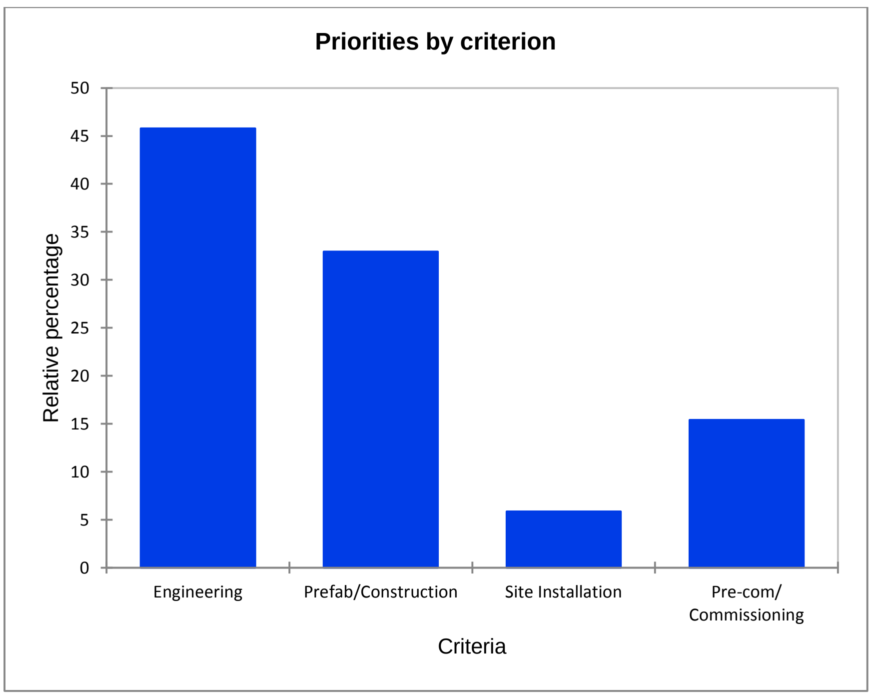
Results obtained from the ratings of evaluator EVG:

Priorities by criterion:

Criteria	%
Engineering	45.80
Prefab/Construction	32.93
Site Installation	5.86
Pre-com/ Commissioning	15.41

IC = 0.722; RC = 80.22%

Figure: Priorities by criterion

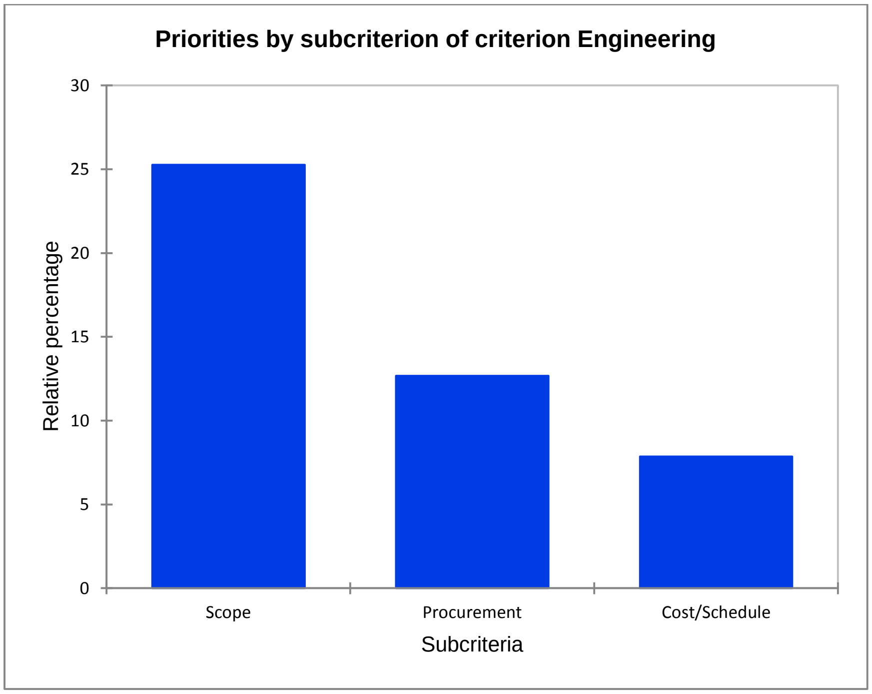


Priorities by sub criterion of the criterion:

Engineering	%
Scope	25.26
Procurement	12.68
Cost/Schedule	7.86

IC = 0.189; RC = 32.54%

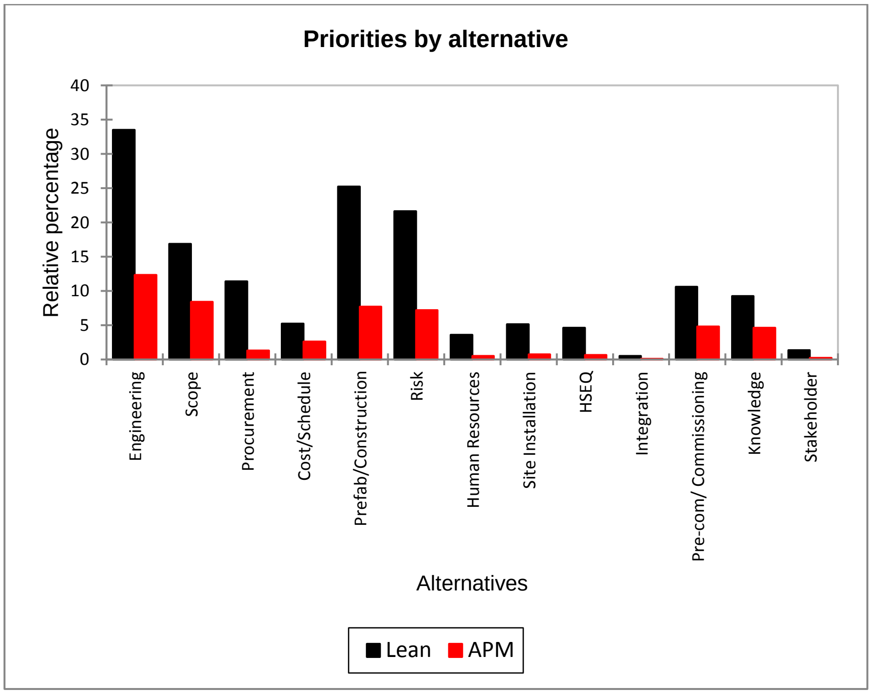
Figure: Priorities by sub criterion of criterion Engineering



Priorities by alternative:

Crit./Alt.	Lean	APM	IC	RC
Engineering	33.49	12.31	0.00	0.00
Scope	16.84	8.42	0.00	0.00
Procurement	11.41	1.27	0.00	0.00
Cost/Schedule	5.24	2.62	0.00	0.00
Prefab/Construction	25.21	7.72	0.00	0.00
Risk	21.61	7.20	0.00	0.00
Human Resources	3.60	0.51	0.00	0.00
Site Installation	5.13	0.73	0.00	0.00
HSEQ	4.61	0.66	0.00	0.00
Integration	0.51	0.07	0.00	0.00
Pre-com/ Commissioning	10.59	4.82	0.00	0.00
Knowledge	9.25	4.62	0.00	0.00
Stakeholder	1.35	0.19	0.00	0.00

Figure: Priorities by alternative



Appendix E1: Actual Onshore Piping Fabrication Man-hours

Actual Onshore Piping Fabrication Man-hours	
Trade	**Man-hours**
Welders	11,997.91
Pipe Fitters	18,610.15
Riggers	4,847.85
Total	**35,455.91**

Appendix E2: Topside Planned Piping Fabrication Progress Summary (Onshore Fabrication)

TOPSIDE PLANNED PIPING FABRICATION PROGRESS SUMMARY (Onshore Fabrication)				
S/N	SYSTEM DESCRIPTION	Budget Hrs (CPY)	% Completed	SPOOLS TO BE FABBED
1	WATER INJECTION	3,113.73	100.00%	44
2	PRODUCTION FLOWLINE	2,987.08	100.00%	64
3	PRODUCTION MANIFOLD	699.57	100.00%	13
4	GAS LIFT	1,990.95	100.00%	40
5	FLARE HEADER	418.87	100.00%	19
6	PIGGING LIQUID SUPPLY/RETURN	2,526.53	100.00%	24
7	FUEL GAS	184.73	100.00%	12
8	METHANOL	20.93	100.00%	1
9	AIR INSTRUMENT	1,516.92	100.00%	95
10	OPEN DRAIN	611.15	100.00%	26
	TOTAL	14,070.47	100.00%	338

Appendix F1: Offshore Construction and Installation Man-hours

Discipline	Budgeted MH	Discipline	Actual MH	Additional Hours	% Increase
Electrical	19,700.00	Electrical	27,335	7,635.00	39%
Equipment/Mob	2,417.00	Equipment/Mob	2,506	89.00	4%
Instrumentation	27,115.00	Instrumentation	30,381	3,266.00	12%
Painting	1,642.00	Painting	4,745	3,103.00	189%
Piping	44,188.00	Piping	55,898	11,710.00	27%
Scaffolding	21,993.00	Scaffolding	29,731	7,738.00	35%
Structural	8,388.00	Structural	18,232	9,844.00	117%
		Leak test assistance	1,661	1,661.00	-
Overall Progress	**125,443**	Mechanical	226	226	
		Pre-commissioning	880	880	
		SURF	1,407	1,407	
		NDT	650	650	
		Offshore job preparation Allowance	198	198	
		Supports	1,650	1,650	
		Overall Progress	**175,500**	**50,057.00**	**40%**

Appendix F2: Site Query Log and Impact (Past Revamp Project - Case Study 2)

S/N	Description	Discipline	Reason	Comments
1	Lifting Methodology for EPC1 for damaged cabinet 1A on Module F LER	E&I	Equipment Damage	Lifting lugs were damaged when received at site
2	REPAIR METHODOLOGY FOR PIPE SUPPORT PS-L- 1332 ON BELOW MODULE L2	PI	Fabrication / Design	Pre-drilled holes on bolting plate did not match size of existing beam at site
3	INSTALLATION OF MCT FRAME IN LER F BATTERY ROOM (1-F-MCT-LV-105)	E&I	Brownfield	Existing beam was in the way of proposed transit frame
4	REPAIR METHODOLOGY FOR PIPE SUPPORT PS-L- 1403 ON BELOW MODULE L2	PI	Fabrication / Design	Pre-drilled holes on bolting plate did not match size of existing beam at site
5	Modification of pipe support PS-L-1354 Rev1	PI	Engineering	Engineering did not capture position of existing pipe during design of support.
6	Modification of pipe support PS-L-1415 Rev 2	PI	Engineering	Pre-drilled holes on bolting plate did not match size of existing beam at site
7	Modification of pipe support PS-L-1353 Rev1	PI	Brownfield / Engineering	Existing pipe support clashed with pipe support end plate
8	Clash pipe support, NORTHEAST BRACING with existing Gas exchanger	PI	Engineering & PDMS	Clash with existing Gas exchanger line
9	Repair methodology for Pipe Support PS- L-1354 on below Module L2	PI	Engineering	Pre-drilled holes on bolting plate did not match size of existing beam at site
10	ISSUE WITH CLASHING BETWEEN 2 INFILL BEAMS AND EXISTING STRUCTURE KNOT	PI	Engineering	Cancelled. Convert to TQ
11	Swap SPCU cabinets around in LER F	E&I	Engineering	Drawing and numbering logic did not match.
12	Pipe support PS-L1366 is clashing with existing Inst. Air lines.	ST	Engineering	Position of designed support clashed with exist Instrument Airline. Relocated Pipe support S to resolve

Appendix F3: PRE-SHUTDOWN SCOPE SCHEDULE SUMMARY ANALYSIS

Piping and Structural				
Systems	**Duration (Days)**	**Duration (Days)**	**Delayed (Days)**	**Execution Delays**
PLR Package	69	367	-59	**298**
ISU TUTA Package	54	290	37	**236**
Methanol Package (skid)	14	292	-30	**278**
HPU Package (skid)	159	281	28	**122**
Main TUTA Package (skid)	9	285	-18	**276**
Chemical Package (skid)	66	260	67	**194**
DEX - Deck Extension	153	309	26	**156**
Safety Equipment	25	256	3	**231**
Pigging Liquid	139	414	-131	**275**
Production Flowline	131	299	34	**168**
Production Manifold	195	277	32	**82**
Umbilical	120	287	-29	**167**
Gas Lift	124	414	-141	**290**
Fuel Gas	109	281	-45	**172**
Subsea Chemical	131	247	25	**116**
Methanol	106	414	-166	**308**
Water Injection	195	415	-82	**220**
Flare	162	298	4	**136**
Air Instrument	125	300	-28	**175**
Open Drain	64	285	-71	**221**

Electrical

	-14 PLAN	ACTUAL		
Systems	**Dur (Days)**	**Dur (Days)**	**Delayed Start (Days)**	**Execution Delays (Days)**
Pigging Liquid	69	95	31	**26**
Production Flowline	10	90	-19	**80**
Production Manifold	1	1	-56	**0**
Umbilical	44	236	-55	**192**
Subsea Chemical	20	172	20	**152**
Electrical	68	121	9	**53**
Cable Trays & MCT's	51	337	-56	**286**
UPS	167	240	25	**73**
Lighting	152	290	-9	**138**
HPU	62	93	-18	**31**

Instrumentation

Systems	**Dur (Days)**	**Dur (Days)**	**Delayed Start (Days)**	**Execution Delays (Days)**
Pigging Liquid	43	179	24	**136**
Production Flowline	110	186	53	**76**
Umbilical	65	292	-67	**227**
Gas Lift	128	152	64	**24**
Subsea Chemical	91	238	-19	**147**
Methanol	65	219	-46	**154**
Water Injection	70	170	20	**100**
ICSS	106	159	63	**53**
F&G	37	288	-124	**251**
HPU	27	207	-90	**180**