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# Effectiveness of Engineering, Procurement and Construction (EPC) Major Projects in Abu Dhabi's Oil And Gas Industry: End-User's Perspective

Mohamed Salem Obaid Aldhaheri

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United Arab Emirates University

College of Business and Economics

EFFECTIVENESS OF ENGINEERING, PROCUREMENT AND  
CONSTRUCTION (EPC) MAJOR PROJECTS IN ABU DHABI'S OIL  
AND GAS INDUSTRY: END-USER'S PERSPECTIVE

Mohamed Salem Obaid Aldhaheri

This dissertation is submitted in partial fulfilment of the requirements for the  
degree of Doctorate of Business Administration

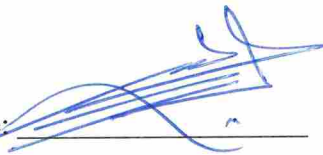
Under the Supervision of Dr. Maqsood Ahmad Sandhu

May 2016

### Declaration of Original Work

I, Mohamed Salem Obaid Aldhaheri, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled “*Effectiveness of Engineering, Procurement and Construction (EPC) major projects in Abu Dhabi’s oil and gas industry: End-user’s perspective*”, hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Maqsood Ahmad Sandhu, in the College of Business and Economics at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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## **Abstract**

Even though project management discipline is gearing towards the improvement of project effectiveness, traditional project management is responding slowly due to either false preconceptions or ineffective communication among project parties. A research study is needed to contribute to knowledge and practice on the effectiveness of Engineering, Procurement and Construction (EPC) contracting strategy and consequently increase the chance of achieving product success at the site level. The objective of the research presented herein is to assess the effectiveness of EPC contracting strategy in meeting product objectives, from the end-user's perspective. Required data are collected using an online survey questionnaire targeting end-users working in six major oil and gas projects in Abu Dhabi. The questionnaire data are analysed using the structural equation modeling (SEM) statistical technique. Research findings reveal statistical significant correlations between the "effectiveness" concept and its respective factors. Being the first known research evaluating the influence of both "end-user's engagement" and "alignment of objectives" criteria on project effectiveness, it provides several contributions to literature and practice. These contributions are particularly illustrated as 1) the development of a conceptual measurement model for the "effectiveness" phenomenal concept, which could be applicable to researchers interested in examining such concept, 2) the identification of possible factors shaping the conceptual domain of "end-user's engagement" and "alignment of objectives" criteria in the oil and gas industry, 3) the operationalization of the conceptual measurement model based on measurement instruments verified by both literature and industry experts, and 4) the assessment of the strengths of influence of the causal factors on the effectiveness of EPC as well as the statistical significance

of these relationships. The present research raises the awareness of oil and gas industry practitioners towards the influencing factors of “effectiveness”, “engagement” and “alignment” concepts. The generated SEM model thus serves as a motivation tool for acknowledging the end-user’s participation in various project phases and maintaining a proper alignment between project objectives and product objectives for the purpose of improving the project effectiveness.

**Keywords:** Oil and gas industry, Engineering Procurement and Construction (EPC), Project management, Effectiveness, Engagement, Alignment, Formative measurement model, End-user, Abu Dhabi

## Title and Abstract (in Arabic)

فعالية عقود التصميم، التوريد والتشييد (EPC) في تنفيذ مشاريع النفط والغاز الكبرى  
في أبوظبي: وجهة نظر المُشغَل

### الملخص

بالرغم من استمرار جهود إدارة المشاريع في تطوير فعاليتها، فلا تزال هناك ضرورة لتحسين استجابة إدارة المشاريع التقليدية، إما بسبب القناعات المسبقة غير الدقيقة أو التواصل غير الفعال بين أطراف المشروع. وهنا تبرز الحاجة إلى دراسة بحثية للمساهمة في المعرفة حول فعالية استراتيجية مشاريع التصنيع والامداد والتشييد (EPC)، وبالتالي زيادة الفرص لتحقيق نجاح مخرجات هذه المشاريع على الامد الطويل. ان الهدف من هذا البحث هو تقييم فعالية استراتيجية مشاريع التصنيع والامداد والتشييد في تحقيق أهداف المنتج من وجهة نظر المُشغَل. يتم جمع البيانات المطلوبة باستخدام استبيان الكتروني، الذي يستهدف المُشغَلين العاملين في ستة مشاريع كبرى للنفط والغاز في اماره أبوظبي. ويتم تحليل بيانات الاستبيان باستخدام الأسلوب الإحصائي المعروف بنموذج المعادلة الهيكلية (SEM). وتكشف نتائج البحث الارتباطات ذات الدلالة الإحصائية بين مفهوم "الفعالية" وعواملها. وحيث أنه أول بحث معروف لتقييم تأثير كل من معيار "مشاركة المُشغَل" و "التوافق بين الأهداف" على فعالية المشروع، فهو يوفر العديد من الإسهامات النظرية والعملية. تتلخص هذه الإسهامات فيما يلي، وعلى وجه الخصوص:

(1) تطوير نموذج قياس مفاهيمي لمفهوم "الفعالية" والذي من شأنه أن يخدم الباحثين المهتمين بدراسة هذا المفهوم، (2) تحديد العوامل المحتمل ان تشكل مفهوم مناسب لمعيار "مشاركة المُشغَل" و "التوافق بين الأهداف" في صناعة النفط والغاز، (3) تفعيل نموذج القياس النظري باستخدام أسئلة الاستبيان التي تم اقتباسها من البحوث السابقة والتأكد من دقتها من قبل خبراء في هذه الصناعة، (4) تقييم تأثير كافة العوامل المسببة لفعالية مشاريع التصنيع والامداد والتشييد بالإضافة الى الأهمية الإحصائية لهذه

العلاقات. ويهدف هذا البحث الى رفع درجة الوعي للعاملين في صناعة النفط والغاز لأهمية العوامل المؤثرة لمفاهيم "الفعالية" و "المشاركة" و "التوافق". لهذا فإن النموذج الناتج عن المعادلة الهيكلية في هذا البحث، بمثابة أداة تؤكد أهمية مشاركة المُشغَل في مختلف مراحل المشروع والحفاظ على التوافق البنّاء بين أهداف المشروع وأهداف المنتج لغرض تحسين فعالية المشروع في الامد الطويل.

**مفاهيم البحث الرئيسية:** صناعة النفط والغاز، مشاريع التصنيع والامداد والتشييد، إدارة المشاريع، الفعالية، المشاركة، التوافق، نموذج قياس بنائي، المُشغَل، أبوظبي.

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## Dedication

*To UAE, my great country, to my beloved parents, and particularly to my dear father  
who was the source of all the inspiration throughout this journey.  
To my adored wife for her understanding and tolerance.*





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## **Appendix H**

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## List of Abbreviations

ADNOC	Abu Dhabi National Oil Company
AFC	Approved for Construction
AMOS	Analysis of a Moment Structures
APA	American Psychological Association
BOQ	Bill of Quantities
CC	Commissioning Certificates
CDS	Crude Degassing Station
CTN	Contract Trend Notices
DEP	Design and Engineering Practice
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement and Construction Management
FAC	Final Acceptance Certificate
FEED	Front-End Engineering Design
FEL	Front End Loading
FP	Facility Planner
GUP	General Utilities Plant
HAZOP	Hazard and Operability
HP	High Pressure
HSE	Health, Safety and Environment
HSEIA	Health, Safety and Environmental Impact Assessment
ICS	Integrated Control Systems
IGD	Integrated Gas Development
IS	Information Systems

IT	Information Technology
LLD	Linear Low Density
LLI	Long Lead Item
MGL	Main Gas Line
NCB	New Control Building
NED	Non-engineering Deliverables
NGL	Natural Gas Liquids
OAG	Offshore Associated Gases
O&M	Operation and Maintenance
PAC	Provisional Acceptance Certificate
PFD	Process and Flow Diagram
P&ID	Piping & Instrumentation Diagram
PLS	Partial Least Squares
PMC	Project Management Consultant
PMT	Project Management Team
PMTC	Project Management Team and Consultant
PVL	Project Vendor List
QA	Quality Assurance
QMS	Quality Management System
RAM	Reliability, Availability and Maintainability
RFC	Ready for Commissioning
RFCC	Residue Fluid Catalytic Cracking
SEM	Structural Equation Modeling
SIS	Satellite Instrument Shelters
SOW	Scope of Work

SPC	Supreme Petroleum Council
TBE	Tender Bid Evaluation
UAE	United Arab of Emirates

## **Chapter 1: Introduction**

### **1.1 Introduction**

This chapter provides an overview of the research topic aiming at examining the effectiveness of Engineering, Procurement and Construction (EPC) major projects in Abu Dhabi's oil and gas industry from the end-user's perspective. Based on a preliminary literature review, management problems related to project effectiveness are identified. The existence of such reported problems is also supported by the researcher's long professional experience in Abu Dhabi's oil and gas industry. The research topic is thus justified, and gaps in both literature and practice in relation to this topic are analyzed, confirming the need for a research study to fill such gaps. The main objectives of this study are then demonstrated for the purpose of addressing the research problem and consequently bridging the gaps in both literature and practice. The main research contributions are highlighted. Subsequently, the research questions are illustrated as the base for constructing the theoretical model and building up the questionnaire required for data collection.

The remaining part of this chapter includes a brief description of the research methodology as well as the general outline of the dissertation including 1) introduction, 2) literature review, 3) research methodology, 4) data analysis, and 5) conclusions and recommendations. The design of this chapter is shown in Figure 1.1, depicting main sections and highlighting the main contents of each section.



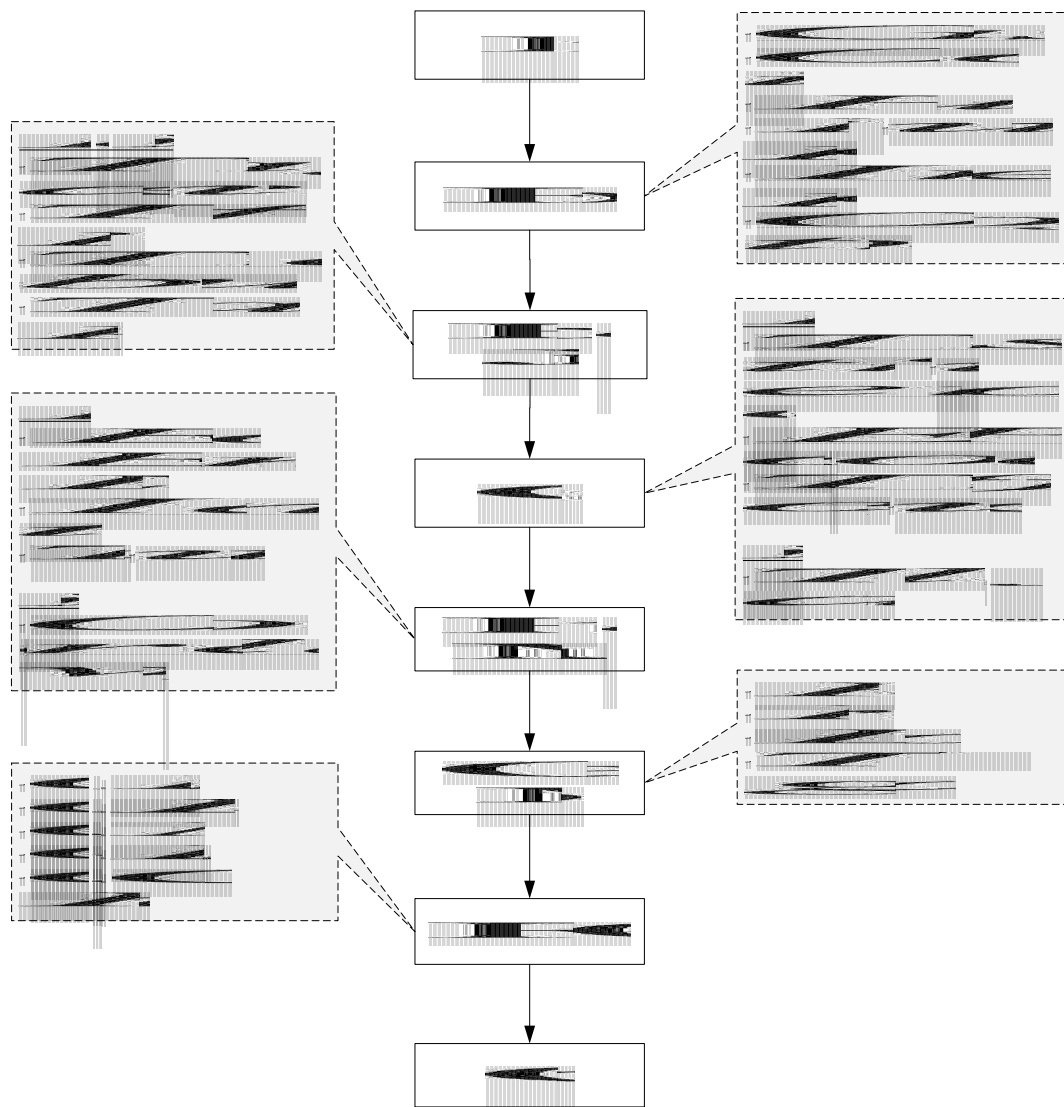


Figure 1.1: The design of chapter 1

Source: Developed for this research

## 1.2 Research Background

The strong growth of the oil and gas industry over recent decades has made it one of the largest and most active industries worldwide. Oil and gas are currently deemed as being part of the world's most important resources. Petroleum is considered as a primary fuel source as well, thereby illustrating the critical role of this industry in driving the global economy (BERA, 2006). Long-term market investigations reveal the extensive global demand for these resources. The world consumption of oil is 30 billion barrels per year, with developed nations being the largest consumers (Alekkett, 2012). Moreover, the global population is expected to increase by more than 1.1 billion persons between 2010 and 2025, yielding an increase of 1.2% to 1.5% in the demand of oil between 2025 and 2030 (Lukoil, 2013).

The world's conventional oil and gas proven reserves are mainly owned by the Middle East Gulf region with around 54% for oil and 40% for gas, in addition to considerable amounts of unproved and undiscoverable reserves (Crescent-Petroleum, 2014). For instance, the United Arab Emirates (UAE) holds the world's seventh-largest proven reserves of oil and natural gas, estimated at around 97.8 billion barrels and 6091 billion cubic meters respectively (OPEC, 2015). In spite of the low prices of oil, UAE produced 3.5 million barrels per day of petroleum in 2014, of which 77% was crude oil that was mostly exported to Asian markets. It is also expected that crude oil production in the UAE will increase by 30% by 2020, making the UAE one of the world's most important energy and financial centers and a main trading center for the Middle East. Abu Dhabi, the focus of this research, holds around 94% of UAE's oil reserves, allowing it to join the ranks of the world's biggest oil producers (EIA, 2015).

Given the significant impact of the oil and gas industry on the global economy, oil and gas industry specialists are currently under pressure to promote more effective strategic planning. In this context, more investments have to be made for the implementation of new technologies, the development of new operation facilities, and the construction of new infrastructure in the upstream and downstream sectors. These investments can be effectively justified and implemented through proper definition of the industry objectives, policies and strategies, which are currently established by the Supreme Petroleum Council (SPC) in the case of Abu Dhabi. In practice, the development of these plans as well as the management of day-to-day operations of oil exploration and extraction is carried out by the Abu Dhabi National Oil Company (ADNOC). ADNOC operates 16 subsidiaries throughout the oil, gas and petroleum sector in Abu Dhabi. ADNOC's goal is the integration of oil and gas industry in the exploration, production, processing, transportation, distribution, and other activities in the UAE (EIA, 2015). In this regard, ADNOC has attempted to properly manage all the processes involved so as to achieve projects success illustrated through meeting projects objectives.

Companies operating in the oil and gas industry aim towards achieving project success illustrated through addressing two types of project objectives, short-term and long-term. Some research studies demonstrate that project success means meeting short-term project objectives in relation to time, cost and quality (e.g. Baccarini, 1999). However, others consider that meeting end-users' expectations in relation to end-product reliability and response time (i.e. the long-term objectives) defines the success of the project (e.g. Wateridge, 1995). In other words, the project success, based on its former definition, is indicated throughout the project execution stage up to the hand-

over to the end-user on behalf of the owner. On the other hand, the latter definition, which refers to “product success”, focuses on the entire project life cycle from initiation to operation. It is important to note that the end-user in the oil and gas industry, the focus of this dissertation, is responsible for the operation and maintenance (O&M) of the facility on behalf of the owner – the so-called “operator”. In Abu Dhabi, the government is the owner and majority shareholder of the oil and gas facilities.

Several studies reveal that product success is highly influenced by the end-user’s involvement in various project phases at both the development and the implementation stages (Atkinson, Waterhouse, & Wells, 1997). The significant influence of the end-user’s participation on product success is not only addressed in oil and gas industry related studies but also highlighted in those directed at the construction industry, information systems (IS) and information technology (IT). For instance, a study conducted by Christiansson, Svidt, and Pedersen (2011) considers end-user’s involvement as one of the critical factors for the success of a construction project. Similarly, Palanisamy and Sushil (2001) highlight the positive correlation between the end-user’s engagement and the IS project implementation success. For this reason, it is of great importance to understand and be aware of the influence of end-user’s involvement on the achievement of product success.

Not only does the end-user’s involvement play an important role in shaping the product success but also the achievement of end-user’s requirements has a significant impact on the effectiveness of a given project in meeting the end-user’s satisfaction. While some studies address effectiveness as the capability of producing a desired result (e.g. Belout, 1998; Drucker, 1985), others approach it as the extent to which the end-users’ needs are satisfied (e.g. Shenhar, Levy, & Dvir, 1997; Takim & Akintoye,

2002). For instance, Takim and Akintoye (2002) and Balfour, Skorupka, and Turzyńska (2012) insist that end-users are satisfied if they are engaged and involved in various activities within the main phases of the project. The study conducted by Atkinson et al. (1997) reveals that end-users are also satisfied when the end product succeeds in meeting their requirements in relation to life cycle cost, time frame, quality, functionality and delivery performance standards. These requirements are also addressed by Takim and Akintoye (2002) and classified as value for money, use of project, free from defects, fitness for purpose, pleasant environment, and social obligation. It is worth noting that both classifications correspond to project objectives (i.e. cost, time, quality), where the correspondence between project objectives and end-users' requirements is referred to as "alignment" (Tech-Target, 2015). In this context, Deane, Clark, and Young (1997) and Thamhain (2014) ascertain the necessity of aligning project objectives with product objectives for accomplishing end-user's satisfaction and consequently product success. Therefore, 'end-user's engagement' and "alignment of objectives" are two essential criteria for the assessment of project effectiveness.

In this regard, having a contracting strategy that entails involving the end-user in various project phases as well as facilitates attaining a proper alignment between project and product objectives is essential to the achievement of project effectiveness. As such, the selection of an appropriate contracting strategy not only helps overcome the challenges that might arise between project stakeholders during project planning and implementation (Schramm, Meißner, & Weidinger, 2010) but also facilitates accomplishing product success defined in terms of meeting long-term project objectives.

Regarding the importance of the selection of contract type, it is important to note that there exist several contracting strategies used in major projects in the oil and gas industry. Engineering, Procurement and Construction (EPC) is widely used in major projects due to several key advantages that aid in achieving project objectives. It provides a single point of responsibility between the owner and the EPC contractor. It is also based on a fixed project cost, which results in a low financial risk for the owner and a high risk for the contractor. The contractor, in turn, is committed to meet the required performance based on a defined and agreed project schedule (Schramm et al., 2010). In addition to these advantages that boost the efficiency of EPC contract in achieving the short-term project objectives from the owner's perspective, EPC contract requires the participation of the end-user in various phases of a project at both the development (i.e. planning) and the implementation stages. For example, a study conducted by Bubshait and Al-Musaid (1992) illustrates that the end-user's involvement in the development stage helps in 1) optimizing the project's quality, cost and schedule, 2) improving the critical operating requirements, and 3) facilitating the progress towards the EPC execution phase. In addition, the EPC execution strategy necessitates the involvement of the end-user in various tasks and activities during project implementation, such as approving construction documents, running operational tests and approving test runs during the construction, commissioning and hand-over phases respectively (Gasco, 2011).

### **1.3 Research Problem and Justification**

The previous section focuses mainly on the influence of the “end-user’s engagement” and the “alignment of objectives” criteria on product success. It also provides an overview of the main advantages of an EPC contracting strategy that necessitates the implementation of both criteria for achieving project effectiveness. This present section sheds light on management problems pertaining to the state-of-the-practice regarding these two criteria, with emphasis from both literature and practice, thus justifying the research topic.

#### **1.3.1 Problem identification from literature**

Even though reviewing the literature shows that an EPC contracting strategy would increase the probability of reaching product success through the participation of the end-user and the alignment of objectives, project management discipline is responding slowly to implementing these requirements. For instance, a study conducted by Bryde and Robinson (2005) reports that end-users’ involvement during implementation stages for the purpose of accomplishing their needs is not exhibited by project management practices, as it might lead to challenging and costly design changes. These changes are commonly translated as variation orders, leading to either an increase in the project cost or a delay in project completion (Keane, Sertyesilisik, & Ross, 2010). Such concerns, according to Balfour et al. (2012), are raised due to the lack of awareness of project management towards the importance of the end-user’s participation in achieving both project objectives and product objectives. Additionally, industry investigations carried out by Patanakul and Shenhar (2012) reveal that alignment of objectives is not properly planned and achieved at the site level even

though the majority of project teams support the needs for strategic alignment between both objectives.

### **1.3.2 Support from industry practice**

The aforementioned management problems are not only reported in literature but also supported by the researcher's 28 years' professional experience, the majority of which (22 years) were gained in Abu Dhabi's oil and gas industry. For a period of 5 years within project management teams, the researcher was subjected to enormous tasks during various phases of ADNOC major oil and gas projects (i.e. from initiation to commissioning). During the second phase of his oil and gas industry experience within ADNOC group (spanning 22 years), he was responsible for managing the end-user teams in various gas processing, refining and shipping operations. While interacting with both project and operations teams, the researcher experienced ineffective communication among these teams in addition to improper alignment between project objectives and product objectives (i.e. end-user's requirements). Arising out of such non-synchronized objectives, the operations team, in several cases, missed the opportunities to implement development or corrective jobs due to the project teams' false preconception of getting in conflict with project time and/or budget constraints. Additionally, the non-involvement of end-users at the right time resulted in considerable rework, lack of resources and unnecessary expenditures by the end-user after the hand-over of facilities for operation.

An interview with an "End-user Project Coordinator", having 19 years of professional experience in ADNOC major refining and gas projects, was conducted in an attempt to gain more insight into the state-of-the-practice regarding the end-user's



participation in Abu Dhabi's oil and gas industry. The interviewee provided several cases in which the involvement of the end-user's team at early phases of the project helped benefit from the team's expertise, in-depth understanding of the work context, and the lessons learned from previous projects. For instance, changes in design and materials were submitted to project teams during the development phase, which in turn saved around 3 to 5 million dollars as well as improved the quality of the plant facility. On the other hand, other opposing cases were highlighted, where the late involvement of the end-user's team after several months of proceeding with the detailed engineering work led to the dismissal of their suggestions. Even though the suggested changes were proved to enhance the product quality, the project teams compromised the quality so as not to increase the project cost or delay the project completion if these suggestions were implemented. Such decisions ascertain that the project teams failed to align the project objectives with the product objectives (i.e. end-user's requirements).

### **1.3.3 Justification of research topic**

A basic justification of the research topic thus derives from 1) the alleged reluctance of project owner/managers to adequately acknowledge the engagement of end-users in various project phases, 2) the false preconception of challenging the achievement of the short-term objectives if the end-user is involved, 3) the failure to maintain proper alignment between project objectives and product objectives, and 4) ineffective communication among project parties. All of these management problems, emphasized in both literature and practice, contribute to frequent failures in achieving end-users' satisfaction. This fact highlights the need for improving project effectiveness in attaining proper synchronization at the site level. In this regard, the following section focuses on identifying and analysing research gaps pertaining to the

justified need for enhancing project effectiveness and achieving the end-user's satisfaction.

#### **1.4 Gap Analysis**

Even though the reported literature ascertains the importance of the end-user's engagement and alignment of objectives in achieving product success, none of the studies examines the influence of both criteria on achieving project effectiveness. While some research studies only explore the effect of end-user's engagement on achieving end-user's requirements (i.e. product success) (e.g. Atkinson et al., 1997; Balfour et al., 2012), others demonstrate the importance of attaining strategic alignment between short-term and long-term objectives in reaching product success (e.g. Patanakul & Shenhar, 2012; Thamhain, 2014). Furthermore, reviewing the relevant literature reveals research studies that address project success only from the project owner's and/or contractor's perspectives (e.g. Schramm et al., 2010), where this subject has still not been comprehensively examined from the end-user's perspective. Chens and Bryant (1984) add that a study requiring sensitive, private or confidential data might face some challenges related to obtaining factual data needed to conduct rigorous analysis on this research topic. These challenges are due to either the non-availability of key experienced personnel after project completion or their refusal to share data related to the company's performance and policies during data collection process. As such, having a research study that bridges both gaps in literature and practice, by 1) addressing the influence of both end-user's engagement and alignment of objectives in achieving project effectiveness, 2) capturing the perceptions

of end-users, and 3) conducting the analysis on real factual data, is highly important for the improvement of the oil and gas industry's performance.

### **1.5 Research Questions and Main Contributions**

It is the purpose of this dissertation to bridge the gaps in literature and practice, contributing to knowledge on the effectiveness of EPC contracting strategy and increasing the chance of achieving product success at the site level. In particular, it examines the effectiveness of EPC in reaching product success defined in terms of both the end-user's engagement and alignment of objectives criteria. Given that project effectiveness is concerned with end-product success, capturing the end-users' perceptions towards the effectiveness of EPC in the execution of major oil and gas projects provides critical data required to conduct rigorous analysis. For this reason, the evaluation of the effectiveness of EPC, in the context of the present research, is carried out based on examining the perceptions of end-users working in Abu Dhabi's major oil and gas projects. It is worth mentioning that the effectiveness of EPC contracting strategy is evaluated not from the development and formulation side of the business but rather from its implementation aspect. In addition, researcher's long professional experience in the oil and gas industry as well as his close personal relationships with ADNOC Group companies, from which data is collected, helps overcome the data collection challenges mentioned previously.

The present research, therefore, aims at:

1. Examining the effectiveness of EPC contracting strategy in achieving product success from the end-user's perspective by targeting end-users working in major projects in Abu Dhabi's oil and gas industry
2. Identifying factors pertaining to both the "end-user's engagement" and the "alignment of objectives" criteria
3. Constructing a theoretical model that shows possible relationships between the effectiveness of EPC and these criteria
4. Assessing the strengths of influence of the causal factors on the effectiveness of EPC as well as the statistical significance of these relationships
5. Investigating the differences in such relationships among the three industries (i.e. refining, gas, petrochemical) in Abu Dhabi

In order to fulfil these objectives, two main questions are addressed in the present research:

**Question 1**

**To what extent does the end-user consider EPC contracting strategy effective in the execution of major oil and gas projects?**

**Question 2**

**Is there a statistical significant difference in the relationships between the effectiveness of EPC contracting strategy in achieving product success and the "end-user's engagement" and "alignment of objectives" criteria among refining, gas and petrochemical industries in Abu Dhabi?**

The first main research question helps investigate the effectiveness of EPC in facilitating and expediting the project execution stage as well as fulfilling the end-user's requirements. In order to answer this question, two sub-questions are addressed:

**Question 1.1**

**To what extent is the end-user engaged in various phases of the project?**

**Question 1.2**

**How well the project objectives and the product objectives are aligned?**

While the first sub-question (i.e. question 1.1) aims at examining the end-user's engagement in various project activities, the second one (i.e. question 1.2) explores the alignment of both short-term project objectives and long-term product objectives. The first research question along with its two sub-questions are essential to actually assess the effectiveness of EPC contracting strategy in achieving product success in the oil and gas industry as perceived by the end-user. The second main research question, on the other hand, is required to examine whether the relationships between the effectiveness of EPC and the two main criteria differ among the three industries (i.e. refining, gas, petrochemical) in Abu Dhabi.

## **1.6 Overview of Research Methodology**

While the previous section highlights the main research questions to be addressed for the fulfilment of the research objectives, the present section provides a general overview of the research methodology adopted. In this regard, end-users working in six major oil and gas projects in Abu Dhabi were surveyed in attempt to capture their

perceptions towards the effectiveness of EPC in executing major projects, which in turn constitutes one of the main contributions of this research study.

Chapter 3, which focuses on explaining the research methodology, consists of two main parts, theoretical and practical. While the theoretical part entails the selection of an appropriate paradigm within which to conduct the research, the practical one covers the quantitative procedure adopted for data collection. The quantitative method consists of conducting a structured questionnaire survey with end-users of major oil and gas projects in order to collect data required for statistical analysis. To analyse the data, structural equation modeling (SEM) technique is applied on the theoretical model to generate the structural model representing the possible relationships between the effectiveness of EPC and the two main criteria (i.e. “end-user’s engagement” and “alignment of objectives”). It is imperative to mention that the research questions form the backbone of this dissertation, as they are the basis for constructing the theoretical model and building up the questionnaire required for data collection.

## **1.7 Research General Outline**

The research study is fully discussed over five chapters that are organized as follows:

Chapter 1 (introduction) provides an overview of the research topic, which in turn introduces the research problem and highlights the need for a new research study that targets this problem. The research study’s main objectives are stated, and the research questions are proposed accordingly. The methodology is then summarized, and a general outline is provided.

Chapter 2 (literature review) introduces the concepts of effectiveness of EPC contracting strategy viewed from the end-user's perspective. A detailed review of literature related to the current status of the oil and gas industry in UAE, with a focus on Abu Dhabi, is conducted. In addition, a comprehensive literature review is carried out focusing on project success and product success, main project stakeholders including the end-user, main contract types employed in the oil and gas industry, and main project phases with a focus on EPC in the execution phase. Possible factors affecting end-user's satisfaction falling under the umbrella of the two main criteria, "end-user's engagement" and "alignment of objectives", are also identified. As the examination of the effectiveness of EPC contracting strategy in achieving product success is the focus of this study, main activities that necessitate the participation of the end-user to generate main project deliverables are highlighted. In addition, a deeper insight into the current state-of-the-practice regarding the alignment of project objectives with product objectives is provided. Finally, the research hypotheses are constructed accordingly.

The output of the literature review helps construct both the theoretical model that identifies possible factors affecting the effectiveness of EPC and the questionnaire required for data collection.

Chapter 3 (methodology) reviews the four research strategies, i.e. inductive, deductive, retroductive and abductive, and justifies the inductive approach as the strategy best suited to conduct this research. In addition, it sheds light on the three research paradigms, i.e. positivism, realism and phenomenology, and provides a justification for considering positivism as the research paradigm of this dissertation. The quantitative research methodology is introduced to collect data required for the

analysis. This chapter also addresses the critical steps related to research empirical process, starting from conceptualization of the theoretical/measurement model. It proceeds towards model identification, operationalization of research instruments, assessment of validity and reliability of these instruments, ethical considerations, data collection and data processing.

Chapter 4 (data analysis) presents the findings from the quantitative survey, where a structural SEM model relating the effectiveness of EPC contracting strategy with the two main criteria (i.e. “end-user’s engagement” and “alignment of objectives”) and their influencing factors is generated. A further investigation is carried out to examine whether these relationships differ among the refining, gas and petrochemical industries in Abu Dhabi, and the reasons for these differences, if they exist, are analysed.

Chapter 5 (conclusions and recommendations) summarizes the main findings of the dissertation, illustrates the main applications of the “Effectiveness of EPC” structural model, discusses research limitations, and proposes topics for future research work.

## **1.8 Conclusion**

Based on the preliminary literature review and the researcher’s long professional experience in Abu Dhabi’s oil and gas industry, management problems highlighted in both literature and practice were reported. The research problem was thus identified, and the research gaps were then analysed. The need for the present research study to fill these gaps was justified, and the main research contributions were consequently established. The research methodology, documented in detail in chapter 3, was briefly reviewed, and a general outline of the research was illustrated.



## Chapter 2: Literature Review

### 2.1 Introduction

Chapter 1 illustrated the scope of this research by introducing the efficiency of the EPC contracting strategy in achieving short-term project objectives and ascertaining the need to assess the effectiveness of EPC in meeting long-term product objectives from the end-user's perspective. Abu Dhabi's oil and gas industry, with its significant position among the world's biggest oil producers, was highlighted as the scope of application for fulfilling the research objectives.

The purpose of the present chapter is to conduct a comprehensive literature review to engage with previously published research relevant to the topic of interest and thus identify gaps that requires further investigation. It specifically: 1) illuminates the two main sectors of the oil and gas industry, 2) sheds light on several important aspects of a project in the oil and gas industry, including project success, product success, key project stakeholders, main project contracts, and main EPC project phases, 3) presents existing studies that demonstrate the efficiency of EPC from the project owner's perspective, highlighting a deficiency in research studies evaluating the effectiveness of EPC from the end-user's perspective, 4) identifies possible factors that might have significant influence on the end-user's satisfaction, 5) examines the "effort curve" in relation to end-user's participation in early stages of design, the challenges and conflicting perceptions regarding the participation, and a set of recommendations for proper participation, 6) provides an insight into the current state-of-the-practice regarding the alignment of project objectives with product objectives in addition to a set of recommendations for proper alignment, and 7) constructs research hypotheses

correlating the effectiveness of EPC and the identified influencing factors. The design of this chapter is illustrated in Figure 2.1.

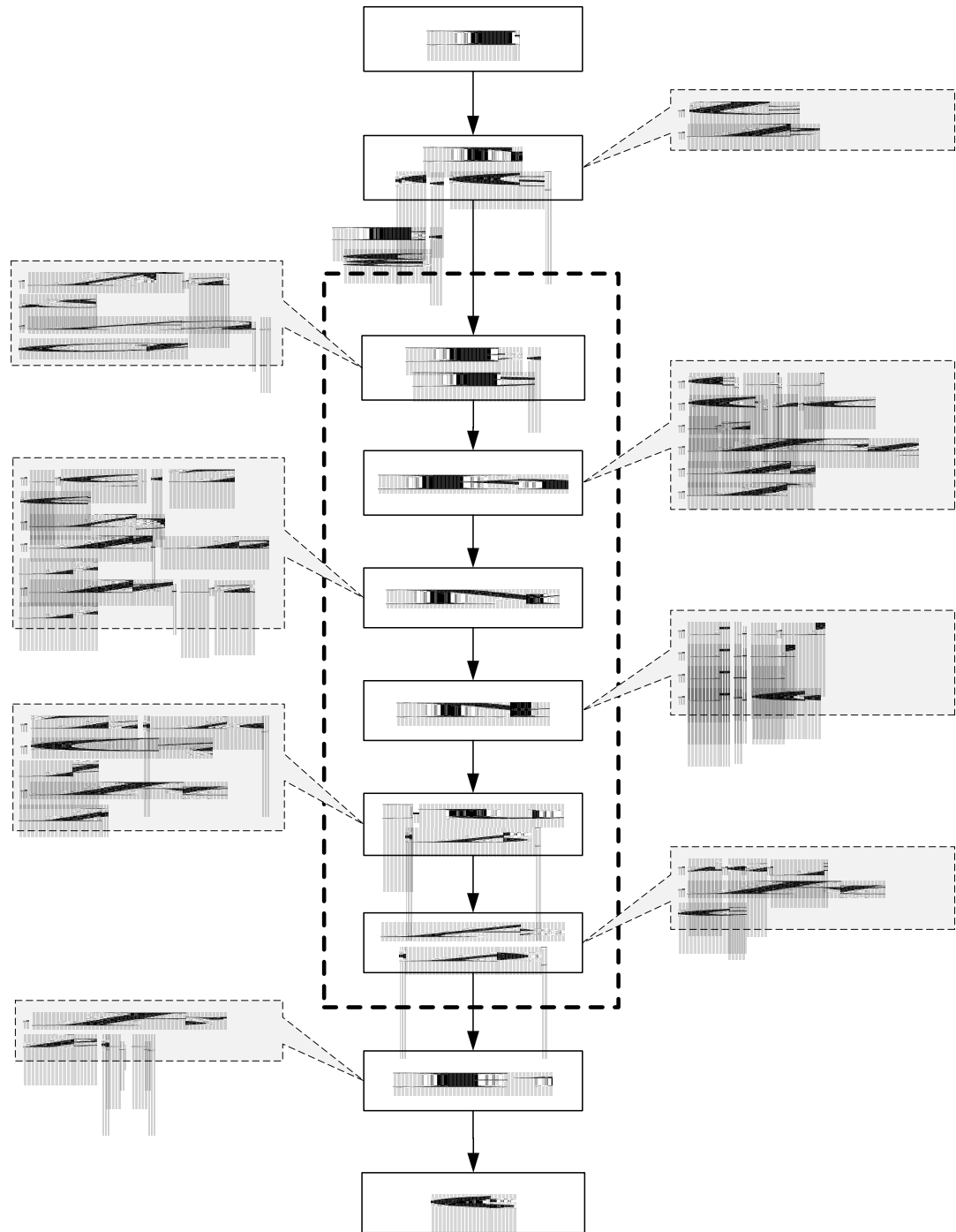


Figure 2.1: The design of chapter 2

Source: Developed for this research

## **2.2 The Oil and Gas Industry**

A project in the refining, gas and petrochemical industries generally falls under two main sectors, upstream and downstream. The upstream sector relates to obtaining crude oil and gas from natural resources, such as exploration of new oil and gas reserves or development of oil and gas production facilities. The downstream sector, on the other hand, relates to the refining of petroleum crude oil and the purifying of raw natural gas received from the upstream sector using oil refineries, petrochemical plants and gas processing, thus providing products ready for distribution using pipelines and pumping systems (EKT, 2015; NI-Business, 2015).

This dissertation, as previously noted, focuses on Abu Dhabi's oil and gas industry that constitutes the backbone of its economy. Abu Dhabi is the main holder of UAE oil reserves (around 94%), the UAE being one of the most significant oil producers and exporters in the world. In this context, Figure 2.2 illustrates the significant increase in UAE petroleum supply and consumption from 2004 to 2013, making UAE the sixth highest producer of petroleum with an average of 3.5 million barrels per day in 2014 (EIA, 2015).

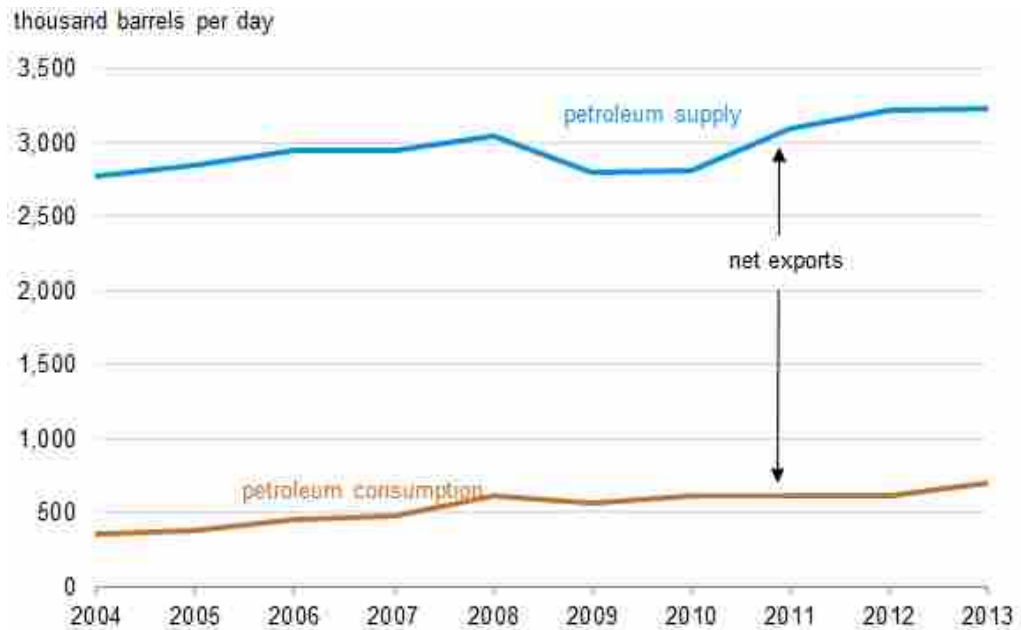


Figure 2.2: UAE petroleum and other liquids supply and consumption, 2004-2013

Source: (EIA, 2015)

## 2.3 Projects in the Oil and Gas Industry

What follows is a relevant review of literature related to several aspects of a project in the oil and gas industry including 1) project success and product success, 2) key project stakeholders, 3) main project contracts, with a focus on EPC contracting strategy, and 4) main EPC project phases, highlighting various activities that entail the end-user's participation.

### 2.3.1 Project success and product success

A project is a non-routine set of interrelated tasks that have to be executed to accomplish a specific goal. These tasks need to be performed and delivered under certain constraints, known as quality, time and cost. In other words, a project has to meet the technical performance requirements (i.e. quality) over a fixed period of time,

where a start-date and an end-date are defined and agreed on by project stakeholders, and with a specific budget and resources (Harrison, 1992). These constraints are usually referred to as “project management Iron Triangle”, presented in Figure 2.3, where each side represents a constraint that cannot be changed without affecting the others (Atkinson, 1999; Baccharini, 1999).

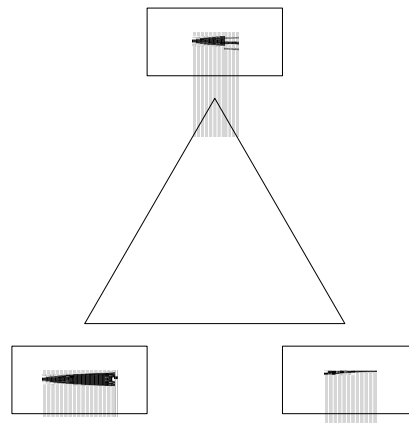


Figure 2.3: Project management Iron Triangle

Source: (Atkinson, 1999)

It is worth mentioning that project success, as illustrated in Figure 2.4, refers to *efficiency* and *effectiveness* measures. The achievement of the three constraints of the project management triangle demonstrates the accomplishment of short-term project success (i.e. efficiency), whereas the attainment of the end-user’s satisfaction through meeting the desired needs adheres to long-term product success (i.e. effectiveness) (Chan & Chan, 2004; Takim & Akintoye, 2002).

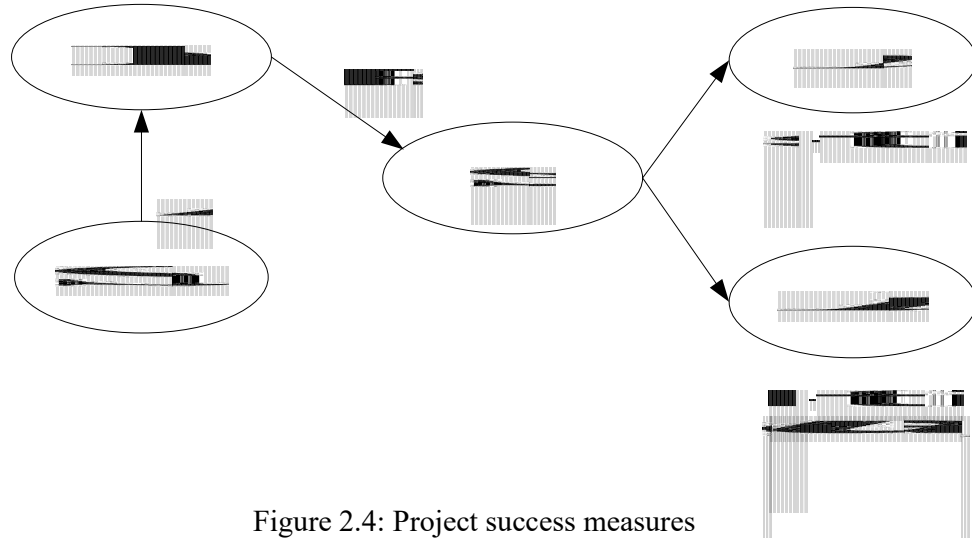


Figure 2.4: Project success measures

Source: (Takim & Akintoye, 2002)

While the present section highlights the importance of attaining the end-user's satisfaction for the purpose of achieving the product success, the next section sheds light on the main indicators that shape such satisfaction.

### 2.3.1.1 Main indicators of end-user's satisfaction

According to Atkinson, Waterhouse, and Wells (1997) and Atkinson (1999), successful project performance is achieved not only when short-term objectives are met but also when the end-user is satisfied. As such, the identification of factors that affect the end-user's satisfaction is essential to meet product success (i.e. long-term objectives). In this context, some research studies argue that the end-user's "engagement" in various project phases positively influences the level of satisfaction (e.g. Balfour, Skorupka, & Turzyńska, 2012; Takim & Akintoye, 2002). Other studies, on the other hand, demonstrate that the end-user's satisfaction is correlated with meeting end-product requirements in relation to life cycle cost, time frame, quality, functionality and delivery performance standard (e.g. Atkinson et al., 1997). Takim

and Akintoye (2002), as well, classify the end-user's needs as value for money, use of project, free from defects, fitness for purpose, pleasant environment and social obligation. All these classifications are in correspondence with short-term project objectives (i.e. cost, time, quality), thereby confirming Deane, Clark, and Youngs' (1997) argument that a project is ineffective if project objectives and end-user's needs are not aligned. Thus, "alignment", which represents the correspondence between project objectives and end-user's requirements (CII, 2015; Tech-Target, 2015), is another factor that has a significant impact on the effectiveness of a given project in achieving the end-user's satisfaction. Thamhain (2014), as well, ascertains that focusing on short-term objectives does not necessarily lead to desired business results. The achievement of long-term objectives, instead, requires strategic alignment of short-term project objectives with the business objectives (i.e. end-user's requirements). In this regard, the alignment of project objectives with product objectives is highlighted as "the effective linkage[] between project-related operations and the strategic goals and objectives of the enterprise to achieve project results with the highest value and competitive advantage" (Thamhain, 2014, p. 62). Patanakul and Shenhar (2012), on the other hand, describe the alignment of project management with business requirements as a collaborative state of management, where the participation of the operation team in supporting the strategic goals plays a significant role in bridging the gap between project objectives and product objectives to ensure the desired results.

As such, engaging end-users in various activities during project development and implementation in addition to aligning both project and product objectives are two

main criteria that are necessary to achieve project effectiveness illustrated through meeting the product success.

Given the significant role that oil and gas major projects play for Abu Dhabi's economy, achieving both project success and product success are essential for continuous improvement of the industry's performance. The nature, complexity, and the extensive implementation of these projects make them a challenging environment. The following section provides more details about such environment.

### **2.3.1.2 Abu Dhabi's oil and gas projects: A challenging environment**

The oil and gas major projects are known to be capital intensive, with an average of six years from planning to commissioning and hand-over (Likierman, 1980). For example, a contract of around 9.6 billion US dollars has been awarded by the Abu Dhabi Oil Refining Company (Takreer) to expand the "Ruwais Refinery" for the purpose of enhancing its refining capacity by 417 thousand barrels per day. This project requires about 10 thousand workers of various skills in addition to a huge amount of construction materials, including around 800 thousand cubic meters of concrete, 200 thousand tons of structural steel, 8.5 million meters of electrical cables, and 35 thousand of instruments (Takreer, 2014). Similarly, according to Gasco (2012), Abu Dhabi Gas Industries Ltd (Gasco) has invested around 12.6 billion US dollars for the development of gas facilities in Ruwais and Habshan, where the material quantities used in these facilities are estimated as follows: around 780 thousand cubic meters of concrete, 114.2 thousand tons of structural steel, 1.87 thousand kilo-meters of piping, 160 kilo-meters of pipelines, 11.67 thousand kilo-meters of electrical and



instrumentation cables, 2.15 thousand mechanical equipments, and 2.95 thousand electrical and instrumentation equipments.

These very large financial obligations and technical requirements exert substantial responsibilities and challenges on project stakeholders, which in turn might delay project completion. As such, a close coordination and team work between key project stakeholders (including the end-user) as well as a proper management for the relationships between them are essential to successfully achieve project objectives (Sandhu & Gunasekaran, 2004). The following two sections shed light on key project stakeholders along with a proper legal agreement that governs the relationships between them – the so-called “contract”.

### **2.3.2 Key project stakeholders**

Project stakeholders are “individuals, groups, or organizations who may affect, be affected by, or perceive themselves to be affected by a decision, activity, or outcome of a project” (PMI, 2013, p. 393). These stakeholders have an interest or a gain upon a successful completion of a project and may exert positive or negative influence over the project and its deliverables. These entities may be working not only inside the project organization with different levels and authorities (e.g. owner, contractor) but also outside the performing organization (e.g. financial institutes, insurance institutes). According to Baram (2005), key project stakeholders are as follows:

*Project owner:* also called a “client”, is responsible for securing the financial resources required for the capital investment. In the present research, the project owner is mainly the Abu Dhabi National Oil Company (ADNOC) on behalf of the government of Abu Dhabi.

*Project management team (PMT)*: responsible for managing the project on behalf of the project owner and entitled for ensuring project delivery.

*Project management consultant (PMC)*: responsible for providing specialist assistance and help to the project management team, when required, to ensure that the contractor is carrying out the work in accordance with both the agreed scope of work and the contract.

*Contractor*: specialized in the design, architecture and evaluation of the technology involved in the project as per the project owner's requirements during the development stage in addition to the construction responsibilities during the implementation stage.

*Sub-contractor*: specialized in the installation of the required systems as per the contract's specifications and thus involved in the implementation stage of the project.

*End-user*: the end-user of the project differs based on the project industry. For instance, in the Information Technology (IT) sector, the end-user is the customer who actually buys and uses the finished product. On the other hand, in the oil and gas industry, the "operator", the focus of this dissertation, is the end-user responsible for the operation and maintenance (O&M) of the facilities after being handed-over from both the project and contractor teams.

*Equipment vendors and suppliers*: responsible for providing materials and equipments as per the project specifications.

*Insurance institute*: responsible for the additional costs incurred due to incidents that may occur to either project personnel or equipment during project implementation.

These costs are usually estimated based on rigorous risks management analysis that takes into consideration the project type, size, and complexity.

*Financial institute:* in case of major projects, local and international banks are needed to provide loans that aid in covering the huge financial commitments of such projects. The financial risk consultant is responsible for estimating the amounts of these loans based on the risk associated with the projects as well as defining the policies that secure the lending terms based on projects feasibility, market conditions, and securities.

It is important to note that the number of stakeholders on a given project varies based on the project type, size and complexity. Given that the influence of these stakeholders on the project completion may not become evident until later stages in the project, it is critical for project success to 1) identify project stakeholders at an early stage, 2) analyse their level of interests, level of involvement and possible influence on project completion, 3) regularly review and update this early assessment, and 4) properly manage the relationships between them to avoid unexpected mistakes and ensure smooth project progress (PMI, 2013).

The relationships between project stakeholders can be properly managed based on a contract, which is a legal agreement between two parties to deliver a certain product or service based on a specified price and execution time (Lori, 2004). The proper understanding of various types of contracting strategies in addition to effective implementation of the applied strategy are considered as managerial assets necessary to ensure the success of the project (Olsen, Haugland, Karlsen, & Husøy, 2005). The next section illustrates main contract types that are adopted in major oil and gas projects.

### **2.3.3 Main project contracts**

Before providing an insight into various types of contracts adopted in major oil and gas project, this section sheds light on the pre-qualification and technical evaluation processes.

#### **2.3.3.1 Pre-qualification and Technical evaluation**

As mentioned previously, having a contract that manages the relationships between project stakeholders is essential for the achievement of project objectives and consequently project success. Given that major oil and gas projects are of high capital investment and require advanced technical expertise, it is critical to identify contractors who are capable of such commitments. Pre-qualification process is usually carried out before tendering for the actual contract so as to reduce the need to evaluate unqualified bidders. It is an effective means for narrowing the field to only those who have the requisite ability to comply with the terms of the contract as well as the financial capability to undertake the work. In addition, the assurance that unqualified bidders are excluded from bidding encourages leading contractors to price their bids more competitively taking into consideration that they are competing with other qualified bidders meeting realistic minimum competence criteria (NADB, 2015).

Once qualified contractors are identified, Gasco (2011) highly recommends carrying out a technical evaluation for the pre-qualified bids to ensure that all contract bidders are properly understanding the project scope and requirements. This technical evaluation should be conducted with complete transparency, which in turn facilitates achieving project objectives during implementation. Figure 2.5 presents main steps that should be followed during the technical evaluation of contract bids.

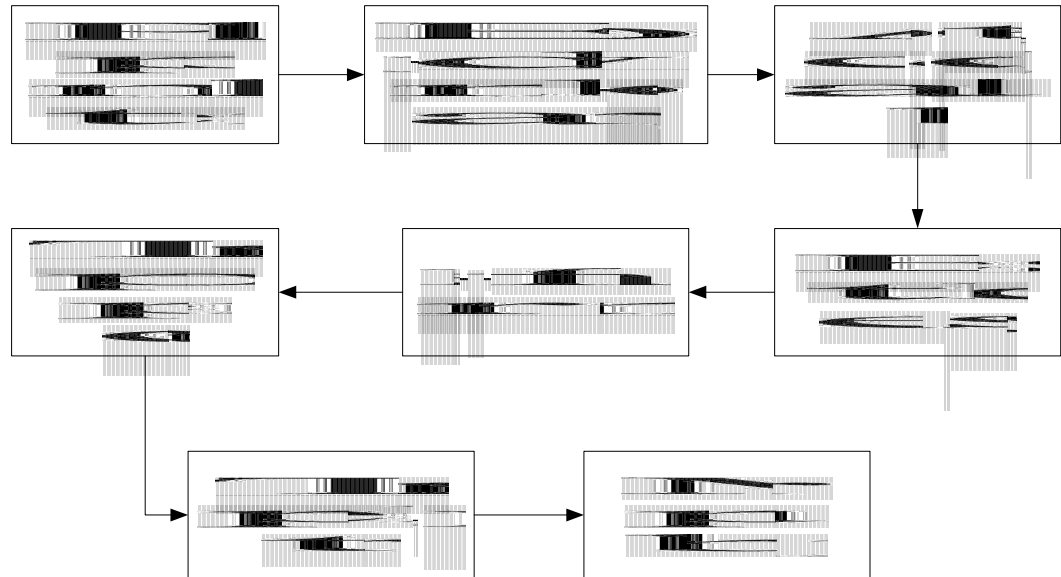


Figure 2.5: Bid technical evaluation flowchart

Source: (Gasco, 2011)

### 2.3.3.2 Main contract types

In oil and gas projects, there are various types of contracts involved between the project owner and the contractor, such as Engineering Procurement and Construction (EPC), Engineering Procurement and Construction Management (EPCM), cost reimbursable (also called cost-plus), and cost-plus incentive fee contracts. The project contracting strategy is usually driven by the project's main objectives and emphasis. For instance, if the project has to be strictly finished within its specified time regardless of the cost, then the cost reimbursable contract type has to be applied. In such a contract, the contractor is paid for all incurred expenses in addition to extra payment to allow for a profit. The cost-plus incentive fee contract also accounts for technical performance incentives paid for the contractor when the project performance objectives are fulfilled (Berends, 2000; Kemp & Stephen, 1999; Takreer, 2012).

According to Bubshait (2003), the evaluation of the contractor's performance is based on some criteria, such as utilization of resources, productivity and responsiveness, determined by the owner and established in the contract. These two types of contracts (i.e. "cost reimbursable" and "cost-plus incentive fee") contrast with fixed-price contracts (e.g. EPC, EPCM), in which the contractor is paid a fixed amount regardless of the incurred expenses. EPC contracting strategy (also known as "Lump-Sum Turnkey") involves producing the engineering design drawings, identifying and delivering all materials and machines needed for construction, and implementing the project to deliver a functioning facility, whereas EPCM contracting strategy has the same scope except for the construction stage. In the construction stage of EPCM, the contractor has to ensure smooth coordination during the project implementation phases without being entitled to actually construct the project (Berends, 2007; Loots & Henchie, 2007; Schramm, Meißner, & Weidinger, 2010). Figure 2.6 demonstrates the difference in the relationships between the project owner and the contractor in case of EPC and EPCM contracts.

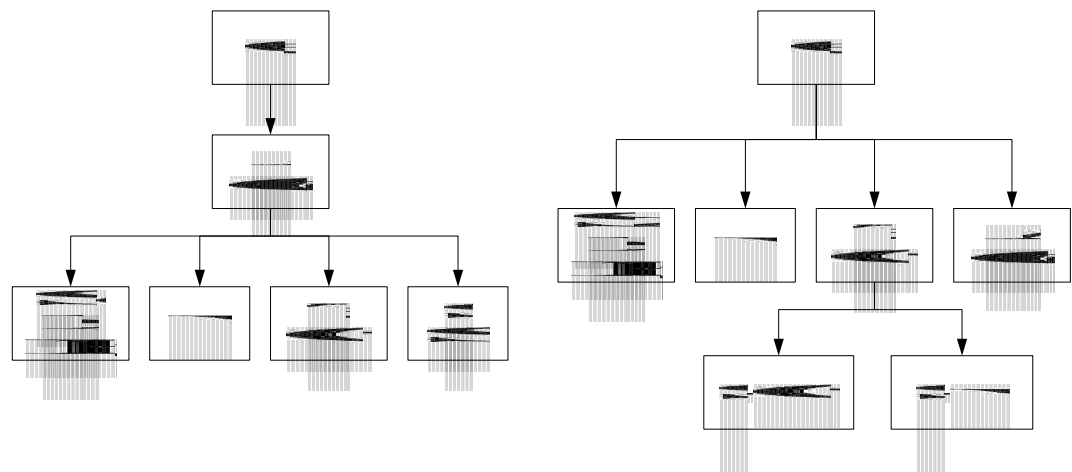


Figure 2.6: Relationships between owner and contractor in case of EPC and EPCM contracts

Source: (Loots & Henchie, 2007)

In addition to the contract that should be engaged between the project owner and the contractor, there are other contractual structures that have to be involved with other project stakeholders (Baram, 2005). Figure 2.7 presents a typical general contractual structure between various project stakeholders with the involvement of EPC contract/agreement. While this section briefly discusses main characteristics of various types of contracts, the next section elaborates more about the main advantages of EPC contract, as it is the focus of this dissertation.

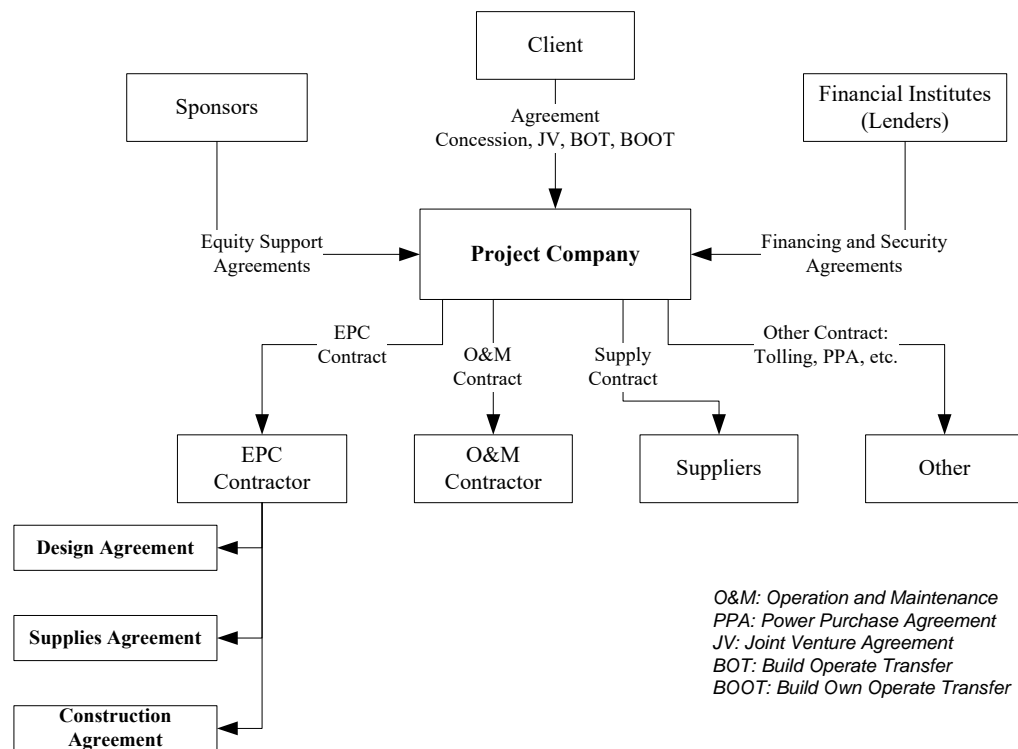


Figure 2.7: Relationships among various project stakeholders involving EPC agreement

Source: (Baram, 2005)

### 2.3.3.3 Efficiency of EPC: Project owner's perspective

The EPC contract is widely used in major projects in the oil and gas industry due to several key advantages that boost the efficiency of such a contract from the project owner's perspective (i.e. project success). As mentioned in chapter 1, EPC entails a fixed project cost, which in turn allocates a low financial risk to the owner and a high risk to the contractor who must meet the required performance based on a defined and agreed project schedule (Schramm et al., 2010). However, the fixed-cost characteristic of the EPC contract, which is usually considered as an advantage to the owner, can be undermined by having a series of change orders (also known as "variation order") that delegate additional expenses to the owner for the advantage of the contractor. These variations are caused due to suspension or delay of work, change in the project scope and regulations, and submission of incomplete design (Al-Momani, 1996; Kartam, Al-Daihani, & Al-Bahar, 2000). In order to gain additional time and monetary benefits, the EPC contractor's organization dedicate contract specialists, after the commencement of an EPC project, to identify project variations that would be considered as change orders (Levy, 2010). For this reason, von Branconi and Loch (2004) recommend the involvement of not only legal contract experts and technical project managers but also top management of the contracting organization during contract negotiations to increase the efficiency of the EPC contract from the contractor's perspective. On the other hand, Grynbaum (2004) argues that the low EPC lump-sum bid might not be an efficient alternative for the owner as the bidding contractor might be relying on submitting variation orders, after the project commencement, to recover the profit. As such, the efficiency of EPC contracts in achieving project objectives from the owner's perspective requires stable project



conditions, transparent technical evaluation to effectively appraise the submitted bids, and minimal scope and change orders (Ud Din Tahir, 2004).

The EPC contract not only entails a specified project schedule and a fixed project cost but also involves a single point of responsibility defined between the owner and the EPC contractor. The improvement of such a relationship has gained considerable attention from researchers, as both the owner and the contractor teams have to work together during the development and implementation stages for an average of six years under very intense and demanding environments (Berends, 2007). Given these working challenges, the relationship between the owner and the contractor might be subject to various conflicts. These conflicts, as stated by Jaffar, Tharim, and Shuib (2011), are classified into behavioral, contractual and technical. The behavioral conflicts might arise due to multicultural clashes, poor communication among the project team, and poor supervision and follow-up required for project constructability and completion. In addition, conflicts might arise due to contractual-related problems such as submission of improper project schedule and extension of implementation time from the contractor side as well as delay in responding to contractor's financial and technical requests from the owner side. On the other hand, contractor's failure to provide the highest quality service/product and inability to estimate project expenses correctly might also induce technical conflicts between the two parties.

Grynbaum (2004) ascertains that having an adversarial project team relationship potentially leads to contractual disputes and claims that undermine the project successful outcomes. Such disputes have historically contributed to the downfall of reputable contractors, such as Raytheon, Marrison Knudsen and Stone & Webster. For this reason, Pinto, Slevin, and English (2009) highlight the important role of trust and

control in effectively managing the relationship between the owner and the contractor, which in turn facilitates the management of relationships with other project stakeholders. Therefore, having a project management team (PMT) that deals with the contractor on behalf of the project owner is highly recommended to alleviate the adverse impacts of the conflicts that might arise during project implementation, and thus ensure effective monitoring and management of project execution. It is thus necessary for the PMT to coordinate with all project stakeholders for their input, timing, comments, reviews, and approvals as necessary (Takreer, 2012). The successful implementation of large projects, as stated by Lampel (2001), also relies on the ability of EPC team to properly manage the relationships between project stakeholders, balance core competencies, and capture contract opportunities as they emerge. The EPC team should thus consist of an integrated team of specialists who have the ability to cover the entire project requirements during the development and implementation stages. Figure 2.8 shows a typical organization chart in EPC projects.

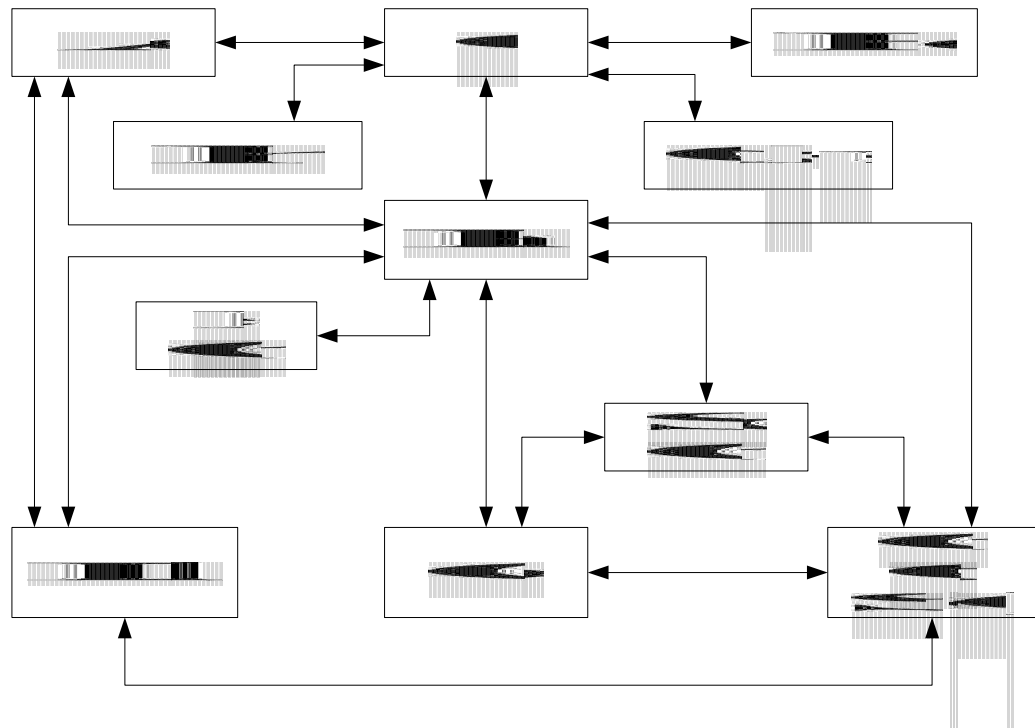


Figure 2.8: Typical organization chart in EPC project

Source: (DAH, 2006)

#### 2.3.3.4 Effectiveness of EPC: End-user's perspective

Given that the efficiency of the EPC in achieving the short-term project objectives from the owner's and the contractor's perspectives has been widely discussed and evaluated in literature, there is still a considerable need to assess its effectiveness in achieving long-term project objectives (i.e. product success). As such, this dissertation aims at fulfilling this need by evaluating the effectiveness of this contracting strategy from the end-user's perspective. The assessment of the effectiveness of the EPC is carried out based on the "end-user's engagement" and "alignment of objectives" criteria. These criteria represent the end-user's satisfaction due to participating in various project activities or achieving the desired product requirements that are in correspondence with project objectives.

Knowing that the EPC contracting strategy requires the participation of the end-user in various phases of a project at both the development (i.e. planning) and the implementation stages, it is highly important to shed light on such phases. What follows is a review of relevant literature related to main EPC project phases, with a focus on activities that entail the end-user's engagement.

### 2.3.4 Main project phases: End-user's participation

The development and implementation of major oil and gas projects pass through four main phases, namely Pre-FEED, FEED, Execution and Operation (Gasco, 2011; Takreer, 2012). These phases, demonstrated in Figure 2.9, cover the whole project life cycle from initiation to hand-over to end-users for operation.

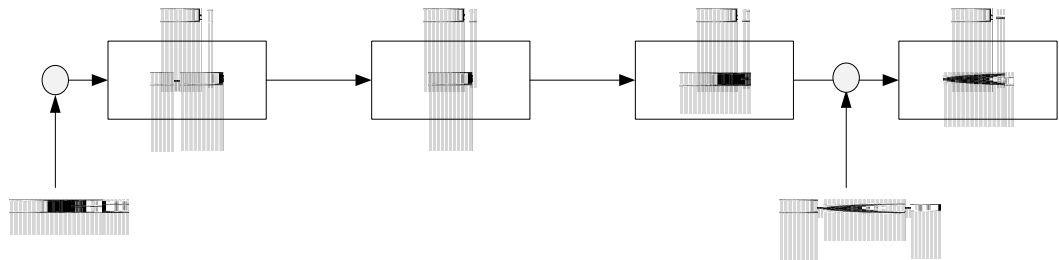


Figure 2.9: Main phases of the project life cycle

Source: (Gasco, 2011)

In this research, EPC contracting strategy is employed in the execution phase to actually implement the project. Under each project phase, the engineering firm/contractor has to accomplish various activities that are necessary to achieve project objectives. In order to study the effectiveness of EPC contracting strategy in achieving product objectives from the end-user's perspective, it is imperative to highlight these main activities, especially the ones that necessitate the involvement of end-users to generate main project deliverables. Figure 2.10 illustrates main activities

that require the end-user's involvement for each of the four project phases as well as the main deliverables generated from these activities. The technical details that relate to the flow of processes and activities in each phase along with its main deliverables are included in Appendix A.

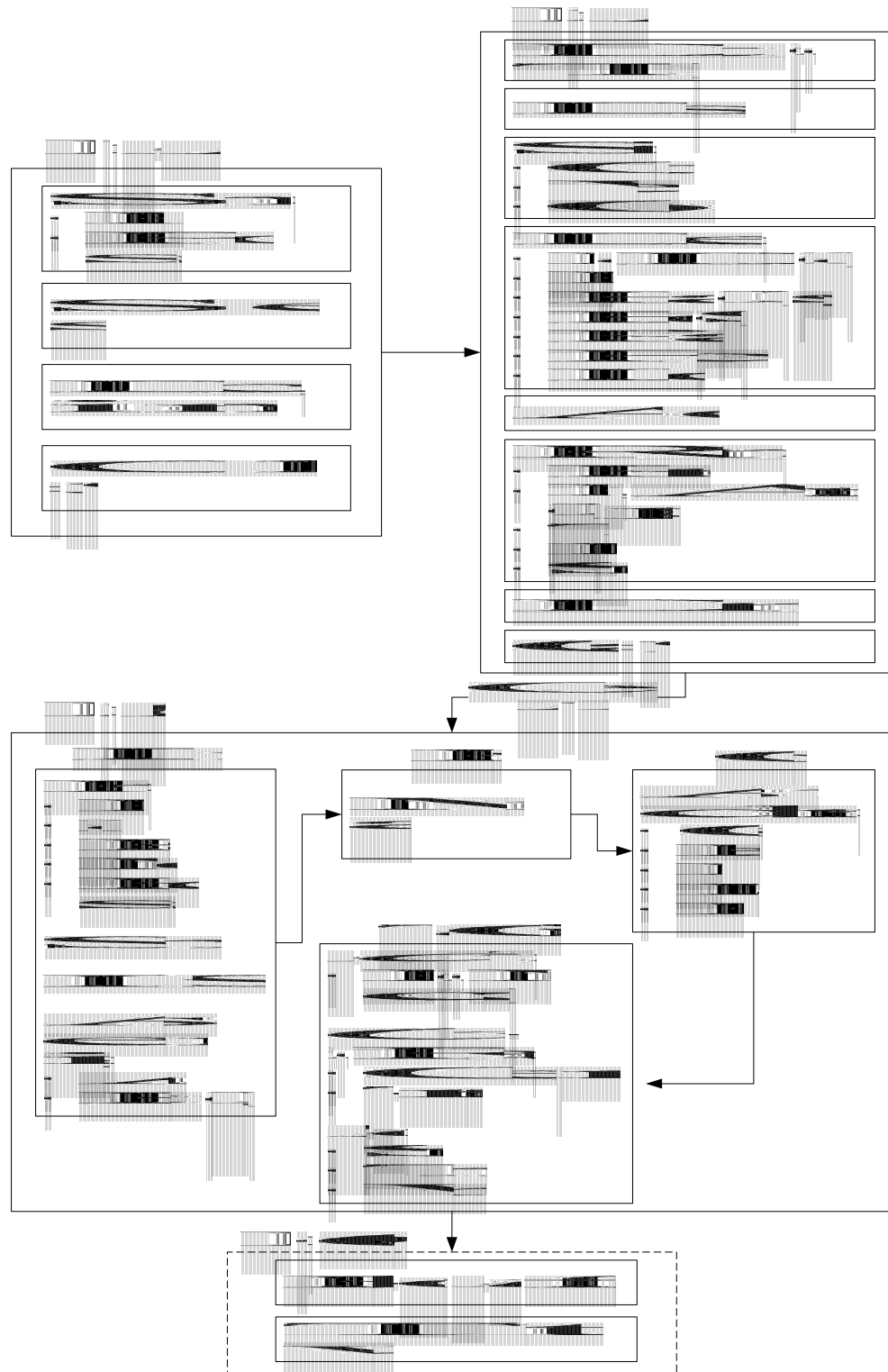


Figure 2.10: Main end-user related activities and deliverables of EPC project life cycle

Source: Developed for this research

#### **2.3.4.1 Pre-FEED phase**

The Pre-FEED phase of the project, or Pre-Front End Engineering Design, refers to the concept stage of the project where main objectives are defined and basic scope is outlined. Additionally, possible alternatives for contracting strategies that are likely to be cost-effective (i.e. feasible) along with their completion schedules are considered. The viability of these alternative scenarios is assessed by conducting a techno-economic feasibility study to determine the most effective solution for delivery (EPC-Engineer, 2014; Takreer, 2012). The involvement of the end-user in the selection of the optimal project execution strategy is crucial at this phase, as it aids in optimizing project objectives in relation to quality, cost and schedule at later stages (Bubshait & Al-Musaid, 1992). This activity is thus highlighted, in Figure 2.10, as one of the main activities that entails the end-user's involvement and is considered as a factor that might play a role in assessing the effectiveness of EPC strategy in achieving product objectives.

#### **2.3.4.2 FEED phase**

The FEED phase of the project, which stands for Front End Engineering Design, is a basic engineering design phase that comes after the conceptual design phase and is considered as the basis for bidding the execution phase contracts – the EPC strategy in this research. The first responsibility of the project team in the FEED phase is the development of the EPC strategy after being selected in the Pre-FEED phase. It focuses on the development of technical requirements in addition to the rough estimation of project cost, which are necessary to make effective decisions for proceeding towards the EPC stage for the project implementation. These project-

specific requirements have to be properly specified so as to avoid significant changes during the execution phase, and thus reduce the overall project costs. As such, a close communication between the project owner, contractor and operator (i.e. end-user) is required, in this phase, to identify such critical requirements (EPC-Engineer, 2014; Gasco, 2012) and produce main deliverables necessary for project implementation. These main deliverables, as illustrated in Figure 2.10, consist of:

#### *Piping & Instrumentation Diagram (P&ID)*

A P&ID is a primary schematic drawing that shows the physical interconnection of piping, instrumentation and process equipment components, which is necessary for the process control (PCS, 2008). P&IDs provide the basis for developing detailed piping layouts and system control schemes during EPC phase as well as conducting further safety and operational investigations (such as Hazard and Operability study) (IAM, 2015).

#### *Plot Plan*

A plot plan is an accurate dimensional drawing that shows the size and shape of the plant with adjacent reference points. It identifies what currently exists in the site and what is proposed to be done, including any proposed changes to physical project units or existing structures (WELD, 2012). It is used to highlight the equipment and supporting facilities (e.g. pipe racks) along with their basic shapes, designated amount, and locations. The proper arrangement of a plot plan is essential to produce a safe and cost-effective operational plant as well as provide the necessary access for operation and maintenance. Therefore, any errors in arrangement have to be recognized and eliminated during the plot plan development carried out during the FEED phase (Jadel, 2015). For this reason, the end-user's participation in reviewing the plot plan is highly



required to ensure comfortable access to equipments and avoid undesirable operational problems that would be costly once the plant is in operation (Chugh, 2011).

#### *Plant layouts*

A plant layout is a dimensional drawing that covers the graphical representations of the locations of all main units and equipments of the plant as well as general piping layouts. During the development of the plant layouts, it is critical to ensure that the spacing of the main equipment minimizes interconnecting pipe work and structural steel work, production lines do not cross, and operators have enough working space. These considerations would consequently save time and cost, increase production, and help prevent accidents (BIS, 2008; Chugh, 2011). The revision process of plant layouts thus entails the participation of all project stakeholders, including the end-user, due to their critical impact on the achievement of project and product objectives.

#### *Hazard and Operability (HAZOP) study*

A Hazard and Operability (HAZOP) study, part of the Health Safety and Environment (HSE) studies, is a structured and qualitative examination of a process or operation for the identification and evaluation of potential hazards and operational problems in terms of plant design and human error. The development of this study is carried out by an experienced multi-disciplinary team at this project phase, whereas the implementation takes place during the final design phase before the commencement of the construction (Qureshi & Shakeel, 2013).

#### *EPC Scope of Work (SOW)*

A Scope of Work (SOW) is an agreement that describes work to be performed. EPC SOW specifically contains any milestones, reports, deliverables, and end-products that are expected to be provided by the EPC contractor, with a time-line for all these

deliverables (Udemy, 2014). A common problem that occurs with SOW is a lack of the specificity that is needed to support both the contractor and the project team when any dispute arises during project implementation. As a consequence, the higher the accuracy of the scope, the greater is the control and alleviation of the potential risks and technical changes.

#### *Product Specifications*

The product specifications, identified during the basic design process, represent the requirements that must be accomplished in order to meet the end-user's needs (BBC, 2014). These specifications guide the EPC contractor during all stages of EPC phase, i.e. from the detailed design engineering work to hand-over of the finished product to end-user for operation, to ensure that the end-product is fit for purpose.

#### *Licensed Technologies*

In oil and gas projects, some specialized technologies are owned by international engineering companies and provided to such projects based on a license contract. This agreement has become a significant revenue producer for the licensor and a very helpful and handy legal mechanism to facilitate the upward trend in the oil and gas industry (OGM, 2012). A techno-economic assessment is carried out, at the FEED phase, to identify and evaluate the ability of these technologies to meet project requirements. Given the huge license fees, the end-user's participation is crucial in examining the appropriateness of such technologies so as to avoid the consequences of undesirable operational difficulties and a shortfall between expectations and reality (Damodaran, 1996).

The EPC contract necessitates the participation of the end-user not only in the development of these deliverables but also in the approval of the shortlist depicting

technically qualified vendors. Additionally, the end-user's revision for the tender package is required at this project phase, especially the section related to:

#### *Performance Guarantee*

A Performance Guarantee is a business agreement between the project owner and the EPC contractor which obligates the latter to perform all the obligations under the contract. In case the assigned contractor fails to perform as expected, this agreement protects the owner against the losses incurred and necessitates the engagement of an alternative contractor (Business-Dictionary, 2015). As a result, this agreement aids in attaining the desired results in relation to project and product objectives and thus achieving the end-user's satisfaction.

#### *Reliability, Availability and Maintainability (RAM)*

RAM analysis is an essential study that enables the project owner to ensure that systems are designed and operated in an optimized way. The primary performance indicator is "availability", which denotes the fraction of time a system is fully functional. "Reliability" represents the fraction of time a system produces correct outputs, whereas "maintainability" refers to the speed a system can be repaired. RAM analysis produces various simulations that estimate the availability indicator, taking into consideration both equipment reliability and maintainability (MITRE, 2013). The most critical measures of a RAM analysis are system capabilities, failure rates, consequences of failures, spare parts availability, mobilization times, resources supply, planned maintenance periods and operating rules. Such measures are used to estimate productiveness as well as examine possible causes of production losses, spare parts consumption, maintenance requirements and system alternatives. The RAM analysis not only provides valuable results for the assessment of technical and operational

measures for both the design and operational phases but also supports lifecycle cost analysis, thereby serving as a cost-benefit analysis tool. For this reason, the higher the accuracy of this analytical study, the lower is the project cost and the higher is the end-user's satisfaction (EP-Consult, 2005; LR-Consulting, 2015).

The portion of the tender package which requires the end-user's involvement also contains details about training, insurance and spare parts that form the basis for the project hand-over. In addition, the participation of the end-user in the development of the commissioning strategy in the FEED phase facilitates testing and commissioning activities in EPC phase, which in turn increases the possibility of achieving the product objectives (Gasco, 2011). Therefore, the end-user's involvement in various activities of FEED phase plays a significant role in improving project quality, cost and schedule as well as examining critical operational requirements (Bubshait & Al-Musaid, 1992). For this reason, the end-user's confirmation is highly required to proceed from FEED to EPC phase.

#### **2.3.4.3 EPC Phase**

The EPC phase of the project, which normally follows the FEED phase, is the execution phase that covers project implementation and is constituted of four main stages including detailed engineering, procurement, construction and commissioning. Similarly, to the FEED phase, the EPC phase includes various activities that entail the end-user's participation to generate the main deliverables needed to move towards the operation phase and consequently achieve product objectives. These activities, as illustrated in Figure 2.10, are categorized under the four main EPC stages.

During the detailed engineering stage, it is essential to engage the end-user in the finalization of various deliverables that were initiated and developed in the FEED phase, including plot plans, P&IDs, plant layouts, model review, and finished product specifications. In addition, the end-user's involvement in the selection process of licensed technologies, identified in the FEED phase, is very critical to assess the appropriateness of these technologies and avoid undesirable problems during operation (Damodaran, 1996). Health Safety and Environment (HSE) studies, including HAZOP, are implemented in the EPC phase as well, where the end-user's past experience in oil and gas projects plays a vital role in the successful development and implementation of these studies. Key engineering documents, such as Approved for Construction (AFC) drawings of all project disciplines and Bill of Quantities (BOQ), are also approved in the detailed engineering stage. A well-prepared BOQ, which is a document that provides project specific material quantities identified from the drawings and specifications, requires a complete and accurate design (Designing-Buildings, 2015a).

The output of the detailed engineering stage, which includes the aforementioned deliverables (i.e. AFC drawings, material quantities, specifications, procedures and standards), is an essential requirement for the procurement stage in which the EPC contractor has to purchase materials, equipments, and services necessary for construction. Materials evaluation and approval in addition to the approval of construction documents for all disciplines (e.g. civil works, electrical, piping, instruments, equipments) are significant activities that require the engagement of the end-user for the purpose of ensuring successful testing and commissioning as well as

fulfilling project specifications and contractual requirements (Gasco, 2011; Takreer, 2012).

The operational unit, responsible for end-users (i.e. operators), is responsible for ensuring the participation of operators in the pre-commissioning, commissioning and hand-over periods of the testing and commissioning stage. During the pre-commissioning period, end-users gain in-depth practical understanding of the plant and equipment, which in turn verifies the status of entire installation and prepares the plant for the commissioning step. One of the significant deliverables of pre-commissioning is Mechanical Completion Checklist (also known as Punch List), which is a list of tasks that have to be carried out on equipment and construction to confirm that the installations are in accordance with drawings and specifications, in compliance with project requirements, and ready for commissioning (NORSOK, 1996). During commissioning, the end-user has to approve commissioning manuals, participate in conducting test-runs, and approve test reports after required revisions. After the acceptance of test reports, the plant facility is formally handed-over to the end-user for operation, making sure that required spare parts, training manuals and warranty periods are adequately provided (Takreer, 2012).

#### **2.3.4.4 Operation Phase**

During the operation phase and the warranty period, both the PMT and EPC contractor are available to ensure the reliability of the handed-over facility. Additionally, a post-implementation review is carried out, and the Final Acceptance Certificate (FAC) is consequently issued. It is important to note that the post-implementation review, which usually takes place about six months after the hand-

over, aims at reviewing the performance of the facility and identifying any further works required for improvement (Wallace, 2014). The FAC, on the other hand, is issued by the end-user at the end of the warranty period after making sure that the EPC contractor has fulfilled all contract obligations (Designing-Buildings, 2015b). After the disengagement of the EPC contractor, the end-user is responsible for operating and maintaining the facility using in-house resources.

### **2.3.5 End-user's participation: A deeper insight**

While the previous section sheds light on the main activities that entail the end-user's participation for generating main project deliverables, the present section provides a deeper insight into the importance of engagement in early stages of design for improving the project effectiveness.

#### **2.3.5.1 The effort curve**

The “fixed-cost” characteristic of EPC contract, as mentioned previously, is usually challenged by the change orders (also known as “variations”) that the EPC contractor strives to uncover to charge additional expenses to the project owner. Most of these variations, as argued by Al-Momani (1996), are due to the submission of an incomplete design. The cost of design changes, during Pre-FEED and FEED phases of the project (i.e. during concept and development), are minimal compared to the case when the project is in the execution or EPC phase. Figure 2.11, which represents the MacLeamy curve (also known as “Effort curve”), highlights the difficulties in controlling the construction cost and changes in design as the project moves forward (AEC, 2015). During the construction phase, any design change is challenging and

costly, which in turn might delay reaching both project and product objectives. For this reason, the end-user's participation in early stages of design ensures that the design properly suits the end-user's requirements, and consequently reduces the amount of design and construction changes during implementation. It is worth noting that these changes, if not avoided with early involvement, might oblige the end-user to either adapt to the non-achievement of product requirements or plan the desired enhancements after the hand-over of the plant facility. In such cases, the end-user's satisfaction and product success would not be accomplished. As a consequence, shifting the efforts of involving the end-user forward in time (i.e. from Pre-FEED phase) alleviates the adverse impacts of design changes as well as increases the ability to save cost, improve performance, and increase end-user's satisfaction.

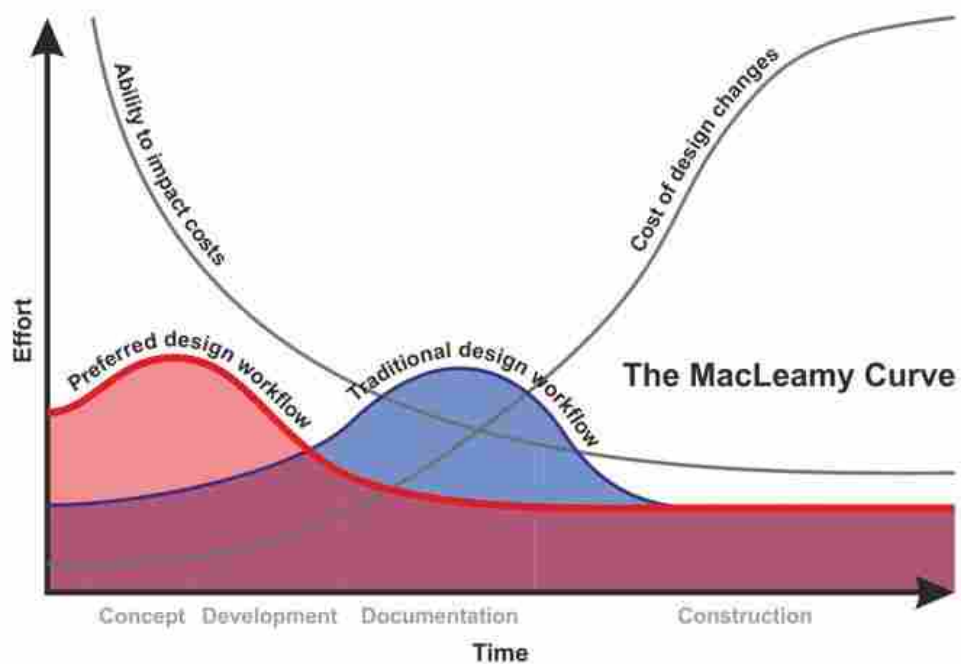


Figure 2.11: The MacLeamy effort curve

Source: (AEC, 2015)



The involvement of the end-user in early stages of design is similar to the concept of participatory design suggested by Balfour et al. (2012). The participation of the end-user as an active stakeholder in the design process is highly recommended to benefit from the end-user's expertise and in-depth understanding of the work context, which in turn increases the probability of acceptance for the proposed design and thus allows for more efficiency and effectiveness at the site level.

While reviewing the literature reveals the critical impact of the end-user's participation in reducing the amount of design changes and consequently achieving project objectives, a study conducted by Bryde and Robinson (2005) reflects the consistent resistance of the project teams to any improvements raised by the end-user (i.e. operator). Such resistance is due to negative perceptions towards the end-user's involvement. The following section sheds light on the challenges and the conflicting perceptions towards the end-user's participation.

### **2.3.5.2 Challenges and conflicting perceptions**

According to Bryde and Robinson (2005), the operation team is always perceived as a technical multi-disciplinary team that aims at challenging and delaying the project progress in an attempt to ensure the compliance and quality of deliverables as well as avoid any future maintenance and operability concerns. In addition, Balfour et al. (2012) reflects the perceptions of project stakeholders towards the end-user's participation, where it is also perceived as a challenge to the achievement of short-term project objectives. As such, convincing the stakeholders about the benefits of end-user's participation is demonstrated as the most challenging task at the site level. On the other hand, Pemsel, Widén, and Hansson (2010) highlight the lack of awareness

of end-users towards the importance of their involvement in reaching their requirements due to negative attitudes and ineffective communication with other project parties during previous projects. Having such negative and conflicting perceptions towards the importance of the end-user's participation induces conflicts between the project management and contractor teams from one end and the operation team from the other end. These conflicts often lead to "poor" alignment between project objectives and product objectives (i.e. end-user's requirements). For this reason, Lundvall (1992) argues that increasing end-user's participation is not enough to achieve project objectives and increase the end-user's satisfaction. It is rather a matter of improving the communication and properly managing the participation. What follows is a set of recommendations that help manage the end-user's participation at the site level and consequently retain the alignment between project and product objectives.

### **2.3.5.3 Recommendations for proper participation of end-users**

Managing the participation of end-users throughout a project requires understanding the attitude of project stakeholders towards the end-user's participation. Pemsel et al. (2010) recommends having a facility planner (FP) who is responsible for raising the awareness towards the advantages of the end-user's involvement in various activities in achieving project objectives and product requirements as well as providing the end-user with sufficient support during involvement. Being able to overcome the difficulties of having negative attitudes and frustrations would improve the communication between the project management and the end-user, leading to smoother project progress, less design and construction changes, higher satisfaction, and better alignment between project and product objectives. In addition, Joyce (2005)

demonstrates the critical roles of “realism” and “objectivity” towards achieving successful communication between the contractor and the end-user, which in turn results in effective control and management on site. Fadol and Sandhu (2013), as well, highlights the vital role of “trust” in building well-functioning relationships among the project parties, which in turn enhances the communication and cooperation at the site level.

Ross (2012), as well, ascertains that competency of the operation team plays a significant role in achieving the product requirements. In this context, Freeman (2013) defines “operator competency” as the ability to effectively apply experience in performing a specific task properly. Even though the application of operator competency management might induce challenges to project teams (i.e. PMT, PMC, EPC contractor) in relation to the accomplishment of short-term project objectives, project management is gearing towards developing and sustaining operator competency to achieve the desired end-results as well as create competitive advantages (Ross, 2012). Therefore, the achievement of proper and effective participation necessitates having an end-user team that is technically qualified and competent enough to challenge the project teams to ensure product success. It is worth noting that the competency of the operation team can be assessed using an Operator Competency Checklist that includes key skills, knowledge and experience related to various aspects, such as technical systems requirements and operational safety (MPQC, 2012).

### **2.3.6 Alignment of objectives: A closer approach**

The previous section highlights the need for managing the involvement of the end-user at the site level and concurrently proposes recommendations for proper participation. The present section, instead, focuses on the “alignment of objectives” criterion, where the state-of-the-practice is illustrated, and recommendations for proper alignment are provided.

#### **2.3.6.1 State-of-the-practice**

Given the fundamental role of aligning project objectives with product objectives (i.e. end-user’s requirements) in achieving product success, industry investigations carried out by Patanakul and Shenhar (2012) reveal that alignment is not properly planned and achieved at the site level even though the majority of project teams support the concepts and needs for strategic alignment between both objectives. In addition, Shenhar, Milosevic, and Thamhain (2007) argue that although project management is changing towards a new era of aligning project objectives with business requirements, traditional project management discipline is responding slowly, which in turn necessitates having appropriate techniques to overcome obstacles to achieve better alignment. What follows is a set of recommendations that help attain proper alignment between project objectives and product objectives.

#### **2.3.6.2 Recommendations for proper alignment**

True strategic alignment, as suggested by Thamhain (2014) , requires a considerable shift in managerial perspective from a narrow focus on efficiency to both efficiency and effectiveness. This suggestion is also supported by Shenhar et al.

(2007), where project managers and project teams are recommended to learn how to think more strategically and become responsible for business performance and end-results in addition to short-term project objectives. In this context, Villachica, Stone, and Endicott (2004) recommend carrying out “alignment meetings” on a regular basis for the purpose of attaining better alignment between project and product objectives throughout the whole project lifecycle. Representatives of project management, EPC contractor, and end-user have to attend these meetings for the purpose of reviewing the project objectives and the alignment requirements. By having all key project stakeholders meeting together, reviewing the same issues and caring for the achievement of the end-user’s needs, negative attitudes and disappointments would be reduced, leading to more effective engagement, better alignment, and higher satisfaction.

## **2.4 Research Hypotheses**

As mentioned previously in section 2.3.1, product success (i.e. meeting product objectives) is achieved through meeting the end-user’s satisfaction. Reviewing the literature reveals that “end-user’s engagement” and “alignment of objectives” are two criteria that have significant impacts on end-user’s satisfaction, and thus can be used to assess the effectiveness of a given project in meeting product success. In an attempt to evaluate the effectiveness of EPC contracting strategy in achieving product success (i.e. end-user satisfaction), these two criteria are used as the basis to formulate main research hypotheses and consequently build the theoretical model. Two main research hypotheses are, thus, constructed as follows:

H1: There is a positive correlation between the effectiveness of EPC and the end-user's engagement.

H2: There is a positive correlation between the effectiveness of EPC and the alignment of project objectives with product objectives.

These two research hypotheses are formulated based on the literature review, and the theoretical model (presented in chapter 3) considers the two criteria (i.e. "end-user's engagement" and "alignment of objectives") as main factors that potentially have significant impact on the effectiveness of EPC in achieving product success. The theoretical model also includes sub-factors that are used to measure the impacts of these criteria, where these sub-factors are extracted from the literature review conducted in the present chapter. The structural SEM model, on the other hand, not only examines the statistical significance of the relationships between "effectiveness of EPC" and these two criteria but also distinguishes if one criterion has higher or lower influence than the other one on the "effectiveness" variable.

As mentioned in chapter 1 (section 1.5), this research also aims at examining whether these relationships between the effectiveness of EPC and the two main criteria differ among the three industries (i.e. refining, gas, petrochemical) in Abu Dhabi. In an attempt to address this research objective, a third research hypothesis is formulated as follows:

H3: There is a difference in the relationships between effectiveness of EPC and end-user's engagement as well as alignment of objectives among refining, gas and petrochemical industries.

## **2.5 Conclusion**

In the course of this literature review, several aspects related to a project in the oil and gas industry were examined. The efficiency of EPC contracts in meeting project objectives from the project owner's perspective has been well presented in literature, where a deficiency related to the evaluation of the effectiveness of EPC from the end-user's perspective was highlighted.

Arising out of this deficiency, factors influencing the effectiveness were identified. In this context, the end-user's engagement in various project activities targeted at producing the main deliverables in addition to the achievement of the end-user's satisfaction by aligning project objectives with the product objectives shapes the effectiveness of EPC contract in meeting product success.

Given the significance of the end-user's participation in early stages of design in reducing the amount of design and construction changes and consequently saving cost, negative and conflicting perceptions regarding the involvement of end-users were also demonstrated, thereby shedding light on the necessity of properly managing the participation. Raising the awareness of project stakeholders towards the importance of the end-user's engagement in meeting product success as well as carrying out "alignment meetings" to follow up on the alignment progress were proposed as recommendations for proper end-user's participation and alignment of objectives.

## Chapter 3: Research Methodology

### 3.1 Introduction

Based on a comprehensive literature review and the author's long professional experience in the oil and gas industry, gaps in both literature and practice have been identified. Four research questions were constructed to fill these gaps and address the research problem. The research objectives were demonstrated in an attempt to examine the effectiveness of EPC contracting strategy in achieving product success from the end-user's perspective, and three main research hypotheses were then formulated to address these objectives. Figure 3.1 outlines the design of this research study, where research hypotheses are illustrated as the basis for the justification of research paradigm and methodology as well as the research process, which in turn constitute the focus of this chapter.

In this context, section 3.2 sheds light on possible research strategies and paradigms. "Inductive" and "positivism" are respectively justified as the strategy and the paradigm within which this research was conducted. In addition, it identifies three research methodologies (i.e. qualitative, quantitative, mixed-method) and describes the reasons for adopting a quantitative method to answer the research questions. Section 3.3, on the other hand, represents the research process, which demonstrates the stages followed to reach the "research reporting" stage starting from the stage of "conceptualization".



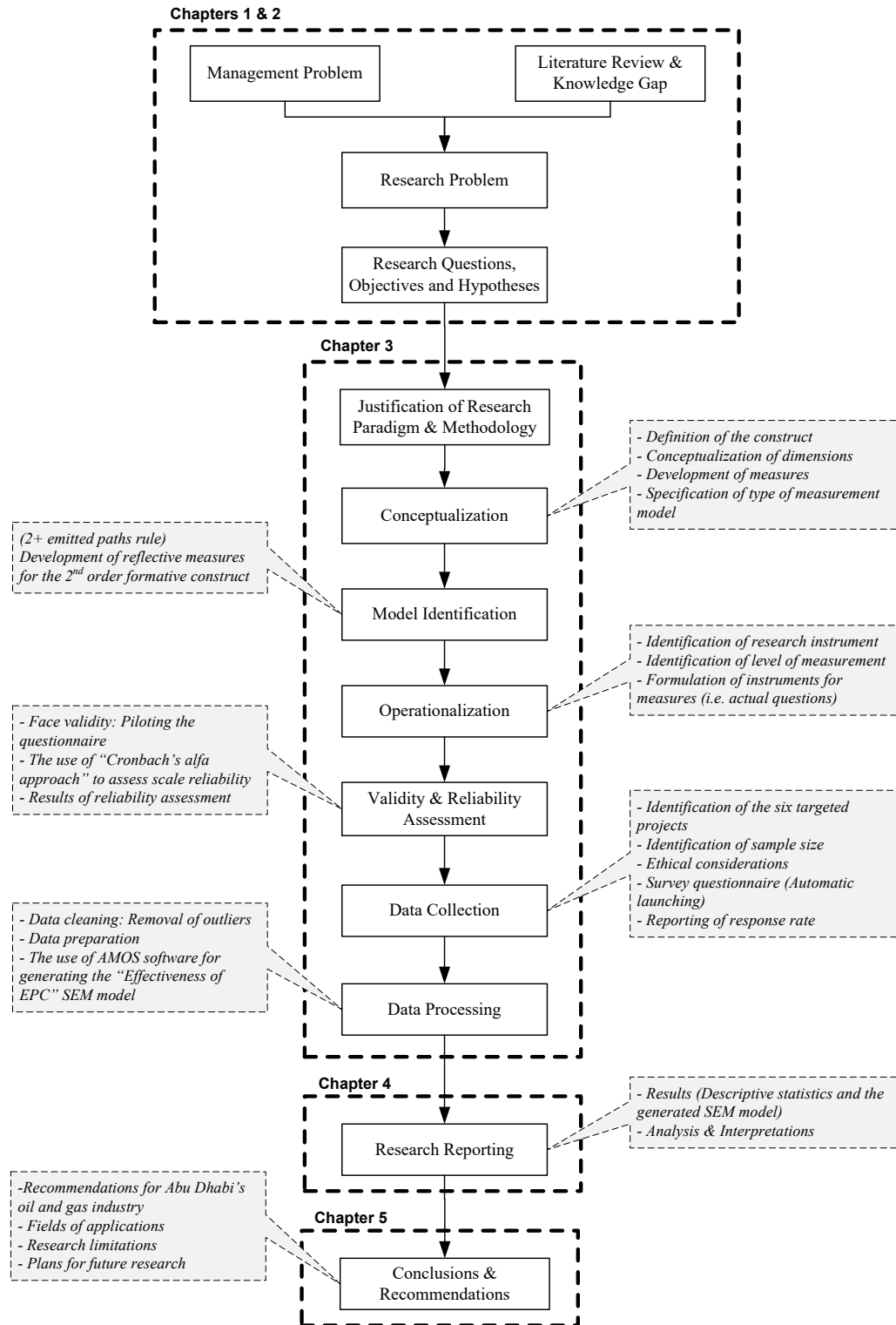


Figure 3.1: Research design  
 Source: Developed for this research

## **3.2 Research Philosophical Background**

The empirical research requires a linkage between practice and theoretical concepts to identify the appropriate research strategy, paradigm and methodology within which to conduct the research. Choosing suitable approaches, as demonstrated by Punch (1998), is critical for achieving research objectives. This section sheds light on various aspects related to the philosophical research platform and justifies the research paradigm and methodology adopted in this research study.

### **3.2.1 Research strategy**

The critical task, after the formulation of research questions, is to decide upon the procedure that should be followed to answer these questions. This procedure involves the logic behind the generation of new knowledge and is commonly referred to as a “research strategy”. The research strategy provides a starting point and a series of steps by which main research objectives can be met, and consequently the research questions can be answered (Blaikie, 2007). There are four distinct research strategies, including inductive, deductive, retroductive and abductive, where each strategy starts with a different point yielding to the desired research objective (see Table 3.1).

Table 3.1: The logic behind main research strategies

Strategy Element	Inductive	Deductive	Retroductive	Abductive
<b>Start</b>	A set of empirical observations	A theory	A phenomenon	Social world of social actors (lay accounts of everyday life)
<b>Outcome</b>	Generalized patterns	Validated hypotheses	An explanation of the phenomenon	Technical, scientific and expert descriptions of social life
<b>Objective</b>	To find universal generalizations to be used as explanations of further observations	To test the theory by matching the developed hypotheses with the collected data	To build a hypothetical model that explains the real mechanism underlying the phenomenon	To produce technical and scientific descriptions for social actors' lay accounts so as to be used as explanations of typical situations

Source: Developed for this research

The *inductive* research strategy starts with the collection of empirical observations from social life, seeking patterns during analysis and consequently deriving universal generalizations out of the established patterns. Other specific events can then be explained by projecting them to the generalized patterns (Blaikie, 2007; Feeney & Heit, 2007). As such, this approach moves from data (i.e. specific) to theory (i.e. general). Unlike the inductive approach, the *deductive* research strategy moves from a general level to a more specific one. According to Blackstone (2012) and Blaikie (2007), the deductive approach involves starting with a social theory and then developing hypotheses from that theory. During data analysis process, the researcher tries to match the hypotheses with the collected data, where successful matching indicates the validation of the theory under consideration. The social theory, on the other hand, has to be modified or eliminated when hypotheses fail to match the data.

The *retroductive* research strategy is, as well, a process that works back from the data to an explanation, but it seeks a different type of explanation. It specifically starts from an empirical phenomenon and aims at building a hypothetical model that demonstrates the mechanism responsible for producing that phenomenon (Meyer & Lunnay, 2013). The model is constructed based on either mechanisms used in other fields of research or the researcher's creative imagination and analogy (Blaikie, 2007). The last type of research strategy, i.e. *abductive* approach, has a distinctly different logic as compared to the aforementioned strategies. Its main objective is to deeply understand different aspects of the participants' social life. The researcher, in particular, targets the social actors' everyday lay concepts, understandings and motives and then tries to produce technical and scientific descriptions, which can be used to interpret other typical actions. It is worth noting that the researcher, following this approach, has to be immersed in the social situation and rely on his/her intuition and personal experience for understanding the reasons accompanying the social activities (Blaikie, 2007; Meyer & Lunnay, 2013).

The main objective of this research study is to evaluate the effectiveness of EPC contracting strategy in accomplishing product success from the end-user's perception. In this regard, it aims at targeting a sample of end-users working in various projects in Abu Dhabi's oil and gas industry and capturing their perceptions towards the effectiveness of EPC in the execution of major projects. Based on the collected data, generalized patterns, representing possible causal relationships between the effectiveness of EPC and its respective factors, have to be established. In turn, these patterns can serve as a basis for the achievement of end-user's requirements in Abu

Dhabi's oil and gas industry. As such, this research follows the inductive research strategy for achieving its main objective.

Blaikie (2007) argues that research strategies involve a wider scope than choosing methods to be used for data collection and consequently the achievement of research objectives. Instead, they are located within the broader frameworks of philosophical perspectives, commonly referred to as "paradigms". The following section sheds light on main research paradigms along with basic assumptions underlying each paradigm.

### **3.2.2 Research paradigm**

A paradigm is a conceptual framework consisting of a set of beliefs or assumptions that act as a guide for the researcher while conducting the research work (Guba & Lincoln, 1994). It is defined based on various aspects related to social reality. Social reality, in turn, represents the materials that construct the social world and have impacts on people's lives in terms of providing opportunities and placing restrictions, such as individuals' motives and social interactions (Ramazanoglu & Holland, 2002).

#### **3.2.2.1 Basic assumptions**

Research paradigms, as demonstrated by Perry, Riege, and Brown (1999), differ based on three distinguishing philosophical assumptions of social reality, including ontology, epistemology and methodology. While *ontology* refers to the nature of the social reality being investigated, *epistemology* represents the characteristics of the knowledge obtained about that reality as well as the relationship between the reality and the researcher (i.e. researcher's stance). *Methodology* refers to the technique/procedure used by the researcher to discover the reality. Quantitative,

qualitative and mixed-method techniques are the three main methods for conducting a research.

A research project adopting the quantitative methodology seeks to quantify observations about the human behavior by employing surveys and experiments for the collection of numeric data. It typically uses closed-ended questions and unbiased highly-structured approaches. This method applies statistical procedures and the reliability/validity standards for the verification of theories as well as the identification of variables and possible causal relationships between them (Creswell, 2003). The challenge of such methodology is the necessity to have a sample size sufficient for the generalization of conclusions (Saunders, Lewis, & Thornhill, 2000).

Unlike the quantitative technique, the qualitative methodology is less concerned with the generalization of research findings. Instead, it focuses on a phenomenon that occurs in the social world and aims at studying this phenomenon with all its complexity (Leedy & Ormrod, 2005). According to Creswell (2003), a qualitative research follows a narrative-based strategy that uses open-ended questions for data collection. The researcher collaborates with the participants to gain deep understanding of their concepts and meanings to events and consequently report the non-statistical interpretations of the collected data (Dooley, 1990).

The mixed-method approach combines both the quantitative and the qualitative research methods. This methodological approach, as demonstrated by Creswell (2003), requires the collection of numeric and non-numeric data using both open-ended and closed-ended questions, which in turn exerts some challenges on the researcher. Hanson, Creswell, Clark, Petska, and Creswell (2005) demonstrate that dealing with mixed-method research strategy requires considerable expertise in both

the quantitative and the qualitative approaches. The combination of the two methodologies requires extensive data collection as well as significant time and effort for the analysis of both numeric and text data.

### **3.2.2.2 Main research paradigms**

Scientific research, as demonstrated by Perry et al. (1999), is conducted within four main paradigms, including positivism, realism, critical theory and constructivism. However, some studies, e.g. Easterby, Thorpe, and Lowe (1991), combined the last two paradigms into one paradigm, known as phenomenology. Table 3.2 sheds light on the characteristics of the three key paradigms (i.e. positivism, realism, phenomenology) based on the aforementioned basic assumptions (i.e. ontology, epistemology, methodology).

Table 3.2: Characteristics of main research paradigms

Assumption Paradigm	Ontology	Epistemology		Methodology
		Findings Characteristics	Researcher's stance	
<b>Positivism</b>	<ul style="list-style-type: none"> <li>• A single real and apprehensible reality</li> </ul>	<ul style="list-style-type: none"> <li>• Findings are:               <ul style="list-style-type: none"> <li>- True</li> <li>- Objective</li> <li>- Value-free</li> <li>- Generalizable</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Outside Expert</li> <li>• Researcher does not intervene in the reality under investigation</li> </ul>	<ul style="list-style-type: none"> <li>• Quantitative technique</li> <li>• Data Collected in a structured manner (e.g. surveys, experiments)</li> <li>• Verification of hypotheses</li> </ul>
<b>Realism</b>	<ul style="list-style-type: none"> <li>• Reality is imperfectly and probabilistically apprehensible</li> <li>• Not empirically tested</li> </ul>	<ul style="list-style-type: none"> <li>• Knowledge obtained is considered real but fallible</li> <li>• Findings are probably true</li> </ul>	<ul style="list-style-type: none"> <li>• Researcher is part of the research but remains as objective as possible</li> </ul>	<ul style="list-style-type: none"> <li>• Mixed-method</li> <li>• Triangulation of data</li> </ul>
<b>Phenomenology</b>	<ul style="list-style-type: none"> <li>• Reality is shaped with historically situated structures</li> <li>• Transformation of social, political, cultural, economic, ethnic and gender values</li> </ul>	<ul style="list-style-type: none"> <li>• Findings are:               <ul style="list-style-type: none"> <li>- Created</li> <li>- Subjective</li> <li>- Value-dependent</li> </ul> </li> <li>• Generalization is less valuable</li> </ul>	<ul style="list-style-type: none"> <li>• Inside Learner</li> <li>• Researcher is engaged in close relationships with the research participants</li> </ul>	<ul style="list-style-type: none"> <li>• Qualitative technique</li> <li>• Case studies: process-oriented</li> <li>• Focus group</li> <li>• Data analysis:               <ul style="list-style-type: none"> <li>- Transformative</li> <li>- Intellectual</li> <li>- Interpretive</li> <li>- Depends on researcher's interpretive ability</li> </ul> </li> </ul>

Source: Developed for this research

### *Positivism*

The positivism research paradigm, as demonstrated by Perry et al. (1999), deals with a real and apprehensible social reality. The aim of the research is to verify hypotheses based on highly-structured data collected using quantitative techniques (e.g. questionnaire surveys, experiments) (Guba & Lincoln, 1994). The researcher maintains a professional distance from the research participants (i.e. Outside expert), seeking true, objective, value-free and generalizable findings (Blaikie, 2007; McNeill, 1986; Saunders et al., 2000).



### *Realism*

In the realism research paradigm, the reality is imperfectly and probabilistically apprehensible, as it reflects the realists' perceptions towards the actual reality (Godfrey & Hill, 1995). The researcher's perception of reality must thus be triangulated with several perceptions of that reality to gain a clearer picture of the actual one. As such, knowledge obtained is considered real but fallible. The mixed-method technique is used for data collection, where the researcher tries to remain as objective as possible (C. Perry et al., 1999).

### *Phenomenology*

The reality, in the phenomenology paradigm, is shaped with historically social situations. The research aims at criticizing and transforming social, political, cultural, economic, ethnic and gender values, with less consideration for generalization of the results. Process-oriented case studies are employed for data collection, where the researcher develops close relationships with research participants to capture narrative and non-numeric data illustrating their concepts (Blaikie, 2007; Guba & Lincoln, 1994; C. Perry et al., 1999). As such, data analysis highly depends on the researcher's interpretive ability, and research findings are considered created, subjective and value-dependent (Saunders et al., 2000).

#### **3.2.2.3 Justification of research paradigm and methodology**

The selection of an appropriate research paradigm is a critical step in conducting a research. This research aims at capturing end-users' perceptions towards the effectiveness of EPC in the execution of major oil and gas projects at different project phases. Data were collected using an online structured survey questionnaire,

distributed to a sample of end-users. Given that quantitative data have the advantage of providing conclusions that can be generalized to a large population, the *quantitative* methodology was employed for data collection. The collected numeric data were analysed using statistical procedures, and findings were then extrapolated and generalized to the level of Abu Dhabi's oil and gas industry. As such, based on the characteristics of research paradigms illustrated in Table 3.2, *positivism* paradigm offered the most suitable platform for data collection and analysis and consequently the achievement of research objectives.

In an attempt to identify the ontological as well as the epistemological assumptions behind the adopted research paradigm, relevant literature was reviewed. As demonstrated by Blaikie (2007), the *cautious realist* assumption is the ontology on which the research paradigm is based. In particular, this ontological assumption deals with human's perceptions and experiences and seeks to derive patterns out of these empirical observations for generalization purposes. Due to human frailties and imperfections in capturing the accurate individuals' senses, the researcher has to be "cautious" during data collection and analysis. As for the epistemological assumption, this research followed the *pragmatic conventionalism* approach. It particularly adopted a pragmatic scientific procedure to develop a statistical tool that identifies factors affecting the effectiveness of EPC projects and the causal relationships between these factors. The generated model serves as a convenient generalized tool for raising the awareness towards the influencing factors of the effectiveness of oil and gas projects, which in turn can be used to solve typical social problems.

### **3.3 Research Process**

The previous section justifies the use of a quantitative methodology to capture the end-user's perception in an attempt to examine the effectiveness of EPC contracting strategy in achieving product success. On the other hand, the present section demonstrates the process followed to generate a statistical model that assesses the significance of the relationships between the effectiveness of EPC and its respective factors. This process starts with the "conceptualization" stage, which in turn focuses on the development of the theoretical model, showing possible influencing factors based on a comprehensive literature review. What follows is a description of each step applied to generate the structural model, report the results, and conduct rigorous analysis and interpretations based on these results.

#### **3.3.1 Conceptualization**

As previously mentioned, the main objective of this research is to examine the effectiveness of EPC in achieving product success through building a model that identifies possible factors that have significant impacts on effectiveness. The structural equation modeling (SEM) statistical technique is used to generate the model and assess the significance of possible relationships among respective factors.

SEM is an advanced prescriptive data-analytic technique that has become an increasingly popular statistical analysis option due to its various strengths. One popular feature of SEM is that it deals with complex models comprising of a set of relationships between several independent and dependent variables. Another strength of SEM is its ability to specify latent variables (i.e. unobserved variables) and measure the parameter estimates (i.e. path coefficients) of relations with their indicators (i.e.

observed variables). These coefficients represent the influence of their related paths on the outcome variable (i.e. dependent variable). In addition, SEM can capture the relationships between independent and dependent variables through indirect and interactive influences, known as “mediation” (Crossman, 2015; Tomarken & Waller, 2005). The following section sheds light on basic terms and concepts required to build a SEM model.

### 3.3.1.1 SEM language: basic terms and concepts

Given that the factor at hand (i.e. effectiveness) is a phenomenon of theoretical interest that is difficult to observe directly, its existence can be inferred based on a set of observed indicators. As a conceptual term, this phenomenon is defined as a *construct*, whereas the observed variable is referred to as *indicator* or *measure* (Edwards & Bagozzi, 2000; Podsakoff, Shen, & Podsakoff, 2006). The next critical step, after the definition of the construct and its possible indicators, is the specification of the conceptual relationships between them, the so-called “direction of causality” (Bollen & Lennox, 1991). In this context, the direction of the relationship is either from the construct to the measures or from the measures to the construct. In the former case, the type of the measurement model is reflective, whereas it is formative in the latter.

Diamantopoulos and Winklhofer (2001) highlight the necessity of paying close attention to whether the indicators should be specified as reflective or formative while conceptualizing a given construct. This argument is, as well, ascertained by Podsakoff et al. (2006) for avoiding the measurement model misspecification, which refers to situations in which constructs having formative measures are incorrectly

conceptualized as having reflective measures, or vice versa. This incorrect specification can have severe consequences on the conclusions regarding the fundamental relationships between constructs and measures. Jarvis, Mackenzie, and Podsakoff (2003), for instance, investigate the impacts of incorrect specification on parameter estimates for the relationships between constructs and measures. Findings reveal that the estimates of relationships (i.e. paths coefficients) are either overestimated or underestimated as a result of measurement model misspecification. Mackenzie, Podsakoff, and Jarvis (2005), as well, demonstrate that misspecification even yields incorrect results for the statistical significance of these estimates. In particular, the impact of the variable is reported as significant, despite its not being in the correct specification, leading to overestimation of the variable's impact on the focal construct. The goodness-of-fit indices might also be affected due to any bias in the estimates produced by the misspecification, resulting in a poor model fit for the data.

In all these cases, measurement model misspecification leads to undesirable and misleading effects on the substantive interpretation of the structural model relationships. For this reason, it is important for researchers to correctly specify the measurement models in their analysis. What follows is a review of relevant literature on both types of a measurement model (i.e. reflective and formative), with a focus on main criteria used to distinguish between them.

### **3.3.1.2 Reflective vs. formative measurement: first-order model**

In the reflective measurement model (see Figure 3.2, Panel 1), measures represent effects (also known as manifestations) of the construct, and the causality is thus from the construct to its measures. In other words, the construct is an exogenous variable

that acts as a predictor for other variables without being caused by others in the model, whereas measures are endogenous variables that are caused by one or more variables in the model (i.e. have at least one arrow leading into them) (Kenny, 2011b). The latent construct ( $\eta$ ), in the reflective model, forms the common cause of all measures/indicators ( $x_1, x_2, x_3$ ), where each indicator has an independent measurement error ( $\varepsilon_1, \varepsilon_2, \varepsilon_3$  respectively). In addition,  $\lambda_1, \lambda_2$  and  $\lambda_3$  represent coefficients that capture the effect of  $\eta$  on  $x_1, x_2$  and  $x_3$  respectively. Since reflective indicators are equivalent manifestations of the same construct, they are expected to be interchangeable; i.e., any change in the construct leads to variation in all measures simultaneously, and the omission of any measure does not have a significant impact on the conceptual domain of the construct (Bollen & Lennox, 1991; Diamantopoulos, Riefler, & Roth, 2008).

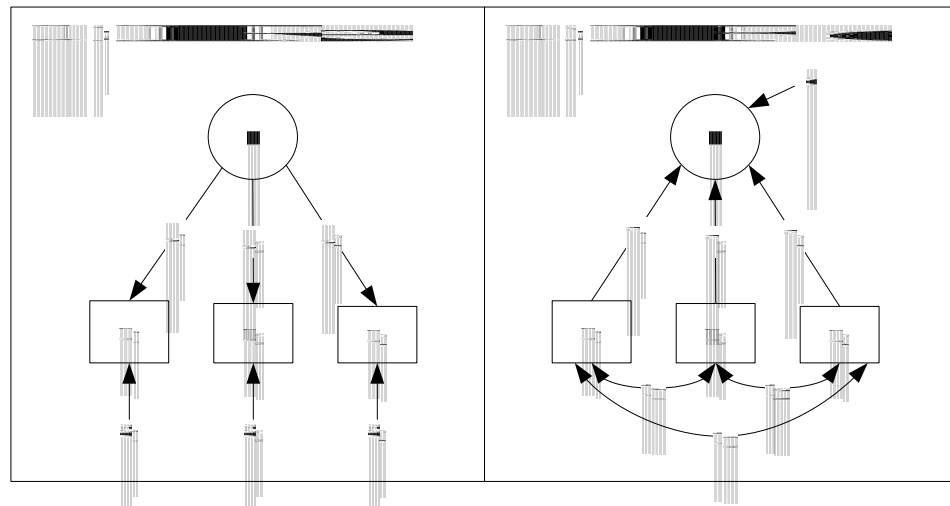


Figure 3.2: Alternative measurement models

Source: (Diamantopoulos et al., 2008)

In the second type of measurement model, i.e. the formative model, measures are causes of a construct rather than its effects, where the causality is from the measures to the construct. In other words, measures are exogenous variables that form the theoretical determinants of the construct (i.e. endogenous variable) (see Figure 3.2,

Panel 2). The coefficients  $\gamma_1$ ,  $\gamma_2$ , and  $\gamma_3$  capture the effect of exogenous indicators  $x_1$ ,  $x_2$  and  $x_3$  on the construct ( $\eta$ ) respectively. It is important to note that formative measures have no associated error terms; instead, a disturbance term ( $\zeta$ ) is specified at the construct level. The disturbance term, in turn, encompasses the remaining causes of the construct which are not reflected by its formative measures (Edwards & Bagozzi, 2000). As a result, the more comprehensive the set of measures specified for the construct, the smaller is the influence of the disturbance term (Diamantopoulos et al., 2008). A fundamental characteristic of a formative model is that each measure captures a unique aspect of the construct's domain and are not expected to be interchangeable. As such, omitting any of these measures potentially alters the nature of the construct and subsequently leads to construct measurement deficiency (Bollen & Lennox, 1991; Podsakoff et al., 2006).

### 3.3.1.3 Higher-order measurement model

A construct, by itself, could represent either a manifestation of another construct (the case of reflective measurement model) or a distinct facet of another construct's domain (the case of formative model). In such a case, the former construct is defined as a *dimension* of the latter. The analysis of at least two levels of conceptualization, one relating measures to first-order dimensions and the other one relating dimensions to the second-order construct, refers to a multi-dimensional measurement model (Jarvis et al., 2003; Mackenzie et al., 2005). At each level, reflective or formative specification is applicable, thus presenting four types of multidimensional measurement models, including 1) formative first-order formative second-order, 2) formative first-order reflective second-order, 3) reflective first-order formative second-order, and 4) reflective first-order reflective second-order. The following

section focuses on the conceptualization of the “Effectiveness of EPC” construct, the focus of this research study, based on the aforementioned concepts.

#### **3.3.1.4 The case of “Effectiveness of EPC” construct**

This research study aims at examining the effectiveness of EPC contracting strategy in achieving product success. The “effectiveness” variable, as mentioned previously, is a phenomenon-related theoretical construct that cannot be observed directly. Instead, it can be inferred by a set of observed indicators (i.e. measures). Given the main advantage of SEM statistical technique in assessing unobserved variables, it is used in this research to generate the structural model depicting the statistical significance of the relationships between the “effectiveness” phenomenal variable and its respective factors. In this regard, the identification of possible dimensions of the “effectiveness” construct along with their measures as well as the determination of the type of the measurement model are key steps in conceptualizing this construct. It is important to note that, hereafter, all variables (measures or constructs) are represented in the text by *italics*.

The dimensionality of the focal construct (i.e. *Effectiveness of EPC*) is clearly articulated by the comprehensive literature review conducted in chapter 2. *End-user’s engagement* and *Alignment of objectives* criteria, which are identified as possible influencing factors for the project effectiveness in chapter 2, are conceptualized as two possible dimensions of *Effectiveness of EPC* construct as per SEM language. Consequently, two main hypotheses (H<sub>1</sub> and H<sub>2</sub>), correlating *Effectiveness of EPC* with *End-user’s engagement* and *Alignment of objectives* respectively, have been formulated. Once the conceptual definitions of *Effectiveness of EPC* construct and its



dimensions have been established, it is essential at this step to examine whether these dimensions are interchangeable manifestations or distinct facets of the construct. Reviewing the literature reveals that engaging end-users in various activities during project development and implementation in addition to aligning project objectives with product objectives (i.e. end-user's requirements) are two critical requirements for achieving project effectiveness illustrated through meeting product success (i.e. end-user's satisfaction) (refer to section 2.3.1.1 for details). As such, *End-user's engagement* and *Alignment of objectives* dimensions are not interchangeable. Instead, each dimension represents a distinct facet of the *Effectiveness of EPC* construct's domain, and the omission of any of them causes a deficiency in the measurement of the construct. For this reason, the direction of causality is from these two dimensions to the construct, making the focal construct of this research, i.e. *Effectiveness of EPC*, a formative construct (see Figure 3.4, Panel 1).

Both *End-user's engagement* and *Alignment of objectives* dimensions are, by themselves, theoretical constructs that cannot be observed directly using any research instrument (e.g. survey, interview). Observable indicators have to be identified to measure these dimensions. Section 2.3.4 of chapter 2 (Literature Review) focuses on the identification of main activities that entails the engagement of end-user in various project phases to generate main project deliverables at both the development and the implementation stages. These activities, illustrated in Figure 2.10 (chapter 2), fall under four main categories including 1) the finalization of execution and commissioning strategies, 2) the development and finalization of plant layout of project facilities, 3) the finalization and approval of key engineering documents in addition to the selection of technologies, and 4) the approval of construction, pre-

commissioning, commissioning and hand-over related-documents. As such, four main indicators are identified for *End-user's engagement* dimension as follows: *Studies and Strategies*, *Plant Layout*, *Engineering and Procurement*, and *Construction and Commissioning*. Given that the end-user has to be engaged in all these activities to achieve better engagement, which in turn yield to higher satisfaction, these four indicators are all required to capture the actual aspects of the conceptual domain of *End-user's engagement* construct/dimension. In other words, these indicators are not interchangeable and thus omitting any of them is expected to change the construct's domain. For this reason, the direction of causality is from these indicators to *End-user's engagement* construct. Figure 3.4 (Panel 2) shows the formative model of *End-user's engagement* dimension.

*Alignment of objectives* dimension, on the other hand, represents the correspondence between project objectives and product objectives (i.e. end-user's requirements). This synchronization has to be maintained within the three aspects of quality, cost and time so as to achieve project effectiveness illustrated through the accomplishment of end-user's satisfaction (refer to section 2.3.1.1 for details). In this context, reviewing the literature reveals that retaining high-quality performance necessitates having systems that are designed to ensure the required percentages of reliability, availability and maintainability (RAM) performance criteria during operation. These systems, as well, have to attain the desired specifications under the contract (i.e. performance guarantee) (refer to section 2.3.4.2 for details). In addition, achieving a proper alignment requires a correspondence between the lifecycle cost and the delivery schedule of the end-product with the project cost and time respectively.

Figure 3.3 illustrates the alignment criteria between project objectives and product objectives.

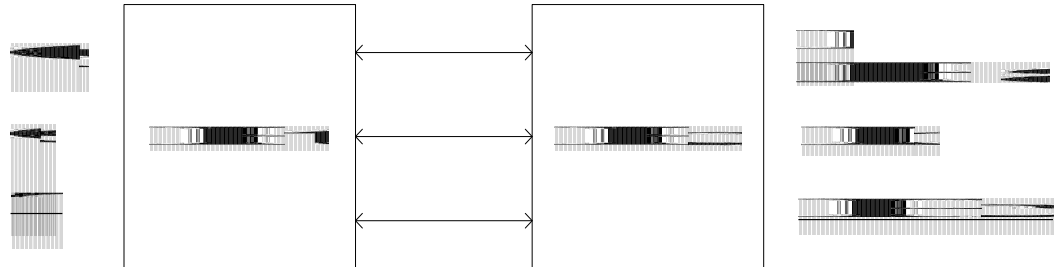


Figure 3.3: Alignment of project objectives with product objectives

Source: Developed for this research

In an attempt to conceptualize *Alignment of objectives* dimension, four observable measures are specified including *RAM*, *Performance Guarantee*, *Lifecycle Cost*, and *Product Delivery Schedule*. The attainment of a proper alignment between project objectives and product objectives for the purpose of achieving project effectiveness (i.e. end-user's satisfaction) necessitates a correspondence across the three aforementioned aspects (i.e. quality, cost, time). For this reason, the four measures are all required to reflect the actual conceptual domain of *Alignment of objectives* dimension. Consequently, these measures have to be modelled as formative, and the direction of causality is thus from these measures to the *Alignment of objectives* dimension (see Figure 3.4, Panel 3).

Given that each of *End-user's engagement* and *Alignment of objectives* dimensions has formative measures and are both, by themselves, formative dimensions of the *Effectiveness of EPC* construct, the type of measurement model of this research (Figure 3.4) is formative first-order formative second-order. The dimensions constitute the first-order level, and the construct represents the second-order analysis.

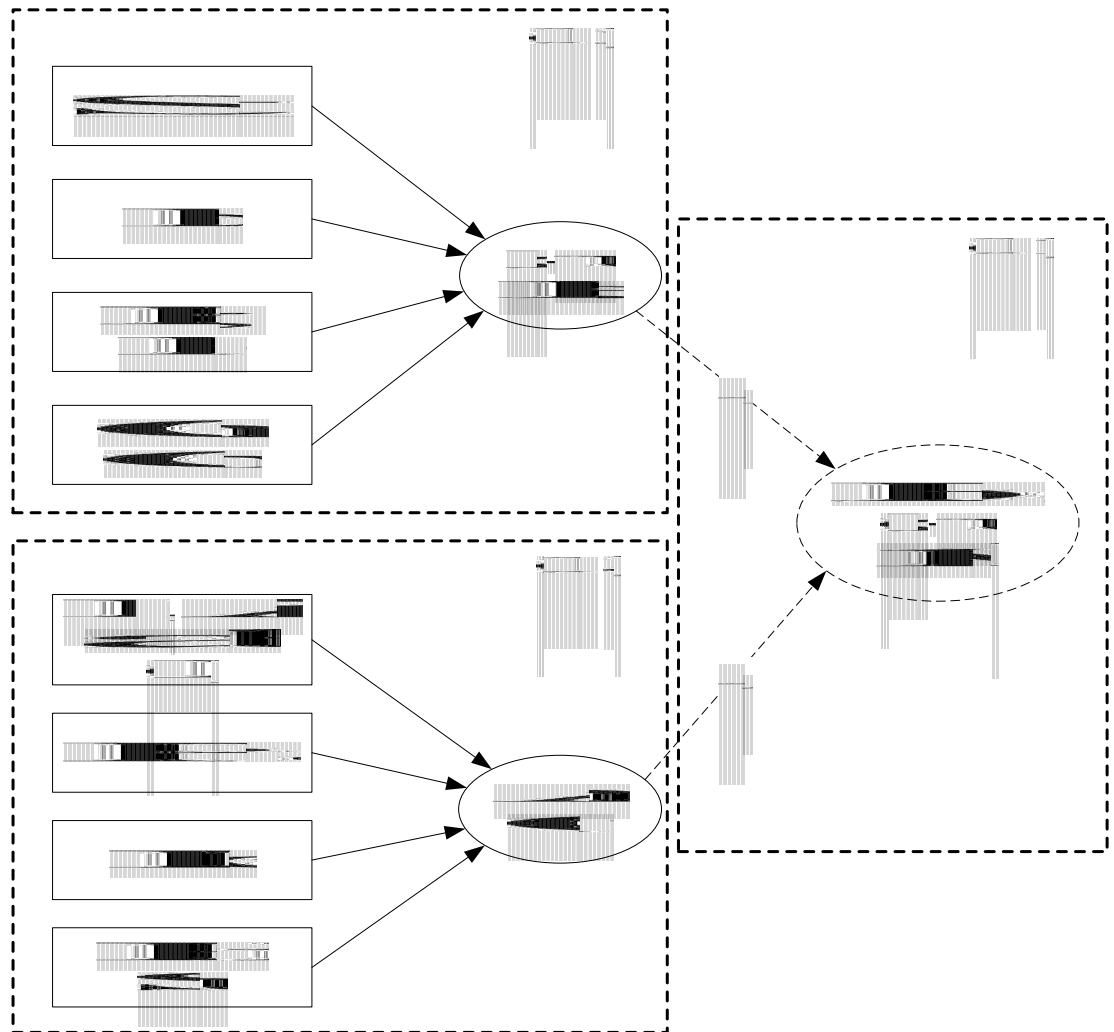


Figure 3.4: The conceptualization of the Effectiveness of EPC measurement model

Source: Developed for this research

*Dotted ellipse: second-order construct;*

*Dotted arrow: relationship between a construct and its dimension;*

*Continuous ellipse: first-order construct & dimension of the second-order construct;*

*Continuous arrow: relationship between a construct and its formative measure;*

*Continuous square: formative exogenous measure.*

In order to examine the significance of the relationships of *Effectiveness of EPC* with its respective factors, model parameters (i.e. paths coefficients) have to be estimated. Several studies highlight that formative measurement models, unlike reflective models, are under-identified and thus cannot be estimated (e.g. Bollen & Lennox, 1991). Model identification, according to Kenny (2011), refers to the ability of known information (i.e. variances and covariances) of the SEM model to imply one best value for each model parameter (i.e. unknown information). Given that the inability to consider identification can lead to misleading results during analysis, model identification remains as one of the challenging aspects of SEM models dealing with latent variables (Bollen & Davis, 2009). For this reason, several procedures are provided in literature to ensure model identification and consequently enable its estimation. The following section illuminates the procedure used to identify the measurement model of this research, leading to a theoretical model that can be estimated and subsequently operationalized to generate the “Effectiveness of EPC” SEM model.

### **3.3.2 Model identification**

Given that model identification has to be considered to estimate the formative measurement model, MacCallum and Browne (1993) demonstrate that the consequences (i.e. effects) of the focal unobserved variable have to be incorporated in order to identify the associated disturbance term ( $\zeta$ ) and consequently enable its estimation. In this context, Bollen and Davis (2009) recommend the application of the 2+ emitted paths rule that requires the release of at least two paths from the formative construct in question to other reflective constructs or indicators. Reviewing the literature reveals three approaches for applying the 2+ emitted paths rule, including 1)

adding two or more reflective indicators to the formatively-measured construct, 2) adding two reflectively-measured constructs, and 3) adding one reflectively-measured construct and one reflective indicator (Jarvis et al., 2003; Mackenzie et al., 2005).

In this research, the first option is adopted to identify the measurement model (illustrated in Fig. 3.4) by adding three reflective endogenous indicators that are emitted from the focal second-order construct (i.e. *Effectiveness of EPC*). These reflective measures, illustrated in Figure 3.5, reflect 1) the perception towards effectiveness of EPC in executing major projects, 2) the perception towards meeting end-user's requirements, and 3) the preference towards EPC over other execution models.

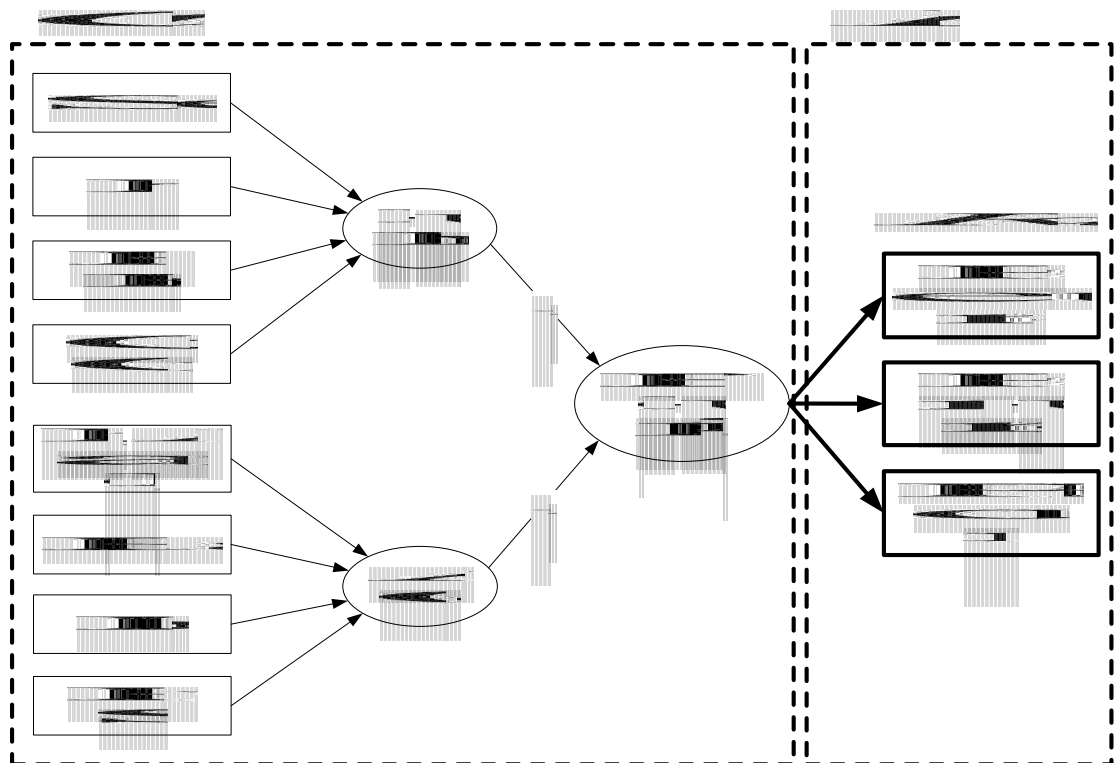


Figure 3.5: The “Effectiveness of EPC” measurement model after the identification of the Effectiveness of EPC construct

Source: Developed for this research

After the addition of the three reflective measures to the model for identification purpose, this model could be interpreted in three ways: 1) as a formatively-measured construct (through two formatively-measured dimensions) that influences three manifest measures (i.e. the aforementioned interpretation of the model), 2) as two formatively-measured constructs influencing a reflectively-measured construct, or 3) as a single endogenous construct with two formatively-measured dimensions and three reflective measures. These interpretations of the relationships between constructs and measures, according to Jarvis et al. (2003), only differ at the conceptualization level. However, they are empirically indistinguishable, as they all produce the same parameter estimates (i.e. paths coefficients) of the relationships.

Once model identification is established and thus model estimation is applicable, the next step is to operationalize the model at hand. Operationalization refers to the development of specific operational procedures (e.g. survey questions, interview schedules) that capture empirical observations representing the indicators (formative and reflective) included in the model (Leggett, 2011). The following section demonstrates the operationalization of the “Effectiveness of EPC” measurement model.

### **3.3.3 Operationalization**

In the operationalization stage, the level of measurement (i.e. data type) is identified, and subsequently measures are formulated into instruments (i.e. actual research questions). As mentioned in section 3.2.2.3, a survey questionnaire is used as the research instrument for collecting information about the observed variables. The impact of these variables on their respective constructs is measured through a set of

questions with an ordinal categorical level of measurement on a 5-point Likert scale (strongly disagree, disagree, uncertain, agree, strongly agree). For each formative measure (i.e. indicators of *End-user's engagement* and *Alignment of objectives*), 3-to-4 questions are used to estimate its impact. On the other hand, the influence of the three reflective measures, which are added to the model for the identification of *Effectiveness of EPC* construct, is captured using only one survey question for each measure. Table 3.3 illustrates the operationalization of each measure through its related set of questions.

The survey questions used for the operationalization of the measurement model are built based on the literature review conducted in chapter 2. A brief description about each question is included in Table 3.3, wherein more details are presented in section 2.3.4 (chapter 2). It is worth noting that the operationalization table (i.e. Table 3.3) has been reviewed and approved by three oil and gas industry experts to validate its technical-accuracy. After the measurement model is operationalized using survey questions, the next step is to assess the validity and reliability of these instruments.



Table 3.3: The operationalization of the formative and reflective measures of the measurement model

Construct	Measure	Survey Question	Description	Reference
<i>End-user's Engagement</i>	<i>Studies and Strategies</i>	End-user's endorsement is taken on project execution strategy	End-user is participating in the development of the project execution strategy. The strategy may include aspects such as endorsing contracting/packaging plan, overall schedule and key milestones and the approach towards project management.	(Bubshait & Al-Musaid, 1992)
		End-user's endorsement is taken to proceed from FEED to EPC phase	End-user is involved in reviewing/endorsing key FEED stage deliverables prior to proceeding with EPC. Typical FEED stage deliverables that may require end-user's review include specifications, operating philosophies, P&IDs, layouts, 3D models, HAZOPs, execution schedules, interface documents and selection of process technologies.	(Gasco, 2011)
		End-user is involved in development of EPC contractor selection strategy	End-user's consent is taken on the EPC Contractor Selection Strategy involving past experience of similar technology prior to finalization of EPC Contractor Bidder List as well as evaluation of technical tenders.	(EPC-Engineer, 2014) (Gasco, 2012)
		End-user's endorsement is taken on project commissioning strategy	End-user is involved in providing input and/or reviewing documents related to commissioning strategy, including commissioning philosophies, plans and procedures approval.	(Gasco, 2011)
	<i>Plant Layout</i>	End-user is involved in the review of plant facilities spacing layout for maintainability requirements	End-user is involved in providing input and/or reviewing documents related to plant physical locations and configurations to ensure ease of access to equipment for maintenance.	(BIS, 2008) (Chugh, 2011)

		End-user is involved in project facilities model review	End-user is involved in reviewing and providing input on 30%, 60% and 90% 3D model (three-dimensional electronic model that displays a picture in a form that appears to be physically present) during the EPC phase to ensure operability, maintainability and all related lessons learned are considered.	(Chugh, 2011)
		End-user is involved in finalization of project facilities plant layout	End-user is involved in providing input and reviewing documents related to facilities most appropriate physical location arrangements. This is to ensure maintainability and safety requirements are met.	
	<i>Engineering and Procurement</i>	End-user is involved in approval process of key engineering documents	End-user is involved in reviewing key engineering documents during the EPC stage, including review of specifications, drawings and operating philosophies procedures.	(Gasco, 2011) (Takreer, 2012)
		End-user's feedback is taken in the vendor selection of project equipment	End-user is involved in reviewing and approving project vendor lists of critical equipment and major machinery prior to inclusion in the EPC contract.	(Damodaran, 1996)
		End-user is involved in project Piping & Instrumentation Diagram (P&ID) review	End-user is involved in reviewing the process designers routing for pipes, pumps, valves, etc. As well as providing comments during the EPC stage of the project.	(IAM, 2015)
		End-user is involved in project Hazard and Operability (HAZOP) study	End-user operations, maintenance, process and safety engineers are involved in the process of risk assessment to eliminate the existence of hazards in equipment and avoiding vulnerability of its operation.	(Qureshi & Shakeel, 2013)

	<i>Construction and Commissioning</i>	End-user is involved in approval process of construction documents	End-user is involved in reviewing of construction documents, ensuring that all past experiences are incorporated.	(Gasco, 2011) (Takreer, 2012)
		End-user is involved in the pre-commissioning project activities	End-user's involvement during pre-commissioning typically include review of pre-commissioning procedures, attendance during pre-commissioning checks, operability tests and on the job training.	(Takreer, 2012)
		End-user is involved in the project commissioning activities	End-user's involvement during commissioning typically include review of commissioning procedures, attendance during commissioning/performance tests and review of commissioning/performance test results for smoother take-over of facilities.	
		End-user's participation in construction and commissioning adds value to the project	End-user's past experience and lessons learned in commissioning activities have immense value addition due to the real time expertise in handling of such plants and facilities ensuring product success.	
<i>Alignment of Objectives</i>	<i>Reliability, Availability, and Maintainability (RAM)</i>	End-user is involved in selection of technologies to be used	End-user is involved in the selection of technology such as proprietary/ patented process license technologies or any other major plants and equipment considered for the project.	(Damodaran, 1996) (OGM, 2012)
		Project achieved Reliability, Availability, and Maintainability (RAM) percentage as per the EPC project	Major project design typically targets a high Reliability, Availability, and Maintainability (RAM) percentage of 95 to 98. End-user endeavors to achieve project's RAM target in up to one year of operation.	(EP-Consult, 2005) (LR-Consulting, 2015) (MITRE, 2013)
		End-user's No Objection is taken while issuing acceptance certificates for project facilities	In a typical EPC contract, a provisional acceptance certificate (PAC) is issued to the contractor upon completion of work and transfer of custody to end-user and a final acceptance certificate (FAC) is issued upon expiry of the warranty period. End-user's consent should be obtained prior to issuing these certificates to	(Takreer, 2012)

			the contractor. Through this process, the end-user has an opportunity to flag issues that are not in accordance with the EPC contract prior to issuance of the completion certificates.	
		Project team continues to provide the support, if required by end-user, during operation of plant facilities under custody of end-user	Project team are expected to provide support to the end-user after commencement of operation. Typically, this support is expected to continue during the warranty period in closing out the outstanding punch list and warranty notifications.	(Wallace, 2014)
	<i>Performance Guarantee</i>	End-user is involved in development of EPC Scope of Work (SOW)	End-user's feedback is obtained in the development of Statement of Requirement and EPC Project definition report (PDR) as part of Invitation to Tender (ITT) representing EPC Scope of Work.	(Udemy, 2014)
		End-user is involved in defining finished product specifications requirement	End-user is involved in defining design basis which includes finished product specifications requirement, as these are included in the EPC contract.	(Damodaran, 1996)
		Project met end-user's finished product specifications	72 hours' test runs are conducted following successful commercial production to ensure that project meets customer finished product specifications in terms of quantity and quality.	(Business-Dictionary, 2015)
		End-user is involved in specifying project facilities warranty period	End-user expects to be involved in specifying the warranty period for the project or any part thereof. Most projects are based on a standard industry accepted warranty period of one year. It is not uncommon to have extended warranty periods for critical equipment and systems.	(Gasco, 2011)
	<i>Lifecycle Cost</i>	Spare parts requirements are discussed and agreed with end-user	1-to-2 year operational spares as well as critical insurance spares are typically procured as part of an EPC contract. The end-user's involvement in deciding the type and quantity of procured spares supports streamlining lifecycle project costs.	

		Project operating cost is within acceptable range to end-user	End-user endeavours to keep capital costs as well as operating costs as low as possible, as it affects product competitiveness illustrated in its selling price to external customers.	(Bubshait & Al-Musaid, 1992)
		Project major equipment vendor is selected based on lifecycle cost analysis	EPC contractor typically procures plants and machinery including major equipment from an approved vendor list with the lowest capital cost (capex). End-user selection is based on evaluation of lifecycle cost, i.e. capex and opex (operating costs), as well as after sales services.	(EP-Consult, 2005) (LR-Consulting, 2015)
	<i>Product Delivery Schedule</i>	Project completion schedule includes interface plan with existing facilities	All hardware and software interfaces and tie-ins with existing facilities are developed during EPC engineering phase with full participation and involvement of end-user. This is to ensure on time commissioning and product success.	(Bubshait & Al-Musaid, 1992) (Chugh, 2011) (Gasco, 2011)
		Project completion schedule covers interface plan with other interconnected new facilities	All hardware and software interfaces and tie-ins with new interconnected facilities are developed during EPC engineering phase with full participation and involvement of the end-user. This is to ensure on time commissioning and product success.	
		End-user is involved in defining project completion schedule	The end-user is involved in defining the project completion schedule that is critical from the end-user's perspective, such as pre-commissioning and commissioning, to ensure finished product on-time availability for the external customer.	(Bubshait & Al-Musaid, 1992)
		Project completed within customer time frame requirements	The project completion schedule has to be in line with the end-user's schedule requirements. This is to ensure finished product on-time availability for the external customer.	

<i>Effectiveness of EPC (Identification purpose)</i>	<i>Perception towards effectiveness in executing major projects</i>	EPC strategy is effective in execution of major projects from end-user's perspective	The execution of the EPC projects is perceived effective for major projects from an end-user's perspective.	(Added to the model for the identification of <i>Effectiveness of EPC</i> construct)
	<i>Perception towards meeting end-user's requirements</i>	EPC strategy sufficiently meets end-user's requirements in major projects	The execution of the EPC projects is perceived as adequately meeting the end-user's requirements for major projects from an end-user's perspective.	
	<i>Preference towards EPC over other execution strategies</i>	End-user prefers EPC strategy over other strategies in execution of oil and gas major projects	The end-user prefers EPC strategy in the execution of the major oil and gas projects over other project execution models.	

Source: Developed for this research

### **3.3.4 Validity and reliability assessment**

Before starting the data collection process, the validity and reliability of model indicators have to be assessed (Diamantopoulos et al., 2008). This section examines the assessment of the research quality by testing the validity of measurement instruments (i.e. survey questions) and subsequently their reliability in generating stable measures.

#### **3.3.4.1 Validity assessment**

Validity assessment refers to the evaluation of the suitability of the measurement instrument to measure its associated model indicator (Leedy & Ormrod, 2005). Ensuring that a correct measurement concept is obtained necessitates understanding the meaning of indicators and their related survey instruments (Hair, Black, Babin, Anderson, & Tatham, 2006). According to Cavana, Delahaye, and Sekaran (2001), the validity of measures can be assessed based on four types of validation, including face validity, construct validity, content validity and criterion-related validity.

“Face validity” concept, which assesses the simplicity, understandability and accuracy of measurement instruments through a pilot survey, is often regarded as the most important validity assessment concept (Gallagher, Ting, & Palmer, 2008; Hair et al., 2006). It was applied in this research to evaluate the validity of survey questions in measuring both formative and reflective indicators, and accordingly assess whether the operationalization of a measure accurately reflects its construct. The operationalization table (i.e. Table 3.3), constructed based on the literature review conducted in chapter 2, illustrates each indicator with its related measurement

instruments as well as the literature references supporting each instrument. This table thus proves that survey questions used for data collection are validated by literature. To ensure a high level of validity for the measure, the questionnaire was also verified by 12 industry experts through a pilot survey to ensure that the questions are simple, understandable, and technically-accurate. A list of the pilot survey participants along with their professional job titles is included in Appendix B (Table B.1).

“Content” validity, on the other hand, refers to the ability of the scale items to cover the required measures of the construct. Literature, qualitative research, and the judgement of a specialist panel are possible ways for assessing the content validity (Cavana et al., 2001). In the present research, the conceptual domain of the two formatively-measured dimensions (i.e. *End-user’s engagement*, *Alignment of objectives*) are sufficiently shaped by their four formative indicators, which are identified from literature (refer to section 3.3.1 for more details). The survey instruments of these measures, as previously noted, are also constructed based on literature and reviewed by industry experts. As such, the content validity of the survey items is confirmed.

The “construct” validity examines the correlation among the data related to the same concept. Convergent validity and discriminant validity are two possible means for examining the construct validity (Cavana et al., 2001). The results of these two forms of validity, assessed using the complete survey data, are discussed in chapter 4 (section 4.5).



### 3.3.4.2 Reliability assessment

As discussed previously, the validity of the questionnaire instruments was verified by both literature and industry experts. The next step, after validity assessment, is to evaluate the reliability of these instruments. A measurement instrument, as described by Leedy and Ormrod (2005), is considered reliable when it constantly yields a certain result. In the context of SEM, Ntoumanis (2001) demonstrates that reliability relates to the stability of the effects of the questionnaire scale, where a scale represents the set of measurement items (i.e. instruments). In other words, the ability of a given measure to remain stable over a period of time demonstrates the consistency of its related scale in providing similar effects during that period (Yin, 2013). Cronbach's alpha coefficient ( $\alpha$ ), which reflects the homogeneity or the average correlation among the items of a scale, is the most common approach used for assessing scale reliability. The alpha coefficient should be in the range of 0.7 to 0.9, demonstrating an acceptable internal consistency of the scale in the case of 0.7 and an excellent consistency in the case of 0.9 (Ntoumanis, 2001). Given that measures are considered reliable when producing same results (i.e. influence) over a period of time, the evaluation of scale reliability consequently assesses construct validity, which is concerned with the quality, consistency and overall reliability of the measurement (Gallagher et al., 2008; Hair et al., 2006).

In the present research, the Cronbach's alpha approach was applied on the 12 responses of the pilot survey, using the reliability command on SPSS, to assess the reliability of the measurement scale consisting of 33 items (i.e. questions). Findings, illustrated in Table 3.4, reveal an excellent internal consistency of 0.904, demonstrating that the measurement instruments are highly consistent in reflecting the

true score (i.e. actual measurement) of the intended concept (i.e. *Effectiveness of EPC* construct).

Table 3.4: Results of reliability analysis of the scale items

Cronbach's Alpha	Cronbach's Alpha based on Standardized Items	N of Items
0.904	0.912	33

Source: Developed for this research

### 3.3.5 Data Collection

Once the measurement model is conceptualized, identified and operationalized, both the validity and the reliability of survey questions can be assessed. Thereafter, the data collection process can be initiated. This section sheds light on the data collection process conducted in this research to gather observations related to model indicators, which in turn provide the theoretical measurement model with data necessary to generate the structural “Effectiveness of EPC” SEM model.

#### 3.3.5.1 Targeted major oil and gas projects

As this study aims at evaluating the effectiveness of EPC execution strategy in achieving product success from the end-user’s perspective, the evaluation was conducted on a sample of six major oil and gas projects executed based on the EPC model and located in Abu Dhabi, UAE. These projects are comprised of three gas, two refining, and one petrochemical. Table 3.5 provides a brief description of these projects targeted for data collection, and more details are presented in Appendix C.

All six targeted projects fall under the downstream sector of Abu Dhabi's oil and gas industry due to the intention of reducing the variations among various sectors and thus maintaining homogeneity of data. The researcher's tenure in the ADNOC group, as well, provides easy access to projects in the downstream sector for data collection. The six targeted projects were selected based on close coordination with the management of the four operating companies (i.e. Gasco, Takreer, Alhoson, Borouge), which in turn might boost the willingness of participation during the data collection process.

As illustrated in Table 3.5, the six selected projects are technically complex and capital-intensive, which require highly skilled and experienced end-users who would be responsible for the facilities during operation. The valuable experience of such end-users represents a vital source of information that would serve the main objective of the present research in examining the effectiveness of EPC contracting strategy in accomplishing product success from the end-user's perspective. Given that the selected projects were recently commissioned and handed-over for operation (refer to Appendix B, Table B.2), the end-users who were engaged with the project teams would probably be available during data collection to share their valuable experience.

Table 3.5: Major projects targeted for data collection

<b>Project Name</b>	<b>Project 1 (Habshan-5 Process Plant)</b>	<b>Project 2 (Ruwais-4 NGL Train)</b>	<b>Project 3 (Shah Gas Development)</b>	<b>Project 4 (Ruwais Refinery Expansion)</b>	<b>Project 5 (Green Diesel)</b>	<b>Project 6 (Borouge-3)</b>
<b>Project location</b>	Habshan	Ruwais	Shah	Ruwais West	Ruwais East	Ruwais
<b>Operating Company</b>	Gasco	Gasco	Alhosn Gas	Takreer	Takreer	Borouge
<b>Industry Type</b>	Gas	Gas	Gas	Refining	Refining	Petrochemicals
<b>Project Scope</b>	Process 2,150 MSCFD Gas Process 1.8 MBPD Condensate	Process 27,000 TPD of NGL/LPG Produce 4,750 TPD of Ethane Produce 7,850 TPD of Propane Produce 9,360 TPD Butane	Sales Gas 504 MMSCFD NGL 4400 Tones/Day Condensate 33000 Barrels/Day Sulphur 9090 Tones/Day	417,000 BPSD New Refinery	85,000 BPSD 10ppm Diesel (low Sulphur)	150 Kta Ethylene Unit Two 540 Kta Polyethylene Two 480 Kta Polypropylene
<b>Project Cost</b>	\$6,500 Million	\$2,311 Million	\$10,000 Million	\$10,500 Million	\$1,200 Million	\$4,074 Million
<b>Completion Period</b>	4.2 years	4 years	4.5 years	4.3 years	3.5 years	4.75 years
<b>Number of End-users engaged with project &amp; EPC teams</b>	80	65	65	90	30	70
<b>Number of End-users Surveyed</b>	65	40	40	63	22	45

Source: Developed for this research

The targeted projects constitute around 29% of the total major oil and gas projects in the downstream sector (21 projects) and 21% of those in both the downstream and the upstream sectors (28 projects), during which the targeted projects were in progress (2007-2015) (MEED, 2016). A list of these 28 major oil and gas projects (i.e. downstream and upstream) is included in Appendix B (Table B.2). The sample of chosen projects is thus representative of Abu Dhabi's oil and gas industry, the focus of this research. Details about the sample size, representing the adequate number of end-users required to generalize the research results, are provided in the following section.

### **3.3.5.2 Research sample of end-users**

The determination of the sample size is a critical task in any research study. Inappropriate and inadequate sample size influences the quality and accuracy of research. In this regard, the sample has to be representative of the entire population so that the results can be generalized. It is unrealistic in practice not to assume the existence of sampling error since no sample can perfectly reflect the whole actual population. As such, the determination of an adequate sample size depends on the population size, the confidence level, and the margin of error (Bartlett, Kotrlik, & Higgins, 2001), where sample size calculators are available online (e.g. Survey-Monkey, 2016b). For the categorical data type, a 5% margin of error is acceptable, whereas a 3% margin of error is suitable for continuous data (Krejcie & Morgan, 1970).

Some studies link the estimation of an adequate sample size to the number of variables incorporated in the model, especially when dealing with multiple regression analysis. As

a rule-of-thumb, having a ratio of 10 observations for each variable is required to ensure that the generated model fits the sample data (Halinski & Feldt, 1970; MacCallum, Widaman, Zhang, & Hong, 1999; Miller & Kuncce, 1973). Another rule-of-thumb for the identification of an adequate sample size takes into consideration the number of constructs in the model, the number of indicators related to each construct, and the communalities (see Table 3.6). Communalities, in turn, are the squared factor loadings representing the percentage of variance of a model indicator reflected by its respective construct (Hair et al., 2006).

Table 3.6: Adequate sample size guidelines

<b>Number of construct variables</b>	<b>Lowest number of indicators in a construct</b>	<b>Communalities</b>	<b>Appropriate sample size</b>
> 6	< 3	Low	>500
≤ 5	> 3	High	100-150
≤ 5	< 3	Modest	> 200
≤ 5	< 3	Low	> 300

Source: (Hair et al., 2006)

In an attempt to evaluate the effectiveness of EPC contracting strategy in achieving product success from the end-user's perspective, the perceptions of end-users were captured through a structured questionnaire survey that was built based on the literature review. As illustrated in Table 3.5, the total number of end-users who interacted and engaged with the project and EPC teams in various project phases is approximately 400, representing the total population of end-users from which the research sample was selected. Considering this population size, a 95% confidence interval and a 5% margin of error (categorical data), the optimal sample size for the present research is around 200,

estimated based on an online sample size calculator (Survey-Monkey, 2016b). The measurement model includes three constructs, two of which (i.e. *End-user's engagement*, *Alignment of objectives*) have four indicators, and *Effectiveness of EPC* has three indicators. The appropriate sample size, as illustrated in Table 3.6, should range between 100 and 150 responses. On the other hand, the total number of variables (constructs and measures) in the measurement model (Figure 3.5) is 14, thus the minimum sample size required for the model to fit the sampling data is 140, based on the aforementioned ratio rule-of-thumb. As such, a sample size that ranges between 140 and 200 is adequate to collect representative data, which in turn help achieve reliable and generalizable results during statistical analysis.

It is important to note that the survey questionnaire has to comply with the ethical principles of conducting research. The next section illustrates the principles of the American Psychological Association (APA)'s Ethics Code and justifies the compliance of the questionnaire used to survey the sample of end-users with these principles.

### **3.3.5.3 Ethical considerations**

Several principles, according to APA's Ethics Code, have to be considered when conducting research studies. Individuals should be voluntarily participating in the research with the rights to decline to participate and withdraw from the research without any liability or anticipated risks. In addition, researchers are required to inform the participants about the purpose of the research, research benefits, expected duration and procedures. It is highly important, as well, to provide anonymous questionnaires, for which disclosure

of responses would not affect participants' employability or reputation, and respect confidentiality and privacy (Smith, 2003).

The survey questionnaire of this research has complied with the aforementioned code of ethics by starting with a cover letter demonstrating the main research objective of investigating the effectiveness of EPC contracting strategy in meeting product success from the end-user's perspective. The cover letter, as well, illustrates the research benefits in improving the EPC execution strategy in Abu Dhabi's major oil and gas projects. Individuals were provided with the rights to voluntarily participate or refuse to do so without any liability. Anonymity, privacy and confidentiality were also assured. The cover letter ended with the specification of expected time needed to fill in the questionnaire (i.e. 15-to-20 minutes) as well as the researcher's appreciation for the participants' interest and their valuable time. The next section focuses on main components of the survey questionnaire along with the questions related to each component.

#### **3.3.5.4 Survey questionnaire**

The questionnaire, used for data collection, is composed of two main parts, with a total of 44 questions. The first part, consisting of nine questions of categorical data type, reflects the participant's profile (e.g. academic qualifications, years of professional experience, supervision skills, engagement with project teams and end-user team), where descriptive statistical analysis is based on the responses of these questions. On the other hand, the second part of the questionnaire, which includes 35 questions, captures the end-user's perspective. In particular, 33 of these questions, which are used for



operationalization purposes (Table 3.3), represent the observations related to formative and reflective indicators of the measurement model (Figure 3.5). Two more questions are included in the second part, one is of a categorical data type which is used to identify outliers (discussed in detail in section 3.3.6), whereas the other one is an open-ended question. The latter question provides the participant with an option to share any valuable experience, during which the participation of the end-user has led to the accomplishment of product objectives (i.e. end-user's requirements). The full survey questionnaire in addition to the attached cover letter are presented in Appendix D. Recall that the survey questions, as discussed in section 3.3.3, are constructed based on literature review conducted in chapter 2. The operationalization table (Table 3.3) shows each survey item with its related literature reference.

After the survey questionnaire was piloted and validated by 12 industry experts (as mentioned in section 3.3.4), it was automatically launched and distributed through an online survey software, known as "Survey-Monkey". This survey development tool provides the ability to customize the questions, distribute the questionnaire on the web, and collect data in real time. The collected responses can be exported to various file formats, including Microsoft Excel and SPSS file formats (Survey-Monkey, 2016a). The total number of responses and the response rate achieved in this research are mentioned in the following section.

### **3.3.5.5 Response rate**

When the data collection process was initiated, around 275 end-users, out of the total population of 400, were still active in the selected projects. Therefore, 275 questionnaires were distributed among these end-users (see Table 3.5). The researcher's tenure with the ADNOC group has helped maintain good connections with management of the targeted operating facilities, which in turn assisted in achieving a high response rate of 77% within a four-week period. In this respect, 213 responses were received through the researcher's "Survey-Monkey" account and exported to SPSS file for data processing. Data processing involves cleaning and preparing data for analysis by removing outliers, handling incomplete responses, and combining multiple responses into one variable required for analysis (Pink, 2010). The following section focuses on the data processing applied on the 213 collected responses before starting the data analysis process.

### **3.3.6 Data processing**

One of the survey questions targets the perception of the end-user towards the effectiveness of EPC in the execution of major projects (i.e. question 31, Part two). An opposite question was added to the questionnaire (i.e. question 34, Part two) in an attempt to identify outliers and consequently exclude them during analysis. In this regard, questionnaire responses including any of the eight cases illustrated in Table 3.7 were removed from the sample data. In particular, 19 out of the 213 collected responses were considered outliers.

Table 3.7: Possible cases for the identification of outliers

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
<b>Question 31</b>	Strongly disagree	Strongly disagree	Disagree	Disagree	Agree	Agree	Strongly agree	Strongly agree
<b>Question 34</b>	Strongly disagree	Disagree	Strongly disagree	Disagree	Agree	Strongly agree	Agree	Strongly agree

Source: Developed for this research

The collected data were, as well, reviewed to identify incomplete responses. It was revealed that 24 participants just initiated the survey without answering any of the questions. These 24 responses, in addition to the 19 outliers, were thus excluded from the sample data, leaving a total of 170 responses suitable for data analysis. The distribution of these 170 responses, based on the industry type, is 129, 28, and 13 for the gas, refining and petrochemical industry respectively. As previously noted, a sample size of 140 to 200 responses is required to achieve results that can be generalized during statistical analysis. Therefore, the 170 complete responses represent an adequate sample for generalizing the research findings first to the level of the six targeted projects and, consequently, to the level of Abu Dhabi's oil and gas industry.

As illustrated in Table 3.3, each formative measure is operationalized by multiple survey instruments (i.e. questions). As such, the value of the indicator, which represents the impact on its respective construct, is estimated as the rounded average score of its related questions.

After outliers and incomplete responses were removed and the values of all factors of the measurement model (Figure 3.5) were estimated, the data were ready to be compiled

for the generation of the “Effectiveness of EPC” SEM model. According to Joshi, Kale, Chandel, and Pal (2015), researchers have to consider the distribution of data while choosing the appropriate statistical tests during analysis. In the present research, the assessment of the normality of data reveals that the data is not normally distributed (refer to section 4.2.1 for more details). Therefore, non-parametric statistical techniques have to be applied for data analysis. The structural equation modeling technique that is based on the partial least squares algorithm (i.e. PLS-SEM), unlike the Covariance-based SEM (i.e. CB-SEM), is a non-parametric statistical method that does not require the data to be normally distributed (Hair, Hult, Ringle, & Sarstedt, 2013). For this reason, the PLS-SEM method was used, in the present research, to generate the “Effectiveness of EPC” structural model.

As described in chapter 3, the theoretical model in the present research is conceptualized as a multi-dimensional formative model, particularly “formative first-order formative second-order”. Various statistical software packages are used for structural equation modeling and path analysis, such as AMOS, LISREL, and SmartPLS (Perry, Álvarez, & López, 2014). “AMOS” software, which is an added SPSS module, is commonly used in research studies to generate structural models having only reflective latent variables (Arbuckle, 2012; Diamantopoulos & Winklhofer, 2001; IBM, 2016). “SmartPLS” statistical software, which is suitable for the partial least squares (PLS) path modeling, has the capability of compiling formative models (Gudergan, Ringle, Wende, & Will, 2008; Perry et al., 2014). “SmartPLS” software was thus used, in the present research, to generate the “Effectiveness of EPC” structural model. This model shows the

path estimates of the relationships between *Effectiveness of EPC* construct and its respective factors as well as the statistical significance of these relationships.

### **3.4 Research Reporting: A General View**

During the data analysis process (see chapter 4), results were analysed based on descriptive statistics, which were mainly applied on responses of the “participant’s profile” survey section. Additionally, once the structural SEM model was compiled and model estimates were generated, more rigorous analysis was accordingly conducted. In this respect, estimates (i.e. paths coefficients) and their statistical significance values were interpreted in an attempt to answer research questions and validate the two main research hypotheses (i.e. H<sub>1</sub>, H<sub>2</sub>) representing the correlations between *Effectiveness of EPC* construct and its respective dimensions (i.e. *End-user’s engagement*, *Alignment of objectives*). The third research hypothesis (i.e. H<sub>3</sub>) was also tested to examine whether there exists a difference in these relationships among refining, oil and petrochemical industries.

Based on the results and discussions reported in chapter 4, recommendations for Abu Dhabi’s oil and gas industry were proposed in chapter 5, and fields of applications of the generated “Effectiveness of EPC” SEM model were identified. Limitations of this research study were then highlighted, and plans for future research were recommended accordingly.

### 3.5 Conclusion

This chapter is composed of two main parts, a philosophical background section and a practical process section. In the philosophical section, main research strategies, paradigms and data collection techniques were reviewed. The appropriate research strategy (i.e. inductive), research paradigm (i.e. positivism) and the associated data collection methodology (i.e. quantitative) were selected and justified. The philosophical platform was demonstrated as the basis within which the empirical methodology (i.e. research process) was conducted.

In the research process section, possible factors affecting the effectiveness of EPC in achieving product success were identified, and the measurement model was accordingly conceptualized. In this context, the type of the model was conceptualized as a multi-dimensional model, specifically as formative first-order formative second-order. The 2+ emitted paths rule was adopted by adding three reflective indicators for model identification and estimation purposes. Model indicators were then operationalized using multiple survey questions of categorical data type (5-point Likert scale), and the validity and reliability of measurement instruments (i.e. survey questions) were assessed. Research instruments were not only validated by literature using “face validity” concept but also verified by 12 industry experts through a pilot survey. Cronbach’s alpha test was employed to assess the reliability of the measurement scale, revealing an excellent internal consistency of 0.9. Ethical research considerations were maintained, and the data collection process was consequently initiated. The survey questionnaire was sent to 275 end-users working in six major oil and gas projects in Abu Dhabi, and a 77% response

rate was achieved. Findings of the data analysis are reported in chapter 4 of this research study.

## Chapter 4: Data Analysis

### 4.1 Introduction

A review of the four main research strategies and the three primary research paradigms was undertaken in chapter 3. Additionally, the three main research methodologies along with their associated data gathering techniques were revisited. In this context, the inductive strategy and the positivism paradigm utilizing the quantitative methodology were justified as the most appropriate approach to conduct the present research. The research process, on which the philosophy of the research platform was based, involves mainly the conceptualization, identification, and operationalization stages. The “Effectiveness of EPC” model was conceptualized and identified based on literature, and the model indicators were operationalized using multiple survey items (i.e. questions). The reliability and the validity of the scale items were assessed, and various issues related to data collection were discussed, including the targeted major oil and gas projects, the sample of end-users, the adequate sample size, ethical considerations, the survey questionnaire, and the response rate. Chapter 3 concluded with the processing of the data and an introduction to the data analysis process, which is the focus of the present chapter.

It is the objective of chapter 4 to present the collected data and conduct an in-depth analysis for the purpose of testing the research hypotheses and answering the research questions. Figure 4.1 illustrates the design of the present chapter. In this regard, descriptive statistics are used to highlight the data type and provide summaries about the sample demographics and the survey respondents’ data (section 4.2). A valuable insight



into the current practice regarding the end-user's engagement and the achievement of the product objectives, in Abu Dhabi's major oil and gas projects, are then provided, using data from both the closed-ended questions and the open-ended question (section 4.3). The main activities, in which the end-user's team had significant participation, are identified. Additionally, the product objectives that are achieved are highlighted, as well. A considerable need to improve the effectiveness of major projects in Abu Dhabi's oil and gas industry is subsequently confirmed. A structural model depicting the potential causal relationships between the project effectiveness and its respective factors is derived as an appropriate means for possible improvement. The partial least squares structural equation modeling (PLS-SEM) statistical technique is used to generate such model (section 4.4). An assessment of the generated structural model is carried out before interpreting the statistical significance of the causal relationships (section 4.5). For the reflectively-measured construct, the internal consistency reliability, the convergent validity, and the discriminant validity of both indicators and constructs are evaluated. The convergent validity assessment, at both the indicator and construct levels, is conducted for the formatively-measured constructs. The formative indicators are also appraised to check whether multicollinearity problems exist among them. Based on the statistical analysis (section 4.6), the two research hypotheses ( $H_1$ ,  $H_2$ ) are tested, and the goodness-of-fit measurement of the structural model is then examined.

A further analysis is conducted on the collected data to investigate whether the causal relationships differ among the three industries (i.e. refining, gas, petrochemical). The third research hypothesis ( $H_3$ ) is accordingly tested using the Kruskal-Wallis test (also known as "one-way ANOVA on ranks"), which is suitable for ordinal data (section 4.7).

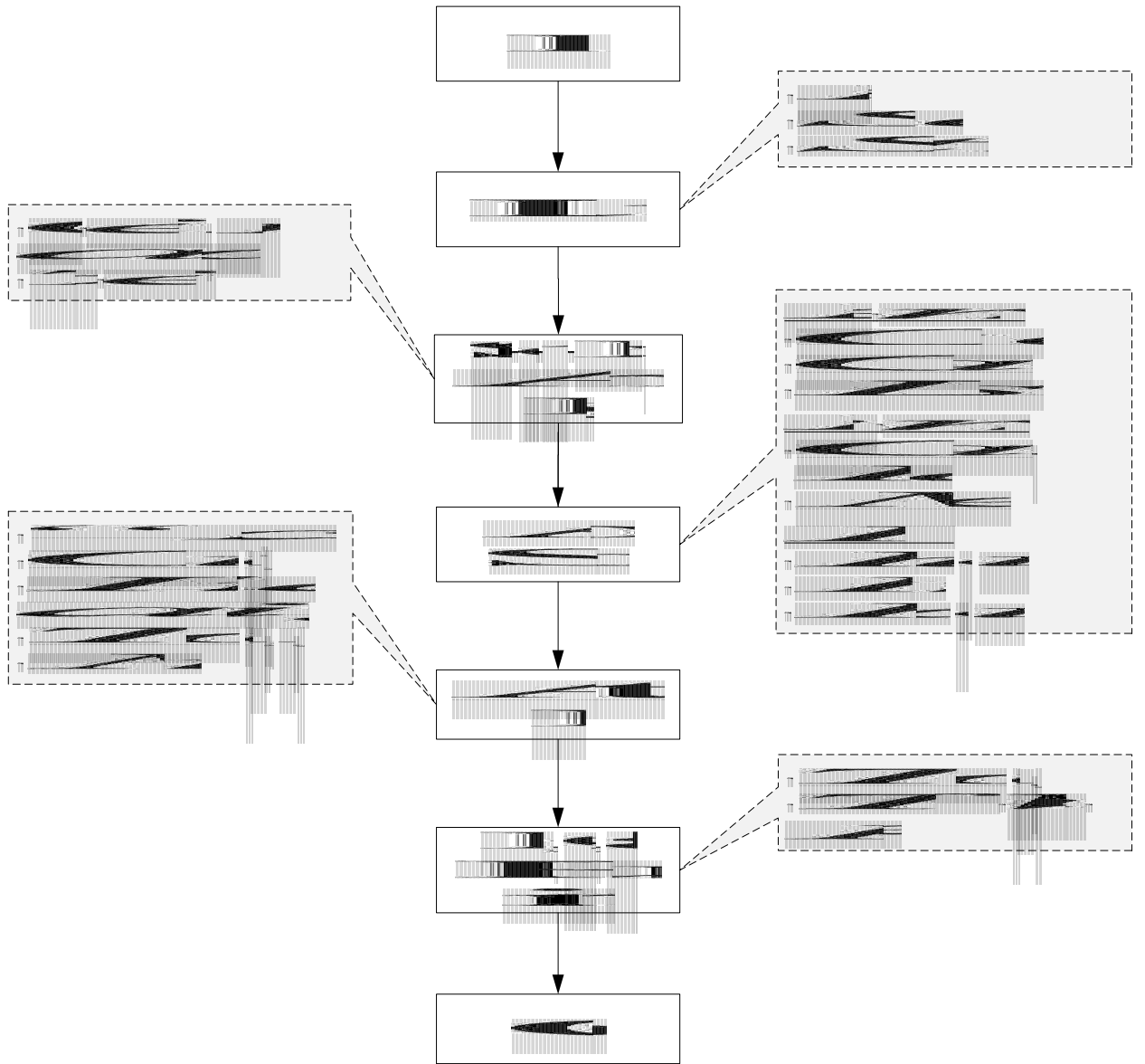


Figure 4.1: The design of chapter 4

Source: Developed for this research

## 4.2 Descriptive Statistics

Descriptive statistics is the term given to the analysis of data that provides summaries and presents the data in a more meaningful way. Such analysis can help identify patterns, but it cannot draw conclusions about the research hypotheses. In contrast, the inferential statistics is suitable for testing the statistical hypotheses and making generalizations about the population (Laerd-Statistics, 2013a). Before conducting a rigorous analysis using the structural equation modeling statistical technique, the present section focuses on several types of descriptive statistics that are used to describe the collected data. While the normality of data is examined in section 4.2.1, the percentage distribution and the frequency distribution are applied in section 4.2.2 and section 4.2.3, respectively.

### 4.2.1 Data distribution

According to Joshi, Kale, Chandel, and Pal (2015), researchers have to consider the distribution of data while choosing the appropriate statistical tests during analysis. The Kolmogorov-Smirnov test and the Shapiro-Wilks test, as demonstrated by Mooi and Sarstedt (2011), are often used to assess the normality of data. While testing normality, the tests compare the data to a normal distribution with the same mean and standard distribution deviation as of the sample. A  $p$ -value greater than 0.05 indicates normal distribution of data. Additionally, researchers have to examine two measures of distributions, skewness and kurtosis. Skewness assesses the symmetry of the distribution. If the distribution of the data is stretched to the right or the left tail, then the distribution is considered “skewed”. As a general guideline, a skewness value greater than +1 or lower

than -1 reveals a substantially skewed distribution. Kurtosis, on the other hand, is a measure of whether the distribution is too peaked (i.e. a very narrow distribution with most of the responses in the center). The distribution of data is considered too peaked if the kurtosis value is greater than +1. However, if the value is less than -1, the distribution is too flat. When the skewness and kurtosis values are close to zero, the pattern of responses is considered normally distributed (Hair et al., 2013).

In the present research, the normality of data was examined using SPSS statistical software. As shown in Table 4.1, both tests reveal a *p*-value of less than 0.05, indicating that the data is not normally distributed. Regarding the skewness measure, as reported in Table 4.2, it is approximately -1, which reveals that the distribution of data is skewed. The kurtosis value of approximately +2 indicates that the distribution is too peaked. Therefore, both measures affirm that the data of the present research are not normally distributed.

Table 4.1: The significance results of the normality of data

Dependent	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Significance	Statistic	df	Significance
<i>Effectiveness of EPC</i>	0.375	170	0.000	0.758	170	0.000

Source: Developed for this research

Table 4.2: Descriptive measures of the *Effectiveness of EPC* variable

Dependent	Measures	Statistic
<i>Effectiveness of EPC</i>	Mean	3.76
	Median	4.00
	Variance	0.46
	Standard deviation	0.68
	Minimum	1
	Maximum	5
	Range	4
	Interquartile Range	1
	Skewness	-0.95
	Kurtosis	1.91

Source: Developed for this research

It is important to note that non-parametric tests have to be applied when the distribution of the data does not meet the normality requirements (Joshi et al., 2015). As previously mentioned in chapter 3 (section 3.3.5.4), the structural equation modeling technique that is based on the partial least squares algorithm (i.e. PLS-SEM) is a non-parametric statistical method that does not require the data to be normally distributed (Hair et al., 2013). For this reason, the PLS-SEM method was used, in the present research, to generate the “Effectiveness of EPC” structural model. Additionally, the Kruskal-Wallis test was applied, instead of the ANOVA test, to examine whether a statistical significant difference exists among independent measures. Before starting the data analysis process, the subsequent section sheds light on data demographics, which are useful to attain a clearer perception of the sample of end-users surveyed in the present research.

#### 4.2.2 Sample demographics

The percentage distributions of responses for four questions (Part 1 of the questionnaire) are reported, in the present section, to shed light on the demographics of the targeted sample of end-users. Results reveal that the vast majority of the sample (65%) have earned a Bachelor's degree, and approximately 18% are holding a Master's degree (Figure 4.2, Panel 1). Additionally, approximately 91% of the targeted end-users have more than 10 years of professional experience, 52% of which have more than 20 years of experience (Figure 4.2, Panel 2). Regarding their experience in the oil and gas industry, 84% of the end-users have more than 10 years of experience in that industry, and around 15% have 5 to 10 years of experience (Figure 4.2, Panel 3). Furthermore, approximately 56% of the sample have supervised more than 10 staff, and 24% of them have advanced supervisory skills, where their teams include more than 50 members (Figure 4.2, Panel 4). As such, the sample of end-users surveyed 1) are highly qualified academically, 2) have vast professional expertise, 3) have considerable oil and gas industry relevant experience, and 4) have substantial relevant supervisory skills. All these facts authenticate the legitimacy of the collected responses.

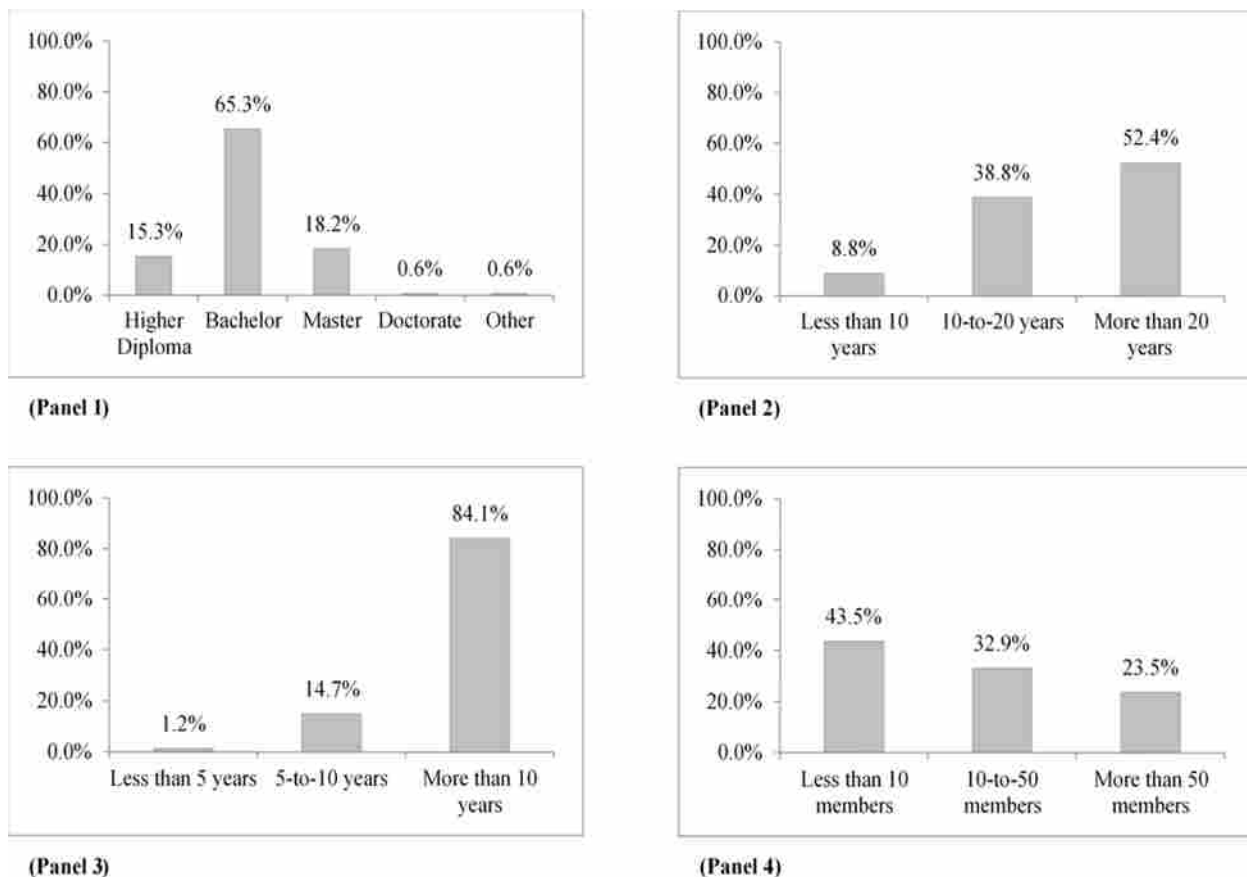


Figure 4.2: The percentage distributions of the sample's (1) academic qualification, (2) total professional experience, (3) experience in the oil and gas industry, and (4) supervisory skills

The frequency distributions of the survey responses (Part 2 of the questionnaire) were useful, as well, to gain an insight into the collected data. These distributions are highlighted in the following section.

#### 4.2.3 Survey respondents' data

In the second part of the questionnaire, a 5-point Likert scale was used, specifically Strongly disagree (SD), Disagree (D), Neutral (N), Agree (A), and Strongly agree (SA).

The frequency distributions of the responses of 33 closed-ended questions are reported in Table 4.3. The percentage distributions of these survey items are illustrated in Appendix E (Figure E.1 to Figure E.33).

Table 4.3: Frequency distributions of the survey responses

Survey question (second part of the questionnaire)	Frequency distribution (N = 170)				
	SD	D	N	A	SA
End-user's endorsement is taken on project execution strategy	7	26	28	88	21
End-user's endorsement is taken to proceed from FEED to EPC phase	3	15	37	85	30
End-user is involved in development of EPC contractor selection strategy	10	50	58	41	11
End-user's endorsement is taken on project commissioning strategy	1	13	23	102	31
End-user is involved in the review of plant facilities spacing layout for maintainability requirements	1	11	24	83	51
End-user is involved in project facilities model review	1	6	23	83	57
End-user is involved in finalization of project facilities plant layout	0	16	25	94	35
End-user is involved in approval process of key engineering documents	2	23	19	83	43
End-user's feedback is taken in the vendor selection of project equipment	9	25	42	70	24
End-user is involved in project Piping & Instrumentation Diagram (P&ID) review	2	5	10	91	62
End-user is involved in project Hazard and Operability (HAZOP) study	0	5	10	74	81
End-user is involved in approval process of construction documents	5	38	48	69	10
End-user is involved in the pre-commissioning project activities	1	5	8	80	76
End-user is involved in the project commissioning activities	0	2	4	67	97
End-user's participation in construction and commissioning adds value to the project	1	3	12	52	102
End-user is involved in selection of technologies to be used	4	22	49	66	29
Project achieved Reliability, Availability, and Maintainability (RAM) percentage as per the EPC project	3	12	53	88	14



Table 4.3: Frequency distributions of the survey responses  
(cont'd)

Survey question (second part of the questionnaire)	Frequency distribution (N = 170)				
	SD	D	N	A	SA
End-user's No Objection is taken while issuing acceptance certificates for project facilities	1	11	23	96	39
Project team continues to provide the support, if required by end-user, during operation of plant facilities under custody of end-user	5	25	30	94	16
End-user is involved in development of EPC Scope of Work (SOW)	5	21	37	81	26
End-user is involved in defining finished product specifications requirement	1	9	35	90	35
Project met end-user's finished product specifications	1	6	30	102	31
End-user is involved in specifying project facilities warranty period	3	28	57	64	18
Spare parts requirements are discussed and agreed with end-user	2	14	31	82	41
Project operating cost is within acceptable range to end-user	1	13	81	67	8
Project major equipment vendor is selected based on lifecycle cost analysis	4	21	69	61	15
Project completion schedule includes interface plan with existing facilities	0	6	19	102	43
Project completion schedule covers interface plan with other interconnected new facilities	1	5	28	106	30
End-user is involved in defining project completion schedule	2	32	50	74	12
Project completed within customer time frame requirements	5	33	51	69	12
EPC strategy is effective in execution of major projects from end-user's perspective	0	11	19	98	42
EPC strategy sufficiently meets end-user's requirements in major projects	1	14	25	116	14
End-user prefers EPC strategy over other strategies in execution of oil and gas major projects	2	11	40	98	19

Source: Developed for this research

The frequency distributions, detailed in Table 4.3, provide preliminary observations about the survey data. It is revealed that, for the vast majority of the questions (i.e. 82%), the answering option “Agree” receives the highest number of responses, whereas the “Strongly disagree” obtains the lowest. Such observation indicates that the involvement of the end-users in various project phases was adequately acknowledged at the site level, and the alignment between their desired product objectives and the project objectives was probably met. Additionally, the descriptive statistics, discussed in section 4.2.2, demonstrate the high competency of the end-user’s teams, who are qualified academically, technically, and professionally. Such high competency, according to Ross (2012), is critical for the achievement of proper and effective participation at the site level. In other words, if the end-user’s participation is acknowledged by project management, the high competency of the end-user’s team induces a constructive competition with the project teams, leading to better synchronization between the project objectives and the product objectives. As such, gaining an insight into the current practice regarding the end-user’s engagement in major oil and gas projects in Abu Dhabi as well as the achievement of the product objectives helps 1) examine if the end-user’s participation is adequately acknowledged at the site level, 2) identify various activities in which the involvement is accepted, and 3) investigate whether the high competency of the end-user’s team is actually facilitating the participation, exerting effective communication among the project parties, and helping achieve the end-user’s requirements. The following section thus sheds light on the state-of-the-practice regarding the involvement of the end-users and the accomplishment of their requirements in Abu Dhabi’s oil and gas major projects.

### **4.3 State-of-the-Practice: Abu Dhabi's Oil and Gas Industry**

The present section focuses on the current practice regarding the end-user's engagement and the achievement of the product objectives. In this regard, the main activities, in which the end-user's team had significant participation, are identified. Recall that 15 closed-ended questions (in Part 2 of the questionnaire) relate to the end-user's engagement concept, where data from 14 out of these 15 questions (i.e. survey items 1 to 14) were used to identify the main activities of involvement. The other question (i.e. survey item 15) was not considered, as it does not serve the objective of the present section. Additionally, responses of other 15 closed-ended questions (i.e. survey items 16 to 30) were analyzed to gain an insight into the achievement of the product objectives (section 4.3.1). The end-users' responses to the open-ended question were also helpful in attaining a clearer picture of the practices of engaging the end-user's team for the purpose of generating main project deliverables and reaching the end-user's requirements (section 4.3.2).

#### **4.3.1 Closed-ended questions**

Ranking analysis was applied on the responses of 14 closed-ended questions related to main activities that necessitate the involvement of the end-user. The analysis is based on the weighted average concept (depicted in Equation 1), where the weights (i.e. 1, 2, 3, 4, 5) relate respectively to the five points of the Likert scale used in the present study (i.e. Strongly disagree, Disagree, Neutral, Agree, Strongly agree).

$$\text{weighted average} = \sum_{i=1}^5 (w_i * n_i) / N \quad (1)$$

where  $w_i$ : weight  $i$

$n_i$ : number of responses for weight  $i$

$N$ : total number of responses (i.e. 170 in the present research)

As presented in Table 4.4, 13 activities of involvement were identified from the 14 survey questions mentioned above, where two questions relate to the “review/finalization of the plant facility spacing layout” activity. The weighted average of this activity was estimated as the mean of the weighted averages of its two related scale items (i.e. survey questions). Results of the ranking analysis, illustrated in Table 4.4, reveal that the highest involvement of the end-user was in the EPC phase for the purpose of conducting pre-commissioning and commissioning activities as well as reviewing/finalizing main project deliverables. These deliverables are, in particular, Hazard and Operability (HAZOP) study, Piping & Instrumentation Diagram (P&ID), model review, and spacing of the plant layout. Such involvement emphasizes that the invaluable in-house know-how of the end-user is captured in Abu Dhabi’s major oil and gas projects. The least involvement, on the other hand, was in the Pre-FEED phase, specifically during the selection of the project execution and commissioning strategies, in addition to the development of the EPC contracting strategy. Additionally, the involvement of the end-user’s team for the approval of the construction documents as well as the selection of project equipment was minimal.

Table 4.4: Ranking of the activities of involvement

Activity of Involvement	Weighted Average	Rank
Project commissioning activities	4.5	1
Finalization of Hazard and Operability (HAZOP) study	4.4	2
Project pre-commissioning activities	4.3	3
Revision/finalization of Piping & Instrumentation Diagram (P&ID)	4.2	4
Revision/finalization of project facility model review	4.1	5
Revision/finalization of plant facility spacing layout for maintainability requirements	4.0	6
Selection of project commissioning strategy	3.9	7
Approval of key engineering documents	3.8	8
Approval to proceed from FEED phase to EPC phase	3.7	9
Selection of project execution strategy	3.5	10
Vendor selection of project equipment	3.4	11
Approval of construction documents	3.2	12
Development of EPC contracting selection strategy	3.0	13

Source: Developed for this research

The ranking analysis statistical technique was applied on 15 closed-ended questions, which refer to various aspects under the main product objectives (i.e. RAM, Performance Guarantee, Lifecycle Cost, Product Delivery Schedule). The weighted average of each objective was estimated as the mean of the weighted averages of its related scale items, and the product objectives were ranked accordingly. The results, described in Table 4.5, show that the performance guarantee, which refers to the achievement of the desired specifications under the EPC contract, attains the highest rank, followed by the two

objectives of meeting the product delivery schedule and the lifecycle cost respectively. The lowest rank, on the other hand, belongs to the accomplishment of the reliability, availability, and maintainability (RAM) performance criteria. Based on the comprehensive literature review conducted in chapter 2, it is demonstrated that although reaching the desired product objectives in relation to the delivery schedule and cost is essential to meet the end-user's requirements, achieving a plant facility with high-quality performance is of higher importance to the end-user's team. Such performance helps avoid undesirable operational problems that would be costly once the plant is in operation. Recall that retaining high-quality performance necessitates not only meeting the desired specifications under the contract (i.e. performance guarantee) but also operating based on the RAM performance criteria. As such, even if the RAM and performance guarantee aspects are grouped together, the product quality objective would attain a weighted average of 3.7, which is the same as the product schedule objective, followed by the product cost objective of around 3.6. For this reason, more efforts have to be made to improve the quality of the handed-over facility and accordingly increase the end-user's satisfaction.

Table 4.5: Ranking of the four main product objectives

Product Objective	Items under the product objective	Weighted average (item)	Weighted average (objective)	Rank (product objective)
<i>Performance Guarantee</i>	The issuance of the acceptance certificates for project facilities upon the confirmation of the end-user	4.0	3.9	1
	Project met the finished product specifications	3.9		
	The end-user's requirements are considered when defining the finished product specifications	3.9		
	The end-user's agreement is taken during the development of EPC Scope of Work (SOW).	3.6		
<i>Product Delivery Schedule</i>	Project Completion schedule includes interface plan with existing facilities	4.1	3.7	2
	Project Completion schedule covers interface plan with other interconnected new facilities	3.9		
	The end-user's agreement is taken when defining the project completion schedule	3.4		
	Project is completed within the end-user's timeframe requirements	3.3		
<i>Lifecycle Cost</i>	Spare Parts requirements are discussed and agreed with the end-user	3.9	3.6	3
	Project operating cost is within an acceptable range to the end-user	3.4		
	Project major equipment vendor is selected based on the lifecycle cost analysis	3.4		
<i>Reliability, Availability, and Maintainability (RAM)</i>	The achievement of the RAM percentage as per the EPC contract	3.6	3.5	4
	The end-user's acceptance is considered during the selection of technologies to be used	3.6		
	Support is provided, by project team, for the operation of plant and facilities, under the custody of the end-user	3.5		
	The end-user's acceptance is taken when specifying the project facilities warranty period	3.4		

Source: Developed for this research

The present section thus sheds light on the level of involvement of the end-user's team in various project activities. It also gives a valuable insight into the current practice regarding the achievement of the product objectives. The following section provides more details regarding the end-users' participation and the accomplishment of the product requirements. Some concerns, which are related to other practices applied at the site level, are also reported.

#### **4.3.2 The Open-ended question**

Despite lower response rates and the difficulty to code and analyze the responses compared to closed-ended questions, qualitative data from open-ended questions can still provide rich information about the public opinion from relatively few respondents (Geer, 1991; Krosnick, 1999). In the present research, as noted in chapter 3 (section 3.3.5.4), an open-ended question (question 35, Part 2) was included in the questionnaire. This question aims at capturing the respondents' valuable experience regarding their participation in the accomplishment of the main project activities, from the early stages of design till the hand-over of the plant facility for operation. An approximately 40% response rate on this question was achieved, thus providing useful insight into the current practice regarding the end-user's engagement in various phases of major oil and gas projects in Abu Dhabi. These responses are included in Table F.1 (Appendix F).

The analysis of the responses reveal that the project management, in some projects, adequately acknowledged the end-user's participation and considered their suggestions for the achievement of product specifications. In this regard, the end-user's team was



involved in both the development and the implementation stages. Responses demonstrate that the end-user's participation in early stages of design (i.e. FEED phase) helped 1) benefit from the team's expertise, in-depth understanding of the work context and the lessons learned from previous projects (i.e. capitalizing on the end-user's field experience), 2) identify various deficiencies and technical problems, 3) reduce the amount of design and construction changes (i.e. rework) during the EPC execution phase, 4) facilitate the project pre-commissioning and commissioning activities, and 5) avoid undesirable operational problems that would be costly once the plant is in operation (which sometimes would be impossible to eradicate). The end-user's involvement in the development stage has thus proven to be crucial for the achievement of not only the project objectives but also the product objectives. These reported findings are in agreement with the concepts of the MacLeamy curve and the participatory design discussed in chapter 2 (section 2.3.5.1). These concepts highlight the necessity to shift the efforts of involving the end-user forward in time (i.e. at the development stage) to alleviate the adverse impact of design changes on project execution during the EPC phase (AEC, 2015; Balfour et al., 2012).

The end-user's engagement was expanded to the project implementation stage, where the operation team had the chance to 1) review the detailed design developed at the engineering stage of the EPC execution phase, 2) examine and approve the appropriateness of materials, equipment and licensed technologies to be included in the project, and 3) get involved during testing and commissioning to gain advanced experience in running the commissioning activities. The high level of participation in the pre-commissioning and commissioning activities is also supported by the ranking analysis

(conducted in section 4.3.1), in which findings reveal that the end-user's teams were highly involved in accomplishing these activities. Such active participation has not only led to a smooth hand-over of the facility but also ensured an operable plant without considerable bottlenecks and/or constraints. It is important to note that, based on the results of the ranking analysis, the involvement of the end-user's team in the selection of the project equipment vendors was found to be minimal compared to other activities.

During the involvement of the end-user's team in various project phases, main deliverables were generated, e.g. PI&D, plant layout, model review, HAZOP, spare parts list, punch list, warranty notification. Effective communication and significant collaboration with the project teams were experienced, which in turn played a critical role in increasing the end-user's satisfaction and consequently achieving both the project success and the product success. In this regard, respondents demonstrated that the teams' spirits, objectivity, realism and competency were the key success factors to achieve the synchronization between the project objectives and the product objectives. These factors are also highlighted by Joyce (2005) and Ross (2012) as significant requirements for exerting effective communication and control at the site level. The high competency of the targeted sample of end-users is, as well, confirmed by the descriptive statistics conducted previously. The positive influence of such competency thus not only facilitated the active participation but also enhanced the communication among the project parties.

While the majority of respondents acknowledged their participation in generating major project deliverables in various project phases, others reported that their suggestions were not seriously considered. The project management reluctance to embrace the

participation of the end-user's team was due to their false preconceptions that the accomplishment of the project objectives was being challenged. In addition, the involvement of the end-user for the development of the project execution and the commissioning strategies has been viewed as being project management related tasks. The deficiency in the end-user's involvement led to various design problems, such as non-optimized layout, shortage of storage space, inefficient equipment, and lack of office space. Given that the project quality is always compromised so as to abide by the project schedule, options with the least amount of reworks were considered regardless of the troubles that would be faced during and subsequent to the operation phase. Due to the limited participation during the development stage, as evidenced by the responses to the open-ended question, the end-user's team missed some opportunities to apply improvement and corrective actions at the right time. Henceforth, they were forced to compromise and agree to deal with lower standards of equipment and materials specifications. It is important to note that any changes after the hand-over of the facility are not only hard to implement in the running plant but also result in lack of resources and unnecessary expenditures by the end-user. Such limitations, as stated by the respondents, led to ineffective communication that might cause unproductive relationships between the project teams and the end-user's team.

The respondents, as well, showed some concerns related to the bidding process for major oil and gas projects. Projects are usually awarded to the lowest technically acceptable EPC lump-sum bids. In order to cope with such lower bids, bidders offer low-price materials and equipment. The use of such materials would definitely result in an inferior project quality, which negatively affects the HSE standards and the plant integrity.

Additionally, a large number of variation orders would be submitted during various stages of the project. These reported practices support Grynbaum's (2004) argument that the selection of low EPC lump-sum bids have negative effects on both the project objectives and the product objectives. For this reason, some of the respondents raised the possibility of the reactivation of the techno-commercial bid evaluation process. This process offers the opportunity for selecting a better bidder considering his technical evaluation results as well as the value for money. For instance, a bidder "A" has a score of 95% for the technical evaluation versus a bidder "B" with 75%, where their commercial bids are \$2 billion and \$1.95 billion respectively. Based on the prevailing contract award practice, the contract would be awarded to contractor "B" being the lowest technical acceptable bidder. However, saving only 2.5% of the budget would prevent committing with 20% higher qualified contractor, which in the long term would help achieve higher product quality and possibly lower chances of variation orders during project execution.

Other concerns raised by the respondents relate to the concept of separate FEED and EPC contractors. The FEED and EPC packages, in major oil and gas projects, are often assigned to different contractors. The FEED contractor usually develops the preliminary engineering requirements without being generally accountable for the delivery of the finished product which is part of the EPC contractor's responsibilities. When the execution phase starts, various design changes would be suggested by the EPC contractor, which would delay the project completion if considered or the project quality if discarded.

Even though the majority of respondents reported various cases in which the end-user's team was involved, none of these cases occurred at the Pre-FEED phase. This observation is consistent with the results of the ranking analysis, in which the main activities of the Pre-FEED phase were reported as having the least level of involvement. Additionally, the responses of the open-ended question did not indicate any participation in the approval of construction documents, which is also confirmed by the ranking analysis. However, both Gasco (2011) and Takreer (2012) ascertain that the approval of construction documents for all disciplines is a main activity that requires the engagement of the end-user for the purpose of ensuring successful testing and commissioning as well as fulfilling project specifications and contractual requirements. Furthermore, the results of the ranking analysis reveal that the involvement of the end-user's team in the equipment and materials selection process was found to be minimal compared to other activities. Nonetheless, such involvement, as argued by Gasco (2011) and Takreer (2012), is crucial so as to 1) benefit from the end-users' preferences towards certain suppliers based on their previous in-house experience, 2) optimize the project cost and accordingly the lifecycle cost through benefiting from the spare parts available from previous projects, and 3) minimize the training efforts due to operators' familiarity with existing equipment. Ranking analysis, performed on the responses related to the examination of the product objectives, demonstrates that a higher priority should be given to the achievement of the RAM performance criteria so as to improve the quality of the handed-over plant facility.

The examination of the current practice regarding the end-user's participation and the achievement of the product requirements, therefore, confirms that there is still a considerable need to improve the effectiveness of major projects in Abu Dhabi's oil and

gas industry. Such need is justified in chapter 1 (section 1.3.2), as well through the researcher's and the interviewed industry expert's long professional experience in Abu Dhabi's oil and gas industry. To address this need, as previously noted, a structural model is generated to 1) identify factors affecting the project effectiveness, 2) examine the strengths of influence of the causal factors, and 3) assess the statistical significance of these relationships. This model would thus serve as a guide for improving the project effectiveness and consequently meeting the end-user's requirements. Before analyzing and interpreting the generated structural model, an initial assessment for this model has to be established (Hair et al., 2013; Hair, Ringle, & Sarstedt, 2011). The following section (section 4.4) shows the "Effectiveness of EPC" structural model prior to assessment, whereas the evaluation of the model is presented in section 4.5.

#### **4.4 Initial "Effectiveness of EPC" structural model**

The previous section sheds light on the state-of-the-practice regarding the end-users' engagement and the accomplishment of their requirements in Abu Dhabi's oil and gas industry, where the need for improving the project effectiveness has been emphasized. Having a structural model is then suggested as an appropriate means for possible improvement, and the assessment of the generated structural model is highlighted as a necessity before its interpretation. The present section focuses on the generated structural model, where more details regarding the types of causal relationships are provided.

As discussed in chapter 3, the measurement model for the present research is conceptualized as a multi-dimensional formative model. The “SmartPLS” statistical software, which has the ability to compile formative constructs based on the partial least squares (PLS) algorithm, is used to generate the “Effectiveness of EPC” structural model. Figure 4.3 depicts the initial structural model before conducting the assessment process.

The “Effectiveness of EPC” structural model, as illustrated in Figure 4.3, shows the possible causal relationships between the formative constructs and their related indicators in addition to the parameter estimates of these relationships. These relationships are divided into three categories, particularly 1) the relationships between the *Effectiveness of EPC* construct and its two dimensions (i.e. *End-user’s engagement*, *Alignment of objectives*), 2) the relationships between the two dimensions and their related formative indicators, and 3) the relationships between the *Effectiveness of EPC* construct and its reflective indicators, which were added to the model for the purpose of estimation (refer to section 3.3.2 for details).

As previously noted, three categories of relationship paths are shown in the “Effectiveness of EPC” structural model. Each category has a unique term depicting its parameter estimate. In this aspect, the parameter estimate of the relationship linking the focal construct with its dimension is referred to as “path coefficient”, whereas the estimate of the relationship connecting the dimension with its related formative indicator is known as its “outer weight”. “outer loading” refers to the parameter estimate of the relationship associating the focal construct with its reflective indicator (Hair et al., 2011; Wong, 2013).

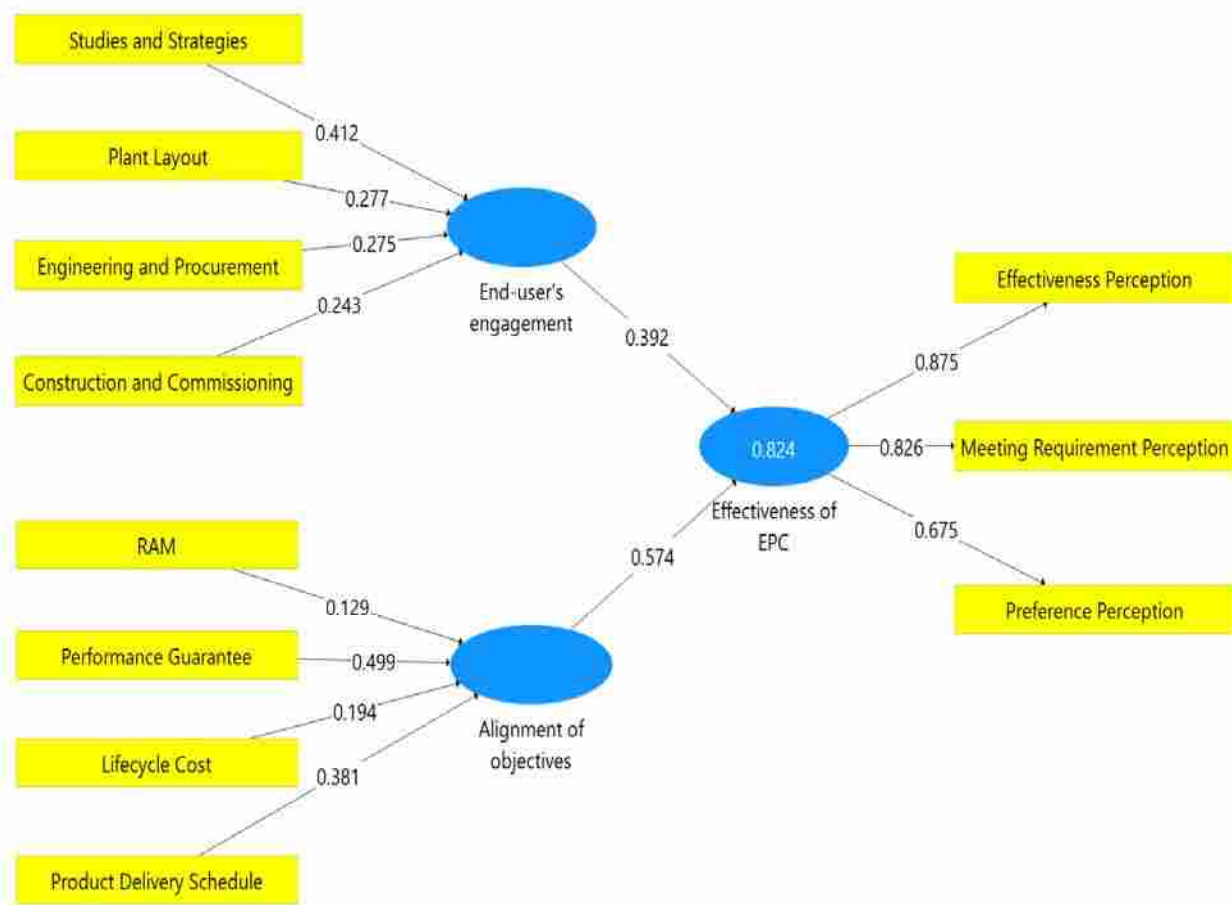


Figure 4.3: The initial "Effectiveness of EPC" structural model prior to assessment

Source: Developed for this research

The coefficient of determination (i.e.  $R^2$ ), which indicates the variability of the dependent variable that is accounted for by the explanatory variables of the model (Wong, 2013), is also reflected in the generated structural model. In this context, the two dimensions (i.e. *End-user's engagement*, *Alignment of objectives*) explain 82.4% of the variance in the *Effectiveness of EPC* construct. Such a high coefficient (greater than 0.75) indicates that the "Effectiveness of EPC" model substantially fits the data (Hair et al.,



2011). The following section focuses on the assessment of the structural model, which is a necessity before conducting a deeper analysis of the causal relationships.

#### **4.5 Assessment of the Structural Model**

The assessment of the “Effectiveness of EPC” structural model is done in the present section. In the case of a higher-order measurement model, multidimensional constructs and their dimensions are treated as theoretical constructs, where each construct has to be individually assessed based on the type of its associated indicators (Edwards, 2001). In this regard, each type of constructs (i.e. reflectively-measured or formatively-measured) has specific evaluation criteria (Hair et al., 2013).

Table 4.6 presents a summary of these criteria, along with their threshold values, for both the reflectively-measured construct and the formatively-measured construct.

According to Hair et al. (2013), the assessment of the PLS-SEM structural model requires not only the evaluation of the constructs individually (i.e. the relationships with their indicators) but also the appraisal of the inner structural model (i.e. the relationship between the higher-order construct with its dimensions). The assessment of the inner model involves five main criteria, including 1) the significance of path coefficients, 2) the level of  $R^2$  values, 3) the  $f^2$  effect size, 4) the predictive relevance ( $Q^2$ ), and 5) the  $q^2$  effect size. The guidelines for such evaluation criteria are summarized in Table 4.7.

Table 4.6: Summary of evaluation criteria for reflectively-measured and formatively-measured constructs

Evaluation criterion	Evaluation level	Reflectively-measured construct	Formatively-measured construct
<b>Reliability assessment</b>	Indicator	<ul style="list-style-type: none"> <li>• Outer loading value &gt; 0.708</li> <li>• If loading value &lt; 0.70, consider the removal of the indicator</li> <li>• Reliability value = square of loading value</li> <li>• Reliability value <math>\geq 0.50</math></li> </ul>	N/A
	Construct	<ul style="list-style-type: none"> <li>• Cronbach's alpha (<math>\alpha</math>) = 0.60 – 0.70 <math>\rightarrow</math> acceptable 0.70-0.90 <math>\rightarrow</math> satisfactory</li> <li>• Composite reliability = 0.60 – 0.70 <math>\rightarrow</math> acceptable 0.70-0.90 <math>\rightarrow</math> satisfactory</li> </ul>	
<b>Convergent validity assessment</b>	Indicator	<ul style="list-style-type: none"> <li>• Significance of the loading: <math>p</math>-value &lt; 0.05 <math>t</math>-value &gt; 1.96</li> </ul>	<ul style="list-style-type: none"> <li>• Significance of the weight: <math>p</math>-value &lt; 0.05 <math>t</math>-value &gt; 1.96</li> </ul>
	Construct	<ul style="list-style-type: none"> <li>• AVE &gt; 0.50</li> </ul>	<ul style="list-style-type: none"> <li>• Conduct “redundancy analysis” on SPSS: Path coefficient between the construct and its global reflective construct <math>\geq 0.80</math></li> </ul>
<b>Discriminant validity assessment</b>	Indicator	<ul style="list-style-type: none"> <li>• Cross-loadings: Outer loading value &gt; all cross-loadings on other constructs</li> </ul>	N/A
	Construct	<ul style="list-style-type: none"> <li>• Fornell-Larcker Criterion: square root of AVE &gt; highest correlation with any other construct</li> </ul>	
<b>Multicollinearity assessment</b>	Indicators of the same construct	N/A	VIF $\geq 5$ or Tolerance $\leq 0.2$

Source: (Hair et al., 2013; Wong, 2013)

Table 4.7: Summary of evaluation criteria for inner structural model

Evaluation criterion	Evaluation level	Measurement	Guidelines for criterion
Significance of path coefficient	Exogenous construct	Relative importance (i.e. strength of contribution)	$t$ -value > 1.96 $p$ -value < 0.05
Coefficient of determination ( $R^2$ )	Higher-order endogenous construct	Model's predictive accuracy	0.25 → weak 0.5 → moderate 0.75 → substantial
$f^2$ size effect	Exogenous construct	Size of the contribution	0.02 → small 0.15 → medium 0.35 → large
Predictive relevance ( $Q^2$ )	Higher-order endogenous construct	Model's predictive relevance	Greater than zero
$q^2$ effect size	Exogenous construct	Size of the predictive relevance	0.02 → small 0.15 → medium 0.35 → large

Source: (Hair et al., 2013, 2011)

In the “Effectiveness of EPC” structural model (Figure 4.3), considering each individual construct with its associated indicators reveals a reflectively-measured construct (i.e. *Effectiveness of EPC*) and two formatively-measured constructs (i.e. *End-user's engagement*, *Alignment of objectives*). The former is assessed in section 4.5.1, whereas the latter two are evaluated in section 4.5.2. The inner structural model, depicting the *Effectiveness of EPC* construct with its two dimensions, is appraised in section 4.5.3. Once the assessment steps are accomplished, the analysis of the structural model can proceed towards the interpretations of the causal relationships (Hair et al., 2011).

### 4.5.1 Reflectively-measured construct

According to Hair et al. (2013), three main steps are required to evaluate the reflectively-measured construct, at both the indicator level and the construct level. These steps are discussed in the present section, including the reliability assessment (section 4.5.1.1), the convergent validity assessment (section 4.5.1.2), and the discriminant validity assessment (section 4.5.1.3).

#### 4.5.1.1 Reliability assessment

Reliability assessment, as discussed in chapter 3, refers to the evaluation of the ability of the scale items (i.e. survey questions) to provide similar effects over a period of time, which in turn demonstrates the stability of the measurement indicators (Yin, 2013). The *Effectiveness of EPC* construct, of the “Effectiveness of EPC” structural model (Figure 4.3), is estimated based on three reflective indicators (i.e. *Effectiveness Perception*, *Meeting Requirement Perception*, *Preference Perception*). The reliability of these indicators, along with their associated construct, is evaluated in the present section.

##### ➤ Indicator reliability

The reliability of an individual reflective indicator, as argued by Hair et al. (2013), is assessed based on the value of its outer loading, with a threshold value of 0.708. A reflective indicator with an outer loading of less than 0.70 should be considered for elimination if the removal increases the composite reliability and the Average Variance Extracted (AVE) measures (discussed below) above their threshold values. As shown in

Figure 4.3, the *Preference Perception* indicator, unlike the other two reflective indicators, has a loading of 0.675 (approximately 0.68), which is less than the required threshold value. For this reason, another structural model was generated after excluding the *Preference Perception* reflective indicator (Figure 4.4). Such model, depicted in Figure 4.4, is referred to as “intermediate structural model”, as the remaining evaluation requirements have to be examined before reaching the “final” structural model that meets all the assessment criteria. As illustrated in Figure 4.4, the coefficient of determination (i.e.  $R^2$ ) is 0.848. Such coefficient indicates that the two dimensions (i.e. *End-user’s engagement*, *Alignment of objectives*) explain 84.8% of the variance in the *Effectiveness of EPC* construct. Such a high coefficient (even greater than the  $R^2$  of the initial structural model) indicates that the “Effectiveness of EPC” model substantially fits the data. Additionally, the remaining two reflective indicators (i.e. *Effectiveness Perception*, *Meeting Requirement Perception*) have outer loadings of 0.874 and 0.885, respectively, where both of them are above the threshold value (i.e. 0.708).

The composite reliability and the AVE concepts are discussed below, and their values are estimated for both structural models (i.e. Figure 4.3 and Figure 4.4). The removal of the *Preference Perception* reflective indicator is assessed accordingly.

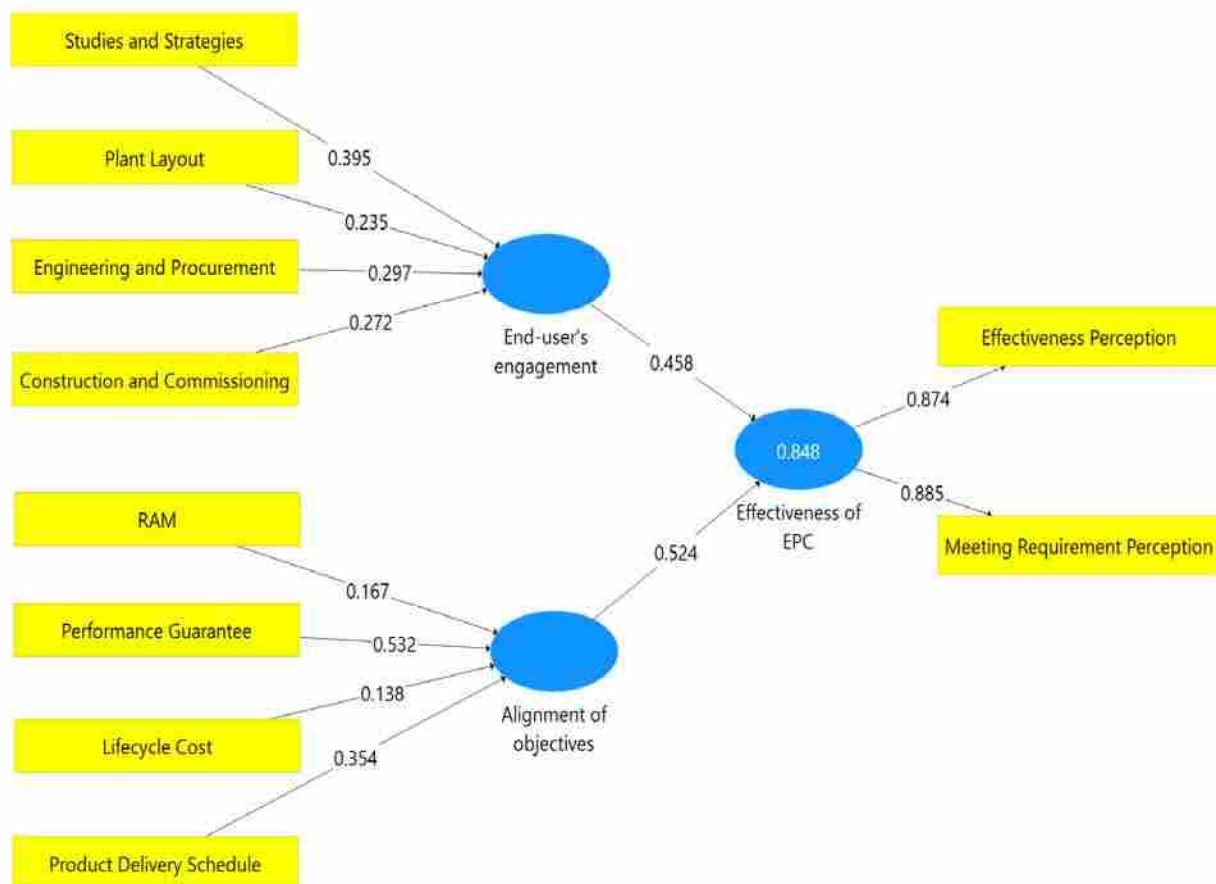


Figure 4.4.: The intermediate "Effectiveness of EPC" structural model after the removal of the *Preference Perception* indicator

Source: Developed for this research

#### ➤ Construct reliability

For a reflectively-measured construct, the first criterion to be evaluated is the internal consistency reliability. Cronbach's alpha coefficient ( $\alpha$ ) is the most common approach used for assessing the internal consistency reliability (also known as "scale reliability"). The scale reliability was assessed in chapter 3 (section 3.3.4) based on the 12 responses of the pilot survey using SPSS statistical software. In the present section, the Cronbach's alpha coefficient is estimated based on the 170 complete responses, using the SmartPLS

software. The alpha coefficient of the initial structural model (i.e. Figure 4.3) and the intermediate structural model (i.e. Figure 4.4) is 0.714 and 0.707, respectively (see Figure G.1 and Figure G.2, Appendix G). Both coefficients reveal a satisfactory internal consistency.

It is worth noting that the Cronbach's alpha assumes that all indicators have equal outer loadings on its associated construct. Another limitation is that this measure often tends to underestimate the internal consistency reliability, as it is sensitive to the number of items in the scale. Given that the PLS-SEM statistical method tends to prioritize the indicators based on their individual reliability, the composite reliability is more suitable for measuring the internal consistency reliability (Hair et al., 2013). The composite reliability takes into account the different outer loadings of the reflective indicators, where a reliability of 0.60 to 0.70 is considered acceptable. On the other hand, a composite reliability of 0.70 to 0.90 is regarded as satisfactory. During the compilation and estimation of the initial "Effectiveness of EPC" structural model (Figure 4.3), the SmartPLS software reveals a composite reliability value of 0.837 (see Figure G.3, Appendix G), which is higher than the internal consistency reliability reflected by the Cronbach's alpha (i.e. 0.714). On the other hand, the composite reliability of the intermediate structural model (Figure 4.4), in which the *Preference Perception* indicator is excluded, is 0.872 (see Figure G.4, Appendix G). Such value is, as well, higher than the Cronbach's alpha coefficient. For both models, the internal consistency reliability results demonstrate that the scale items of the present research are consistent in reflecting the actual measurement of their related indicators and consequently the intended concept (i.e. *Effectiveness of EPC* construct).

It is important to note that the composite reliability is increased from 0.837 to 0.872 upon the removal of the third reflective indicator, thus meeting the first elimination criterion. The following section sheds light on the convergent validity assessment of the *Effectiveness of EPC* construct and its reflective indicators, where the second elimination criterion (i.e. AVE) is assessed.

#### **4.5.1.2 Convergent validity assessment**

In the present section, the convergent validity assessment of the *Effectiveness of EPC* construct and its reflective indicators, is established. Given that the AVE measure of this construct is another critical measure for assessing the removal of the *Preference Perception* indicator, the convergent validity at the construct level is evaluated for both structural models. The assessment at the indicator level is subsequently conducted based on the chosen structural model.

##### ➤ Construct convergent validity

To assess the convergent validity of a reflectively-measured construct, as suggested by Hair et al. (2013), the Average Variance Extracted (AVE) measure has to be evaluated. Such measure indicates the average amount of variance in indicators that a construct has been able to explain. A construct with reflective indicators should have an AVE value of at least 0.5 in order to be considered valid. Regarding the initial “Effectiveness of EPC” structural model (i.e. Figure 4.3), the *Effectiveness of EPC* construct is operationalized through three reflective indicators. The AVE value of 0.634 was estimated by the



SmartPLS software, during the compilation of the model (see Figure G.5, Appendix G). On the other hand, the AVE value of the intermediate structural model (i.e. Figure 4.4), excluding the third reflective indicator, was estimated at 0.773 (see Figure G.6, Appendix G). The AVE values for both models are higher than 0.5, thus confirming the convergent validity of the *Effectiveness of EPC* construct. It is worth noting that the AVE measure is increased from 0.634 to 0.773, which indicates that the second elimination criterion is met. As such, the removal of the *Preference Perception* reflective indicator from the structural model is confirmed, and the intermediate “Effectiveness of EPC” structural model, presented in Figure 4.4, is the final model considered for the analysis of the causal relationships. Accordingly, the outer loadings of the *Effectiveness Perception* and *Meeting Requirement Perception* reflective indicators are 0.874 and 0.885, respectively. The individual indicator reliability of the indicator meeting the loading threshold value is estimated as the square of its outer loading value. As such, the *Effectiveness Perception* indicator has an indicator reliability of 0.764 (i.e.  $0.874^2$ ), while the *Meeting Requirement Perception* indicator has a higher indicator reliability of 0.783 (i.e.  $0.885^2$ ). It is worth noting that an indicator reliability value of at least 0.50 is required (Hair et al., 2013), thus the reliability values of the two reflective indicators are well above the minimum acceptable level. The convergent validity assessment for these two reflective indicators is detailed below.

➤ Indicator convergent validity

Recall that the indicator's outer loading is referred to as the "λ-parameter" based on the SEM conceptualization terminologies (see Figure 3.2). The validity of a reflective indicator can be assessed using the statistical significance of its λ-parameter (Hair et al., 2013, 2011). It is important to note that the PLS-SEM relies on the bootstrapping procedure to assess the statistical significance of the parameter estimates. During bootstrapping, the number of bootstrap samples as well as the number of bootstrap cases have to be specified. In this regard, the recommended number of samples is 5,000, and the number of cases should be at least equal to the number of valid observations in the dataset (i.e. 170 cases in the present research). The *T*-statistic is often used to examine the statistical significance of the estimates, where the large sample critical *t*-value for a two-tailed test is 1.65, 1.96, and 2.58 at 10%, 5%, and 1% significance levels, respectively (Hair et al., 2011). The bootstrapping results reveal a *t*-value of 48.032 and 55.611 for the *Effectiveness Perception* and *Meeting Requirement Perception* indicators, respectively. These values are higher than 1.96, thus demonstrating the statistical significance of these two reflective indicators at a 5% significance level (i.e.  $p$ -value < 0.05) and consequently confirming their convergent validity.

While the present section focuses on the assessment of the convergent validity of the reflective measurement model at both the construct level and the individual indicator level, the subsequent section (section 4.5.1.3) sheds light on the evaluation of the discriminant validity. Such assessment is conducted, as well, at both the indicator and the construct levels.

#### 4.5.1.3 Discriminant validity assessment

Discriminant validity refers to the extent to which a reflectively-measured construct is truly distinct from other constructs in the structural model. The establishment of the discriminant validity indicates that such construct is unique and captures phenomena not reflected by any other construct in the model (Hair et al., 2013; Wong, 2013). Two methods are proposed to estimate the discriminant validity, the cross-loadings and the Fornell-Larcker criterion. The former assesses the discriminant validity of the construct through its reflective indicators (i.e. at the indicator level), whereas the latter evaluates the validity at the construct level.

➤ Indicator discriminant validity

The discriminant validity is established, at the indicator level, if the indicator's outer loading on the associated construct is larger than all of its loadings on other constructs in the model (i.e. the cross-loadings) (Hair et al., 2013).

Table 4.8 reports the cross-loadings of the two reflective indicators, estimated by the SmartPLS software. It is revealed that the outer loadings of both indicators are larger than their cross-loadings on the other two constructs in the structural model (i.e. *End-user's engagement*, *Alignment of objectives*), thus approving the discriminant validity of the two reflective indicators. The entire "cross-loading" analysis matrix is included in Appendix G (Table G.1).

Table 4.8: The cross-loadings of the reflective indicators of the *Effectiveness of EPC* construct

Reflective indicator	Outer Loading	Cross-loading	
		<i>End-user's engagement</i> construct	<i>Alignment of objectives</i> construct
<i>Effectiveness Perception</i>	0.874	0.631	0.840
<i>Meeting Requirement Perception</i>	0.885	0.869	0.696

Source: developed for this research

➤ Construct discriminant validity

The Fornell-Larcker criterion, which is another approach to assess the discriminant validity, compares the square root of the AVE of the reflectively-measured construct with its correlations with all constructs in the model (Hair et al., 2013). The discriminant validity, for a given construct, is established if the square root of the AVE value is larger than the highest correlation with any other construct (i.e. larger than all its correlations with the other constructs). The Fornell-Larcker criterion analysis matrix for the *Effectiveness of EPC* construct, generated by the SmartPLS software, is depicted in Table 4.9. In order to evaluate a reflective construct, the square root of the AVE should be compared with all correlations in both the row and the column of that focal construct. As shown in Table 4.9, the correlation between the *Effectiveness of EPC* construct and the *End-user's engagement* construct is 0.856, whereas its correlation with the *Alignment of objectives* construct is 0.872. As such, the 0.879, representing the square root of the AVE

(0.773), is larger than both correlations, thus confirming the discriminant validity of the *Effectiveness of EPC* construct.

Table 4.9: The Fornell-Larcker criterion analysis matrix

	<i>End-user's engagement</i>	<i>Alignment of objectives</i>	<i>Effectiveness of EPC</i>
<i>Alignment of objectives</i>	0.759	–	–
<i>Effectiveness of EPC</i>	0.856	0.872	<b>0.879</b>

Source: Developed for this research

The reliability assessment of the three reflective indicators, discussed in the present section, highlighted the need to eliminate the *Preference Perception* reflective indicator. Accordingly, the remaining evaluation steps of the *Effectiveness of EPC* construct were conducted on the structural model excluding this indicator. In this regard, the reliability, convergent validity, and discriminant validity of the reflectively-measured construct and its two reflective indicators have been confirmed. The following section (section 4.5.2) sheds light on the assessment process of the formatively-measured constructs (i.e. *End-user's engagement*, *Alignment of objectives*) of the “Effectiveness of EPC” structural model (i.e. Figure 4.4).

#### 4.5.2 Formatively-measured constructs

Regarding the reliability assessment of formative indicators, Diamantopoulos and Winklhofer (2001) argue that assessing their reliability in an internal consistency sense is not meaningful, as they can still serve as significant measures of a construct even if they

are negatively correlated. On the other hand, the evaluation of the validity, at both the individual indicator level and the overall construct level, is essential for the justification of the formative measurement model. Additionally, the assessment of the formative indicators for collinearity issues is another critical criterion for evaluating formatively-measured constructs (Edwards & Bagozzi, 2000; Hair et al., 2013). Section 4.5.2.1 focuses on the convergent validity assessment of the two formatively-measured constructs (i.e. *End-user's engagement*, *Alignment of objectives*) at both the indicator and the construct levels. Section 4.5.2.2, on the other hand, assesses whether the collinearity problem exists among the formative indicators of the two formative constructs.

#### **4.5.2.1 Convergent validity assessment**

The present section discusses the evaluation criterion of the convergent validity, at both the indicator and the construct levels. The *End-user's engagement* and the *Alignment of objectives* formative constructs, in addition to their formative indicators, are assessed.

##### ➤ Formative indicator validity

Given that the  $\gamma$ -parameters (i.e. outer weights) represent the direct contribution of individual indicators to their related constructs (refer to Figure 3.2), the magnitude of these parameters can be interpreted as validity coefficients. The statistical significance of the  $\gamma$ -parameters, therefore, designates the indicator validity, where indicators with non-significant parameters are candidates for elimination (Bollen, 1989; Diamantopoulos & Winklhofer, 2001). However, the elimination of formative indicators, as suggested by

Diamantopoulos and Winklhofer (2001), have to be approached with caution, as the removal of any indicator might change the conceptual domain of its related construct. Recall that a fundamental characteristic of a formative model is that each measure captures a unique aspect of the construct's domain, and such measures are not expected to be interchangeable (refer to section 3.3.1 for more details). The "Effectiveness of EPC" measurement model, as indicated in Figure 3.5, consists of eight formative indicators. The  $\gamma$ -parameters of these indicators and their statistical significance values (specifically  $t$ -values) are shown in Table 4.10.

Table 4.10: The statistical significance values of the  $\gamma$ -parameters of the formative indicators

<b>Formatively-measured construct</b>	<b>Formative indicator</b>	<b><math>\gamma</math>-parameter value</b>	<b><math>t</math>-value of <math>\gamma</math>-parameter</b>
<i>End-user's engagement</i>	<i>Studies and Strategies</i>	0.395	5.244***
	<i>Plant Layout</i>	0.235	4.783***
	<i>Engineering and Procurement</i>	0.297	4.468***
	<i>Construction and Commissioning</i>	0.272	3.504***
<i>Alignment of objectives</i>	<i>RAM</i>	0.167	2.605***
	<i>Performance Guarantee</i>	0.532	7.545***
	<i>Lifecycle Cost</i>	0.138	2.630***
	<i>Product Delivery Schedule</i>	0.354	4.620***

\*:  $p$ -value < 0.1; \*\*:  $p$ -value < 0.05; \*\*\*:  $p$ -value < 0.01

Source: Developed for this research

As illustrated in Table 4.10, the statistical significance values of the  $\gamma$ -parameters of the eight formative indicators are greater than 1.96, thus indicating their statistical significance at a 5% significance level (i.e.  $p$ -value  $< 0.05$ ). More precisely, these indicators are extremely significant with a  $p$ -value of less 0.01 (i.e. 1% significance level). As such, the statistical significance of the eight indicators infers their validity, which in turn provides an empirical support that all these indicators are required to shape the conceptual domain of their related constructs and consequently should be retained in the generated structural model. The next step, after evaluating the validity of the formative indicators, involves assessing the validity of the two formative constructs.

➤ Formative construct Validity

It is important to note that the conventional statistical procedures, which are often used to examine the validity of reflective constructs (e.g. confirmatory factor analysis), are not suitable for formative measurement models (Diamantopoulos & Winklhofer, 2001). Hair, Hult, Ringle, and Sarstedt (2013) and Wong (2013), on the other hand, suggest the application of convergent validity to evaluate the validity of formative constructs. However, the AVE measure, used in the case of reflectively-measured constructs, is not appropriate for formatively-measured constructs. Instead, a “redundancy analysis” has to be carried out to assess the convergent validity of formative constructs. In this regard, for each formatively-measured construct, a new model has to be built, where this construct is conceptualized as predicting another endogenous construct that is operationalized through one or more reflective indicators (see Figure 4.5). The reflective indicator (e.g. “indicator 4” in Figure 4.5) can be a global item in the survey questionnaire that summarizes the



essence of the formatively measured construct. The convergent validity is established if the path coefficient between the two constructs is 0.8 or higher (Hair et al., 2013; Wong, 2013).

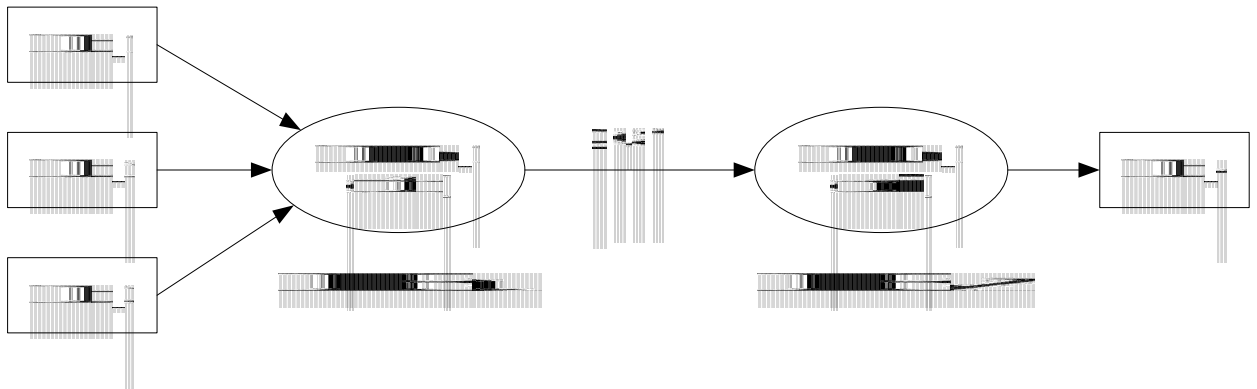


Figure 4.5: General “Redundancy analysis” model for a formatively-measured construct  
Source: Wong (2013)

Regarding the “Effectiveness of EPC” measurement model (Figure 3.5), the *Effectiveness of EPC* construct has two dimensions (i.e. *End-user’s engagement*, *Alignment of objectives*), where these dimensions are formatively-measured constructs. Therefore, the redundancy analysis was conducted in both cases to evaluate their convergent validity.

For the *End-user’s engagement* construct, a new model was created, as shown in Figure 4.6, depicting its relationship with another reflectively-measured construct (known as “Engagement-global”). Recall that the *End-user’s engagement* construct refers to the involvement of the end-user in various project phases represented by the four formative indicators (i.e. *Studies and Strategies*, *Plant Layout*, *Engineering and Procurement*, *Construction and Commissioning*). For this reason, the *Engagement-global* construct is

operationalized through four reflective indicators (i.e. *ER-global<sub>1</sub>*, *ER-global<sub>2</sub>*, *ER-global<sub>3</sub>*, *ER-global<sub>4</sub>*), summarizing the essence of the four main fields of involvement. These reflective indicators are estimated using the survey items “3”, “7”, “9”, and “15” respectively (included in Appendix D). After the compilation of this model, the path coefficient between the *End-user's engagement* and the *Engagement-global* constructs is estimated at 0.894, demonstrating the validity of the *End-user's engagement* construct.

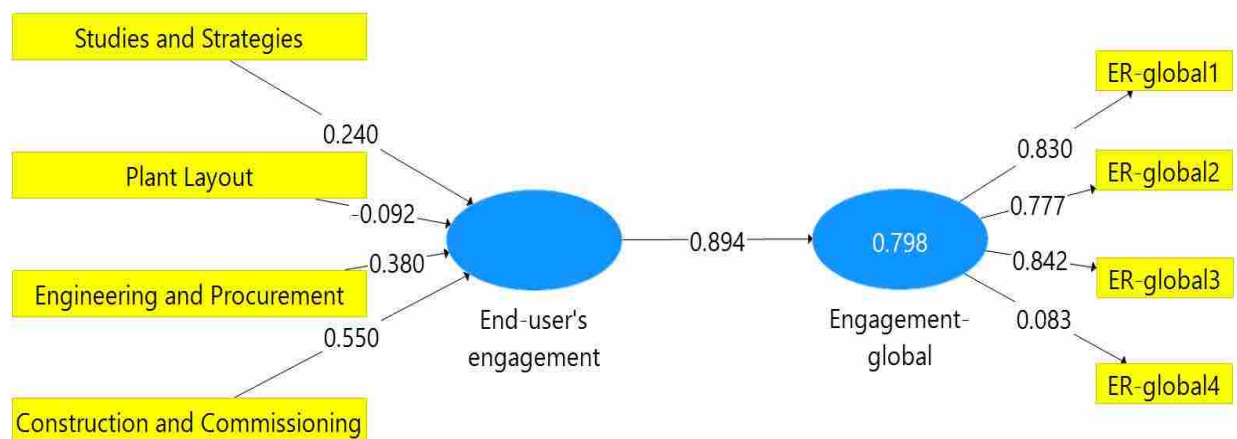


Figure 4.6: Redundancy model of the *End-user's engagement* construct

Source: Developed for this research

Another redundancy model was built (see Figure 4.7), for the *Alignment of objectives* construct, where it is represented as a predictor for a reflectively-measured construct (known as “Alignment-global”). Given that the *Alignment of objectives* construct refers to meeting the product objectives in relation to product quality, cost, and, schedule, the *Alignment-global* construct is conceptualized through three reflective indicators. The *AR-global<sub>1</sub>* reflective indicator refers to the product quality objective and is estimated based on the survey item “22”. The *AR-global<sub>2</sub>* indicator represents the achievement of the

product cost objective, whereas the *AR-global<sub>3</sub>* relates to the accomplishment of the product delivery schedule. The latter two indicators are estimated based on survey items “25” and “30” respectively. As depicted in Figure 4.7, the path coefficient of the relationship between the *Alignment of objectives* and the *Alignment-global* constructs is 0.827. This coefficient is higher than 0.8, thus confirming the convergent validity of the *Alignment of objectives* construct.

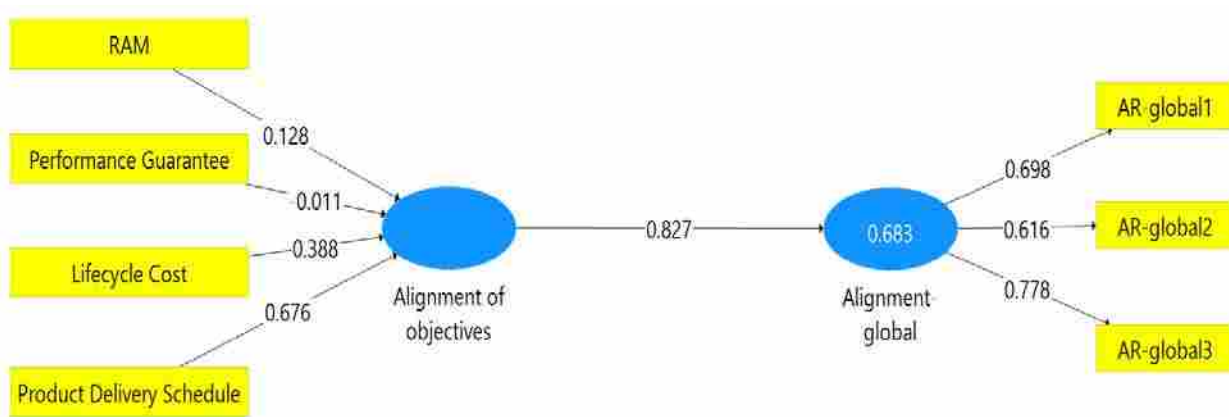


Figure 4.7: Redundancy model of the *Alignment of objectives* construct

Source: Developed for this research

In the present section, the validity of the variables of the structural model is assessed, where the validity is confirmed at both the indicator and the construct levels. Another evaluation criterion for the formative measurement model is to examine whether multicollinearity occurs among the formative indicators. The following section sheds light on the concept of multicollinearity, and the eight formative indicators of the “Effectiveness of EPC” structural model are evaluated accordingly.

#### 4.5.2.2 Multicollinearity assessment

In a formative measurement model, the problem of multicollinearity may occur if the formative indicators are highly correlated to each other. Such substantial correlations result in unstable estimates for the indicator coefficient  $\gamma_i$  in addition to difficulty in separating the distinct influence of individual indicators on their related construct (Diamantopoulos & Winklhofer, 2001; Mackenzie et al., 2005). The values of the Tolerance level and the Variance Inflation Factor (VIF) are often used to examine whether the multicollinearity problem occurs among the formative indicators of a given model. According to Hair et al. (2011), the Tolerance level is estimated as  $(1 - R^2)$ , where  $R^2$  refers to the coefficient of determination of the generated structural model. Additionally, the VIF is the reciprocal of the Tolerance value. As a rule-of-thumb, the multicollinearity problem is avoided if the VIF value of each formative indicator is less than or equal to 5 (i.e. the Tolerance value is 0.2 or higher). In particular, a VIF of 5 indicates that 80% of the indicator's variance is accounted for by the remaining formative indicators related to the same construct.

It is important to note that the SmartPLS statistical software does not provide these indices (Wong, 2013). For this reason, the SPSS statistical software was used instead to examine whether the problem of indicator collinearity exists among the formative indicators of the "Effectiveness of EPC" structural model. In this context, for each group of formative indicators related to the same construct, a secondary model has to be created using a single multiple regression. These formative indicators should be specified as independent variables, and any other indicator, which is not included in that specific

measurement model, should be considered as the dependent variable (Hair et al., 2013). In the “Statistics” window, the “collinearity diagnostics” option is checked before running the regression. The  $R^2$  of the secondary model is calculated, and the VIF values of the independent formative indicators are estimated accordingly. It is important to note that it does not matter which indicator serves as the dependent variable.

Given that the multicollinearity is assessed among the formative indicators related to the same construct, the assessment was conducted for the two formatively-measured constructs of the “Effectiveness of EPC” structural model. In this regard, the four formative indicators of the *End-user’s engagement* construct are evaluated as one block, whereas the other four indicators of the *Alignment of objectives* construct are assessed as another block.

Table 4.11 reports the Tolerance and VIF values for the four formative indicators of the *End-user’s engagement* construct, when the *RAM* formative indicator was specified as the dependent variable of the model and these four formative indicators as the independent variables. It is revealed that the VIF values for the four formative indicators are less than 5, indicating that the collinearity problem does not exist among the formative indicators of the *End-user’s engagement* construct. Even though it does not matter which indicator serves as the dependent variable, this exercise was repeated with all other indicators in the model. For instance, *Performance Guarantee* was specified as the dependent variable and the four formative indicators of the *End-user’s engagement* construct as the independent variables. Results show no collinearity issue among the indicators in all other cases as

well (i.e. all VIF values are less than 5). These results are presented in Appendix G (Table G.2 to Table G.4).

Table 4.11: The Tolerance and VIF values for the case of the *End-user's engagement* formative indicators

Secondary Model (Independent variables)	Collinearity Statistics	
	Tolerance	VIF
Studies and Strategies	0.428	2.335
Plant Layout	0.725	1.380
Engineering and Procurement	0.436	2.295
Construction and Commissioning	0.432	2.313

Dependent Variable: RAM

Source: Developed for this research

Regarding the four formative indicators of the *Alignment of objectives* construct, Table 4.12 shows the Tolerance and VIF values when the *Studies and Strategies* indicator was considered as the dependent variable of the model and these four indicators as the dependent variables. The results reveal that the VIF values for the four indicators are less than 5, indicating that the collinearity problem does not exist among the formative indicators of the *Alignment of objectives* construct. This exercise was repeated with other indicators as the dependent variable, where results show no collinearity problem in all other cases (see Table G.5 to Table G.7, Appendix G).

Table 4.12: The Tolerance and VIF values for the case of the *Alignment of objectives* formative indicators

Secondary Model (Independent variables)	Collinearity Statistics	
	Tolerance	VIF
RAM	0.531	1.884
Performance Guarantee	0.525	1.904
Lifecycle Cost	0.677	1.478
Product Delivery Schedule	0.527	1.898

Dependent Variable: Studies and Strategies

Source: Developed for this research

The reflectively-measured construct and the formatively-measured constructs having been evaluated individually, the next step involves the assessment of the inner structural model. In the present research, such model represents the *Effectiveness of EPC* higher-order construct (i.e. endogenous construct) with its two exogenous constructs (i.e. *End-user's engagement*, *Alignment of objectives*). The evaluation of the inner model is discussed in the subsequent section (section 4.5.3).

### 4.5.3 Inner structural model

In the present section, the inner structural model of the “Effectiveness of EPC” structural model is evaluated based on five main criteria. The first criterion, which examines the significance of the path coefficients of the exogenous constructs (i.e. dimensions of the higher-order construct), is evaluated in the following section (i.e. section 4.5.3.1).

#### 4.5.3.1 Significance of path coefficients

The path coefficient of an exogenous construct, as demonstrated by Hair et al., (2013), depicts the strength of the relationship with its associated endogenous construct. A coefficient close to (+1) indicates a strong positive relationship. The significance of such relationship can be tested using the bootstrapping procedure, discussed previously (section 4.5.1.2). A  $t$ -value of 1.96 or larger reveals the statistical significance at a 5% significance level (i.e.  $p$ -value  $< 0.05$ ). The inner structural path coefficients, given their statistical significance, can be interpreted relative to one another. In other words, if one path coefficient is larger than the coefficient of another path, its effect on the related endogenous construct is greater.

Regarding the two relationships between the *Effectiveness of EPC* endogenous construct and the *End-user's engagement* as well as the *Alignment of objectives* exogenous constructs, their  $t$ -values are 48.032 and 55.611, respectively. Both  $t$ -values are greater than 1.96, confirming that there is a strong statistical evidence, at a 5% significance level, to infer that the two dimensions positively influence the *Effectiveness of EPC* construct. The interpretations of the relative contribution of these two exogenous constructs on their endogenous construct are presented in section 4.6.2. The following section sheds light on the second evaluation criterion of the inner structural model.

#### 4.5.3.2 Coefficient of determination ( $R^2$ )

The coefficient of determination ( $R^2$ ) of the inner structural model is a measure that represents the model's predictive accuracy. It specifically measures the exogenous



constructs' combined effects on the endogenous construct (Hair et al., 2013). The  $R^2$  value ranges from 0 to 1, with higher level indicating higher level of predictive accuracy. In this regard, a value of 0.25 reveals a weak predictive accuracy, whereas 0.5 and 0.75 refer to moderate and substantial accuracy, respectively. As previously noted, the coefficient of determination of the "Effectiveness of EPC" structural model (i.e. Figure 4.4) is 0.848, thus revealing the substantial predictive accuracy of the inner structural model by the two exogenous constructs (i.e. *End-user's engagement*, *Alignment of objectives*). The following section focuses on the third evaluation criterion of the inner model, which is the effect size of the exogenous construct on the endogenous construct.

#### 4.5.3.3 $f^2$ effect size

While the path coefficient value depicts the relative contribution of an exogenous construct on its associated endogenous construct (i.e. higher or lower influence), the actual size of such contribution is reflected by the " $f^2$  effect size" measure. It, specifically, assesses an exogenous construct's contribution to an endogenous construct's  $R^2$  value. In this regard, the  $f^2$  measure is estimated based on the change in the  $R^2$  value when a specified exogenous construct is omitted from the model (Hair et al., 2013). Guidelines for assessing  $f^2$  are that values of 0.02, 0.15, and 0.35, respectively, represent small, medium, and large effects of the exogenous construct. It is important to note that the SmartPLS software does not estimate the actual  $f^2$  measure of exogenous constructs. As such, this measure should be computed manually based on Equation 2.

$$f^2 = \frac{(R_{\text{included}}^2 - R_{\text{excluded}}^2)}{1 - R_{\text{included}}^2} \quad (2)$$

where  $R_{\text{included}}^2$  and  $R_{\text{excluded}}^2$  are the  $R^2$  values of the endogenous construct when a selected exogenous is included in or excluded from the model.

Regarding the effect size of the *End-user's engagement* exogenous construct on the *Effectiveness of EPC* endogenous construct, the  $R_{\text{included}}^2$  represents the  $R^2$  value of the whole “Effectiveness of EPC” structural model that includes both exogenous constructs (i.e. *End-user's engagement*, *Alignment of objectives*). In order to estimate the  $R_{\text{excluded}}^2$  value, a separate PLS-SEM model was generated, in which the *End-user's engagement* exogenous construct is excluded and the *Alignment of objectives* exogenous construct is retained. Figure 4.8 depicts such model, where the  $R_{\text{excluded}}^2$  value, estimated by the SmartPLS software, is 0.775.

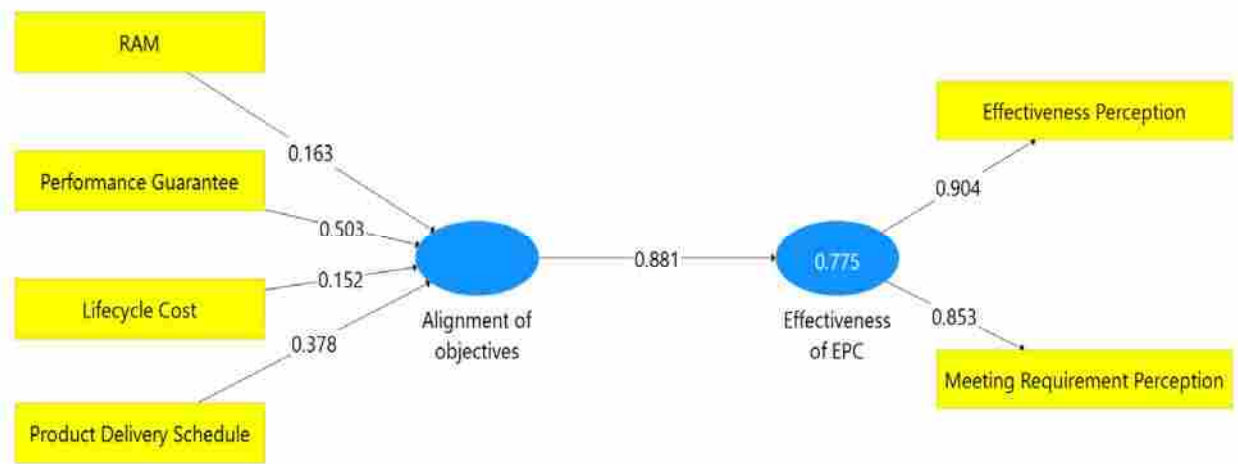


Figure 4.8: The estimated  $R^2$  upon the exclusion of the *End-user's engagement* exogenous construct

Source: Developed for this research

Having an  $R^2_{\text{included}}$  value of 0.848 (refer to Figure 4.4) and based on Equation 2, the  $f^2$  effect size of the *End-user's engagement* construct on the *Effectiveness of EPC* construct is 0.480. Such value indicates that the *End-user's engagement* construct has large effect size on its associated endogenous construct.

For the case of the *Alignment of objectives* exogenous construct, another PLS-SEM model was generated, in which the *Alignment of objectives* exogenous construct is excluded from the model. Such model is illustrated in Figure 4.9, where the  $R^2_{\text{excluded}}$  is estimated at 0.759. The  $R^2_{\text{included}}$  value is, as well, 0.848 (i.e. the  $R^2$  value of the whole structural model), thus leading to an  $f^2$  effect size of 0.585. As such, the *Alignment of objectives* exogenous construct has large effect size on the *Effectiveness of EPC* endogenous construct.

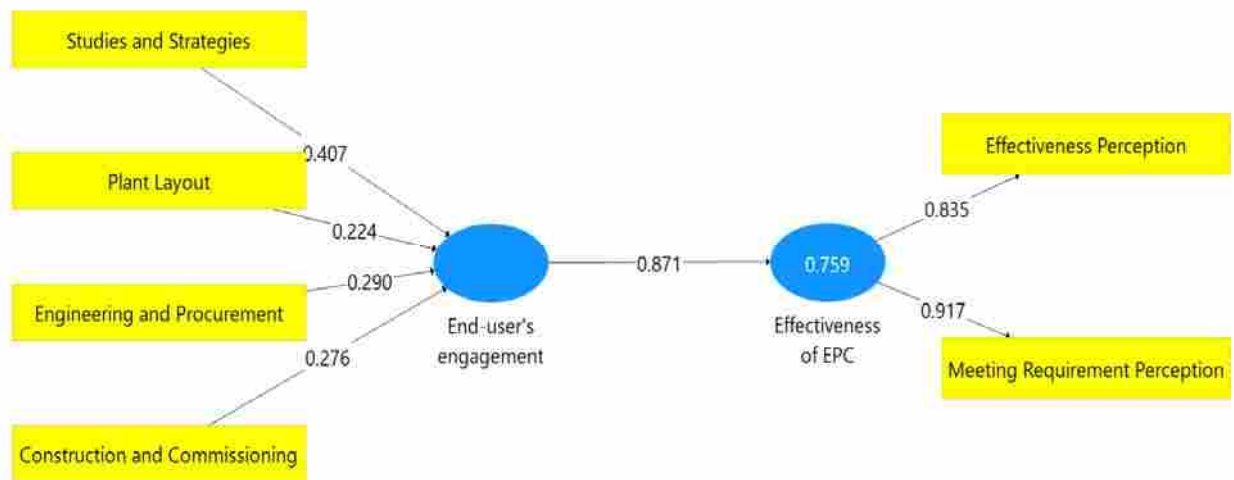


Figure 4.9: The estimated  $R^2$  upon the exclusion of the *Alignment of objectives* exogenous construct

Source: Developed for this research

Even though both the *End-user's engagement* and *Alignment of objectives* have large effect size on their associated endogenous construct (i.e. *Effectiveness of EPC*), the effect of *the latter* is larger than that of the former. The following section sheds light on the predictive relevance evaluation criterion.

#### 4.5.3.4 Predictive relevance ( $Q^2$ )

In addition to evaluating the magnitude of the ( $R^2$ ) values as a criterion of predictive accuracy, researcher should examine the model's predictive relevance (Hair et al., 2013). It is worth noting that the assessment of the predictive relevance is only applicable to reflectively-measured endogenous constructs (i.e. the procedure does not apply to formative endogenous constructs). The predictive relevance can be reflected based on the value of the "Stone-Geisser's  $Q^2$ " measure. The  $Q^2$  value is obtained using the blindfolding procedure for a certain omission distance (D). It is recommended to use a "D" value of 5 to 10, such that the division of the total number of observations by the "D" value does not result in an integer number. A  $Q^2$  value larger than zero for a certain reflectively-measured endogenous construct indicates the path model's predictive relevance for this particular construct. Figure 4.10 depicts the "Effectiveness of EPC" structural model after applying the blindfolding procedure, using the SmartPLS software. It is important to note that the "D" value was specified as "7" since the 170 (i.e. the total number of observations in the present research) does not yield an integer number when divided by this value.

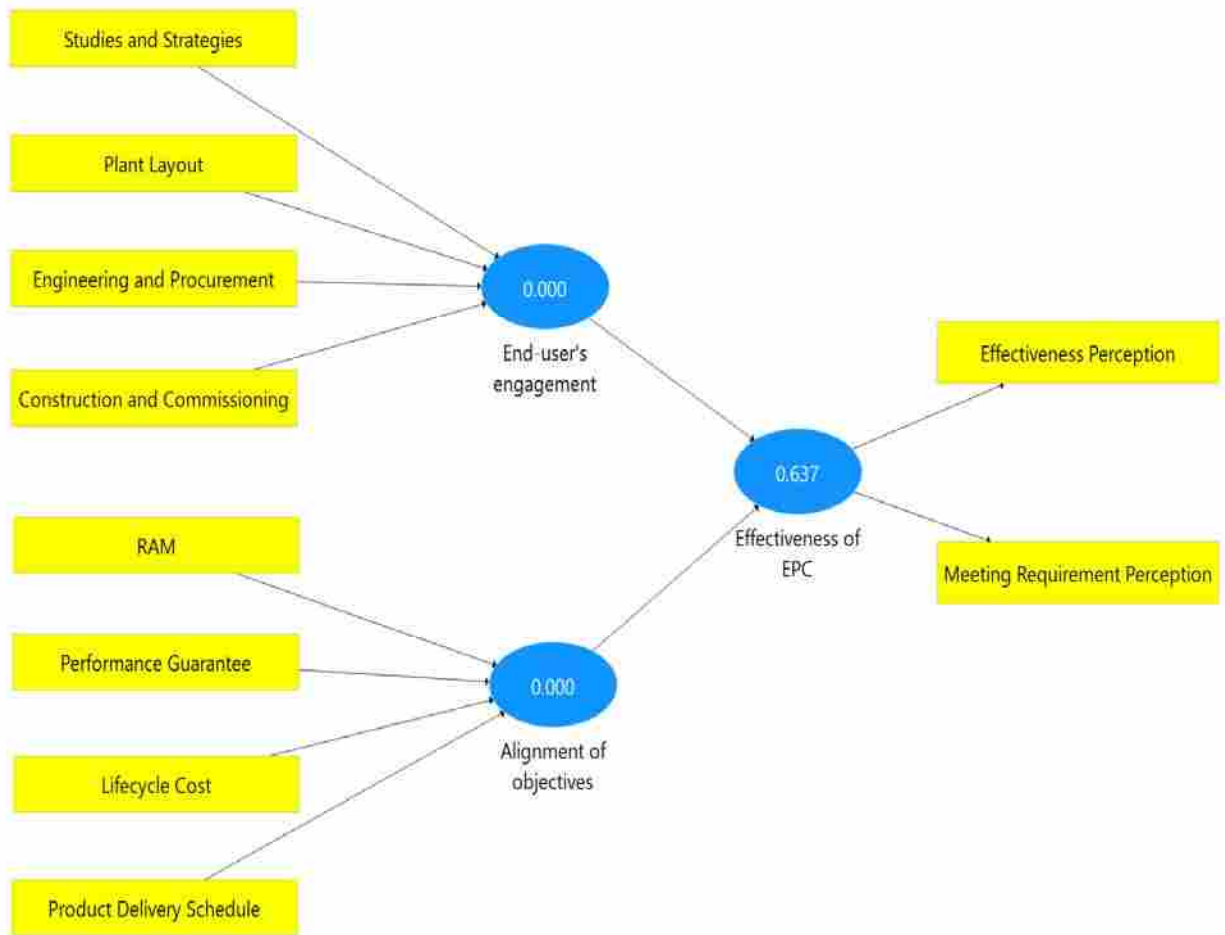


Figure 4.10: The blindfolding analysis ( $Q^2$ ) of the "Effectiveness of EPC" inner structural model

Source: Developed for this research

Figure 4.10 shows that the  $Q^2$  value for the "Effectiveness of EPC" inner structural model is 0.637. Such value is larger than zero, thus affirming the path model's predictive relevance for the *Effectiveness of EPC* reflectively-measured endogenous construct. The size of the relative predictive relevance of each exogenous construct for this endogenous construct is discussed in the following section.

#### 4.5.3.5 $q^2$ relevance size

The  $Q^2$  value, estimated by the blindfolding procedure, represents a measure of how well the path model can predict the originally observed values. The size of the relative impact of predictive relevance of each exogenous construct is reflected by the  $q^2$  effect size. Such measure is estimated based on the change in the  $Q^2$  value when a specified exogenous construct is omitted from the model. As a relative measure of predictive relevance, values of 0.02, 0.15, and 0.35, respectively, indicate that an exogenous construct has a small, medium, and large predictive relevance for its associated endogenous construct (Hair et al., 2013, 2011). Similar to the  $f^2$  effect size, the SmartPLS software does not estimate the  $q^2$  effect size measure. As such, it should be computed manually based on Equation 3.

$$q^2 = \frac{(Q_{\text{included}}^2 - Q_{\text{excluded}}^2)}{1 - Q_{\text{included}}^2} \quad (3)$$

where  $Q_{\text{included}}^2$  and  $Q_{\text{excluded}}^2$  are the  $Q^2$  values of the endogenous construct when a selected exogenous is included in or excluded from the model.

In order to estimate the  $q^2$  effect size value of the *End-user's engagement* exogenous construct, the  $Q_{\text{excluded}}^2$  value should be estimated. Such value represents the  $Q^2$  value of the *Effectiveness of EPC* endogenous construct when the *End-user's engagement* exogenous is excluded from the model. As such, a separate PLS-SEM model was generated (see Figure 4.11), in which the *End-user's engagement* construct is excluded, revealing a  $Q_{\text{excluded}}^2$  value of 0.580. The  $Q_{\text{included}}^2$ , on the other hand, is 0.637, which is the  $Q^2$  value estimated for the whole “Effectiveness of EPC” structural model. Using Equation

3, the  $q^2$  effect size value is 0.157, thus indicating that the *End-user's engagement* exogenous construct has medium predictive relevance for its associated *Effectiveness of EPC* endogenous construct.

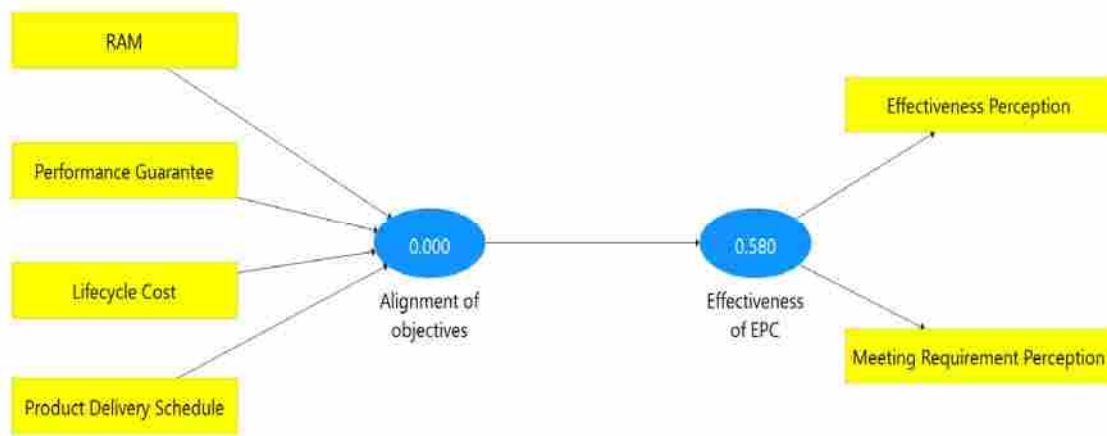


Figure 4.11: The estimated  $Q^2$  upon the exclusion of the *End-user's engagement* exogenous construct

Source: Developed for this research

Regarding the  $q^2$  effect size of the *Alignment of objectives* exogenous construct, another PLS-SEM model (depicted in Figure 4.12) was generated, as well, where this construct is omitted from the inner structural model. The application of the blindfolding procedure on this model reveals that the  $Q^2_{\text{excluded}}$  value of the *Alignment of objectives* exogenous construct is 0.553. Having a  $Q^2_{\text{included}}$  value of 0.637, the  $q^2$  effect size of the *Alignment of objectives* construct is 0.231, thus indicating that this exogenous construct has medium predictive relevance for its associated *Effectiveness of EPC* construct, where such relevance is higher than that of the *End-user's engagement* exogenous construct.

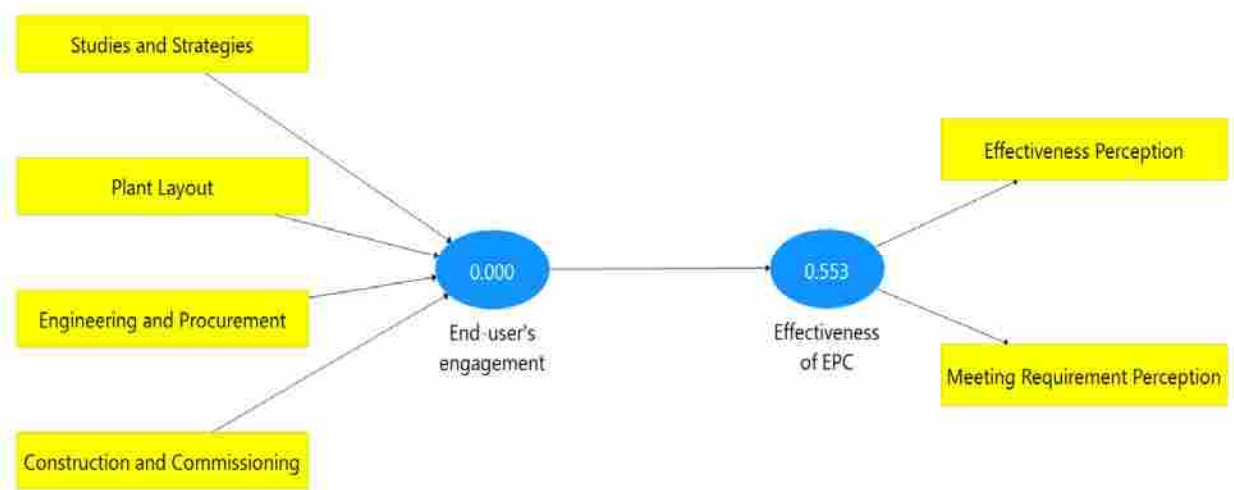


Figure 4.12: The estimated  $Q^2$  upon the exclusion of the *Alignment of objectives* exogenous construct

Source: Developed for this research

Based on the evaluation of the “Effectiveness of EPC” structural model, the reliability and the validity are confirmed, at both the indicator and construct levels. In addition, the multicollinearity analysis shows no collinearity problem among the formative indicators. Table 4.13 summarizes the results of the evaluation process of the reflectively-measured construct. The results of the assessment of the two formatively-measured constructs are summarized in Table 4.14. The assessment of the inner structural model reveals high significant contribution from its exogenous constructs, substantial predictive accuracy, and high predictive relevance. The results of such evaluation are summarized in Table 4.15.



Table 4.13: The results summary of the assessment process for the reflectively-measured construct

Reflectively-measured construct	Reflective indicator	Loading	Reliability assessment		Convergent validity		Discriminant validity	
			Indicator reliability	Composite reliability	Significance of loading?	AVE	Cross-loading ?	Fornell-Larcker criterion ?
<i>Effectiveness of EPC</i>	<i>End-user's engagement</i>	0.874	0.764	0.872	Yes	0.773	Yes	Yes
	<i>Alignment of objectives</i>	0.885	0.783		Yes		Yes	

Source: Developed for this research

Table 4.14: The results summary of the evaluation process for the formatively-measured constructs

Formatively-measured construct	Formative indicator	Weight	Convergent validity		Multicollinearity problem?
			Significance of weight?	Redundancy coefficient	
<i>End-user's engagement</i>	<i>Studies and Strategies</i>	0.395	Yes	0.894	No
	<i>Plant Layout</i>	0.235	Yes		
	<i>Engineering and Procurement</i>	0.297	Yes		
	<i>Construction and Commissioning</i>	0.272	Yes		
<i>Alignment of objectives</i>	<i>RAM</i>	0.167	Yes	0.827	No
	<i>Performance Guarantee</i>	0.532	Yes		
	<i>Lifecycle Cost</i>	0.138	Yes		
	<i>Product Delivery Schedule</i>	0.354	Yes		

Source: Developed for this research

Table 4.15: The results summary of the evaluation process for the inner structural model

Higher-order endogenous construct	Exogenous construct	Path coefficient	Significance of path coefficient	$R^2$	$f^2$ effect size	$Q^2$	$q^2$ effect size
<i>Effectiveness of EPC</i>	<i>End-user's engagement</i>	0.458	Yes	0.848	0.480	0.637	0.157
	<i>Alignment of objectives</i>	0.524	Yes		0.585		0.231

Source: Developed for this research

The initial assessment of the generated structural model indicates that the “Effectiveness of EPC” model findings are meaningful. The following section (section 4.6) sheds lights on these findings.

## 4.6 Analysis of the Structural Model

While the previous section assesses the “Effectiveness of EPC” structural model through evaluating its outer models as well as its inner structural model, the present section focuses on the analysis of this structural model. In this regard, the possible causal relationships, along with their related parameter estimates, are analysed, and concurrently the main model fit measure is interpreted.

### 4.6.1 Final “Effectiveness of EPC” structural model

The current section presents the final “Effectiveness of EPC” structural model (Figure 4.13), which meets all the assessment criteria. The interpretations of the causal

relationships, highlighted in the subsequent section, are based on such model. Recall that the coefficient of determination (i.e.  $R^2$ ) of this model is 0.848.

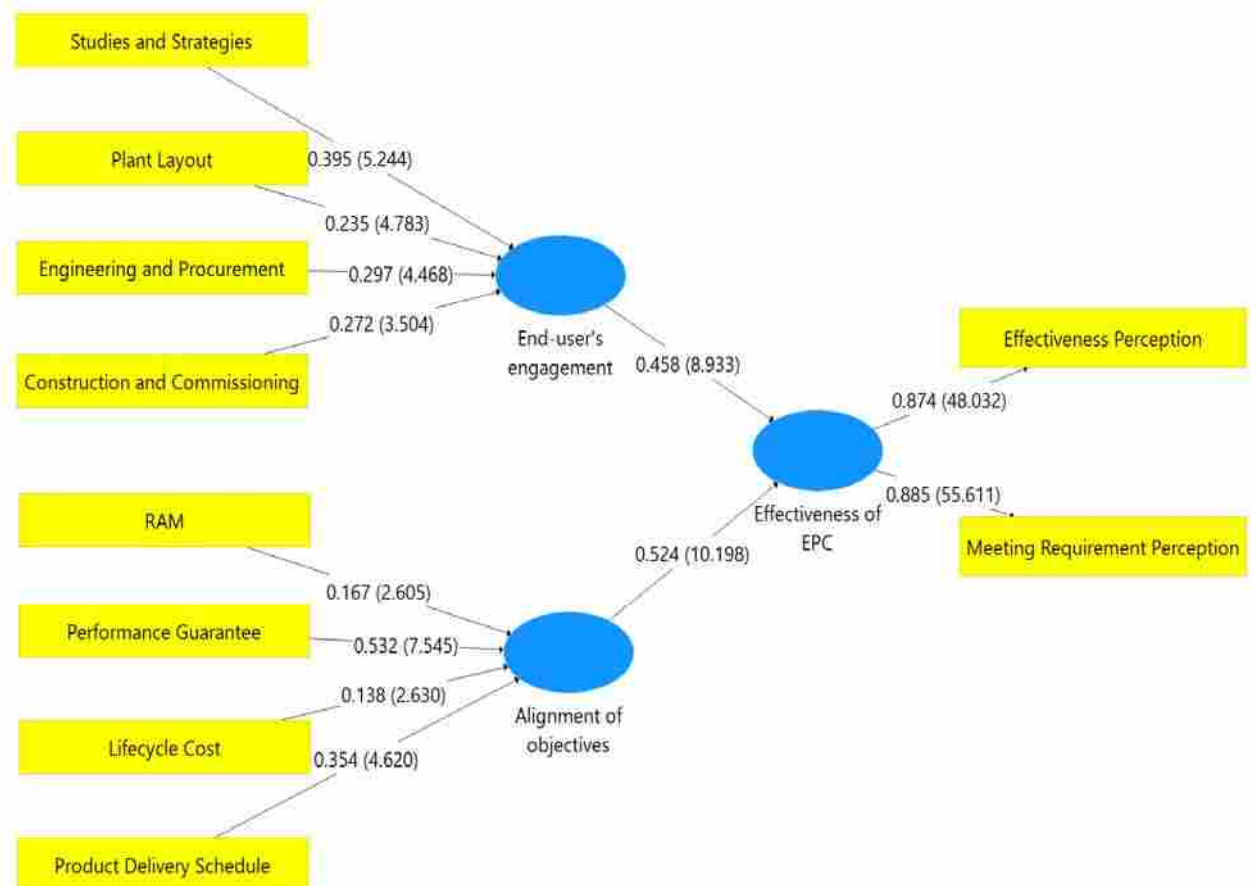


Figure 4.13: The "Effectiveness of EPC" structural model meeting all the assessment criteria, with  $t$ -values in parentheses

Source: Developed for this research

A deeper analysis of the causal relationships as well as more details regarding the model fit are provided in the two subsequent sections.

#### 4.6.2 Interpretations of causal relationships

The parameter estimates of the possible causal relationships and their statistical significance are analysed in the present section. The two research hypotheses ( $H_1$ ,  $H_2$ ) are, as well, tested.

As previously noted, three categories of relationship paths are shown in the “Effectiveness of EPC” structural model. The three categories that these relationships are grouped in, along with their estimates and significance values, are reported in Table 4.16. The  $t$ -values of the estimates are reflected in the parentheses of Figure 4.13. The structural model incorporating the  $p$ -values of the causal relationships is illustrated in Figure H.1 (Appendix H).

Table 4.16: Parameter estimates and significance values of the structural model

Relationship path	Parameter estimate	<i>t</i> -value	<i>p</i> -value
Between construct and its dimension			
<i>End-user's engagement</i> → <i>Effectiveness of EPC</i>	0.458	8.933	0.000
<i>Alignment of objectives</i> → <i>Effectiveness of EPC</i>	0.524	10.198	0.000
Between dimension and its formative indicator			
<i>Studies and Strategies</i> → <i>End-user's engagement</i>	0.395	5.244	0.000
<i>Plant Layout</i> → <i>End-user's engagement</i>	0.235	4.783	0.000
<i>Engineering and Procurement</i> → <i>End-user's engagement</i>	0.297	4.468	0.000
<i>Construction and Commissioning</i> → <i>End-user's engagement</i>	0.272	3.504	0.001
<i>RAM</i> → <i>Alignment of objectives</i>	0.167	2.605	0.009
<i>Performance Guarantee</i> → <i>Alignment of objectives</i>	0.532	7.545	0.000
<i>Lifecycle Cost</i> → <i>Alignment of objectives</i>	0.138	2.630	0.009
<i>Product Delivery Schedule</i> → <i>Alignment of objectives</i>	0.354	4.620	0.000
Between construct and its reflective indicator			
<i>Effectiveness of EPC</i> → <i>Effectiveness Perception</i>	0.874	48.032	0.000
<i>Effectiveness of EPC</i> → <i>Meeting Requirement Perception</i>	0.885	55.611	0.000

Source: Developed for this research

It is worth noting that the “Effectiveness of EPC” measurement model is conceptualized as a higher-order formative model. The outer loadings of the two reflective indicators (i.e. *Effectiveness Perception*, *Meeting Requirement Perception*) of the *Effectiveness of EPC* construct are 0.874 and 0.885, respectively. The *t*-values of these indicators, as illustrated in Table 4.16, are greater than 1.96, which in turn indicate that they are statistically valid to estimate the focal construct at a 5% significance level (i.e. *p*-value < 0.05). Hair et al. (2013) argues that the estimated values of the outer weights in formative measurement models are frequently smaller than the outer loadings of reflective indicators, which is the case of the structural model of the present research.

The statistical significance of the path coefficients of the two relationships between *Effectiveness of EPC* construct and its two dimensions (i.e. *End-user's engagement*, *Alignment of objectives*), as previously noted, was assessed based on the bootstrapping procedure. The path coefficients of the *End-user's engagement* and *Alignment of objectives* dimensions (i.e. first-order exogenous constructs) are 0.458 and 0.524 respectively. The *t*-values of both relationships are greater than 1.96, confirming that there is a strong statistical evidence, at a 5% significance level, to infer that the two dimensions positively influence the *Effectiveness of EPC* construct. The statistical significance of the positive coefficients of the two relationships thus indicate that the two research hypotheses (H<sub>1</sub>, H<sub>2</sub>), constructed in section 2.4, are supported.

The comparison of the two significant coefficients (i.e. relative importance) indicates that the *Alignment of objectives* (0.524) has higher contribution to the *Effectiveness of EPC* endogenous construct than the *End-user's engagement* (0.458). The size of such contribution, as discussed in section 4.5.3.3, is 0.585 for the *Alignment of objectives* construct and 0.480 for the *End-user's engagement* construct. Additionally, the size of their relative predictive relevance is 0.23 and 0.157, respectively, thus indicating that the highest predictive relevance for the *Effectiveness of EPC* construct is from its *Alignment of objectives* exogenous construct. As such, achieving the product success (i.e. end-user's requirements) necessitates the project management to first make the decision to maintain an alignment between the project objectives and the product objectives and then engage the end-user's team in various project phases to generate the main project deliverables.

Given the critical influence of both the end-user's engagement and the alignment of objectives on project effectiveness, it would be beneficial to examine the strengths of the influence of their causal factors and their statistical significance. Recall that the *End-user's engagement* dimension, as illustrated in Figure 4.13, has four influencing formative indicators including *Studies and Strategies*, *Plant Layout*, *Engineering and Procurement*, and *Construction and Commissioning*. The strengths of the influence of these factors, which are referred to as "outer weights", are 0.395, 0.235, 0.297, and 0.272, respectively. Table 4.16 shows that all these weights have *t*-values greater than 1.96, indicating that they are statistically significant at a 5% significance level. These four formative indicators can be relatively ranked based on their weights, which represent their statistical importance to the associated construct. In other words, the values of the outer weights can be compared with each other and can, therefore, be used to determine each indicator's relative contribution to the construct (i.e. relative importance). On the contrary, the outer loadings of reflective indicators do not represent any contributions to its associated reflectively-measured construct (Hair et al., 2013).

In this regard, the *Studies and Strategies* indicator has the highest contribution to the *End-user's engagement* construct, followed by the *Engineering and Procurement*, *Construction and Commissioning*, and *Plant Layout* indicators, respectively. These results are consistent with the literature review (conducted in chapter 2) and the responses of the open-ended question (section 4.3.2) highlighting the current practice regarding the end-user's involvement in Abu Dhabi's oil and gas industry. Both the MacLeamy curve and the participatory design concepts necessitate the participation of the end-user at early phases of design (i.e. starting from the planning stage) so as to alleviate the adverse impact

of design changes on project execution during the EPC phase (AEC, 2015; Balfour et al., 2012). The engagement of the end-user in various project phases, at both the development and the implementation stages, aids in identifying deficiencies and technical problems earlier in time. The recognition of these problems helps reduce the amount of design and construction changes during execution and consequently achieve smooth pre-commissioning and commissioning activities. As such, given that the end-user's involvement is crucial at the construction and commissioning phases, the engagement at the planning stage has higher importance, as it would definitely lead to better commissioning and handing-over.

The *Alignment of objectives* dimension, on the other hand, has four formative indicators, including *RAM*, *Performance Guarantee*, *Lifecycle Cost*, and *Product Delivery Schedule*. These indicators, as depicted in Table 4.16, are statistically significant at a 5% significance level. The indicators' outer weights indicate that the *Performance Guarantee* indicator (0.532) has the highest influence on the *Alignment of objectives* construct, followed by *Product Delivery Schedule* (0.354), *RAM* (0.167), and *Lifecycle Cost* (0.138) indicators, respectively. These findings are in agreement with the results of ranking analysis, conducted in section 4.3.1. The product quality objective (represented by both the *RAM* and *Performance Guarantee* indicators) has higher statistical importance than the other two objectives of meeting the product schedule and cost. In other words, achieving a plant facility with high-quality performance has a higher priority from the end-user's perspective. Such performance helps avoid undesirable operational problems that would result in a lack of resources and unnecessary expenditures from the end-user once the plant is in operation. In other words, the end-user is more favorable to quality as



compared to schedule and cost objectives, which might be due to the nature or requirement of the oil and gas industry to absorb large capital expenditures. Additionally, Adekalu and Ogunjimi (2003) argue that most of the spare parts for drills and machinery in the oil and gas industry are not easily available and are expensive. For this reason, the operational team is often very concerned with the quality of the products and services, as materials and equipment of high quality assures durability and low maintenance cost. Such findings are in agreement with the results of a study conducted by Sylvester, Abdul Rani, and Shaikh (2011), in which “quality” is found to be more important to the owners of the oil and gas companies, followed by time to completion and cost.

The ranking of the product objectives, based on the operational team’s priorities, is the inverse of that of project objectives as per the conventional project management triangle (also known as the “Iron triangle”). Recall that the project teams (i.e. PMT, PMC, contractors) mostly value the cost dimension of the project objectives followed by the schedule, where quality is considered the least influencing constraint in a project (Atkinson, 1999; Sylvester et al., 2011). Therefore, the project teams have to maintain an alignment between the project objectives and the product objectives so as increase the end-user’s satisfaction and consequently achieve product success. This alignment is depicted in Figure 4.14, where the “Project Management Triangle” represents the ranking of the project objectives based on the priorities of the project team, and the “Product Success Triangle” denotes the ranking of the product objectives as perceived by the end-user’s team. The peak of the triangle refers to the objective with the highest priority, whereas its base relates to the objective with the least priority. Figure 4.14 represents the

development of the alignment concept illustrated in Figure 3.3 (chapter 3), based on the findings of the present research.

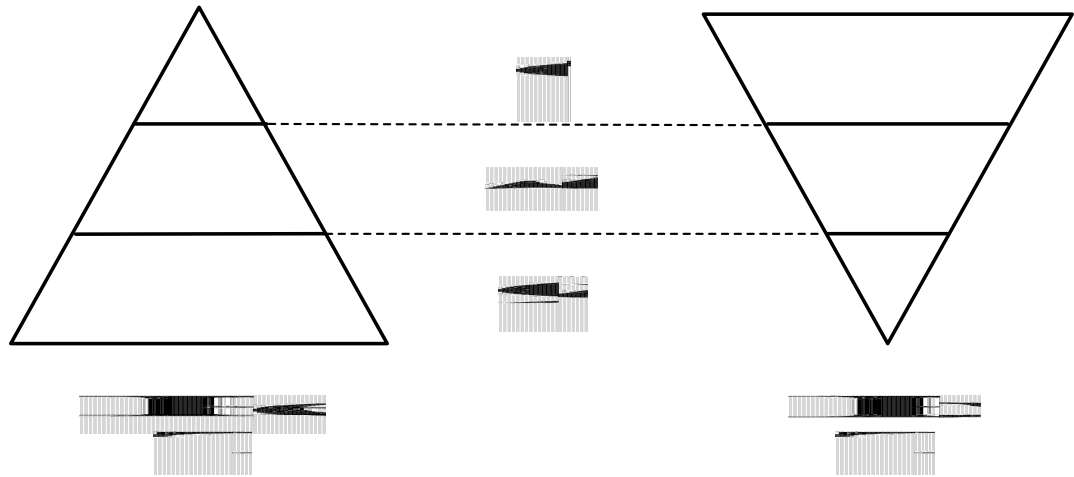


Figure 4.14: Synchronization between the “Project Management Triangle” and the “Product Success Triangle”

Source: Developed for this research

Based on the “Effectiveness of EPC” structural model, described in the present section, 1) factors affecting the project effectiveness are identified, 2) the strengths of influence of these factors are estimated, and 3) the statistical significance of these estimates are evaluated. The generated structural model thus serves as a guide for improving the project effectiveness and consequently meeting the end-user’s requirements. The interpretations of the model are useful for providing suggestions for enhancing the engagement of the end-user and attaining better alignment between the project objectives and the product objectives. These recommendations are further discussed in chapter 5 (section 5.3). It is important to note that the generalization of the findings, extracted from the analysis of the “Effectiveness of EPC” structural model, is

meaningful if the model is proved to fit the data. The subsequent section focuses on the assessment of the model fit measurement of the “Effectiveness of EPC” structural model.

#### **4.6.3 Model fit measurement**

For the case of PLS-SEM formative measurement, Henseler et al. (2014) and Mackenzie, Podsakoff, and Podsakoff (2011) argue that researchers can rely on the standardized root mean square residual (SRMR) measure to assess the goodness of model fit. The SRMR assesses the average magnitude of the discrepancies between observed and expected correlations as an absolute measure of model fit criterion. When compiling the structural model, the SmartPLS statistical software reports two outcomes, 1) the SRMR for composite model and 2) the SRMR for common factor model. The latter report is relevant to models consisting only of reflective measures, whereas the former can be used when having a formative measurement model. In this regard, an SRMR measure with a value of less than or equal to 0.08 is considered a good fit (Hair et al., 2011). For the “Effectiveness of EPC” structural model, the SRMR composite model measure is 0.059, indicating that the model adequately fits the data. As such, findings of the present research can be generalized to the level of Abu Dhabi’s oil and gas industry, where the recommendations provided based on these findings (section 5.3) are useful to improve the effectiveness of major oil and gas projects in that industry. The SRMR composite model correlation matrix, generated by the SmartPLS software, is illustrated in Table I.1 (Appendix I).

A further analysis was conducted on the collected data to investigate whether the causal relationships, assessed in the present section, differ among the three industries (i.e. refining, gas, petrochemical). The results of the assessment are presented in the following section, before stating recommendations for Abu Dhabi's oil and gas industry and describing the implications of this research for both theory and practice (discussed in chapter 5).

#### **4.7 Refining, Gas and Petrochemical Industries in Abu Dhabi**

The "Effectiveness of EPC" structural model, described in the previous section, shows that the relationships between the *Effectiveness of EPC* and the *End-user's engagement* and *Alignment of objectives* are statistically significant. The two research hypotheses, H<sub>1</sub> and H<sub>2</sub>, are therefore supported. In the present section, the third research hypothesis (H<sub>3</sub>) is tested in order to answer the second main research question. This question aims at examining whether the relationships between the *Effectiveness of EPC* and the two main criteria (i.e. *End-user's engagement*, *Alignment of objectives*) differ among the three industries (i.e. refining, gas, petrochemical) in Abu Dhabi.

Given that the data, collected in the present research, is ordinal (section 4.2.1), the one-way ANOVA test cannot be applied (Keller, 2011). The Kruskal-Wallis test (also known as "one-way ANOVA on ranks") is, however, suitable for ordinal data. Before conducting this test, the data have to meet four main assumptions. In addition to the requirement of compatibility with non-parametric data, the measurement scale has to be categorical/ordinal. The number of groups should be at least two, and the participants

cannot be present in more than one group (Keller, 2011; Laerd-Statistics, 2013b). In the present research study, 1) a 5-point Likert scale is used in the survey questionnaire, 2) three groups are available representing the refining, gas, and petrochemical industries, and 3) each survey respondent is working in only one industry, thus meeting all the aforementioned requirements.

In order to properly interpret the results from the Kruskal-Wallis test, the variability of the data in each group has to be considered. In other words, if the distribution of the data of the independent variable, for each group, has the same shape, then the test should be carried out to compare the “medians” of the dependent variable, else the “means” have to be compared (Laerd-Statistics, 2013b). As shown in Figure 4.15 (Panel 1), the distributions of data related to the *End-user’s Engagement* variable for the three groups have the same shape. Regarding the *Alignment of Objectives* variable, the distributions for the three groups have, as well, the same shape (Figure 4.15, Panel 2). As such, the “median” ranks have to be compared so as to test the third research hypothesis (i.e. H<sub>3</sub>). Additionally, it is important to realize that, because the data are ordinal, the Kruskal-Wallis test aims at determining whether the group “locations” differ instead of the group “means”. The null hypothesis and the alternative hypothesis are, therefore, defined as follows:

Null hypothesis (H<sub>0</sub>): The locations of all three groups are the same;

Alternative hypothesis (H<sub>a</sub>): At least two group locations differ.

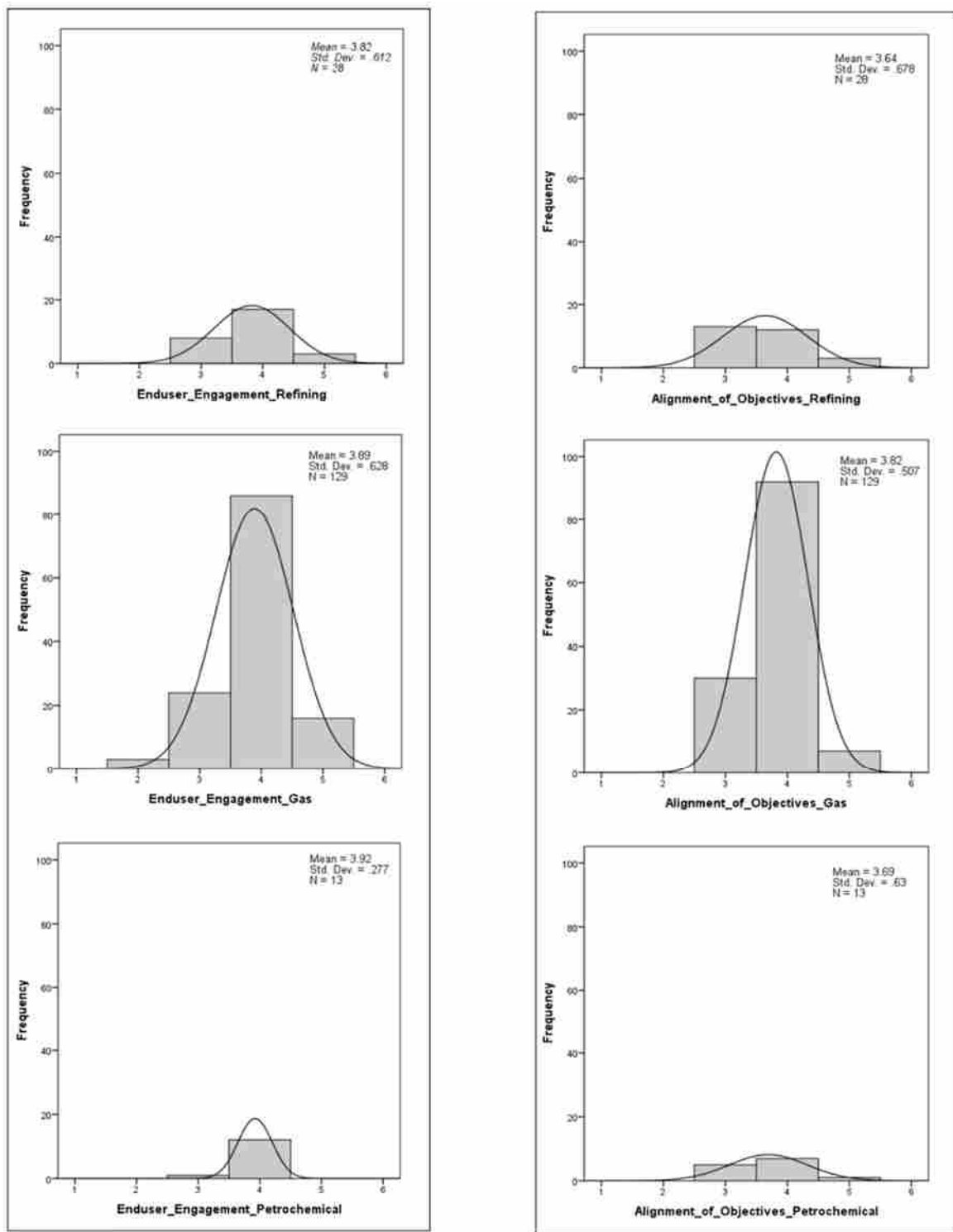
The Kruskal-Wallis test was conducted using the SPSS statistical software package. The results, detailed in Table 4.17, show that there is not enough statistical evidence (i.e.  $p > 0.05$ ) to infer that there exists a statistically significant difference among the three industries in Abu Dhabi, for both the “end-user’s engagement” and “alignment of objectives” criteria. Therefore, in both cases, the alternative hypothesis is rejected, and the null hypothesis is accepted. These findings might be due to the fact that the targeted companies in the three industries do adopt the same overall project systems and procedures, as they all belong to the ADNOC group of companies.

Table 4.17: The statistical significance results of the Kruskal-Wallis test

	<i>End-user’s engagement</i>	<i>Alignment of objectives</i>
<b>N</b>	170	170
<b>Median</b>	4.00	4.00
<b>Chi-Square</b>	1.837	1.098
<b>df</b>	2	2
<b>Asymp. Sig.</b>	.399	.578

Grouping Variable: Project\_Type

Source: Developed for this research



Panel 1

Panel 2

Figure 4.15: The distributions of the data among the three industries for 1) *End-user's engagement* and 2) *Alignment of objectives*

Source: Developed for this research

## 4.8 Conclusion

In the present chapter, a deeper insight into the current practice regarding the end-user's involvement and the achievement of the product objectives, in Abu Dhabi's major oil and gas projects, was provided. The need for improving the project effectiveness in Abu Dhabi's oil and gas industry was accordingly justified. The "Effectiveness of EPC" structural model was generated based on the partial least squares structural equation modeling (PLS-SEM) statistical technique. Based on the evaluation of the reflectively-measured construct, one of the reflective indicators was eliminated from the structural model. The two formatively-measured constructs were, as well, assessed, at both the indicator and the construct levels. The statistical significance of the relationships between the "Effectiveness of EPC" variable and its causal factors (i.e. End-user's engagement, Alignment of objectives) were analysed. The research hypotheses were then tested, and both hypotheses ( $H_1$ ,  $H_2$ ) were statistically supported. The model fit measurement was examined, where the generated structural model was proved to be adequately fitting the data. The generalization of the research findings to the level of Abu Dhabi's oil and gas industry was thus justified. A further analysis was conducted on the collected data to investigate whether a statistical difference exists among the three industries (i.e. refining, gas, petrochemical) regarding the relationships between the "Effectiveness of EPC" variable and its causal factors. The third research hypothesis was statistically rejected.

The research findings are useful for providing suggestions for improving the engagement of the end-user and attaining better alignment between the project objectives and the product objectives, in Abu Dhabi's oil and gas industry. In chapter 5 (conclusions



and recommendations), the findings presented in chapter 4 are summarized, and the recommendations are further discussed. The implications of this research for both theory and practice are then highlighted.

## Chapter 5: Conclusions & Recommendations

### 5.1 Introduction

The data analysis process, consisting of both descriptive statistics and inferential statistics, was described in chapter 4. The “Effectiveness of EPC” structural model helped assess the statistical significance of the causal relationships, and the research hypotheses were consequently tested. The generated structural model was proved to fit the data, thus confirming the generalization of the research findings to the level of Abu Dhabi’s oil and gas industry.

The main research findings, extracted from the literature review as well as the interpretations of the collected data, are summarized in the present chapter (section 5.2). Based on these findings, recommendations regarding the end-user’s engagement and the alignment of objectives, for Abu Dhabi’s oil and gas industry, are derived (section 5.3). These recommendations are useful for improving the project effectiveness at the site level.

The research implications, constituting of both theoretical and practical implications, are articulated and discussed (section 5.4). The limitations of the present research are highlighted (section 5.5), and recommendations for further investigation in the area of project effectiveness in the oil and gas industry are accordingly proposed (section 5.6). The design of chapter 5 is further illustrated in Figure 5.1.

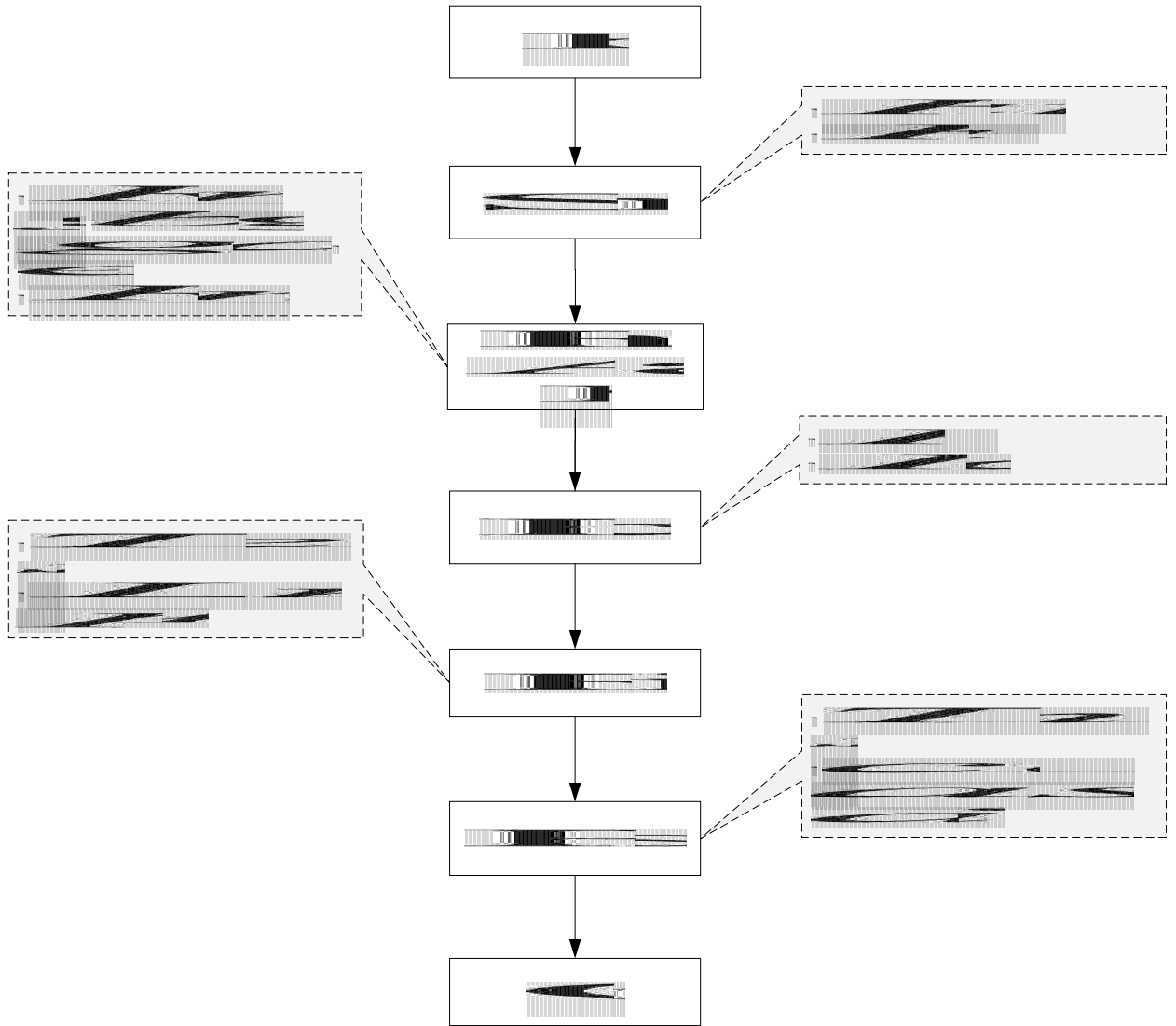


Figure 5.1: The design of chapter 5

Source: Developed for this research

## **5.2 Summary of Findings**

The main research findings are summarized in the present section. The literature review conducted in chapters 2 and 3 provides valuable findings (section 5.2.1). These findings relate to 1) previously published research relevant to project effectiveness in the oil and gas industry, 2) the research philosophical platform, and 3) the empirical research process. Other key findings derived from the data analysis process, carried out in chapter 4, are presented in section □.

### **5.2.1 Findings from the literature review**

A literature review was conducted in both chapters 2 and 3. The review carried out in chapter 2 aims at investigating previously published research relevant to the topic of interest so as to identify gaps that requires further investigation. In this context, it was found that:

- The oil and gas industry specialists are currently under pressure to promote more effective strategic planning for the purpose of achieving the success of major projects in such an ever-growing industry. Main challenges for the industry include 1) technological challenges in which recovering hydrocarbons from sources is more difficult to achieve than ever before, 2) being cost-effective in a market already impacted by over-supply, and 3) competition from unconventional energy sources.

- Project success is illustrated through the achievement of the short-term project objectives (i.e. project efficiency) as well as the long-term product objectives (i.e. project effectiveness).
- The efficiency of EPC contracting strategy in achieving project objectives from the owner's and the contractor's perspectives has been widely discussed and evaluated in literature. However, its effectiveness in accomplishing product objectives has still not been comprehensively examined from the end-user's perspective.
- The identification of factors that affect the effectiveness of EPC as well as the causal relationships between respective factors is crucial to the improvement of project effectiveness.
- The involvement of the end-user in various project phases and the alignment between project objectives and product objectives are potential factors for the achievement of product success.
- Traditional project management is still reluctant to adequately acknowledge the engagement of end-users in various project phases, due to either the false preconception of challenging the achievement of short-term objectives or the ineffective communication with the end-user's team.

The empirical research requires a linkage between practice and theoretical concepts so as to identify the appropriate research strategy, paradigm and methodology within which to conduct the research. The literature review conducted in chapter 3 sheds light on such a philosophical research platform, revealing that:

- There are four distinct research strategies, including inductive, deductive, retroductive and abductive, where each strategy starts with a different point leading to the desired research objective. The logic behind these strategies is illustrated using a “table” structure (see Table 3.1), which helps gain better understanding of the differences between these types.

There are three key paradigms (i.e. positivism, realism, phenomenology), which differ based on three distinguishing philosophical assumptions of social reality, including ontology, epistemology and methodology. Quantitative, qualitative and mixed-method techniques are the three main methods for conducting the research. The characteristics of the three paradigms are tabulated according to the aforementioned basic assumptions (see Table 3.2), thus providing a clearer picture into the differences between them.

The literature review conducted in chapter 3, as well, provides insight into the empirical research process followed to generate a statistical model that assesses the significance of the causal relationships. In this regard, it was demonstrated that:

- The research process starts with the “conceptualization” stage, proceeds towards the “model identification”, “operationalization”, and “assessment of the survey scale” stages, and ends with the “data collection” and “data processing” stages.

- The conceptualization stage involves the definition of the construct and its possible indicators in addition to the specification of the conceptual relationships between them, the so-called “direction of causality”.
- There are two types of conceptual models, reflective and formative. In the reflective measurement model, measures (i.e. indicators) represent effects (also known as manifestations) of the construct, and the causality is from the construct to its measures. In the case of the formative model, measures are causes of a construct rather than its effects, where the causality is from the measures to the construct. A construct, by itself, could represent either a manifestation of another construct (the case of the reflective measurement model) or a distinct facet of another construct’s domain (the case of the formative model). In such a case, the former construct is defined as a dimension of the latter, forming a multi-dimensional measurement model. The “Effectiveness of EPC” measurement model, developed in the present research, is formative first-order formative second-order.
- Given that the model identification has to be considered to estimate the formative measurement model, the application of the 2+ emitted paths rule is recommended. This rule requires the release of at least two paths from the formative construct in question to other reflective constructs or indicators. In this context, three reflective indicators were added to the “Effectiveness of EPC” measurement model for identification purpose.

- In the operationalization stage, the level of measurement (i.e. data type) is identified, and subsequently measures are formulated into instruments (i.e. actual research questions).
- Data processing involves cleaning and preparing data for analysis by removing outliers, handling incomplete responses, and combining multiple responses into one variable required for analysis.

### **5.2.2 Findings from data analysis**

During the data analysis process, conducted in chapter 4, the ranking analysis applied on the quantitative data (from the closed-ended questions) as well as the interpretations of the qualitative data (from the open-ended question) provided a deeper insight into the current practice regarding the engagement of the end-users and the accomplishment of their objectives, in Abu Dhabi's major oil and gas projects. In this aspect, it was revealed that:

- The highest involvement of the end-user is in the EPC phase, for the purpose of conducting pre-commissioning and commissioning activities as well as reviewing/finalizing main project deliverables. The least involvement, on the other hand, is in the Pre-FEED phase, specifically during the selection of the project execution and commissioning strategies in addition to the development of the EPC contracting strategy.



- Even though achieving the desired product objectives in relation to the delivery schedule and cost is essential to meet the end-user's requirements, achieving a plant facility with high-quality performance is of higher importance to the end-user's team. For this reason, more efforts have to be made, in Abu Dhabi's major oil and gas projects, to improve the quality of the handed-over facility and accordingly increase the end-user's satisfaction.
- The examination of the current practice regarding the end-user's participation and the achievement of the product requirements confirmed that there is still a considerable need to improve the effectiveness of major projects in Abu Dhabi's oil and gas industry. Having a structural model was derived as a possible way for such improvement. The partial least squares structural equation modeling (PLS-SEM) statistical technique was used to generate the "Effectiveness of EPC" structural model relating the "Effectiveness of EPC" construct with its causal factors (i.e. End-user's engagement", Alignment of objectives). Before analyzing the generated structural model, the outer reflectively-measured and formatively-measured constructs, in addition to the inner structural model, were assessed. The main evaluation criteria and their related guidelines were summarized in a "table" structure (Table 4.6 and Table 4.7), thus shedding light on the critical steps that should be followed when assessing PLS-SEM models. The interpretations of the causal relationships and their statistical significance indicated that:
  - The *Alignment of objectives* has higher influence on the *Effectiveness of EPC* than the *End-user's engagement*. As such, achieving the product success (i.e. end-

user's requirements) necessitates that project management first make the decision to maintain an alignment between the project objectives and the product objectives and then engage the end-user's team in various project phases to generate the main project deliverables.

- The analysis of the statistical significance of the causal factors of the *End-user's engagement* variable reveals that the *Studies and Strategies* indicator has the highest statistical influence, followed by the *Engineering and Procurement*, *Construction and Commissioning*, and *Plant Layout* indicators, respectively. Such findings confirm the necessity to involve the end-user at early phases of design (i.e. starting from the planning stage) so as to alleviate the adverse impact of design changes on project execution during the EPC phase.
- Regarding the *Alignment of objectives* dimension, it was found that the product quality objective (represented by both the *RAM* and *Performance Guarantee* indicators) has higher statistical importance than the other two objectives of meeting the product schedule and cost. In other words, achieving a plant facility with high-quality performance has a higher priority from the end-user's perspective. Accordingly, a "Product Success Triangle" was constructed, which depicts the ranking of the three product objectives, based on the priorities of the end-user's team as identified from the interpretations of the structural model.

Given that the "Effectiveness of EPC" structural model was proved to fit the data, findings of the present research can be usefully generalized to the level of Abu Dhabi's

oil and gas industry. Accordingly, the recommendations provided based on these findings, presented below in section 5.3, are useful to improve the effectiveness of major oil and gas projects in Abu Dhabi.

### **5.3 Recommendations for Abu Dhabi's Oil and Gas Industry**

It is interesting to note that the survey respondents provided various recommendations, through the open-ended question (i.e. question 35, Part 2), so as to enhance the end-user's engagement and increase the chance of accomplishing the product objectives. In this regard, the present section constitutes of two sets of recommendations. The first set is derived from the respondents' feedback on this question as well as the interpretations of the "Effectiveness of EPC" structural model accomplished in chapter 5 (section 4.6). The other set of recommendations are extracted from the literature review conducted in chapter 2. All of these suggestions provide best practices that can be followed to achieve proper participation and alignment of objectives, and subsequently enhance project effectiveness.

#### **5.3.1 Recommendations from research findings**

The suggestions listed below represents the set of recommendations derived from the open-ended question and the interpretations of the generated structural model.

- The project management and the end-user's team should be aware that objectivity and realism are key requirements for exerting effective communication and collaboration at the site level.

- The end-user's team should be qualified and competent so as to challenge the project teams to ensure the achievement of the desired end-results. Even though the end-user's suggestions are known to be significant for reducing reworks and facilitating the hand-over of the facility, project teams should also be qualified enough to appraise whether these suggestions are actually needed in the project. For this reason, the high level of competency of both the project teams and the end-user's team plays a significant role in improving the project efficiency as well as the project effectiveness.
- Based on the significant role of in-house experience in achieving both the project and product objectives, developing and maintaining in-house core competencies in project management, engineering, operations, and project controls is crucial for improving the effectiveness of the EPC approach. Such an in-house core team may be augmented by external resources as needed.
- In contrast to current false preconceptions, project management should be aware that spending sufficient time during the pre-FEED and FEED project phases improves project execution and facilitates testing and commissioning activities, as the project success highly depends on how the FEED phase was completed. As such, the end-user's approval should be considered to proceed from the FEED phase to the EPC phase.
- In line with the importance of in-house expertise and the critical impact of Pre-FEED and FEED phases on the whole project lifecycle, the Pre-FEED and FEED consultants have to be primarily selected on the basis of technical considerations.

In this regard, it would be beneficial to enter into long-term alliances and partnerships with a few competent consultants. Such alliances would help 1) retain in-house expertise and knowledge, 2) capture the lessons learned from previous projects, 3) save the time spent for the tendering and evaluation of Pre-FEED and FEED consultants for individual projects, and 4) instill a sense of ownership and commitment in consultants and contractors. The Pre-FEED and FEED partners can be engaged as the PMC for the EPC phase so as to benefit from their valuable experience in the project development stage. Such engagement would, in turn, help avoid the possibility of bidding for the EPC, thus eliminating an obvious conflict of interest and consequently delivering better quality in an EPC environment.

- The end-user's team should examine and approve the appropriateness of materials, equipment and licensed technologies so as to avoid the consequences of undesirable operational difficulties after the hand-over of the facility. In this regard, the end-user should be fully involved in the revision of 1) the approved project vendor lists (PVL) before they are included in the contract, 2) the pre-qualification submissions of new vendors if proposed by the EPC contractor, and 3) the technical bid evaluation reports submitted by the EPC contractor prior to actual selection.
- In order to ensure a smooth hand-over of the plant facility, the end-user's team should participate in the pre-commissioning and commissioning activities of the EPC phase, and the spare parts list has to be submitted and reviewed at early stages prior to commissioning.

- The consideration of the end-user's suggestions has to be incorporated into the FEED and EPC specifications so as to ensure capturing of relevant in-house experience that FEED and EPC contractors usually lack.
- Given that the product quality has the highest significant influence on meeting the end-users' requirements and consequently increasing their satisfaction, project management should not compromise the quality of the end-product in order to meet the project schedule. For this reason, having a PMT/PMC with an operational expertise is critical for attaining a plant facility with high-quality performance criteria. Being aware of the importance of the product quality would encourage the project management to maintain an appropriate alignment between the project objectives and the product objectives.
- Due to the significance of product quality for enhancing the project effectiveness, the examination and approval of the project vendor lists shall be based on rigorous technical evaluation, without being over-driven by commercial considerations.
- A separate team has to be embedded within the PMT to ensure proper participation for the end-user's team in various project phases. The goal of such a team is to achieve a proper alignment between the project objectives and the end-user's requirements.
- A "Post Implementation Review" has to be initiated by both the project and the end-user's management so as to assess the level of success of the project after it has been executed, from both the technical and economic aspects. Potential

opportunities for added-value modifications and debottlenecking can consequently be identified.

- Projects should not be awarded to the lowest technically acceptable bids so as to alleviate the adverse impact on the project quality. Instead, the selection of the successful bidder should be based on the techno-commercial bid evaluation process. This process should be conducted with complete transparency and objectivity, due to its criticality in the decision process. The evaluation process allows for the opportunity of selecting a better bidder considering his technical evaluation results as well as the value for money. In this regard, the quality delivered in an EPC environment can be improved through various means, such as 1) improving the quality of the design and specifications during the FEED phase, 2) critically reviewing the vendor lists to ensure that only those of high competency are included, and 3) critically evaluating potential bidders prior to their inclusion in the EPC bidders list. It is worth noting that the techno-commercial selection process shall not only be considered in the EPC phase but also more importantly in the Pre-FEED and FEED phases due to the potential impact of the two latter phases on service quality despite their low contract values.
- Given the nature, complexity, and the extensive implementation duration of the major oil and gas projects, in addition to the rapid pace of technological advancement, the owner should allow for some flexibility in relation to the project schedule and cost. This flexibility would help accommodate the end-user's genuine requirements, enhance the longevity of the projects, and consequently

result in product success. On the other hand, given the potential impact of changes during the EPC execution phase on the project schedule and cost, both the project teams and the end-user's team should resist the temptation to make changes during that phase, unless dictated by safety or other critical reasons. For this purpose, both teams have to ensure that most, if not all, requirements are captured during the FEED phase. If any legitimate changes still have to be made during the EPC phase, the impact of such changes can be minimized by: 1) taking the decision to implement the changes as early as possible in the EPC phase and 2) forming an empowered management committee to review, challenge, and approve the proposed changes in an expeditious manner.

### **5.3.2 Recommendations from literature**

In addition to the aforementioned set of recommendations, other suggestions are provided based on the literature review conducted in chapter 2. These suggestions are presented below:

- Project management should be aware that managing the end-user's participation is essential for achieving the benefits of such an involvement. The utilization of an end-user project coordinator, as recommended by Pemsal et al. (2010), is a useful means for properly managing the engagement of the end-user's team. The coordinator can help raise the awareness towards the advantages of the end-user's involvement as well as provide sufficient support during the participation, which in turn helps achieve effective communication between the project stakeholders.



- Project management should also be aware that meeting the short-term objectives is not enough to ensure the desired project results. The achievement of the end-user's requirements is, as well, necessary for bridging the gap between project objectives and product objectives so as to gain a competitive advantage. For this reason, it would be beneficial to apply Villachica et al.'s (2004) recommendation in carrying out "alignment meetings" on a regular basis. Representatives of PMT, PMC, FEED Engineer, EPC contractor, and the end-user's team have to attend so as to review the project objectives and the alignment requirements. Such close interaction between the project parties would reduce negative attitudes and disappointments, leading to more effective engagement, better alignment, and higher satisfaction.

#### **5.4 Research Implications**

A key required outcome of the present research is a greater understanding of the "effectiveness" concept in order to 1) provide the researchers with better knowledge of the project effectiveness and 2) assist the oil and gas industry practitioners to perform with a greater degree of success at the site level through achieving both project and product objectives (section 1.5). The identification of the critical factors affecting the project effectiveness and the assessment of their influences are thus crucial for achieving such an objective. In this context, this research study, being the first known research evaluating the influence of both the "end-user's engagement" and "alignment of objectives" criteria on the project effectiveness, provides several contributions to literature (section 5.4.1) and practice (section 5.4.2). Therefore, the dissemination of main research findings, discussed

in section 5.4.3, is useful for enhancing the project effectiveness in Abu Dhabi's oil and gas industry and consequently achieving higher end-user's satisfaction.

#### **5.4.1 Implications for theory**

Based on a comprehensive literature review, a deeper understanding of the definition of the project success is gained, detailing both the project efficiency (i.e. short-term objectives) and the project effectiveness (i.e. long-term objectives). Accordingly, two main criteria (i.e. end-user's engagement, alignment of objectives) are identified as possible factors for achieving the project effectiveness illustrated through meeting the product success (section 2.3.1).

A flowchart depicting main project activities (Figure 2.10), which necessitate the involvement of the end-user for the generation of key project deliverables, was constructed. These activities span various project phases at both the development and the implementation stages. The categorization of these activities helps identify the main factors that shape the conceptual domain of the "end-user's engagement" and "alignment of objectives" criteria in the oil and gas industry. A conceptual measurement model for the "effectiveness" phenomenal concept was consequently developed (Figure 3.5), which in turn provides a theoretical foundation for researchers interested in examining such concept.

Shedding light on the activities that entail the end-user's involvement also assisted in the development of measurement instruments, which were used for the operationalization of the entire conceptual measurement model including the three phenomenal constructs

(i.e. engagement, alignment, effectiveness). A table linking each influencing factor with its related instruments and technical descriptions, was developed. This operationalization table (Table 3.3), having been reviewed and approved by oil and gas industry experts, provides a valuable source of information to researchers specifically interested in evaluating the effectiveness of oil and gas projects.

The present research provides literature with an empirical example of employing formatively specified constructs in the field of project management. Such a contribution is pointed out as a need by Henseler et al. (2014) and Reinartz et al. (2004), as the vast majority of researchers engaging in measure development use reflective indicators. The prevalent lack of applications is due to 1) the unawareness towards the suitability of formative measures to operationalize specific constructs (Hair et al., 2011) or 2) the lack of knowledge on how to incorporate formative indicators into structural equation models (Hitt, Gimeno, & Hoskisson, 1998; Podsakoff et al., 2006). This research study provides in depth data on three formative constructs in relation to their conceptualization, identification, operationalization, validation, and estimation. Therefore, it raises the awareness towards the potential appropriateness of formative indicators for operationalizing particular constructs, which consequently improves the quality of research.

### 5.4.2 Implications for practice

The present research raises the awareness of the oil and gas industry practitioners towards the influencing factors of “effectiveness”, “engagement” and “alignment” concepts. By shedding light on the strength of influence of each causal factor along with its statistical significance, the “Effectiveness of EPC” structural model serves as a “motivation” tool for acknowledging the end-user’s participation in various project phases during both the development and the implementation stages. The negative influence of the false preconceptions on the project management decisions will be reduced. Additionally, the industry practitioners will be encouraged to think and act more strategically towards maintaining a proper alignment between project objectives and product objectives for the purpose of improving the project effectiveness and gaining a competitive advantage. The “Product Success Triangle” (Figure 4.14), constructed based on the findings of the present research, provides a useful means for achieving a successful synchronization between both objectives through improving the quality of the end-product.

This study, as well, provides an insight into the current practice regarding the end-user’s involvement as well as a set of recommendations derived from the survey participants’ responses to the open-ended question. The project management of Abu Dhabi’s oil and gas major projects can thus gain a clearer picture of the end-user’s perceptions and concerns. Such feedback is useful for alleviating the impact of ineffective communication among the project parties. Additionally, the best practices, presented in the previous section, offer useful guidance for properly 1) managing the end-user’s

participation, 2) maintaining better synchronization between project objectives and product objectives, and 3) increasing the end-user's satisfaction.

The "Effectiveness of EPC" PLS-SEM model, proposed in the present research, is not only applicable to Abu Dhabi's oil and gas industry, from which data is collected. It can also be adopted by regional and other countries interested in improving their oil and gas industry's performance. Additionally, other industries, such as Water and Electricity, Aluminium and Steel, and any other businesses that employ EPC contracts, can benefit from the proposed "Effectiveness of EPC" model. By incorporating their industry-specific data, the structural model reflecting actual estimates along with the statistical significance values can be then generated. Industry-specific findings can be consequently used to recommend best practices for the improvement of the industry's performance.

### **5.4.3 Dissemination of research findings**

As previously discussed, the examination of the current practice regarding the end-user's participation and the achievement of the product requirements confirmed that there is still a considerable need to improve the effectiveness of major projects in Abu Dhabi's oil and gas industry. The dissemination of the research findings, along with the recommended best practices, would be helpful for improving the current practice regarding the involvement of the end-user's team as well as the alignment between project and product objectives.

In this regard, a copy of the dissertation will be provided to senior executives of Abu Dhabi's oil and gas industry as a source of appreciation for their support in facilitating the

access to the six targeted major projects. Additionally, presentations will be organized to share the main research findings with oil and gas industry personnel who are in a position to “influence” and “bring about a change” within their organizations. In particular, senior project managers, EPC contractors, local operating companies, and government senior leaders are those people who would benefit from a deeper understanding of the research outcomes in order to achieve a real improvement in the current industry practices.

The participation in local conferences, interested in oil and gas industry-related studies, is another appropriate means for disseminating the research findings and raising the awareness of the industry practitioners towards the importance of improving the project effectiveness. Findings from literature and the interpretations of the structural model, in addition to the recommended best practices, offer useful guidance for properly 1) achieving effective communication with the end-user’s team at the site level, 2) adequately acknowledging the end-user’s participation, and 3) maintaining better alignment between project and product objectives.

## **5.5 Research Limitations**

While the previous section highlights the main contributions of the present research study in providing advancement to knowledge in both literature and practice, there still exist some limitations. These limitations are listed as follows:

- The six major projects, targeted in the present study for data collection, fall under the downstream sector of Abu Dhabi’s oil and gas industry. Investigating

additional projects in the upstream sector would provide more representative and generalizable findings for the industry.

- Even though the total number of complete responses (i.e. 170) is considered high enough to compile the “Effectiveness of EPC” model and obtain generalizable findings, there exists a disparity between the distribution of the responses among the gas, refining, and petrochemical industries (i.e. 129, 28, 13 responses respectively). Given the researcher’s considerable efforts and follow-up with the concerned major projects coordinators during the data collection process, the response rates from the refining and petrochemical industries are below the expectations. Even though such low number of responses from these two industries is not a “real” limitation, having higher response rates would help 1) achieve more representative results for both industries and 2) refine the accuracy of the generated model estimates.

## **5.6 Plans for Future Research**

The limitations of the present research, highlighted in the previous section, serve as seeds for future research studies. This section provides an overview of further research opportunities. In this regard, additional research that targets major projects in both the downstream and the upstream projects as well as a higher number of responses from the refining and petrochemical industries would be beneficial to achieve more representative and generalizable findings for Abu Dhabi’s oil and gas industry.

The Kruskal-Wallis test was applied to test whether there exists a statistically significant difference among the three industries regarding the relationships between the Effectiveness of EPC and the two main criteria. It is important to realize that this test, given that the statistical significance is verified, can only recognize a difference between at least two groups, without identifying which specific groups are different from each other. Determining specifically which of the three industries differ is important to gain better insight into the current practice regarding the end-user's engagement and the alignment of objectives in each industry (i.e. refining, gas, petrochemical). As such, it would be interesting to generate a separate "Effectiveness of EPC" structural model for each industry. Such models would help suggest best practices that are more specific to the industry's applications regarding the end-user's engagement and the alignment of objectives. In this regard, it is worth noting that, in order to generate the three structural models, at least 140 complete responses are required from each industry, based on the rule-of-thumb discussed in chapter 3 (section 3.3.5.2).

In addition to the quantitative methodology used in the present research, further independent data can be collected by conducting a focus group, representing various project stakeholders (e.g. PMT, PMC, EPC contractor, end-user). Such data would be useful to validate the results of the proposed "Effectiveness of EPC" structural model generated based on the quantitative procedure (i.e. survey questionnaire).



## 5.7 Final Remarks

In the present chapter, the main research findings were summarized. The literature review conducted in both chapters 2 and 3 was useful for the extraction of some findings. Other findings were derived from the analysis of data collected using the open-ended and the closed-ended questions. The interpretations of the causal relationships of the “Effectiveness of EPC” structural model were, as well, helpful for proposing best practices for improving the effectiveness of EPC major projects in Abu Dhabi’s oil and gas industry.

The recommendations are related to various stages of the project, from the early stages of design to the hand-over of the plant facility for operation. In this regard, it was suggested that the award of the projects to the lowest technically accepted bids has to be reconsidered so as to alleviate the adverse impacts on the project quality, where the end-user’s involvement in the revision of the approved VL before being included in the contract was recommended. Additionally, the selection of the Pre-FEED and FEED consultants based on technical considerations as well as their engagement as PMC for the EPC phase were proposed. Having a PMT/PMC with an operational expertise was highlighted as a critical requirement to attain a plant facility with high-quality performance. Moreover, the participation of the end-user’s team in the pre-commissioning and commissioning activities of the EPC phase was highly recommended. Given the nature, complexity, and the extensive implementation of the major oil and gas projects, in addition to the rapid pace of technological advancement, it was advised that the owner has to allow for some flexibility in relation to the project schedule and cost. However, given the potential impact of changes during the EPC execution phase, the temptation to make

changes during that phase has to be resisted by the project teams and the end-user's team, unless dictated by safety or other critical reasons.

The “Effectiveness of EPC” structural model, generated in the present research, identifies the critical factors affecting the project effectiveness and assesses their statistical influences. By 1) providing the researchers with better knowledge of the “effectiveness” concept and 2) assisting the oil and gas industry practitioners in performing with a greater degree of success at the site level, this research provides contributions to both literature and practice. The theoretical and practical implications, presented in this chapter, have collectively contributed to the body of knowledge.

The main research limitations were highlighted, where only projects from the downstream sector were targeted. The response rates from the refining and the petrochemical industries were below the expectations. The research limitations were highlighted as opportunities for further research in the area of project effectiveness in the oil and gas industry. Targeting projects from both the downstream and the upstream sectors as well as collecting more responses from the refining and petrochemical industries can result in more generalizable findings and refine the accuracy of the model estimates.

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## Appendices

### Appendix A: EPC Project Phases

*Technical details extracted from Gasco (2011)*

#### I. Phase-1- Concept/Pre-FEED (Pre- Front End Engineering Design)

This phase is the concept development stage, where the project initiation by defining objectives and goals to be achieved. An outline of the basic scope is generated. As well as Studying various project strategy alternatives in contracting and implementation of the project for final selection. A techno-economic feasibility study is carried out to determine project alternative scenarios and recommend the most feasible one. This would cover issues such as:

- Best location and optimum layout, process and technology evaluation and selection as well as preliminary design outlines
- Design basis definition
- Conduct techno-economic assessments to enable the identified Options to be compared
- Perform Screening Studies to recommend the optimum Option(s)
- Conduct further studies on the preferred Option after management approval for the same
- Prepare the Execution Strategy for taking the project through the FEED and EPC Stages
- Prepare the detailed scope of work, for the FEED Stage, which includes +/- 30% cost estimate and overall execution schedule covering FEED and EPC phases

Pre-FEED Studies are held in two (2) stages – Screening Stage (Stage 1) and Develop Stage (Stage 2). At the end of each stage of Pre-FEED, the management holds a review

meeting to take a decision on whether to invest in the project further through its subsequent Stage. Figure A.1 depicts the processes involved during Pre-FEED stage.

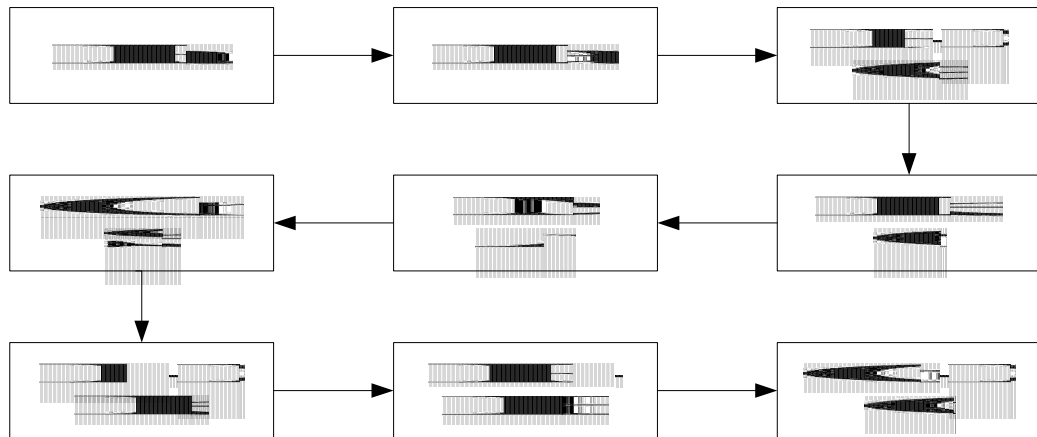


Figure A.1: Pre-FEED Process Flowchart

Source: (Gasco, 2011)

### ***1.1. Project Initiation***

The idea behind a project concept can originate from many sources, such as:

- End user's Operations Group may identify a de-bottlenecking requirement which means more production from existing facilities with some redesign and equipment modifications
- A capacity expansion opportunity
- Government and or Industry Shareholder's needs
- Health Safety and Environment (HSE) requirement
- New technology offering safer and/or more economical and/or energy efficient operation
- Regulatory changes forcing upgrades etc.

Irrespective of how the ideas emerge, each project must be assessed to determine exactly what is required to achieve the objective set out in the Concept as well as the impact that it will have on the End user. At the point when this stage is initiated, the following should be confirmed:

- The Scope of Work and Deliverables of the Stage
- Preliminary schedule and order of magnitude cost estimates for the Stage
- Any critical success factors or specific requirements such as feedstock or product specifications etc.

### *1.2. Develop Strategy*

The first responsibility of the project team is to develop the overall execution strategy for the project and the detailed execution strategy for the Pre-FEED Stage.

The overall project execution strategy must establish, at a high level:

- The overall objectives of the project
- Completion schedules for all alternative strategies
- Interface requirements within end user's facilities and outside

The project execution strategy remains an evolving document. It must be reviewed at the end of the Pre-FEED and FEED Stages. The Execution Strategy for the Stage is a detailed strategy document that defines:

- Which studies are to be undertaken
- If a licensed technology is required or not. If yes, why? And who are the potential technology providers
- The organization structure for undertaking the work
- If a Pre-FEED consultant is required, if yes, then this is to be incorporated in the contracting strategy
- What is going to be produced during this stage aiming at defining the deliverables
- Preliminary cost estimate and schedule for the stage
- Project control & administration mechanism
- Interface management, if applicable
- Involvement of other parties, if any.



Once the execution strategy for the stage with initial cost estimates and schedules for undertaking the work for the stage have been produced, they are submitted to management for review and formal approval. A project may not proceed without a formal approval at this point.

### ***1.3. Engage Pre-FEED Consultant***

Pre-FEED studies are generally undertaken using Pre-FEED consultants, depending on the nature and complexity of the project. When this strategy is adopted, the project must follow company procedure for engaging contractors' consultants. If Pre-FEED consultant is not being used on a project, then the project team moves directly to the next step which is the stage of the execution studies.

### ***1.4. Conduct Screening Studies***

The Project Team manages the execution of the studies as defined in the scope of work. Pre-FEED studies are executed in two stages; the first stage, the 'Screening Phase' where all possible options, including technologies, are studied from technical viability and economic perspectives, leading to the selection of the optimal option.

Before the project may continue with studies to further develop the Option, the outcome of the Screening Studies and the order of magnitude cost estimate (+/- 40% accuracy) must be presented to Management for approval.

### ***1.5. Management Approval***

Once the Screening Studies have been completed and the optimal option has been identified, the Project Team submits its recommendation for the optimal option, including a synopsis of the Screening Studies undertaken, the outcome of those studies and the rationale for selecting the option to management for approval.

Management may request that further studies are performed before approving the continuation of development of the project, or may opt to defer or cancel the project at this time.

“A project may not continue to develop its recommended option before receiving management approval to do so.”(Gasco, 2011)

### ***1.6. Develop selected option***

After Management approval of the recommendations of the Screening Studies, further studies are performed on the selected Option to validate the project concept both commercially and technically. The studies identify:

- Project design basis
- The process schemes, including evaluation of technologies to adopted
- The capacity of the plant to be developed
- The high level location & layout of the proposed plant
- The Process License requirements
- The preliminary cost estimate for the project (+/-30% accuracy).

### ***1.7. Produce Pre-FEED Deliverables***

Following the completion of all required studies, the stage deliverables are produced for review by Management. In addition to the studies, the deliverables of the Pre-FEED stage may include the following:

- Process Scheme
- Process Flow Diagrams (PFD)
- Process Block Diagrams (PBD)
- Stage 1 & 2 Studies Final Report
- Design Basis
- Preliminary Plot Location/Plan

- Hazard and Environmental Identification (HAZID/ENVID) and coarse Quantitative Risk Assessment (QRA)
- Cost Estimates
- Pre-FEED Close Out Report including 'Lessons Learned'

### ***1.8. Proceed from Pre-FEED to FEED***

On all projects, at the end of the Pre-FEED Stage the outputs of the Pre-FEED Studies with Economic Analysis must be submitted to Management for review and formal approval before it can proceed to the next Stage (FEED).

### ***1.9. Closeout Pre-FEED Contract***

Following completion of the Pre-FEED Stage, all Contracts with Contractors or Consultants must be closed out. Prior to closing the Contracts, all documentation required under the terms of the Contract should be reviewed to ensure that it is correct and up to date and all lessons learnt during the Pre-FEED Stage are recorded.

It should be ensured that all outstanding changes have been concluded and final accounts have been agreed with the Contractors prior to releasing final payments and issuing the contractual completion certificates.

## **II. Phase-2 - FEED (Front End Engineering Design)**

The purpose of the FEED Stage is to develop the project definition to a point where management can make a final decision on whether to sanction the project and to start work on developing the project in the EPC Stage. This is done by:

- Performing further optimization studies, as needed
- Conducting Topography/Geographical surveys
- Selecting Process Licensors(s), where needed

- Finalize Process and Flow Diagrams (PFD) and Piping and Instrumentation (P&ID) for which the EPC contractor is bidding
- Developing the Front End Engineering Design (FEED) integrated with Licensor Package(s)
- Equipment list
- Defining the detailed scope of work for the EPC Stage
- Undertaking Health, Safety and Environmental Impact Assessment (HSEIA) Phase 1 Study
- Defining the capacities and the performance guarantees required of the facilities to be built
- Producing the Execution Strategy and Plan for the EPC Stage, detailing among other items:
  - Detailed cost estimates to an accuracy of +/-15% and schedule for the EPC Phase
  - Technical Bid Evaluation for the identified Long Lead items
  - The organization and resources required to perform the work
- Pre-qualifying the proposed Bidders List(s) for the EPC Tender
- Updating the project economics and risk profile

The FEED Stage may only be initiated when a project has been approved by Management after the review at the end of the Pre-FEED Stage. For projects exceeding US\$ 50 million in value, Front End Loading (FEL) and Project Authorization Review is performed, if required, by engaging an external Benchmarking specialist Company, such as Independent Projects Analysis Co. (IPA), to evaluate the quality of FEED execution, scope definition and the associated cost and schedules. Their reports and findings are presented to End user's Projects Steering Committee and Shareholders, as applicable. Figure A.2 depicts all the processes involved in the FEED stage of a project.

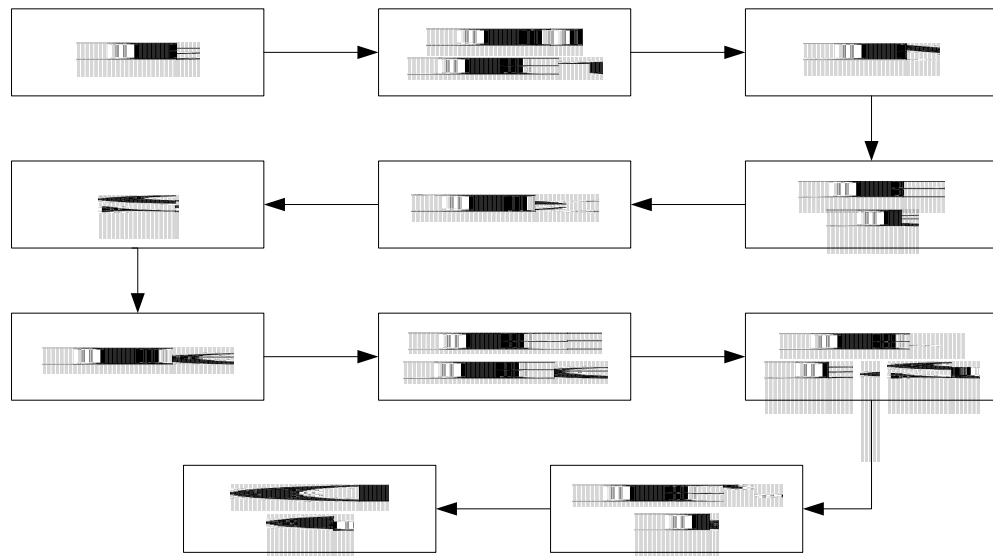


Figure A.2: FEED Process Flowchart

Source: (Gasco, 2011)

### 2.1. Develop FEED Execution Strategy

The first responsibility of the Project Team is to develop the Execution Strategy for the Stage. The FEED Execution Strategy defines the following:

- Organization Structure for undertaking the work
- Contracting Strategy for selection of the FEED Engineer
- Strategy for selecting the Project Management Consultant (PMC)
- Strategy for selecting Licensors, if applicable
- What is going to be produced during the Stage (the deliverables)
- Cost Estimate and Schedule for the Stage

The Project Team will develop the strategy for executing the FEED Stage.

## **Lessons Learned Review**

As part of the review of the Stage Execution Plan the Project Team should actively seek to identify any relevant lessons from other/previous projects so that these may be incorporated into their own plans for the venture. Lessons may be derived from:

- Formal or informal contacts made with other End user's Project Teams
- Formal or informal contacts made with Project Teams in other involved entities
- Formal or informal contacts made by the FEED Engineer with its other Project Teams
- Personal experiences of Project Team members from other projects
- Consultations made with any other 3rd parties
- Lessons learned by the Project Team during earlier stages.

Once the Execution Strategy for FEED, cost estimates and schedules has been produced they are submitted to Management for review and formal approval.

### ***2.2. Engage PMC***

All projects are required to use a Project Management Consultant (PMC) to augment the End user's Project Team. However alternatively, if management decides that no PMC is required, the project moves directly to the next step which is to engage FEED Contractor.

As far as possible if PMC is required, the PMC should be on board prior to award of the FEED Contract.

The role of the PMC is to support the End user's Project Manager in managing the day-to-day functioning of the project under the overall control of the Project Team and to undertake independent reviews and assessments of work undertaken by FEED Engineer throughout the project to support Management decision making.

Depending upon Management decision, PMC may support Project Management Team (PMT) and operate either as a part of an Integrated Project Management Team, which is

a combination of PMT and PMC and known as Project Management Team and Consultant (PMT/C). This set up ensures one owner entity to be interacting with EPC Contractor. Alternatively, PMC may operate as an independent Project Management Consultant to supervise and manage the work of FEED Engineer. In this case, PMT supports PMC in effective management of FEED Engineer's activities.

### ***2.3. Engage FEED Engineer***

The role of the FEED Engineer is to develop the basic engineering design, the EPC scope of work, the EPC tender documents, the cost estimates and detailed EPC schedules etc.

### ***2.4. Identify Interfaces***

All interfaces, whether within End user's facilities or with other third party facilities, are identified and interface specifications including Process and Design parameters as applicable, are agreed mutually between the concerned parties before proceeding with further engineering or facility development. The study must determine the impact of any new equipment on the existing plant facilities and also assess the enhancements or upgrades required if any to the existing equipment to ensure that the new and existing facilities integrate effectively. The Interfaces identified during FEED are managed during the EPC Stage. In addition, definition of the required tie-ins between new and existing facilities is identified as well schedule of implementation is agreed upon.

### ***2.5. Surveys***

Before any design work can be initiated requisite site surveys must be undertaken to determine the layout of existing plant facilities and the logistics & constructability studies should be undertaken for transporting and installing the heavy and over dimensioned equipment on site, during construction.

Specific surveys that should be undertaken include:

- Survey of existing underground and above ground facilities, including piping, cables, equipment layouts
- Control & Instrument schemes / Systems and tie-in points
- Topographic Survey of new site
- Geo-technical/Soil Resistivity
- Survey of new site
- Route Surveys for new pipelines
- Bathymetry Survey for sub-sea work, if any. i.e. sea bed condition assessment

## ***2.6. Licensor Selection***

In oil and gas projects, there are certain specialised processes and technologies which are of proprietary nature and owned by few international engineering companies like Acid Gas Removal Process and Heavy Naphtha Catalytic Reforming are owned by M/s UOP, Sulphur Recovery Process owned by M/s Fluor and Tail Gas Treating Units Process by Exxon Mobil etc. These process owners provide the use of these specialised processes for such Units comprising part of facilities through license contracts based on payment of royalty (license fee) which is in most cases associated to capacity of the licensed units. The process license fees for some units could be as high as US\$ 20 MM throughout the design life of the units.

In line with scope of work, the FEED Engineer identifies and reviews the option for such proprietary technology that is to be used on the project. Generally, only proven and techno-economically feasible technologies should be included in the assessment and an evaluation made of their ability to meet all requirements identified during the Optimization Study, if applicable. In such cases the project team and end user usually would pay a visit to existing facilities operating such licensed technologies to examine and ascertain appropriateness for successful suitability within the project.



## **2.7. Perform Front End Engineering Design (FEED)**

Where possible, in parallel to conducting the Optimization Studies and the Surveys, preparation of the basic engineering design begins.

The FEED engineer performs a series of activities during this stage. The main activities include the following:

- Optimization studies

Where applicable, prior to commencing the Front End Engineering Design (FEED), the Optimization Studies as identified in the FEED Contract are conducted. These studies cover the areas such as capacity creation, process, controls, technological solutions, operations and maintenance. The FEED shall also include identification, evaluation and selection of Process Licensors, as applicable.

- Conduct Specialist Studies

The FEED Engineer, along with the support of company approved third party specialists and the involvement of the PMC and the Project Team, conducts various specialist study workshops such as Hazard Operability (HAZOP), Safety Integrity level (SIL), Safety and Environmental Impact Assessment (HSEIA) etc. to analyse factors such as hazards, operational risks, health & safety concerns etc.

- Manage Health Safety & Environment (HSE) plan

The FEED Engineer produces and implements a FEED HSE Plan. This plan identifies health, safety and environmental risks on the project and identifies how they are to be handled during the FEED Stage and also the principles for HSE Management during the EPC and Operations Stages.

- Manage Quality Assurance (QA)

Quality Management System (QMS) for FEED Services prepared by FEED Engineer shall ensure planned and systematic control of all activities performed during FEED and shall fully satisfy all the Quality Management System requirements as per ISO 9001:2008;

- Undertake Value Improvement / Enhancement Reviews

During the design process a series of facilitated Value Improvement workshops should be held. The purpose of these workshops is to review the project strategically to identify opportunities to enhance the value delivered by the project back to the business – either through cost cutting opportunities or through value improving additions and to establish a method of working that provides the most cost and time effective solution to the project and ensures production rates are achieved quickly and efficiently;

- Perform Early Procurement Activity for Long Lead Item (LLI)

Some of the equipment designed or specified during the FEED Stage will require long periods to manufacture and deliver to site for installation. In order that these items do not delay the construction process they should be identified in order that the technical qualification portion of the procurement process can be undertaken in advance of the EPC Stage. In some cases, the commercial portion of the tender and the award of the Purchase Orders is undertaken by the EPC Contractor during the EPC Stage. These equipments are assigned to the EPC contractor.

During this step, the FEED engineer produces deliverables such as specifications, drawings, materials schedules and layouts for review by PMTC. Main deliverables include:

- Process Flow Diagrams (PFD)

PFDs Show and describe the main steps and interfaces through the manufacturing or processing facility. They identify, but do not specify, the main components, their capacities, as well as their inputs and outputs;

- Engineering Philosophy

Engineering philosophy describes which standards and guidelines are going to be used for designing and specifying the project. These standards and guidelines can be End user's Standards, Industry standards, Regulatory guidelines, Contractor standards or Licensor standards. A typical Oil and Gas Engineering Philosophy Standard is Shell DEP (Design and Engineering Practice).

- **Piping & Instrumentation Diagrams (PI&Ds)**

PI & Ds identify schematically, the layouts for piping as well as the associated control systems and instruments needed to design, construct and operate the facility. Detailed piping layouts and isometrics are produced by the EPC Contractor in the EPC Stage based on the P&IDs. Critical elements of the design should be identified at this point e.g. critical tie-ins.
- **Plant Layouts**

Plant layout would cover graphical representations of the location of all main units and equipment of the plant as well as general piping layouts. This is typically governed by industry and safety regulations as well as end user's operation philosophy and could have very big impact on project cost, hence this requires thorough review by all parties including the end user.
- **Equipment Lists**

Equipment lists would include all main equipment or plant items that will be required in the plant and shall be supplied and constructed by the EPC contractor;
- **Instrumentation Schedules**

This listing is developed from P&IDs and includes all the instrumentation & control system components required for the facility. These are included in the tender documents for the EPC Contract.
- **Electrical Schedules**

It includes take-offs, or listings of all electrical equipment identified on the P&IDs for inclusion in the EPC tender documentation.
- **Project Specifications**

The specifications that will be used by the EPC Contractor when undertaken detailed design work.

## ***2.8. Produce EPC Cost Estimate & Schedule***

The FEED Engineer is responsible for producing detailed Cost Estimates (+ 15% accuracy) and Schedules for the EPC Stage. PMC is also required to prepare an

independent Cost Estimate (+15% accuracy) for the EPC Stage and validates the Schedule produced by the FEED engineer. Where required, the FEED Engineer as well as PMC should perform Quantitative Risk Analysis on the Costs as well as the Schedule.

The cost estimates are reviewed internally by the project owner and comments communicated to the FEED Engineer and or PMC. Where required, FEED Engineer's cost estimate may be audited by the PMTC to determine a realistic estimate. Thereafter the cost estimates are submitted to Management. The cost estimates are used to support:

- The Independent Project Authorization Review
- Updating the Projects Economics
- Management decision-making for selection of the EPC Contractor

Schedules are used to support Management decision-making and high-level schedule requirements are included in EPC tender documents to show key Milestone requirements. These are also used for evaluation of the bids submitted with respect to the manning levels, compliance to Milestones, etc.

### ***2.9. Prepare EPC Tender Package***

The FEED Engineer is responsible for developing the Scope of Work and the tender documentation for the EPC Contract. Besides the commercial & technical bid documents, it must also include the list of Long Lead Items and the short list of technically qualified vendors along with the Technical Evaluation details. The Tender Package is reviewed by PMTC. The PMTC provides the Non-Engineering Deliverables (NEDs) relating to Contractual, Commercial and Project Control sections of the Tender Package to enable FEED Engineer compile the overall EPC Tender Package. Exhibits relating to Quality and HSE shall be provided by the respective entities. End Users review the portions of the Tender document related to Performance Guarantees, Operation, Maintenance and Training as well as the requirements related to Insurance and Operating Spares.

### ***2.10. Closeout of FEED contract***

Following completion of the FEED Stage, all contracts must be closed out. Some contracts may extend into the EPC Stage to ensure that the EPC tender process is managed rigorously and that handover to the successful EPC Contractor is ensured smoothly.

Prior to closing contracts all documentation required under the terms of the contract should be reviewed to ensure that it is correct and up to date.

The Project Manager should ensure that all outstanding changes have been concluded, and should agree the final accounts with the contractors prior to releasing final payments and issuing contractual completion certificates.

FEED translates the concept of the project into basic design that defines main facilities, EPC detailed scope of work in addition to budget estimates with approximate accuracy of  $\pm 15\%$  and implementation schedule. A re-evaluation through an update of the techno- economic feasibility study is also undertaken prior to seek management final approval leading to the commencement of the execution phase of the project, before issuing the inquiries for competitive tenders. FEED is an extensive planning stage that could take more than a year to finish.

## **III. Phase-3 – Execution Phase**

The third stage is the project execution stage that covers the crucial project implementation phase. In which, there are various types of contracts adopted for major oil and gas projects that will be covered in our literature review.

Project strategy is driven by project main objective and emphasis. If a specific time has to be met regardless of the cost incurred, then cost reimbursable plus fees EPC model (called also cost+) must be the adopted. However, the most typical types of contractual strategies or agreements that are usually considered in these main oil and gas contracts are mainly variations of either EPC or EPCM strategies. **Error! Reference source not found.** defines the processes involved in the EPC stage of a project in detail.

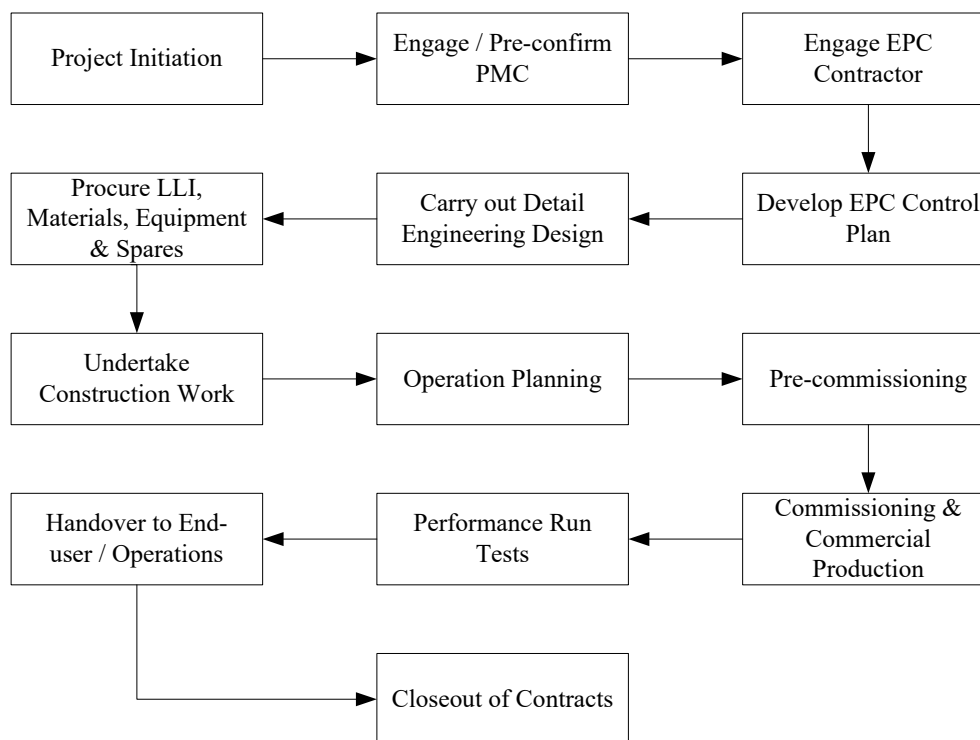


Figure A.3: EPC Phase Process Flowchart

Source: (Gasco, 2011)

### 3.1. Engage / Re-confirm PMC

On all major Projects, a Project Management Consultant (PMC) is generally required to be appointed to support the owner's Project Team.

As far as possible, the PMC should be on board prior to the issuance of the enquiries for the EPC. If this is not possible, PMC must be on board in time to undertake the evaluation of EPC bids prior to award of the EPC Contract.

The role of PMC is to support the owner's Project Team to manage the day-to-day functioning of the project and to provide technical expertise on the project throughout the execution of the project, till completion and handover to Operations of the End Users.

The PMC Contract awarded during the FEED Stage may have included options to re-engage the PMC for the EPC Stage.

### ***3.2. Engage EPC Contractor***

The role of the EPC Contractor is to develop the basic engineering design to a detailed level, to purchase the materials, equipment and services required to construct the plant, to perform, co-ordinate and manage the construction works, to test and commission the plant, to procure spare parts, train Operations personnel and manage warranty issues.

### ***3.3. Develop EPC Control Plan***

Fully detailed Project Control requirements to be implemented by the EPC Contractors are specified in the tender package. These requirements include procedures for preparation of detailed schedules, measuring and reporting progress, for managing changes and for forecasting outturns.

Once appointed, the EPC Contractor must develop a Baseline Plan (Planning Dossier) that describes in detail:

- The activities that will be undertaken throughout the Stage
- The duration of those activities and the logical links (in order to ensure effective monitoring between engineering, procurement and construction)
- The schedule of meeting key Milestones specified in the Contract
- The progress measurement system
- The process for reporting progress
- Detailed Registers for Engineering deliverables, Procurement Services, Manufacturing & Delivery and Sub-contracting Services reflecting the schedules at various stages against each item
- Progress profiles (S-Curves) for Engineering, Procurement, Manufacturing & Delivery and Construction and Project Overall
- Manpower Deployment Schedules and Histograms
- Equipment Deployment Schedules

This plan must be reviewed and approved by the Company PMTC and then incorporated into the progress reporting.

### **Lessons Learned Review**

As part of the review of the EPC Control Plan the PMTC and EPC Contractor should actively seek to identify any relevant lessons from other/previous projects so that these may be incorporated into their own plans for the venture. Lessons may be derived from:

- Formal or informal contacts made with other Project Teams within the same company
- Formal or informal contacts made with Project Teams in other companies with similar past projects
- Formal or informal contacts made by the EPC Contractor with its other Project Teams worldwide
- Personal experiences of Project Team members from other projects
- Consultations made with any other third parties
- Lessons learned by the Project Team during earlier stages of the project

### ***3.4. Carry Out Detail Engineering Design***

The EPC Contractor is responsible for undertaking all detailed design work for the plant. All designs must meet End user specifications and international codes & standards. Any deviations from the specifications must be submitted to PMTC for review before being implemented.

Within the detailed engineering design the EPC Contractor is responsible for:

- Detailed Execution Plan
- Detailed Planning Dossier
- Engineering Studies
- Topography & Geotechnical Surveys
- Detailed Engineering Deliverables
- Materials Requisitions & Purchase Orders



- Detailed Construction deliverables for Plant/Facilities
- Operational Spare Parts Identification
- Health Safety Environment Impact Assessment (HSEIA) Studies
- As-built Documentation & Drawings
- Completion, Test Run and Provisional Acceptance (PAC) Certificates
- HSE (such as HAZOP) and Technical Audit Reports
- Pre-commissioning & Commissioning procedures and manuals
- Operations & Maintenance Manuals
- Training Manuals
- Asset Register
- Project Close-out Report including ‘Lessons Learned’

The output of the Detailed Engineering Design is a set of AFC drawings, data sheets, specifications, standards, procedures and material requisitions that can be used to procure the materials, equipment and services required to construct the plant. All designs must be submitted to the PMTC for information, review and approval in accordance with the document class specified in the EPC Contract.

### ***3.5. Procure Long Lead Items, Materials, Equipment & Spares***

#### **Long Lead Items (LLIs)**

One of the first tasks of the EPC Contractor following appointment is to conclude the process of procuring Long Lead Items (LLIs). This process is initiated during the FEED Stage, when the list of LLIs was identified by the FEED Engineer and technical enquires were issued to the approved list of vendors after a pre-qualification exercise, where required. Unpriced Technical offers received from the approved vendors were also assessed to determine a short list of qualified bidders. The LLI list and the qualified short list are passed to the EPC Contractor during the EPC Contract tender stage. The EPC Contractor must finalize and issue the commercial elements of the LLI Purchase Requisitions and issue them to the short listed vendors. The EPC Contractor is also

responsible for evaluating all technical and commercial issues with the short listed vendors. EPC Contractor then submits Technical Bid Evaluation in the agreed format for PMTC approval. The evaluation is reviewed by Project Team and approval of the appropriate authority is obtained prior to advising the EPC Contractor.

### **Other Materials and Major Equipment**

The pre-approved Project Vendor Lists (PVL) for main goods forms part of the EPC Agreement and the Contractor is free to issue the enquiries to any Vendor on those lists. However, the Tender Bid Evaluation (TBE) must include only Vendors qualified by Company.

For other items and any additional Vendors for major items, EPC Contractor must submit to End user its Proposed Vendor Lists (PVL) along with complete PQ details for review and endorsement in accordance with End user's standard procedure and as set out in the terms of the EPC Contract. All such requests shall be reviewed as per the provision of the EPC Agreement.

The EPC Contractor is responsible for developing the technical and commercial enquiry documents for various materials & equipment, for issuing material requisitions to the vendors and for evaluating the responses. Technical bid evaluations must be submitted by the EPC Contractor to PMTC for review and endorsement before awarding the Purchase Orders.

### **Spare Parts**

The EPC Contractor is responsible for procuring the required commissioning, insurance and operating spare parts. Normally the list of insurance spares is specified in the EPC Agreement and the Commissioning spares requirement is determined by the Contractor. The cost of the identified insurance spares and commissioning spares forms part of the Lump Sum Price.

### ***3.6. Undertake Construction Work***

Contractor is responsible for selecting the Construction sub-contractors, undertaking, managing and coordinating all construction works on site. Specifically, it is responsible for but not limited to:

- Setting up temporary facilities
- Site preparation
- Mobilizing Construction Equipment and personnel
- Supervising, Managing and coordinating all construction activities
- Ensuring that plans relating to HSE are implemented
- Conducting inspections and ensuring strict compliance to QA/QC
- Interface Management
- Measuring and reporting progress and participating in regular Progress Review Meetings
- Presentations to Management

### ***3.7. Operations Planning***

During the EPC Stage, the Operations Unit that will operate the completed facility(ies) are responsible for ensuring that preparations have been made so that Operation and Maintenance personnel are provided the required Training and they can participate as agreed in the Pre-commissioning, Commissioning and Test Runs of facilities, that the organization is ready to take ownership of the facilities when they are commissioned and handed over, and that plans are in place to ensure that the facilities can be adequately maintained.

### ***3.8. Pre-Commissioning (Achieve Mechanical Completion)***

Pre-commissioning (Achieve Mechanical Completion) includes all activities that are essential for making the plant Ready-for-Commissioning. This period is also essential for

the operatives to gain an in depth practical understanding of the plant & equipment and to ensure that operations verify the status of the entire installation. Mechanical Completion (including Pre- commissioning) covers all activities and tests prior to the intake of the feedstock into the plant. Typically, these include:

- All equipment set on foundations grouted and aligned
- Piping erected, pressure tested or hydro tested and fully supported
- Pipeline tested and dried
- Electrical and instrument systems fully installed and checked
- Line and equipment flushing carried out
- Systems blown or dried with air or nitrogen
- No-load test runs of rotating equipment completed
- Loops checked and all instrument systems calibrated
- Electrical Systems tested and checked
- Piping Systems have been chemically protected
- Safety audit recommendations incorporated
- All work is completed to allow End user to introduce feedstock for the purpose of commencing commissioning
- Test records provided to End user
- All items in the Punch List (Mechanical Completion Checklist) have been completed
- Catalyst (if required) is loaded with the required quantity in the respective vessels
- Commissioning spares and two-years operational spares are available at site
- The conditions set out in the approved Mechanical Completion manual have been satisfied
- Commissioning manual has been approved by End user
- Relevant Training of Operational staff is completed

When this Milestone is achieved, Management issues a Mechanical Completion Certificate to the EPC Contractor and authorizes commencement of the commissioning activities by providing the feedstock.

### ***3.9. Commissioning & Commercial Production***

Prior to introduction of hydrocarbons and commencing commissioning activities, as explained under HSE, a Safety Audit is undertaken to ensure complete safety of the new facilities. Commissioning activities commence with the introduction of feedstock in preparation for testing and operation of any system or part of the plant, as applicable, prior to carrying out the test run. Run-in and operational testing are the major activities during the commissioning period. This step is under the responsibility of the EPC Contractor, however End user's Operations team is also involved in assisting capacity. On successful commissioning of the facilities and achieving Commercial Production as per the Agreement requirements, "Commissioning Certificates (CC)" are submitted by Contractor which are approved by Company's competent Authority, after ensuring that all activities as required are complete to End user's satisfaction.

### ***3.10. Performance Test Runs***

Performance Test Runs are undertaken to prove that the plant as designed and built by the EPC Contractor meets the original requirements set out by End user in the EPC Contract. The Test Run provides a clear and unequivocal confirmation of the ability of the plant to meet the guaranteed performance levels on a consistent basis as per the Contractual requirements.

Test Runs should normally be completed soon after completion of commissioning and achieving required commercial production successfully. Several attempts may be required before a test run is successfully completed and modifications may be required during the intervening periods in order for the plant to meet the specified performance criteria. All cost for modifications necessary to meet the performance criteria shall be at the EPC Contractor's expense, unless expressly stated otherwise in the EPC Contract.

Test Runs can only be undertaken following issue of the "Ready for Test Run" Certificate by Management to the EPC Contractor and only when the plant has achieved stable, safe continuous operation at 100% rated capacity for a set period of time (usually 3 to 7 days) meeting all process parameters as specified in the Agreement without leaks

or defects. Other conditions, such as environmental constraints or product mixes, might also need to be achieved. The exact requirements on a given project are specified in the related Agreement.

EPC Contractor must provide End user with the Test Run plan and procedure in advance of commencing the Test Run. It must test the entire plant running simultaneously for the specified duration uninterrupted, unless End user agrees that this is not a requirement.

At the end of the Test Runs, EPC Contractor must submit the Test reports to End user for review and approval.

Upon successful completion of Test Run, the EPC contractor submits a Provisional Acceptance Certificate (PAC) for PMCT approval. Upon acceptance of the same, the care and custody of Installation is transferred to end user.

### ***3.11. Handover to End user / Operations***

This is the process of formally handing over the plant to End user Operations on successful completion and acceptance of Test Runs by End User. Formal handover shall include the following as a minimum:

- Handover of final documents
- Handover of major spares and consumables
- Agreement on the Punch Lists along with an Action Plan

### ***3.12. Closeout of Contracts***

Provided that the EPC Contractor has fulfilled all its obligations under the Contract, the EPC Contract is closed out. Prior to closing the Contracts, all documentation required under the terms of the Contract should be reviewed to ensure that it is correct and up to date.

All outstanding Contract Trend Notices (CTNs)/Claims are concluded, all final accounts have been settled with the Contractors prior to releasing final payments and

issuing the Final Acceptance Certificate, punch lists signed off as complete and warranty notifications closed.

The final Project Close-out Report along with 'lessons learned' and the Asset Register from the EPC Contractor are received as per Agreement requirements.

#### **IV. Phase-4 - Operation**

This phase is mainly related to operations and maintenance of facilities by End User. From the projects perspective, Operate Stage describes the supporting activities that are performed by Project Team on the completed facilities to ensure the smooth operation, and the close-out of any outstanding issues remaining from the project such as Punch-lists and Warranty Issues. Some members of the PMTC may remain involved to close out the project, contracts and any outstanding issues.

During the Operate Phase, project team in conjunction with EPC contractor is available during the warranty period to ensure the reliability of the facilities. Thereafter End User operates and maintains the facilities through their in-house resources. Accordingly, during the operate period and before the EPC Contractor is disengaged, a post implementation review is also carried out and Final Acceptance for Project completion is issued.

##### ***4.1. Warranty Period***

The Warranty period usually lasts 12 months from the effective date of PAC or 15 months from effective date of issuance of Plant Test Run Certificate, whichever is earlier. However, the applicable duration will depend on the provisions specified in the EPC Contract. During this period the EPC Contractor completes any items on the punch list and fixes, maintains or replaces any defective items covered under the Warranty Agreement.

#### ***4.2. Post Implementation Review***

Approximately six months after handover of the completed facilities to the End User/Operations, a Post Implementation Review is held. The objectives of the review are to:

- Review performance of the facilities against those specified (not necessarily against those designed)
- Identify any further projects/works required to improve the efficient, safe operation of the facilities and identify any opportunities for capacity enhancement through e.g. de- bottlenecking any parts of the facilities built

The Post Implementation Review is conducted by an external specialist organization.

#### ***4.3. Issue Final Acceptance Certificate (FAC)***

At the end of the Warranty Period and provided that the EPC Contractor has fulfilled all its obligations under the Contract and all issues concluded between the parties, the EPC Contractor shall submit a request to End user to issue the FAC.

The EPC Contractor must submit a request to End user to issue the Final Acceptance Certificate (FAC) along with the Release Letter as per the EPC Contract. If it is agreed that the FAC should be issued, the Contractor's request, after endorsement from the End User, is submitted to the Management for approval as per the delegation of authority.

This document concludes the Contract between End user and the Contractor, and enables the Contractor to receive final payment, if due, for any outstanding work and the Bank Guarantees. Some extended Warranties (like painting warranty etc) may remain in place.



#### ***4.4. Release of Contractor Performance Bond***

Following issue of the Final Acceptance Certificate (FAC), End user's Projects Control Division arranges for the EPC contractor's Performance Bond to be released. At this point any final accounts, if outstanding, must also be settled.

## Appendix B: Pilot Survey Participants

Table B.1: List of pilot survey participants with related job titles

Participant	Job title	Company
Abdul Razaq Kunnummel	Instrument and control section head	Alhosn Gas
Ahmad Mohamed Aly	Senior control and automation engineer	
Scott Willis	Plant Manager	
Francisco Beraldi	Commissioning Manager	
Sudhir Malhotra	Senior operation engineer	
Mohamed Obaid Alyabhouni	Senior Vice President (Major Projects)	Takreer
Ali Abdul Razaq Alfahim	Chief Projects and Procurement Officer	
Alaa Zeitoun	Executive Director	Emirates Nuclear Energy Corporation (ENEC)
Pat Phelan	Senior Project Manager - Projects Division	Gasco
Raghavan Sundararajan	Senior Project Manager (Commissioning)	
Bharat Mehta	Projects Procurement and Contracts Department Head	
Faisal M Alshemsi	Senior Vice President – Borouge 3	Borouge

Source: Developed for this research

Table B.2: Major oil and gas projects completed between 2007-2015 in Abu Dhabi

Sl.	Name	Industry	Sector	Contract Value (\$M)	Net Project Value (\$M)	Award Year	Completion Year
1	ADCO - 1.8 MMBPD Development	Oil	Upstream	1,876	1,876	2009	2015
2	ADCO - Bab Compression Facilities	Gas		818	818	2009	2012
3	ADCO - SAS Oilfield Development Project: Asab Field	Oil		2,300	2,300	2009	2013
4	ADCO - SAS Oilfield Development Project: Sahil Shah Field	Oil		1,300	1,300	2009	2013
5	ADMA-OPCO - Umm Shaif Gas Injection Facilities (USGIF)	Oil		1,600	1,600	2006	2010
6	ADMA-OPCO - Zakum Field Gas Processing Facility (GPF)	Gas		590	590	2007	2010
7	ZADCO - Upper Zakum Full Field: Early Production Facility: Offshore: EPC 1	Oil		817	817	2012	2015
1	ADGAS - IGD: Das Island Process & Utilities Package	Gas	Downstream	800	800	2009	2013
2	ADGAS - LNG Train 1 & 2 Replacement	Gas		2,500	2,500	2005	2012
3	ADGAS - OAG-1 Das Island Compression Facilities	Gas		610	610	2007	2010
4	AL HOSN GAS - Shah Gas Development (SGD)	Gas		10,000	10,000	2010	2014
5	BOROUGE - Bourouge 2 Expansion Project	Chemical		4,857	4,857	2006	2010
6	BOROUGE - Bourouge 3 Expansion Project	Chemical		4,074	4,074	2009	2015
7	ELIXIER - Mirfa Nitrogen Generation Facilities	Gas		614	614	2007	2011
8	FERTIL - Ruwais Fertiliser Expansion Project	Chemical		1,200	1,200	2010	2013
9	GASCO - Asab Gas Development - Phase II (AGD-II)	Gas		1,240	1,240	2005	2009
10	GASCO - Habshan Gas Complex Expansion (HGCE)	Gas		999	999	2005	2009
11	GASCO - IGD: Habshan 5 Process Plant & Utilities	Gas		6,500	6,500	2009	2012
12	GASCO - IGD: Habshan Sulphur Formation, Granulation and Handling Facilities	Gas		500	500	2010	2015
13	GASCO - IGD: Ruwais 4th NGL Train Package & Storage Tanks	Gas		2,311	2,311	2009	2014
14	GASCO - Maqta - Taweelah Gas Pipeline	Gas		500	500	2012	2014
15	GASCO - OAG project	Gas		690	690	2006	2009
16	GASCO - Onshore Gas Development Phase III (OGD-3)	Gas		1,500	1,500	2004	2009
17	GASCO - Ruwais 3rd NGL Train	Gas		1,450	1,450	2005	2009
18	GASCO - Ruwais Sulphur Handling Terminal - 2	Gas		624	624	2010	2015
19	TAKREER - Green Diesel Project	Refining		1,200	1,200	2007	2011
20	TAKREER - Inter-Refinery Pipelines - Phase II	Refining		894	894	2010	2014
21	TAKREER - Ruwais Refinery Expansion Project (Total 5 EPC packages)	Refining		10,500	10,500	2009	2014

Source: Developed for this research

## Appendix C: The Six Targeted Major Oil and Gas Projects

### I. Gas industry

#### 1. Project 1: GASCO's Habshan-5 Process Plant & Utilities

##### 1.1. Introduction

Abu Dhabi National Oil Company (ADNOC) is planning to transfer additional high pressure gas from Umm Shaif to Habshan via Das Island using the new 30" Offshore Associated Gases (OAG) pipeline, with a total throughput of 1000 mmscfd through the pipeline. The produced gas will initially be processed in the ADMA-OPCO facilities at Umm Shaif, sent to the ADGAS facilities at Das Island, where the gas will be conditioned, and sent through the 30" pipeline to Habshan. At Habshan, the gas will be further processed in existing facilities and new facilities at Habshan 5 for optimum lean gas production. This gas will be sent to the sales gas header and Natural Gas Liquids (NGL) sent to GASCO facilities at Ruwais for further fractionation. Additional capacity will be provided for future expansion for the associated gases from onshore oil production increasing from 1.4 to 1.8 MMBOPD of oil.

The offshore and onshore scope of work has been consolidated into a single Integrated Gas Development (IGD) Scheme which covers facilities at the following locations:

##### 1.2. Offshore

HAP Platform:

- Gas receiving equipment including pig receivers, inlet separators, slug catcher
- Single 220 mmscfd dehydration train
- Glycol regeneration package

- Flare and vent system including a new submarine flare pipeline and flare tower
- Pig launcher for the Habshan Platform (HAP) Main Gas Line (MGL)
- A new gas pipeline from Um Alshaif Super Complex (USSC) to Das Island

### 1.3. Onshore

#### Das Island:

- New gas receiving, dehydration and compression units and some new utilities
- New Offshore High Pressure (HP) Flare
- These facilities will be owned and operated by ADGAS

#### Habshan:

- New gas separators and associated receiving facilities at the existing Habshan 1 site.
- New gas processing complex at a new site called Habshan 5 approximately 10km North-East from the existing Habshan 1 site
- New gas pipeline to connect Habshan 5 to existing NGL Station at Bab
- New pipelines to connect Habshan 5 to Bab Crude Degassing Station (CDS)
- New pipelines to connect Habshan 5 to pipelines in existing pipeline corridor
- These facilities will be owned and operated by GASCO

#### Ruwais:

- New NGL Fractionation (Train 4) at the Ruwais site
- New HP and acid gas flares
- New storage tank facilities at the existing Ruwais site
- New Control Building
- These facilities will be owned and operated by GASCO

#### *1.4. Project Scope*

The major scope of the Project includes Habshan 5 Process Plant comprising the following facilities:

- Two trains (Two x 100% MP trains and Two x 50% Feed Gas trains) of compression for the new associated gas feeds
- One train of condensate stabilization
- Four gas sweetening and dehydration trains (two for rich gas and two for lean gas)
- Two rich gas NGL recovery trains. These trains are designed for high ethane recovery
- Four sulphur recovery units. These trains include tail gas treating units and are designed for 99.9%+ sulphur recovery
- One train of clean and dirty sour water strippers
- One train of MP & LP Fuel Gas system
- One each of Hydrocarbon, Acid Gas and Cold Flares
- Firewater System
- Dedicated, stand-alone offsite and utilities including steam, power generation, NGL and sulphur storage / loading
- Tie-ins at existing Habshan facilities, debottlenecking and new equipment at the existing Bab and Habshan facilities
- New equipment and piping in OAG units 200 and 210
- New pipelines connecting Habshan 5 to existing Habshan & Bab facilities. Including launchers and receivers
- The fire water ring associated with Utilities and offsite units
- Buildings including Control Building and Telecoms Building

*1.5. Projects Cost: Approx. US\$ 6.5 Billion (Habshan-5 Process Plant: US\$ 4.7 Billion & Habshan-5 utilities and Offsites: US\$ 1.8 Billion)*

*1.6. Project Completion Period: 50 Months for Habshan-5 Process Plant and 46 Months for Habshan-5 Utilities and Offsites*

## 2. **Project 2**: GASCO's Ruwais-4 NGL Train

### 2.1. Introduction

The IGD Project and other expansion projects related to GASCO Master Plan will increase the production of NGL and LPG by approximately 18,970 TPD. A new fourth NGL fractionation train at RUWAIS will be installed to process a portion of the NGL products from AGD-0, BAB, BUHASA, HABSHAN 1 (excluding OGD-III) and HABSHAN 5. The Train 4 processing scheme is nearly identical to Train 3.

The new fourth NGL fractionation plant will produce raw ethane, propane, butane, paraffinic naphtha hydrocarbons, and liquid sulphur.

The raw ethane product will be routed to the future Petrochemical Complex as feedstock for ethylene and polyethylene production. The propane and butane liquid products will be stored in refrigerated tanks and loaded onto LPG tankers via the GASCO Ruwais jetty. The paraffinic naphtha product will be stored and loaded on tankers via the GASCO Ruwais jetty. The RVP of the paraffinic naphtha stream will be maintained within specifications by blending with Naphtha produced in the Deheptaniser.

The capacity of Train 4 will be approximately 24300 TPD of NGL/LPG with further 10% design margin is to be added to Train 4 excluding storage and the SRU. New storage tanks will be installed for the propane, butane and paraffinic naphtha products. The new tanks will be interconnected with the Train 1, 2 and 3 product rundown, loading and shipping network so that the contents of any tank can be shipped from any of the berths. In alignment with ADNOC's environmental policy, a new 30 TPD Sulphur Recovery Unit will be installed to handle acid gas flows from Train 4 and acid gas from Train 1, 2 or 3 and vice versa.

The existing RUWAIS facilities comprises of 2 operational NGL Fractionation trains (Trains 1 and 2) and a new Train 3 which is currently under commissioning. NGL is received from AGD-0, BAB, BUHASA and HABSHAN (excluding OGD-III). It is converted into raw ethane, propane, butane, paraffinic naphtha. Propane and Butane liquid products are stored in refrigerated tanks and loaded onto LPG tankers via jetty. Paraffinic Naphtha is stored and loaded onto tankers via jetty.

The RUWAIS 4th NGL train processing scheme is similar in configuration to the Train 3 scheme with a design capacity of 27,000 TPD NGL/LPG (including 10% design margin). The facilities comprise of Fractionation, Treatment and Refrigeration. There is also a 30 TPD Sulphur recovery Unit.

## *2.2. Project Scope*

The primary objectives of the RUWAIS 4<sup>th</sup> NGL Train Project are as follows:

- To fractionate the additional NGL received from HABSHAN, ASAB and BUHASA to marketable products with NIL flaring
- To produce additional C2 feed for BOROUGE

The RUWAIS 4th NGL Train Project commenced with a Pre-FEED study prepared by Fluor U.S in 2006. The FEED was awarded to Fluor UK in 2007 and was completed in 2008. The RUWAIS 4th NGL Train EPC Enquiry package was issued to seven bidders and the EPC works is awarded to the Joint Venture of Petrofac and GS Engineering and Construction South Korea effective from 29th July 2009, with a completion schedule of 44 months and to PAC of 48 months.

The EPC scope of work includes, but not limited, to the following:

- Project design and Engineering services
- Procurement services and supply of all goods for the project
- Construction planning and construction management services
- Construction of the installations, including site preparation and the installation of all facilities together with all pre-commissioning services
- Pre-commissioning and start-up planning and management
- Commissioning and test run
- Training of Company's personnel
- Procurement services (including delivery) of two-year spare parts
- Insurance spares based on a listing defined by Company
- Ancillary design and construction for the project
- Work required to achieve Provisional Acceptance Certificate



- Services during Warranty Period (12 Months)
- Work required to achieve Final Acceptance Certificate

The EPC scope of work for the process plant consists of a turnkey project for the engineering, supply, installation, commissioning and handover of the following process units and facilities:

- Fractionation ( Deethaniser, Depropaniser, Debutaniser and Deheptaniser ) Units
- Propane Treating Unit
- Deethaniser Overhead Gas Treating Unit
- Sulphur Recovery Unit
- Molecular Sieve Unit
- Refrigeration Unit
- Utilities
- Seawater Cooling
- Firewater Unit
- LP Flare Unit

Scope of works includes the following:

- All equipment, material and piping within Train 4 limits
- All pipe racks, foundations and steelwork
- All undergrounds including new seawater cooling basin
- All roads and fencing
- All buildings including the New Main Control Building, sub-stations, FARs, equipment shelters, operator facilities, satellite workshops etc
- Electrical scope includes Main Sub-station and any downstream electrical equipment including bulks
- Instrumentation scope includes FAR and any downstream instrumentation / equipment including bulks
- Migration of control systems from the existing Main Control Room to the New Main Control Room and tie-ins to the existing Trains 1, 2 and 3.

2.3. *Project Cost: \$2,311 Million*

2.4. *Project Completion Period: 4 years*

3. **Project 3**: *Al-Hoson Gas (Shah Gas Development Project)*

3.1. *Introduction*

The SGD project developed and implemented by Abu Dhabi Gas Development Ltd, “A Limited Liability Company” (Al Hosn Gas). The company was established by the Emiri Decree no. (03/2010) issued on 1st February 2010. The new company headquarter is based in the city of Abu Dhabi and recognized and honored as one of the proud ADNOC Group of Companies.

The SGD Project represents a new era in gas development in Abu Dhabi. The SGD project covers an area of 3 x 6 km, and the length of the Sour gas gathering pipelines are 42km in length.

3.2. *Project Scope*

- Machinery & Equipment
  - 2,545 total Equipment Items
  - 100 Equipment Items more than 4 meters in diameter
  - 20 Equipment Items weighing more than 500 tons
  
- Piping
  - 51 KM of cladded of Pipe
  - 11 KM of Liquid Sulphur Pipeline
  - 1,400,000 LM of Process and Utility Piping (Five times the distance between Abu Dhabi and Fujairah)

- Iron construction
  - 200,000 tons of steel, more than four times of the iron used in the Burj Khalifa
  - Each Sulphur Recovery Unit weighs more than 14 Airbus A380s (the largest passenger plane in the world)
  
- Electrical Cable
  - 8,700,000 LM of Electrical Cable; further than a trip from Abu Dhabi to Madrid
  
- Total Design Production in a day:
  - Natural gas (Sales Gas) – 504 MMSCFD – transport by 127 km pipeline
  - Natural Gas Liquid (NGL) – 4,400 tons – transport by 66 km pipeline
  - Condensate – 33,000 barrels – transport by 66 km pipeline
  - Sulfur Granules – 9,090 tons – transport by rail to Ruwais

3.3. *Project Cost: \$10 Billion*

3.4. *Project Completion Period: 4.5 years*

## II. Refining industry

### 4. **Project 4**: *Takreer's Ruwais Refinery Expansion*

#### 4.1. *Introduction*

Abu Dhabi Oil Refining Company (TAKREER) is implementing a new 400,000 bpcd Refinery in Ruwais, United Arab Emirates. The objective of the Project is to safely and economically build a grass roots refinery complex which shall be designed, procured, constructed and commissioned in accordance with Company's requirements utilizing world class execution standards and procedures.

The project will be executed utilizing seven (7) Lump Sum Turnkey EPC Contract Packages as follows:

- Crude Distillation Unit & Associated Downstream Units

- Residue Fluid Catalytic Cracking Unit & Associated Downstream Units
- Offsites & Utilities
- Tankage
- Site Preparation
- Non-Process Buildings
- Marine Facilities
- EPC Packages to include Commissioning/Start up, Performance Testing & Handover

The following entities are part of the project:

- Fluor Mideast Ltd. provided Project Management Consultancy (PMC) Services for FEED Phase
- International Bechtel Company Limited performed the FEED which was completed in the 2nd Quarter 2009
- The process technology is provided by the following LICENSOR(s):
  - Shaw, Stone & Webster – Residue Catalytic (RFCC) and other Refining Technologies, (11 Units)
  - UOP – Hydroprocessing Technologies, (6 Units)
  - CBI Lummus – Olefins Conversion Unit (1 Unit)

#### *4.2. Project Scope*

The scope of the project covers, in general items:

- Site Preparation
- Installation of new process units
- Installation of new utilities units
- Installation of tank farm and offsite facilities
- Integration of new refinery with the existing refinery
- Construction of buildings such as substations, operator shelters, instrument shelters, maintenance building etc. within the new refinery
- Construction of jetty and associated export facilities

- Installation of seawater intake channel, associated pumping facilities and outfall
- Installation of desalinated water line from General Utilities Plant (GUP)
- Installation of electric power feed from GUP
- Installation of crude oil feed pipeline and connection to existing pipeline
- Integration of new refinery with the existing, expanded sulphur handling plant.

The Project will achieve the following:

- Increase future refining capacity at Ruwais by 400,000 barrel per calendar day (bpcd) in a new grass roots facility
- Upgrade bottom of the barrel by Residue Fluid Catalytic Cracking (RFCC) when processing Murban Atmospheric Residue
- Increase gasoline production by an additional 2.7 million tonnes per annum (tpa), to provide an overall production capability of 5.3 million tpa
- Produce 1.1 million tpa of propylene for petrochemicals feedstock

As well as transportation fuels (gasoline, diesel, jet), the Refinery is a World Class producer of polymer grade propylene. The Refinery offers integration opportunities for polyolefin production, (mainly polypropylene).

The execution of the Project is through several lump sum turnkey Engineering, Procurement and Construction (EPC) contracts, and includes as well the responsibility for READY FOR COMMISSIONING (RFC), COMMISSIONING, testing (up to achievement of PROVISIONAL ACCEPTANCE), training and operating assistance to COMPANY during the WARRANTY PERIOD.

Due to the large size of the Project, four Project Management Consultants (PMCs) are deployed for EPC Phase.

*4.3. Project Cost: Approx. US\$ 10.5 Billion*

*4.4. Project Completion Period: 4.3 years*

## 5. **Project 5: Takreer's Green Diesel Project (GDP)**

### 5.1. *Introduction*

The facilities at Ruwais Refinery process 145,000 BPSD of crude and 280,000 BPSD of condensate. TAKREER is proceeding to modernise existing units and add new units to meet the future low sulphur requirements for Green Diesel Project (GDP). A new mild hydrocracker and hydrotreater are being added to treat gas oils and meet project goals. Support units like Sour Water Stripper Unit, Sulphur Recovery Unit and new Hydrocarbon Flare are also being added to GDP.

The Ruwais Industrial Complex, of which the Ruwais Refinery is a part, is located on the Arabian Gulf in the United Arab Emirates, approximately 250 kilometers west of Abu Dhabi City.

### 5.2. *Project Scope*

The execution of the Project, subsequent to Front End Engineering and Design (FEED) work, is through a lump sum turnkey Engineering, Procurement and Construction (EPC) contract, which will include the responsibility for, READY FOR COMMISSIONING (RFC), COMMISSIONING, testing (up to achievement of PROVISIONAL ACCEPTANCE), training and operating assistance to COMPANY during WARRANTY PERIOD.

The scope of the Project covers:

- Installation of new process units in Ruwais Refinery
- Installation of new utilities within the boundaries of existing utility units to support new and revised process units and other offsites facilities
- New tank farm
- Integration of new facilities with the existing facilities
- Expansion of existing utilities facilities

- Construct new buildings such as the New Control Building (NCB), Substations, Satellite Instrument Shelters (SIS), Operator Shelters, New Workshop Building, Analyzer Shelters, etc.
- Integrated Control Systems (ICS)
- New Hydrocarbon Flare and Acid Gas Flare
- Interconnecting Hydrogen Pipeline from Borouge to Ruwais Refinery (Approx. 1.5 KM)
- Revamp of existing process units

5.3. Project Cost: Approx. US\$ 1.2 Billion

5.4. Project Completion Period: 3.5 years

### III. Petrochemical industry

#### 6. ***Project 6: Borouge-3 Expansion***

##### 6.1. *Introduction and Project Scope*

The Borouge-3 Project consists of the following:

- 1,500 Thousand Tonnes per Annum (kta) Ethylene Unit (EU3) (Steam Cracker) based on ethane feedstock to produce polymer grade ethylene
- 28 kta 1-Butene Unit (BU) using high purity ethylene feed from EU3 to produce polymerization grade 1- Butene
- Two 540 kta each Borstar Polyethylene Units (PE4/PE5) for production of linear low density (LLD) and high density (HD) polyethylene
- 350 kta Polyethylene Unit (PE6) consisting of 350 kta LDPE Tubular plant. The LDPE plant will produce film, wire and cable linear low density grades and base polymer as a feedstock for an XLPE Plant
- 80 kta XLPE plant complete with its downstream clean product packaging and handling facilities. plant to produce a very clean cross linked polyethylene for special wire and cable grades
- Two 480 kta Borstar Polypropylene Units (PP3/PP4) for production of polypropylene
- Ethylene and Propylene export / import requirements

- Sufficient Utilities and Offsites to support the expansion
- Product Handling and Container Yard facilities for products to be packed in 25 kg bags, semi bulk as well as in lined 20' or 40' ship containers
- New Marine structures including quay expansion, off-shore channel dredging, sea water intake and outfall, breakwaters and revetments
- Rail facilities (space only) capable to handle total production from B1 + B2 + B3
- New Offices and Buildings including CCB
- External Interconnections

6.2. *Project Cost:* Approx. US\$ 4,074 Million

6.3. *Project Completion Period:* 4.75 years

## **Appendix D: Full Survey Questionnaire**

### Survey Participation Request

Dear Esteemed Participant,

My name is **Mohamed S Aldhaheri**, working with the Abu Dhabi Water and Electricity Authority (ADWEA), a postgraduate student in the Doctorate of Business Administration (DBA) Program in the College of Business and Economics at the United Arab Emirates University. Currently, I am conducting a research that aims at investigating “the effectiveness of Engineering, Procurement and Construction (EPC) in major projects in Abu Dhabi's oil and gas industry from an end user perspective”. This study is being carried out under the supervision of Dr. Maqsood Ahmad Sandhu.

The filling of the questionnaire is voluntary and without any liability to yourself whatsoever. There are no known or anticipated risks in participating in this survey; moreover, the collected information would be of no conflict, and does not reflect the opinion of your affiliated organization, rather than your own professional expertise. The results and findings of this information would be used solely for the academic research and improvements of EPC contracting strategy in major oil and gas projects purposes.

The collected information through the questionnaire would be treated confidentially, not transferred to a third party and merely used for the research purposes of this study; no reference



to you or your organization is mentioned in any part of this study. For the sake of anonymity, your email address or organization's website will not be mentioned.

I appreciate your willingness if you could kindly share your expert opinion in enriching this doctorate dissertation. The questionnaire will take about 10-15 minutes to complete.

Thank you in advance for your kind interest, valuable time and participation in this questionnaire for this research.

Mohamed S Aldhaferi

DBA Program, UAE University

Jan 2016

**PART ONE:** Participant's Profile

1. Type of project?
  - Refining     Gas     Petrochemicals
2. What is your highest academic qualification?
  - Higher Diploma Bachelor Master Doctorate Other: \_\_\_\_\_
3. Which of the following best describes your current position?
  - Process Engineer    Commissioning Engineer    End User Project  
Coordinator Operations Manager    Maintenance Manager    Plant /  
Division Manager
  - Other role - Please specify\_\_\_\_\_
4. How many years of total work experience do you have?
  - Less than 10-years    10 -20 years    More than 20 years
5. How many years have you worked in Refining, Gas and/or Petrochemicals related fields?
  - Less than 5-years    5-10 years    More than 10 years
6. How many years have you worked with current organization?
  - Less than 5 years     5-10 years    More than 10 years
7. What is the average number of the team members under your supervision?

Less than 10      10-50      More than 50

8. How many projects have you been engaged with as an end-user previously?

Less than 2      3-5      More than 5

9. How many projects have you been engaged with as a Project Team Member previously?

Less than 2      3-5      More than 5

### **PART TWO:** End-users' Perspective

Please respond to the following statements by selecting and ticking the closest option representing your own experience:

1. End-user's endorsement is taken on project execution strategy.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

2. End-user's endorsement is taken to proceed from FEED to EPC phase.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

3. End-user is involved in development of EPC Contractor Selection Strategy.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

4. End-user's endorsement is taken on project commissioning strategy.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

5. End-user is involved in the review of plant facilities spacing layout for maintainability requirements.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

6. End-user is involved in project facilities model review.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

7. End-user is involved in finalization of project facilities plant layout.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

8. End-user is involved in approval process of key engineering documents.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly agree

9. End-user's feedback is taken in the vendor selection of project equipment.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
10. End-user is involved in project Piping & Instrumentation Diagram (P&ID) review.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
11. End-user is involved in project Hazard and Operability (HAZOP) study.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
12. End-user is involved in approval process of construction documents.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
13. End-user is involved in the project pre-commissioning activities.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
14. End-user is involved in the project commissioning activities.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
15. End-user's participation in construction and commissioning adds value to the Project.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
16. End-user is involved in selection of technologies to be used.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
17. Project achieved Reliability, Availability and Maintainability (RAM) percentage as per the EPC contract.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
18. End-user's No Objection is taken while issuing acceptance certificates for project facilities.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
19. Project team continues to provide support, if required by End User, for operation of Plant and facilities while under custody of End User.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
20. End-user is involved in development of EPC Scope of Work (SOW).
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
21. End-user is involved in defining project finished product specifications requirement.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
22. Project met customer finished product specifications.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
23. End-user is involved in specifying project facilities warranty period.
  - Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree

24. Spare parts requirements are discussed and agreed with End User.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
25. Project operating cost is within acceptable range to end-user.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
26. Project major equipment vendor is selected based on lifecycle cost analysis.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
27. Project Completion schedule includes interface plan with existing facilities.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
28. Project Completion schedule covers interface plan with other interconnected new facilities.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
29. End-user is involved in defining project completion schedule.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
30. Project is completed within end-user's timeframe requirements.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
31. EPC model is effective in execution of major projects from end-user's perspective.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
32. EPC model sufficiently meets end-user's requirements in major projects.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
33. End-user prefers EPC over other models in execution of oil and gas major projects.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
34. EPC model is NOT effective in execution of major projects from end-user's perspective.  
 Strongly Disagree  Disagree  Uncertain  Agree  Strongly agree
35. Please share your valuable experience by giving example(s) of your effective participation as end user that supported meeting projects objectives. You may add extra notes as needed.

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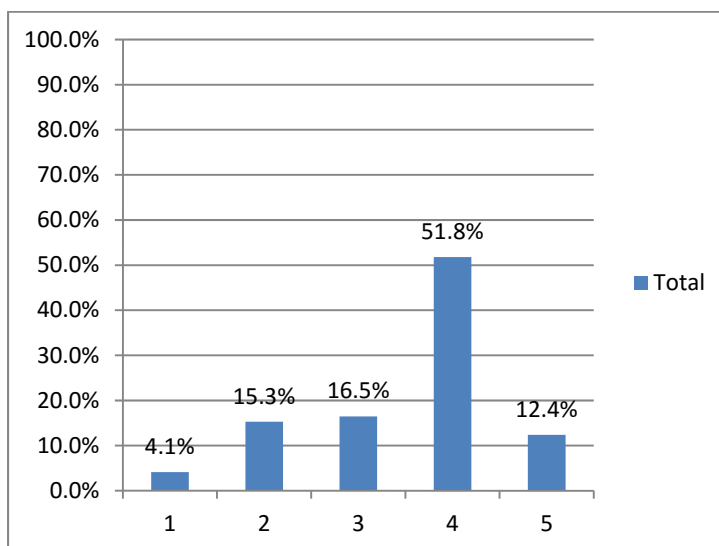
**Appendix E: Percentage distributions of the Closed-ended Questions**

Figure E.1: The percentage distributions of survey item "1"

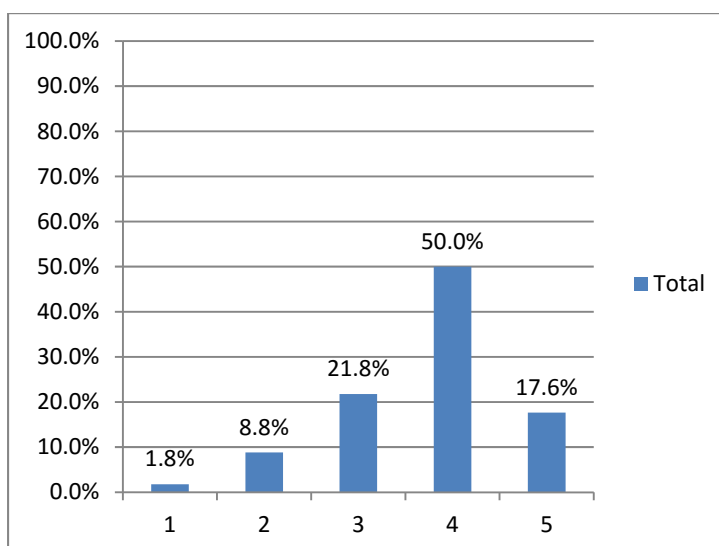


Figure E.2: The percentage distributions of survey item "2"

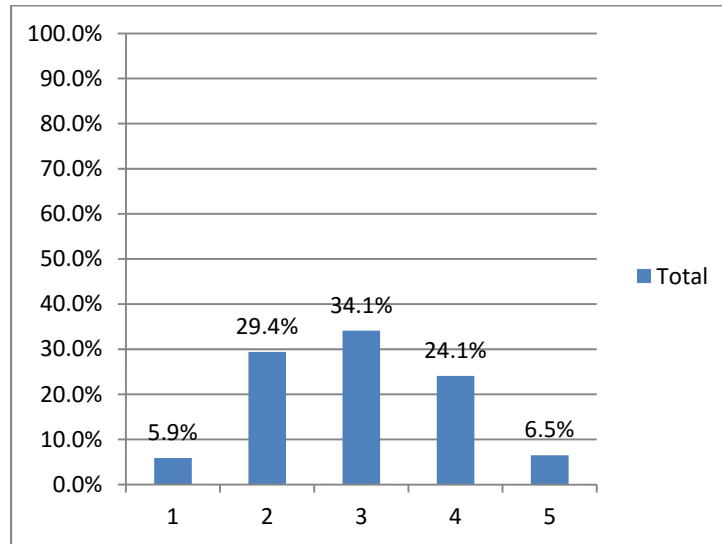


Figure E.3: The percentage distributions of survey item "3"

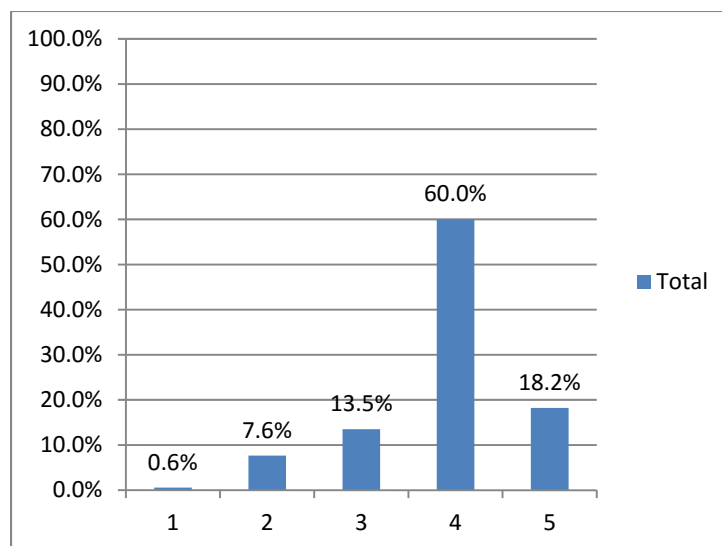


Figure E.4: The percentage distributions of survey item "4"

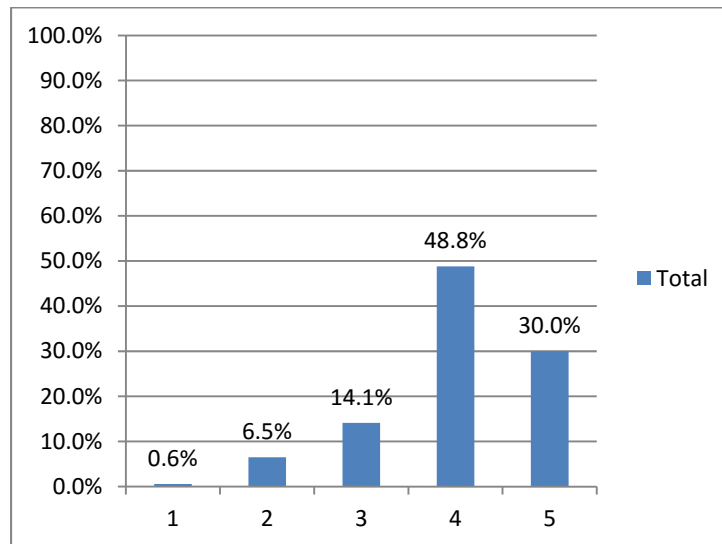


Figure E.5: The percentage distributions of survey item "5"

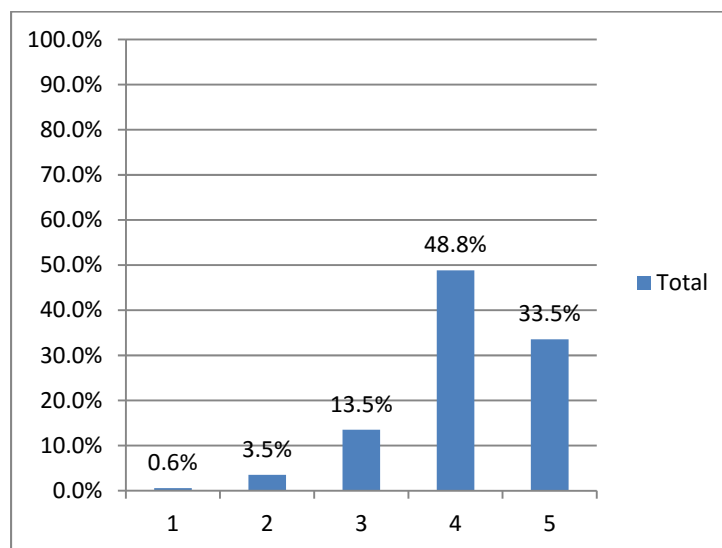


Figure E.6: The percentage distributions of survey item "6"

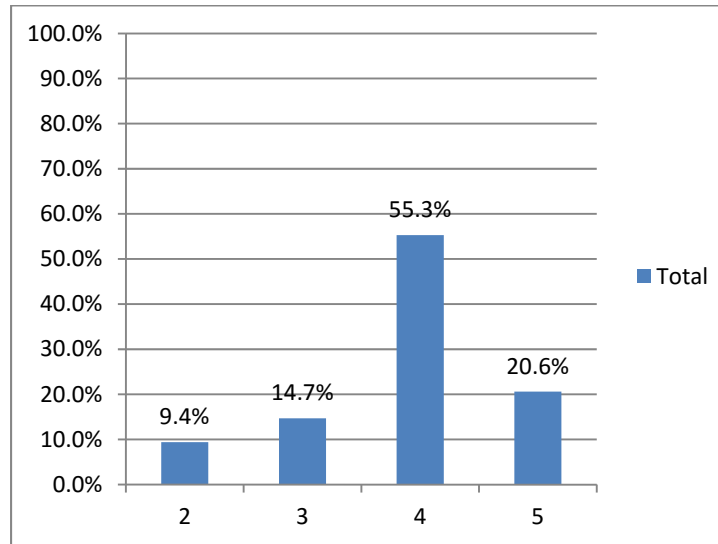


Figure E.7: The percentage distributions of survey item "7"

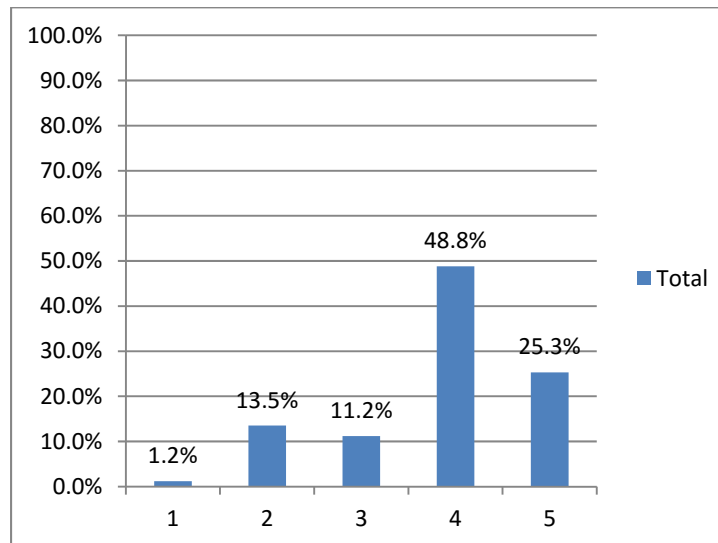


Figure E.8: The percentage distributions of survey item "8"



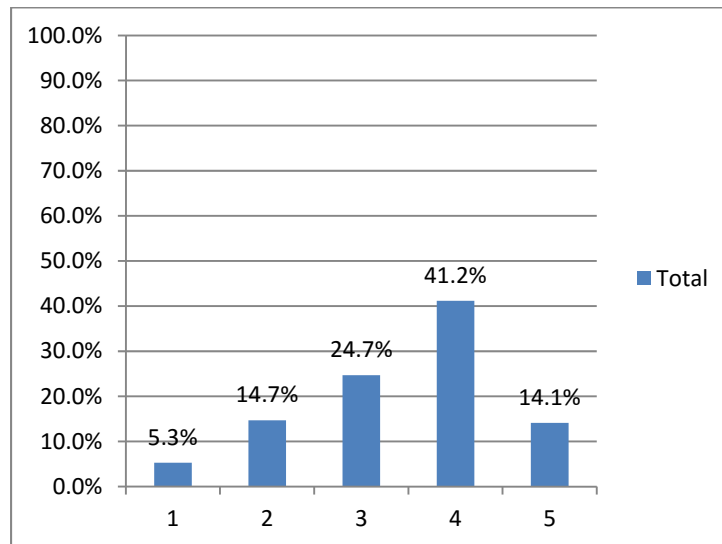


Figure E.9: The percentage distributions of survey item "9"

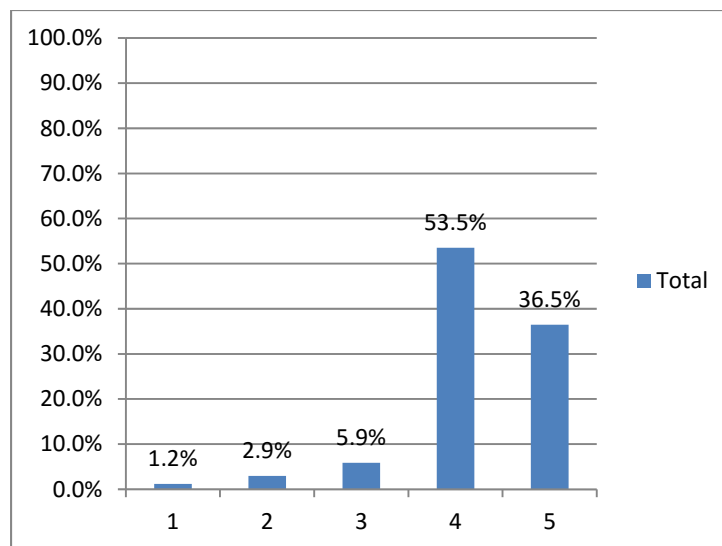


Figure E.10: The percentage distributions of survey item "10"

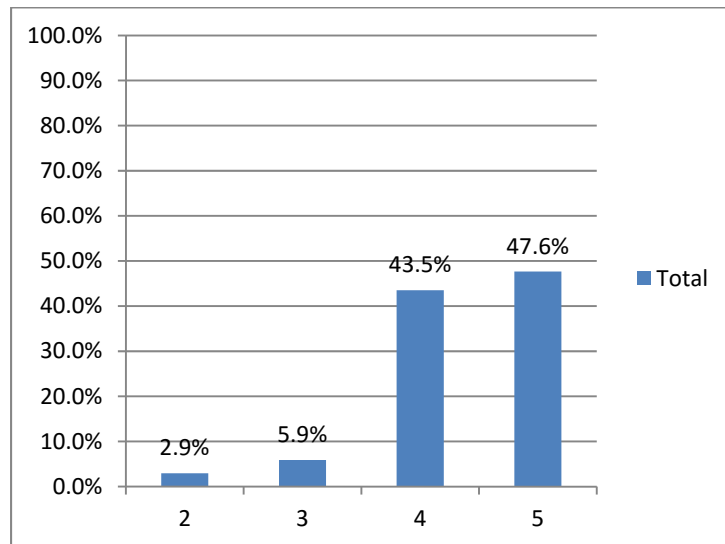


Figure E.11: The percentage distributions of survey item "11"

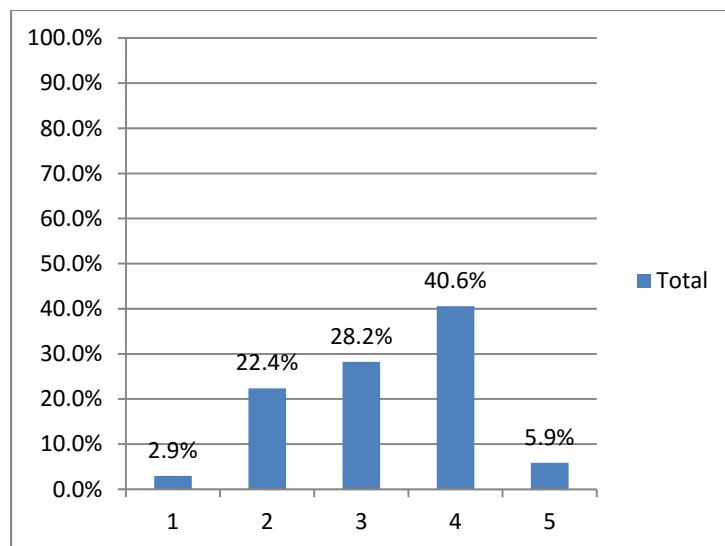


Figure E.12: The percentage distributions of survey item "12"

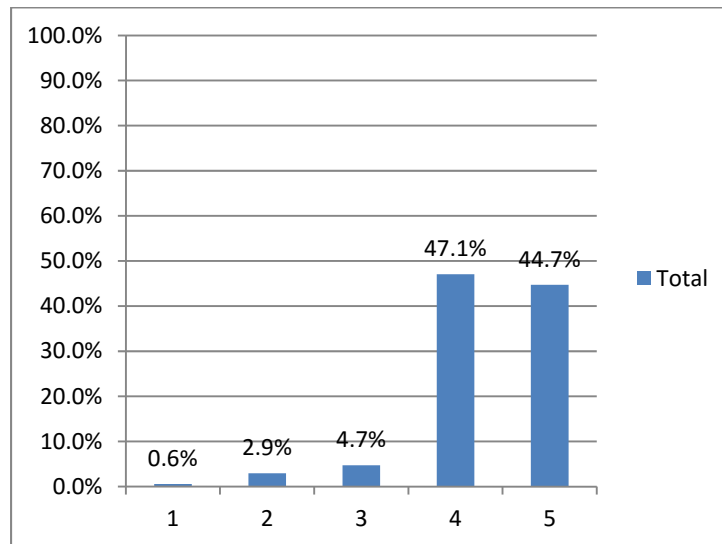


Figure E.13: The percentage distributions of survey item "13"

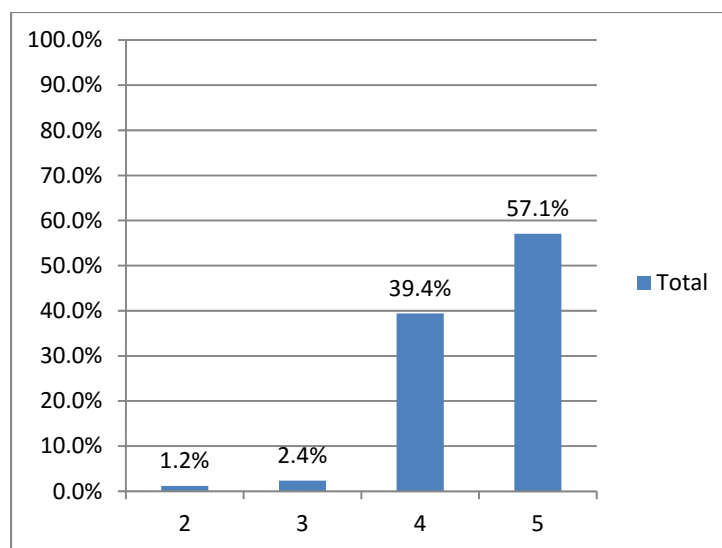


Figure E.14: The percentage distributions of survey item "14"

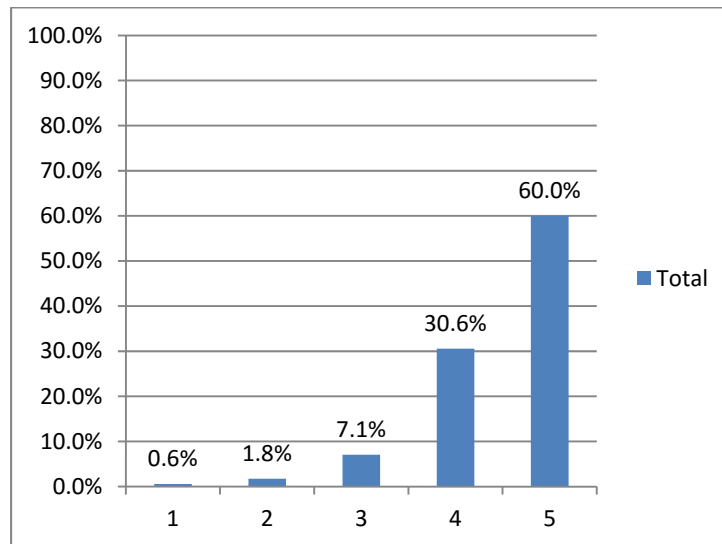


Figure E.15: The percentage distributions of survey item "15"

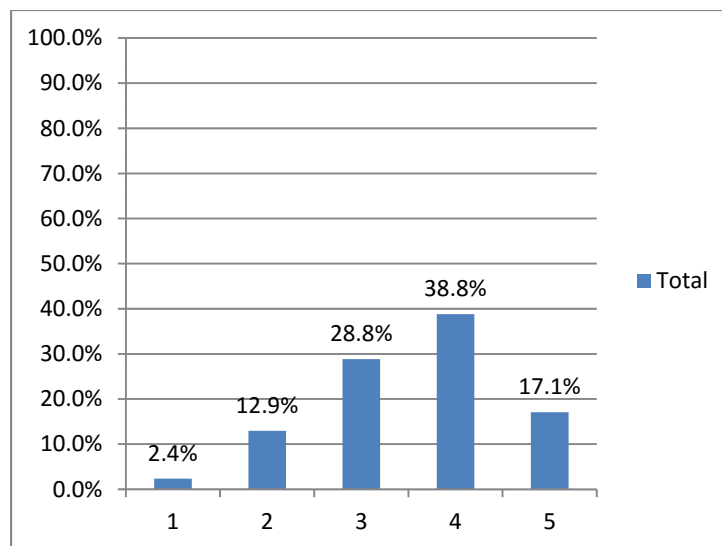


Figure E.16: The percentage distributions of survey item "16"

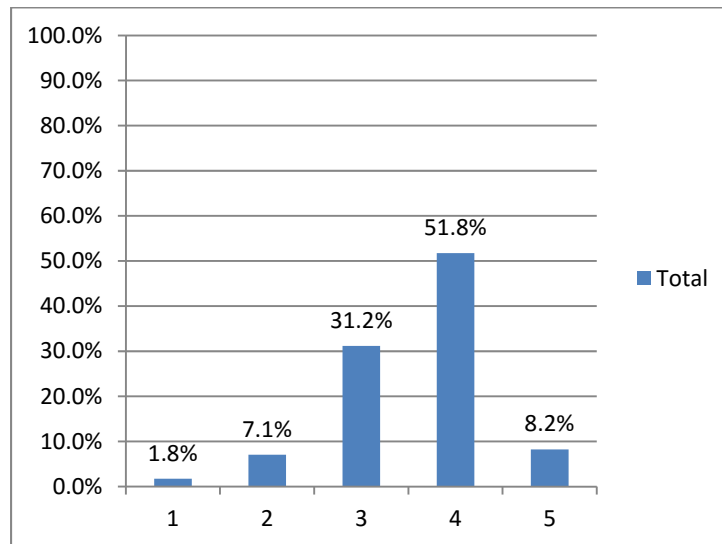


Figure E.17: The percentage distributions of survey item "17"

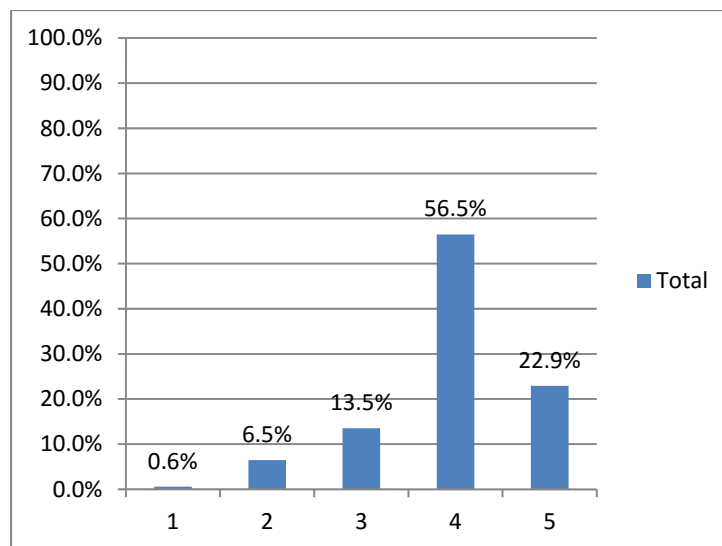


Figure E.18: The percentage distributions of survey item "18"

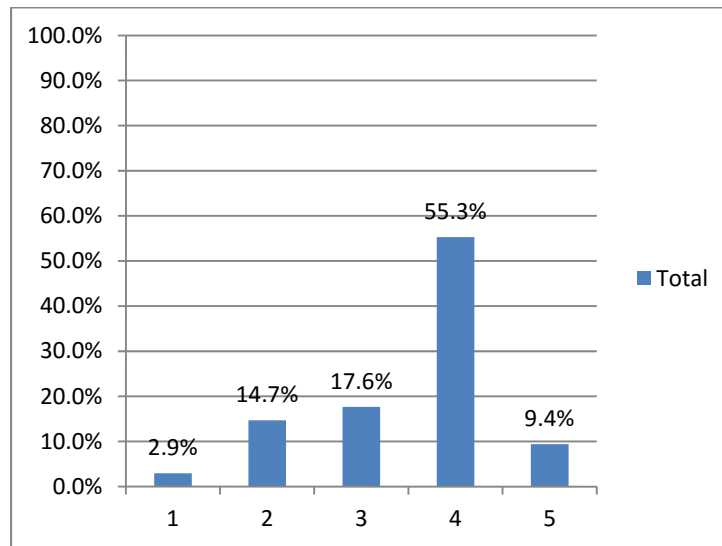


Figure E.19: The percentage distributions of survey item "19"

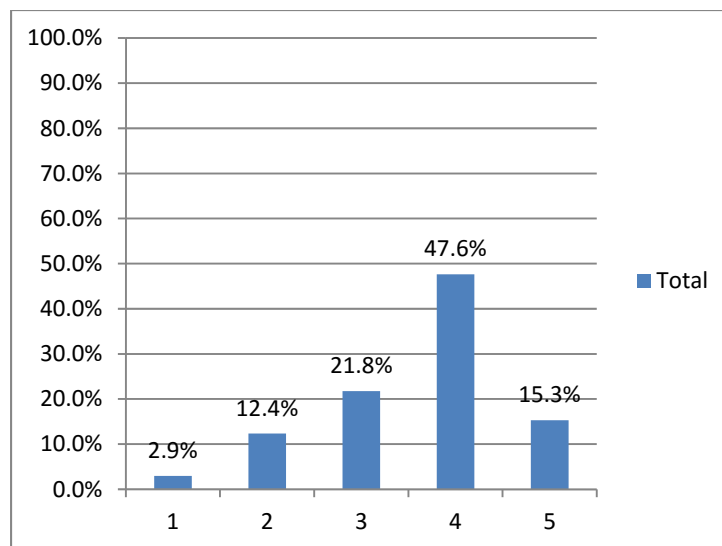


Figure E.20: The percentage distributions of survey item "20"

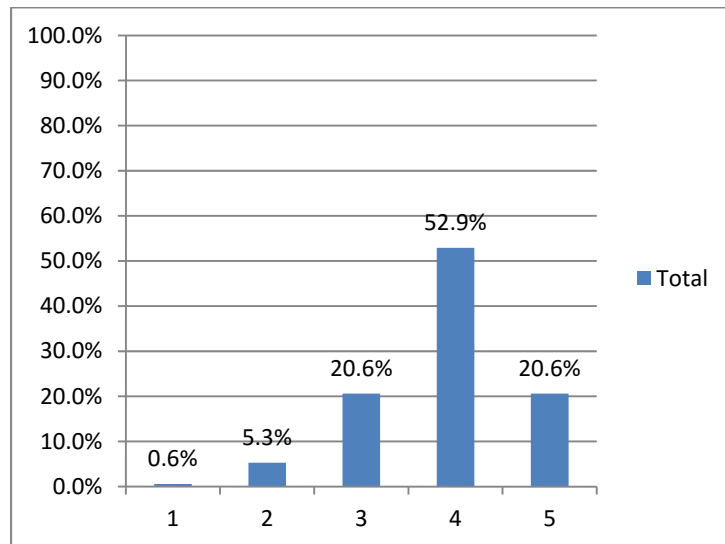


Figure E.21: The percentage distributions of survey item "21"

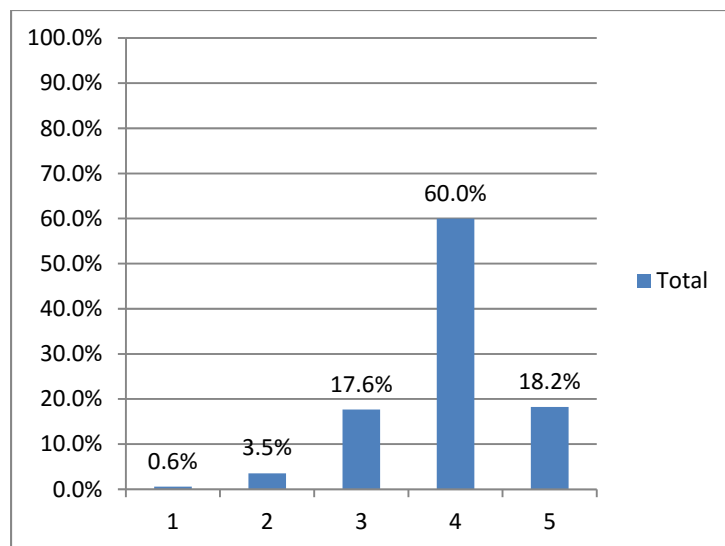


Figure E.22: The percentage distributions of survey item "22"

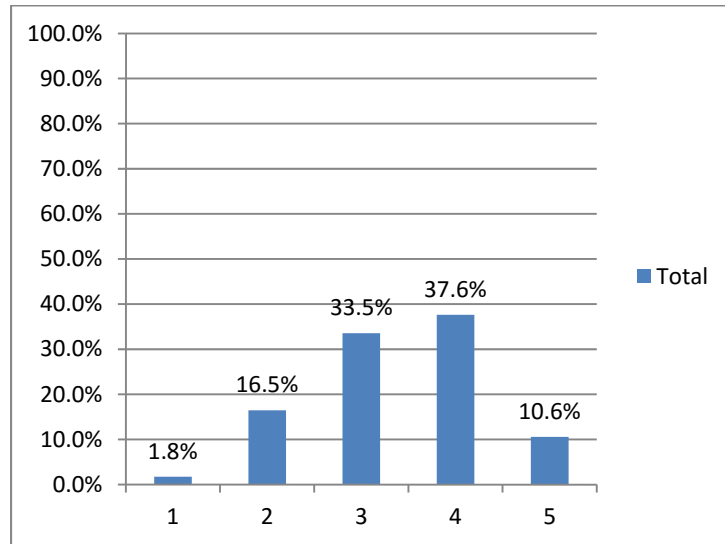


Figure E.23: The percentage distributions of survey item "23"

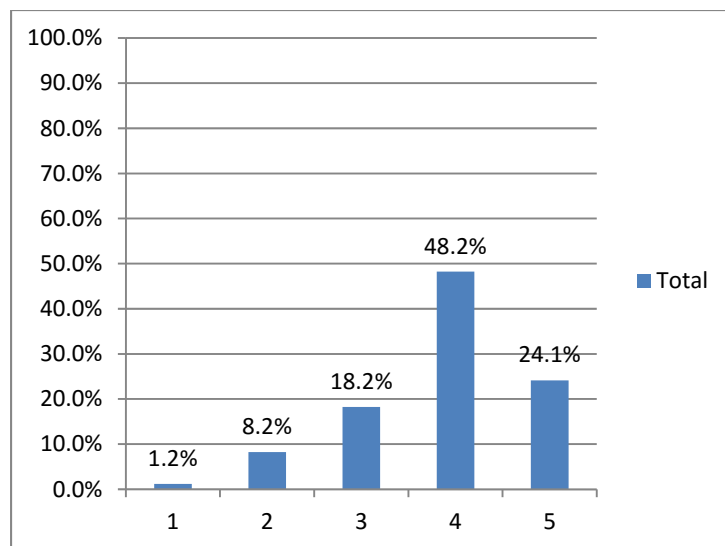


Figure E.24: The percentage distributions of survey item "24"



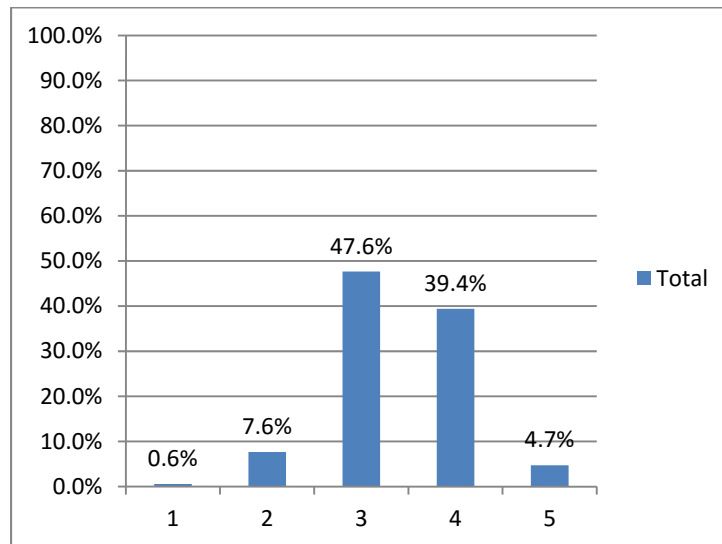


Figure E.25: The percentage distributions of survey item "25"

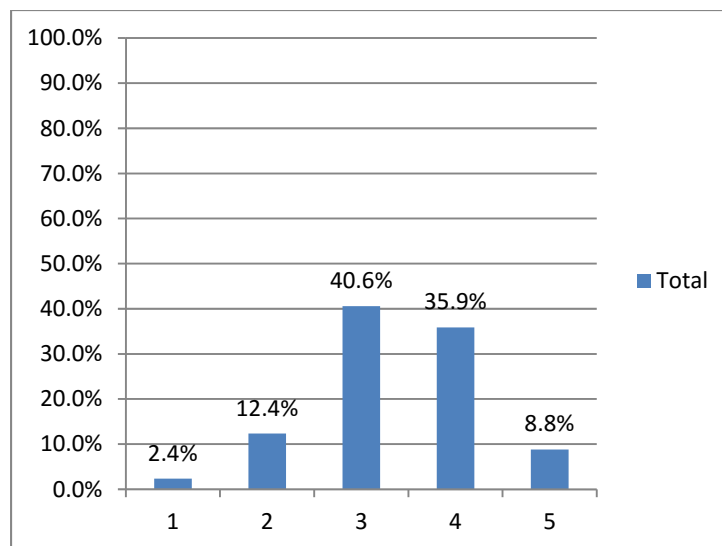


Figure E.26: The percentage distributions of survey item "26"

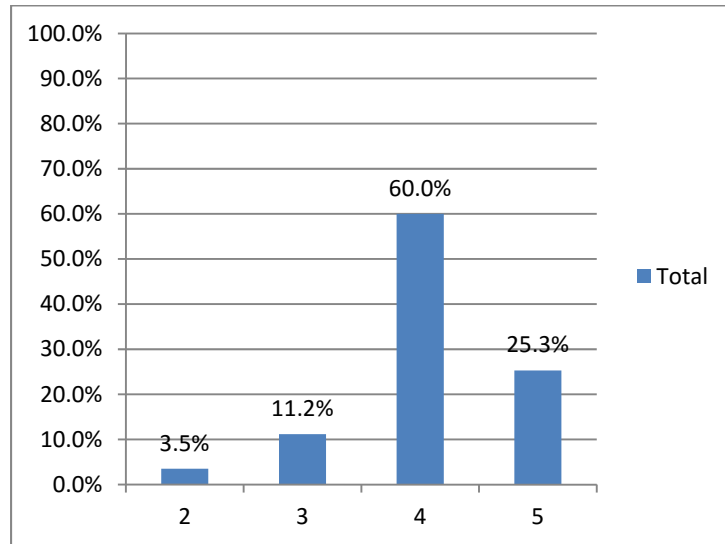


Figure E.27: The percentage distributions of survey item "27"

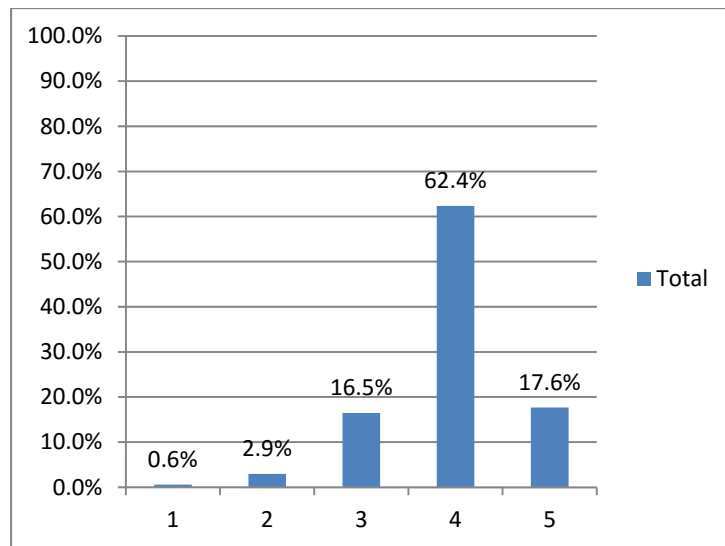


Figure E.28: The percentage distributions of survey item "28"

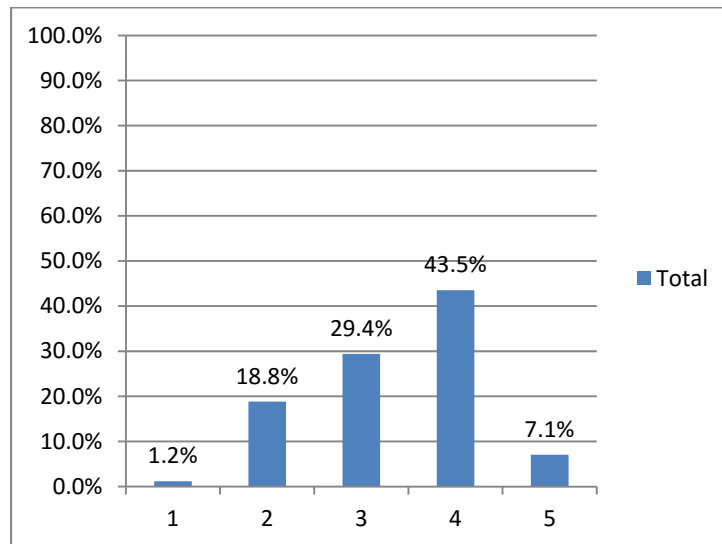


Figure E.29: The percentage distributions of survey item "29"

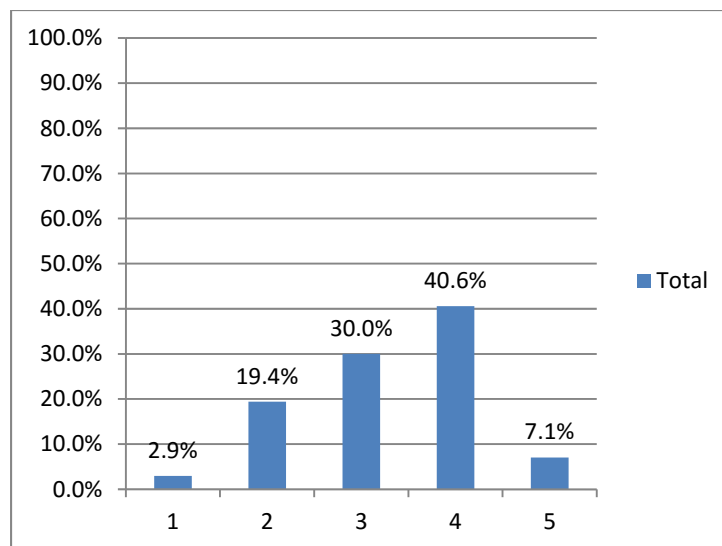


Figure E.30: The percentage distributions of survey item "30"

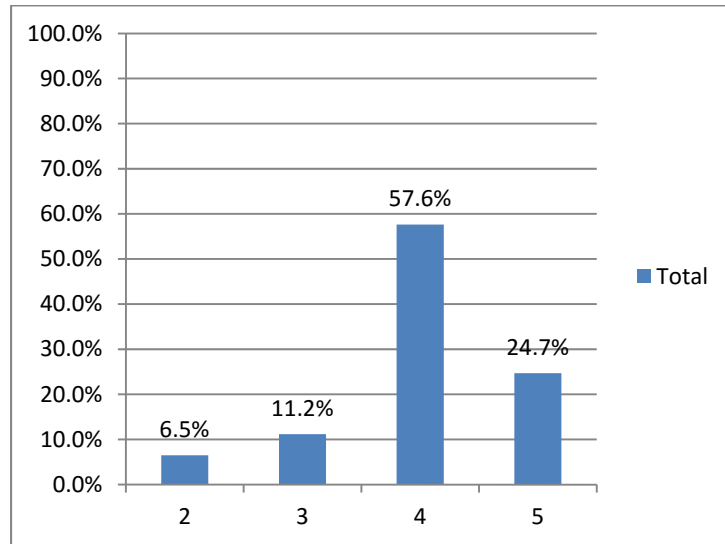


Figure E.31: The percentage distributions of survey item "31"

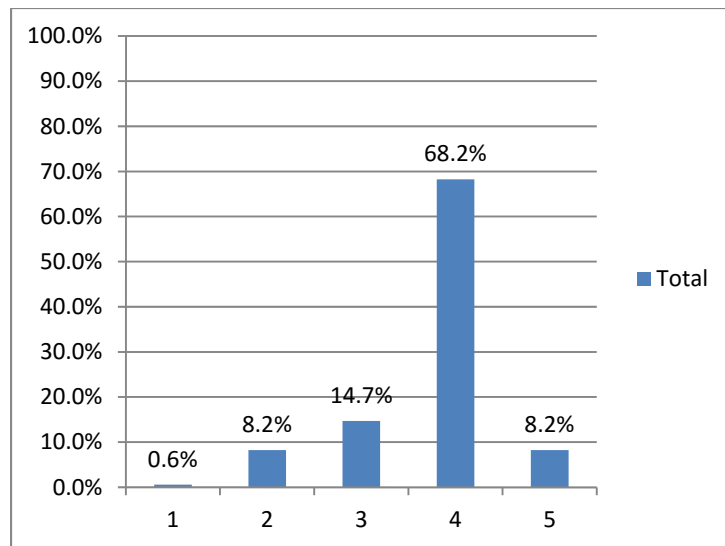


Figure E.32: The percentage distributions of survey item "32"

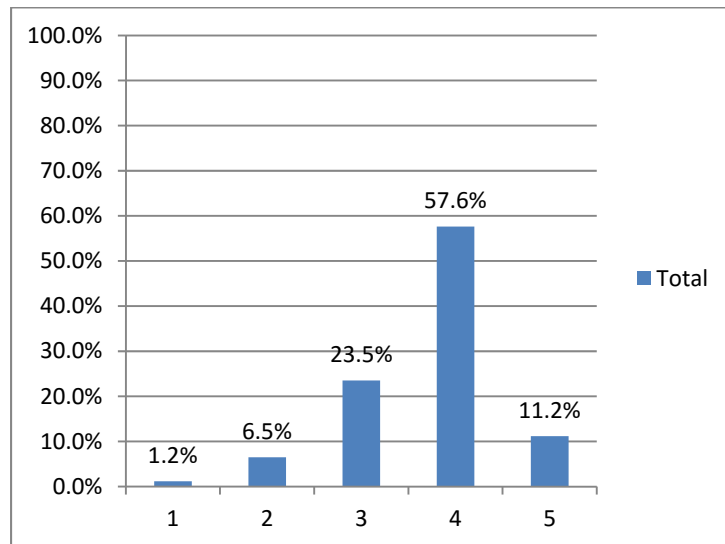


Figure E.33: The percentage distributions of survey item "33"

## Appendix F: Responses from the open-ended question

Table F.1: The responses from the open-ended question

Response #	Response
1	End user involvement from pre-feed till final acceptance certification of any project is a key success.
2	Ruwais NGL - Train 3 and Train 4 projects.
3	Proper handover of the project and related as built documents does not happen smoothly.
4	End user involvement (not the Company project team) in a larger scale in the early phases of the project (e.g. finalizing the project documents, spare parts requirements) can add value to project end quality so long teams benefits. End user comments / requirements at commissioning phase may not get considered as it may have cost implications due to deviation requirements. End user considers long term operational benefits, while the project teams' priority will be on immediate project cost and duration benefits.
5	As an end user, in Operations Managerial capacity, I have been extensively involved in multi USD\$ bn Project Engineering phase, where i attended most of the Complex P&ID, HAZOP, SIL and 30/60/90% 3D Model Review Meetings at the EPC Contractor Home Office.
6	N/A
7	The period of the FEED they have to share the studies with End User to improve the past problem specially for the equipment's related to HSECES
8	Dedicated Quality disciplines of end user to be part of the verification & Execution from maintenance point of view
9	1. End user participation should be there at least from FEED stage. 2. End user's recommendations are to be considered and the same shall have to be incorporated in FEED as well as EPC scope and engineering specifications. 3. End user's suggestions also need to be given due importance during the pre-commissioning and commissioning stages. 4. It is to be noted that End User will be operating and maintaining the plant for the life time. If their suggestions are not considered and the same are not implemented, it will be extremely difficult and sometimes impossible to implement in the running plant. Hence, Project should consider only the project completion as their major achievement and they should also consider to handover a good project/plant which End User will operate and maintain without any bottlenecks and constraints.
10	End User participation in all the stages of the project (EPC) will lead to the successful completion of the project with in the stipulated time frame.
11	Unlike Train#3 project, the end user involvement in the design phase of Train#4 helped to eliminate several significant operation and maintenance issues of Analyzers/QMIs
12	During FAT IFAT of IPCS system, identified many deficiencies and initiated corrective action which supported in smooth commissioning at site.
13	we have helped in commissioning the LPG and floating tanks based on our experience. also, we have facilitated any requirements from the running facilities (like tie in, procedures...etc). early punch listing/warranty notifications.

Response #	Response
14	project team should have Comprehensive team consist of mechanical, civil, instrument, process, HSE and operation. However, right now organization is lacking to have some of these
15	Provided support to commission Train-3 and Train-4 Electrical system.Punch list preparation and warranty notification.
16	Lesson learn and best practice from previous project during engineering stage
17	End user has less intervention during initial stage of project such as project specification development, technology selection and interfacing. Involvement from end user during initial stage will make project more effective in term of integrity and maintainability
18	tr-4
19	As an area maintenance personnel I got highly involved in acceptance of piping and machinery installation, based on Gasco DGS working side by side with PMC. This is very important for end user as they are the ones to run the plant. Also we got involved in review of spares as recommended by vendor, adding and deleting spares required based on our experience.
20	Dedicated EU team to be constituted for Major project development starting from FEED / PRE-FEED stage.
21	Since end user will have the responsibility to operate and maintain the plant after project completion, involvement throughout the different project phases is mandatory.
22	None
23	Maintainability aspects shall be studied in depth prior to the finalisation of EPC so that the Operating cost can be minimised to the best possible. More often cheaper products are procured wherein the maintenance cost becomes higher. This may have impact on the investment cost whereas operational cost on long run may be cheaper.
24	Operability assurance established, Enduser involvement during engineering, selection of equipment, model reviews, layout optimization etc., really beneficial during the operations stage. Vendor factory visits, FAT, SAT, construction, commissioning etc., participation ensure quality and prevent undue delays during start up. Insurance and operation spares requirement finalization end user involvement is a must for any major projects.
25	the current practice of awarding job to lowest bidder pave the way for under quoting using cheaper resources that will have impact on the quality and also later raising the variations. FEED shall take sufficient time without much focus on schedule so that EPC can move faster and in a precise way
26	Recently commissioned Habshan 5 EPC project is a good example of very good collaborative work between End User and Project Team and also EPC team. Since commissioning, Plant is running is smoothly meeting all project objectives and product specifications
27	In my previous job I have participated in Pre Commissioning, Commissioning and successful Master Start-up of Pak-Arab Refinery (Pakistan Abu Dhabi joint Venture, state of the art 100,000 BPSD Mid-Country Refinery) and worked with UOP, COSMO and JGC experts as a member of joint commissioning team. Have participated in three Turnarounds and successful Master start-up of Petroleum Refinery. In my current job at Al-Hosn Gas I have participated in Pre Commissioning, Commissioning and successful Master Start-up of Shah Gas Plant and reaching the feed of the plant up to 1BCF.
28	End used should be embedded with project team
29	None

Response #	Response
30	The main success in EPC contracts depends on the Contractor selection. End user active involvement in various stages of the project definitely will improve the quality, ensure smooth commissioning, and trouble free operation of the plant. Habshan-5 project can be considered as one of the model successful EPC contract on various counts.
31	Greetings. In same project, End user highlighted the future vision such as expansion or modification, but somehow the highlights been ignored due to financial reason or other reason. Later during EPC stage or after completion of the projects, the highlight will be considered and the cost will be doubled for the same job! That way End user involvement is mandatory, but in certain stage, project team have to decide if the request is/are honestly needed or just it will be nice to have it/them. Regards.
32	I am an end user who participated during Commissioning phase of EPC. There was another Coordination team from End User working with project team during earlier involvement in Engineering and Procurement phases. From my perspective, I believe it was definitely valuable having me involved in the pre-com & com activities. I was able to shape the procedures of operations based on my experience and I was able to involve my team to learn and gain an advanced expertise to run the commissioning activities leading to a smoother hand-over and stable operations afterwards
33	EPC Contract is not the only option for execution of projects. Projects execution can be done in a hybrid model i.e., convention + EPC in a most cost effective and within schedules with no compromise on quality
34	Following up QA/QC, Non Destructive Testing, Materials and Stationary Equipment Testing.
35	I was involved in some major projects (Habshan-2, HGCE, and IGD) and my major role was in IGD project (known as Habshan-5 Process) as operations head. One of key success factor was team spirit and the full integration between my team and the EPC contractor team (JGC scope). The common goal was the key in working together and forming a real team. In addition, early planning for manpower and other resources. Other note I need to share is about the EPC model. The system is to start by doing the FEED and then award the EPC package for delivering the project. Usually FEED contractor will make the engineering and will not be worried about the accuracy of data and the best design structures. When ECP contractor starts his work, in the Engineering part (E), many design issues will be highlighted and due to the schedule the project management team will be forced to make short cuts and select the easiest way to move forward and the same pattern will continue throughout the project. As a result, many things will move against the End User wish and will end up constructed and commissioned. I strongly believe that the concept of separate FEED and EPC should be changed. I propose that there should be a design competitive bidding where bidders will make a design proposal and based on this proposal a price will be quoted. Then, client has all the options to select not based only on the price, but on the best design as well. The bidder will try to optimize the design in a smart way where the price will be as low as possible. Client has to specify his requirements like plant reliability, availability, maintainability, sparing philosophy, product specification...etc. Many thoughts can be gathered in this subject.
36	My participation was in Project side.



Response #	Response
37	With past experience and lesson learns from EPC projects management as enduser, I would like to say the contract winners EPC companies who quoted low and we award the contract based on their attractive rates. This will have lot of impact to HSE, quality and asset integrity while executing the project. Most importantly less competent manpower, poor workmanship, time delay, poor management and poor welfare facilities and low wages to their employees. At the end it all effects to delay in delivering the project and quality as well effected. Sometime the contracts are not clear in terms of following the update DGS and application of best practices. Always contractor has conflict to follow the old DGS, method statements, risk management other old standards. There should be comprehensive package of documents which are the update on from project team to deliver it to contractor during bidding stage. More stringent clauses in contract documents. Nowadays, it seems to be a High Risk to award the contracts to companies who has quoted low and at end or during the project commissioning end user suffers a lot as it was not fulfilling to quality works.
38	Engineering company win the EPC contract by quoting lower prices which will affect the quality of project. Money is saved by cutting corners ,designing the equipment tightly without adequate operating margin & supplying inferior equipment which would adversely impact the operation or performance of the plant. This is very apparent in some of the new project which had come up in 1990s as compared to the old plant built in 1970-80s.
39	Provide special materials as loan basis during shutdown (warranty period) to assist the EPC to correct any defects.
40	1. Spare parts to be submitted and reviewed in early stages prior to commissioning.2. Documents also to be submitted for review in early stages.3. End user must have authorization to deal with direct vendor and EPC for any changes or clarifications.
41	Learnings of Fire Protection System commissioning were shared through PLMS portal.
42	During the “EPC” phase, the engineering companies may work with different types of contract, but always under a close follow up of the End User.
43	Our technical authority is the Engineering and Technical divisions, not the end user, Project Management has the final authority of approvals.
44	1.involvement of the end user from the start of the Pre FEED and FEED phase is the best practice which avoid a lot of mistakes as a lesson learn from other previous projects.2 Involvement of end users in the EPC phase engineering/construction /commissioning solves a lot of time and avoid delays
45	Above responses to the Questionnaire is from my prospective as Senior Project Manager in charge of Habshan 5 U&O Project. End User involvement in the project development and execution contributed immensely resulting in completing the project on time and without any technical and contractual issues with CONTRACTOR. This was due to End User involvement in all phases of the project to define and agree on all technical issues resulting in no surprises during the execution.
46	working as one team is the best approach to meet project schedule
47	In my experience end user participation in hazop, model review, precom and commissioning activities greatly helps the project progress.
48	One of most important is pre-commissioning to ensure project can start smoothly
49	End user shall be thoroughly involvement in development of Feed if the Feed is under contract
50	it is proven helpful to assign commissioning as part of EPC (EPCC)

Response #	Response
51	End user inputs were taken in review of process data sheets, addendum to specifications, study reports, chemical consumptions, effluent summary etc to name a few critical ones besides P&ID reviews, HAZOP, model reviews.
52	In SGD project, end user operations representatives are engaged from the start of EPC to review the detail design development and ensure safe and operable facility design. This was successful in eliminating operations issues usually found at the time of handover from project phase and cause delays and bottlenecks.
53	EPC model is always effective in execution of major projects. With my experience of about 5 projects, I were always convinced this strategy & found it more effective.
54	The success of any project depends both on FEED and EPC phases. However, FEED phase has more importance as 70~80% of success of project depends upon how good FEED has completed. End user involvement start from FEED till EPC phase is vital in all gates of project reviews and decision making. This need is acknowledged by major oil and gas companies and that why Operation readiness & assurance teams are built in parallel to project teams which are the final custodians of any facility under project.
55	Enduser involvement during FEED, EPC engineering, construction and commissioning phase is very much essential for achieving the project goals. SGD project is one of the examples wherein a separate team " operability assurance " was embedded with PMT team with this objective. Similar approach need to be followed in all upcoming projects
56	This provided input is based on my previous assignment as Major Projects End User Coordination Manager, I have been assigned as Major Projects Front End Manager for managing Pre-FEED and FEED Phases, "Post Implementation Review" (PIM) was initiated under Front End Division to assess the level of success of Major Projects after execution by EPC Contractor from the technical and commercial view points and identify potential opportunities for an added value modifications and debottlenecking.
57	The best value for end user is when core Operations and Maintenance team is involved since FEED phase, during all engineering-construction-commissioning phase and then actively contributing to successful plant operations
58	EPC model can be improved by increasing the relevant disciplines (Process, Operations, commissioning, instrument, maintenance, reliability) full time staff involvements in the Project team and their inputs should be binding on Project Management team to address & implement
59	I was involved as an end user in three major projects from the beginning of the project phase some time from FEED Stage some time EPC Stage, but as a part of project team. So my main responsibility was to ensure the end user requirements are included at each stage of the project and i found this is the best way to handle any project. All 03 projects were EPC and the strategy works well. Only problem will be if the FEED study is not done proper or with incomplete information the EPC outcome will always be an issue in terms of cost and schedule.
60	Reviewing, participating, leading commissioning.
61	HAZOP; Risk Assessment (interface); MOC/ Test Procedure/ 3D Model/ Start-up reviews; SOW studies
62	Major problem in project execution is PMC role. PMC to be used as consultant and not final signature authority. Final user also should be signatory for all documents.

Response #	Response
63	The quality control part of the project is a matter of concern as is evident from a number of small leaks, False and spurious alarms, break down maintenance of HSECES critical equipment
64	Selection of EPC contract is the most critical point to meet Quality and time schedule. An experience PMC team will assure the technical input however they are not sharing any responsibility after commissioning. It would be advisable to form a local PMC team who can take care of plant after commissioning.
65	I was part of team as end user for water disposal well project. As end user we were involved starting from the conceptual study to commissioning of facility. We were involved at every step of the project and made it as success.
66	1)prompt response to queries from EPC and Vendor. 2)Reviewing vendor technical clarification specification deviation and being practical
67	EPC must support operations team during commissioning and upto warranty shutdown.
68	In an EPC model problems come when the contract is given on lump sum to the cheapest bidder. The formation of PMT/PMC is critical and should include persons with previous operations back ground. In my 26 years of experience I have seen most of the problems faced by end users during operations are due to wrong decisions by PMT/PMC team during approval and or equipment selection process.
70	n/a
71	As an end user i was employed too late in order to have any input in to the design of the laboratory, the equipment, chemicals, general consumables that had been purchased by the EPC contractor as part of the project and therefore was left with a building that was not designed correctly (bad layout, undersized, lack of office space, lack of storage space etc.) and lots of missing equipment, chemicals and general laboratory consumables.
72	First allow an observation. End user input is normally allowed in most projects during FEED and EPC, however it is not normally valued and quite often dismissed as it may affect the project goal of completion on schedule and under budget even if lifecycle cost analysis proves it to be a worthy input. My most effective end user participation has been when the project management endorsed end user participation and enshrined it in the project goals. This gives the best outcome as all participants in the project have the same focus - schedule, cost, operability.
73	In some project cases and since the cost of the EPC is already fixed as a lump sum turnkey basis ,the end users can finds difficulties in making changes dg strategy since project cost is known and fixed but I am not certain whether the End user prefers EPC contracting strategy over other projecuring EPC phase which were overlooked in previous phase open and not fixed .This is why the EPC contracting strategy is prefers e.g FEED .Whereas for other contracting strategy e,g Cost plus for detailed Engineering , the End user can find more freedom(if participated or was involved) to add changes during detailed Engineering which were overlooked in earlier phases since the detailed Engineering cost for this type of contracting strategy is open and not fixed .I think from project team point of view , they definitely prefer the EPC contracting strategy over the cost plus contracting implementation strategy e.g Cost plus for detailed Engineering. The EPC Contracting strategy needs to include a specific lump sum amount of money to allow for cost of changes requested by the End user during the EPC phase

## Appendix G: Reliability, Validity and Multicollinearity Results

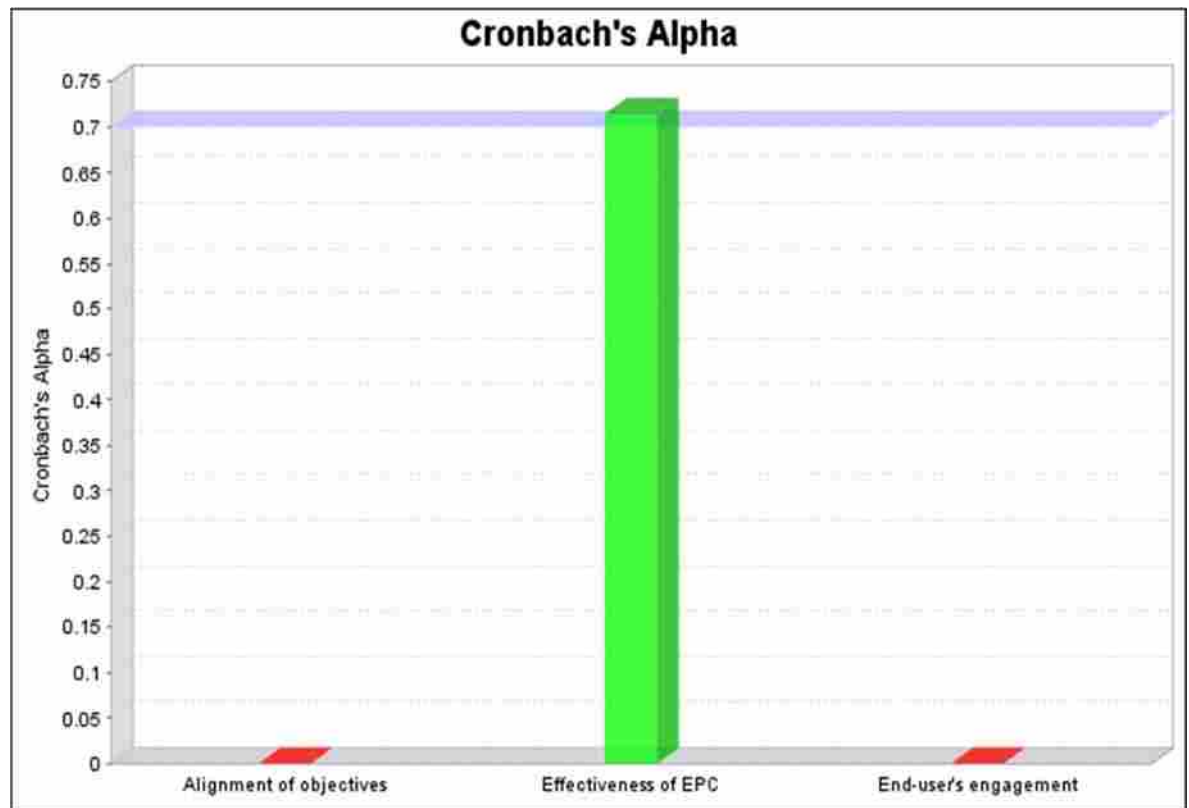


Figure G.1: The Cronbach's alpha of the *Effectiveness of EPC* construct of the initial structural model

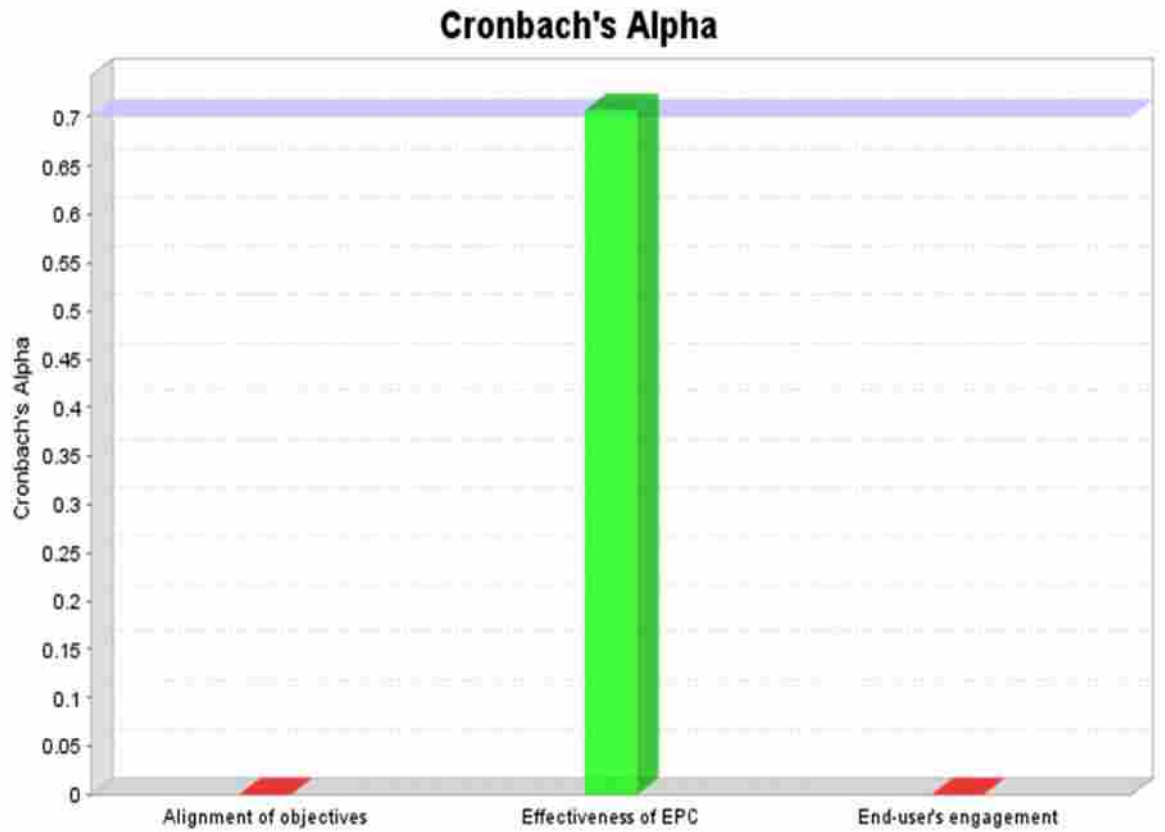


Figure G.2: The Cronbach's alpha of the *Effectiveness of EPC* construct of the intermediate structural model

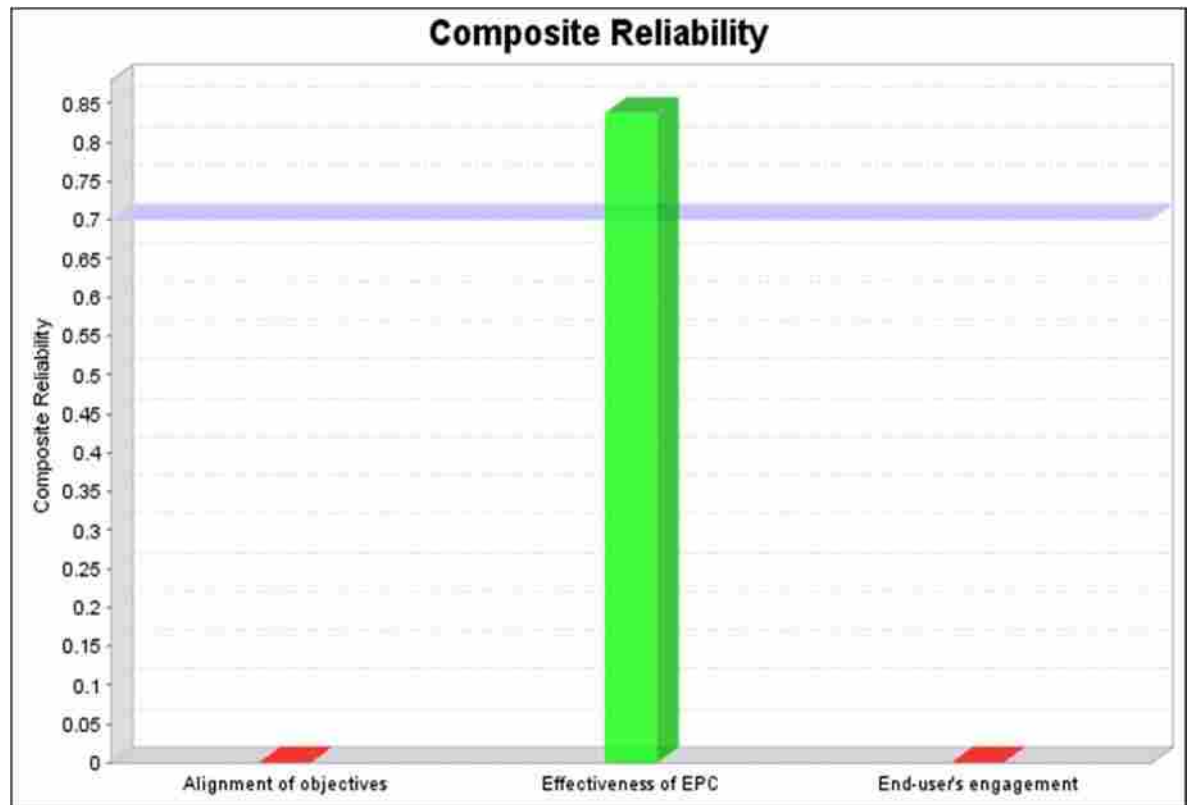


Figure G.3: The composite reliability of the *Effectiveness of EPC* construct of the initial structural model

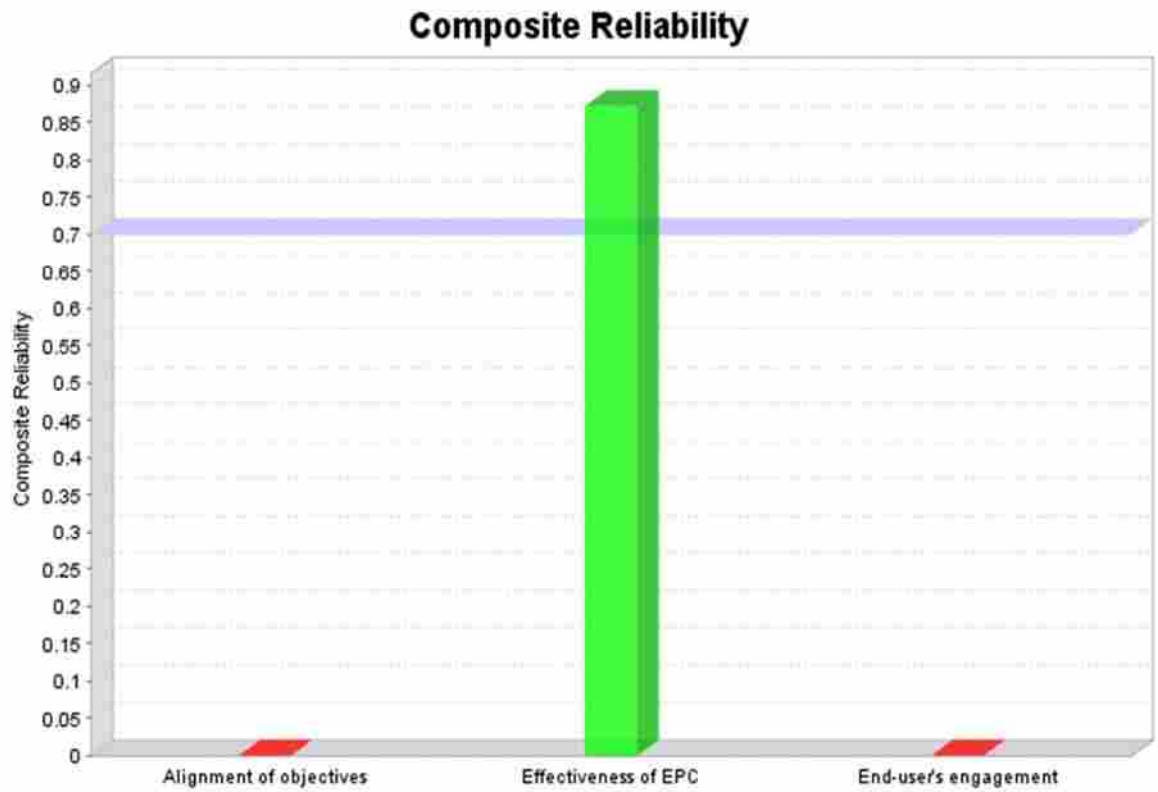


Figure G.4: The composite reliability of the *Effectiveness of EPC* construct of the intermediate structural model

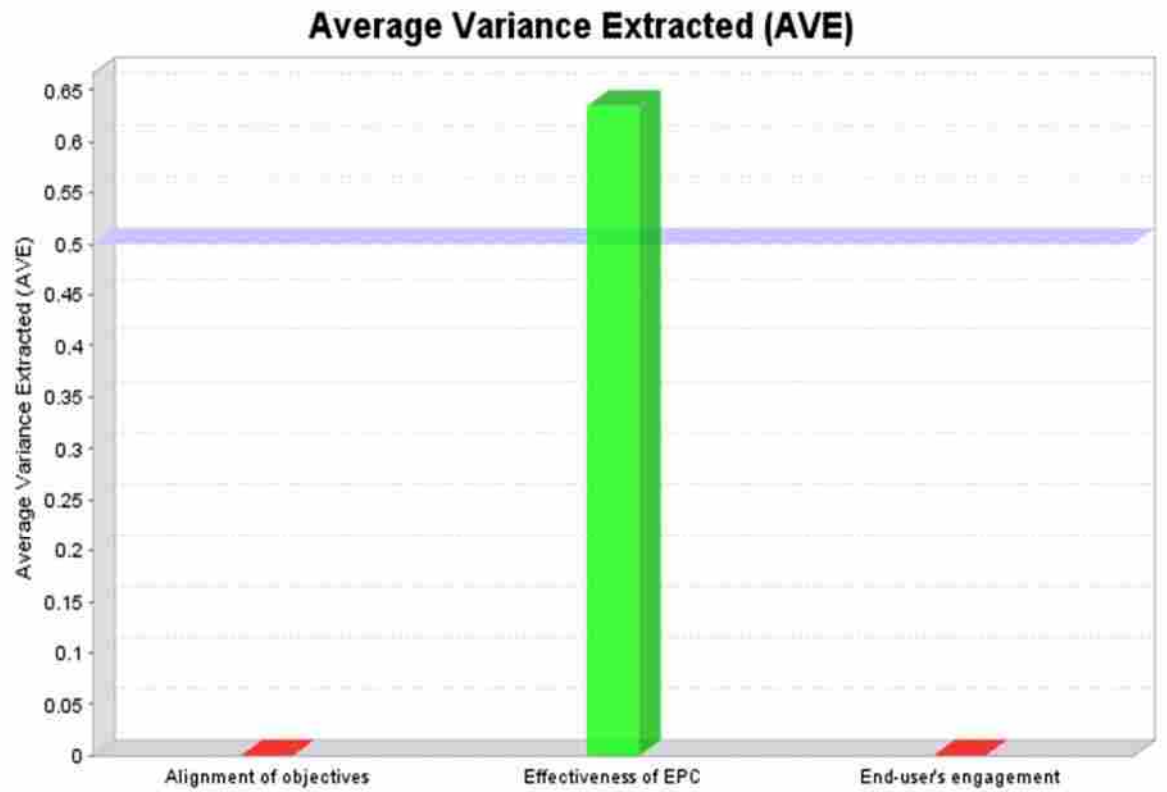


Figure G.5: The Average Variance Extracted (AVE) of the *Effectiveness of EPC* construct of the initial structural model



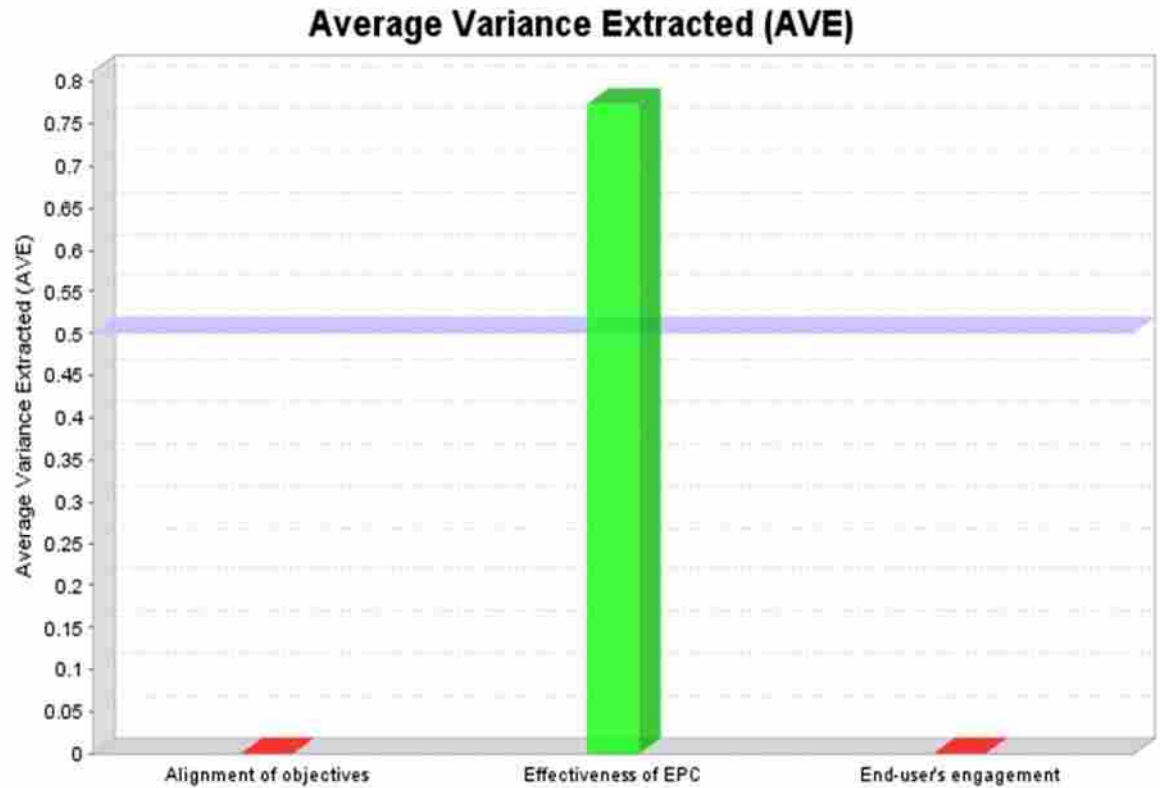


Figure G.6: The Average Variance Extracted (AVE) of the *Effectiveness of EPC* construct of the intermediate structural model

Table G.1: The cross-loading analysis matrix of the intermediate "Effectiveness of EPC" structural model

	Alignment of objectives	Effectiveness of EPC	End-user's engagement
Construction and Commissioning	0.614	0.734	0.858
Effectiveness Perception	0.840	<b>0.874</b>	0.631
Engineering and Procurement	0.658	0.739	0.863
Lifecycle Cost	0.629	0.548	0.409
Meeting Requirement Perception	0.696	<b>0.885</b>	0.869
Performance Guarantee	0.914	0.797	0.748
Plant Layout	0.549	0.577	0.675
Product Delivery Schedule	0.847	0.739	0.610
RAM	0.755	0.658	0.532
Studies and Strategies	0.676	0.760	0.888

Table G.2: The Tolerance and VIF values for the case of *Performance Guarantee* as the dependent variable

Coefficients <sup>a</sup>			
Model	Collinearity Statistics		
	Tolerance	VIF	
1	Studies_Strategies_E1	.428	2.335
	Plant_Layout_E2	.725	1.380
	Engineering_Procurement_E3	.436	2.295
	Construction_Commissioning_E4	.432	2.313

a. Dependent Variable: Performance\_Guarantee\_A2

Table G.3: The Tolerance and VIF values for the case of *Lifecycle Cost* as the dependent variable

Coefficients <sup>a</sup>			
Model	Collinearity Statistics		
	Tolerance	VIF	
1	Studies_Strategies_E1	.428	2.335
	Plant_Layout_E2	.725	1.380
	Engineering_Procurement_E3	.436	2.295
	Construction_Commissioning_E4	.432	2.313

a. Dependent Variable: Lifecycle\_Cost\_A3

Table G.4: The Tolerance and VIF values for the case of *Product Delivery Schedule* as the dependent variable

Coefficients <sup>a</sup>			
Model	Collinearity Statistics		
	Tolerance	VIF	
1	Studies_Strategies_E1	.428	2.335
	Plant_Layout_E2	.725	1.380
	Engineering_Procurement_E3	.436	2.295
	Construction_Commissioning_E4	.432	2.313

a. Dependent Variable: Product\_Delivery\_Schedule\_A4

Table G.5: The Tolerance and VIF values for the case of *Plant Layout* as the dependent variable

Coefficients <sup>a</sup>			
Model	Collinearity Statistics		
	Tolerance	VIF	
1	RAM_A1	.531	1.884
	Performance_Guarantee_A2	.525	1.904
	Lifecycle_Cost_A3	.677	1.478
	Product_Delivery_Schedule_A4	.527	1.898

a. Dependent Variable: Plant\_Layout\_E2

Table G.6: The Tolerance and VIF values for the case of *Engineering and Procurement* as the dependent variable

Coefficients <sup>a</sup>			
Model	Collinearity Statistics		
	Tolerance	VIF	
1	RAM_A1	.531	1.884
	Performance_Guarantee_A2	.525	1.904
	Lifecycle_Cost_A3	.677	1.478
	Product_Delivery_Schedule_A4	.527	1.898

a. Dependent Variable: Engineering\_Procurement\_E3

Table G.7: The Tolerance and VIF values for the case of *Construction and Commissioning* as the dependent variable

Coefficients <sup>a</sup>			
Model	Collinearity Statistics		
	Tolerance	VIF	
1	RAM_A1	.531	1.884
	Performance_Guarantee_A2	.525	1.904
	Lifecycle_Cost_A3	.677	1.478
	Product_Delivery_Schedule_A4	.527	1.898

a. Dependent Variable: Construction\_Commissioning\_E4

## Appendix H: Structural model with *T*-statistics

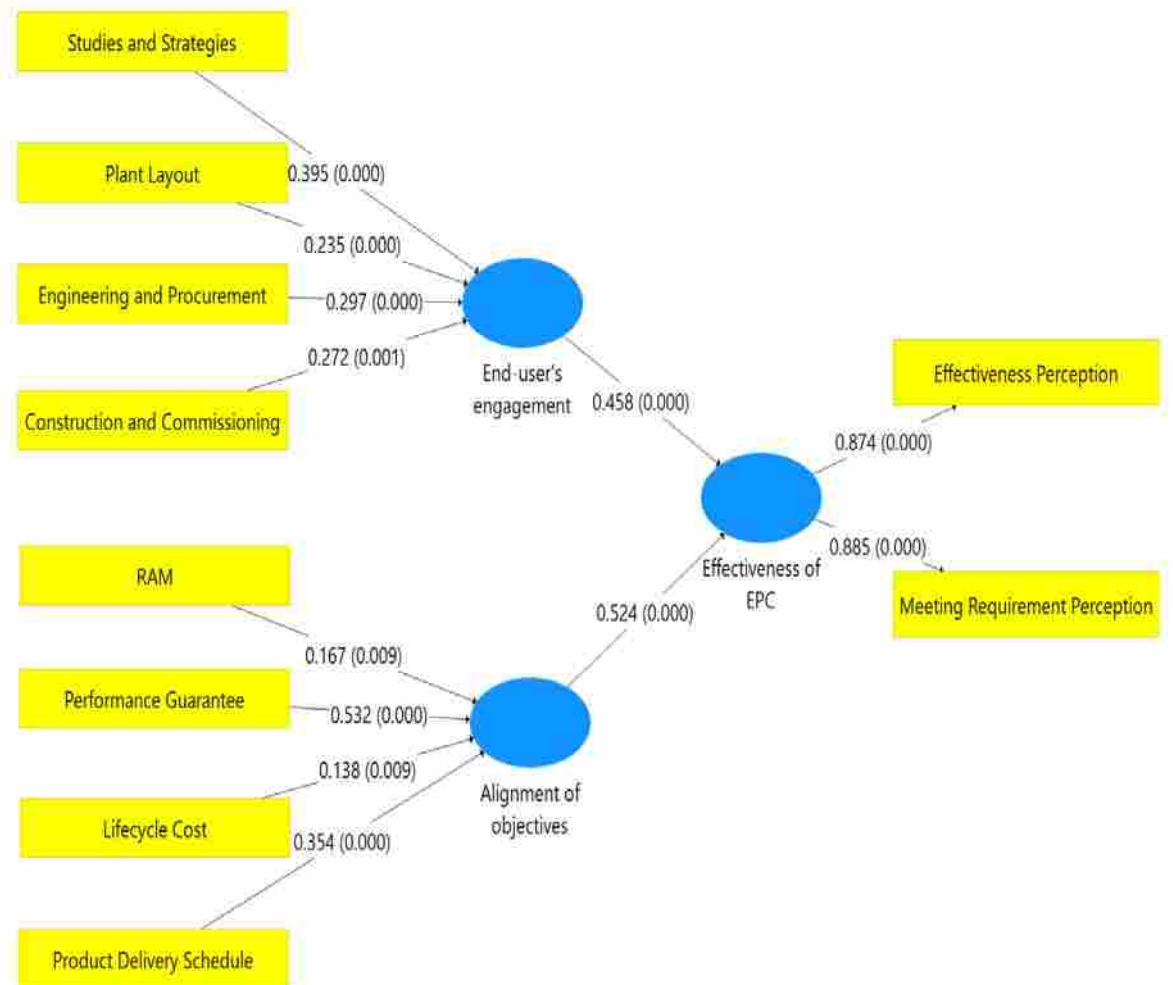


Figure H.1: The "Effectiveness of EPC" structural model showing the t-values of the causal relationships

## Appendix I: Model Fit Measurement (SRMR) Results

Table I.1: Composite Model Implied SRMR Correlation Matrix

	Construction and Commissioning	Effectiveness Perception	Engineering and Procurement	Lifecycle Cost	Meeting Requirement Perception	Performance Guarantee	Plant Layout	Product Delivery Schedule	RAM	Studies and Strategies
Construction and Commissioning	1.000	0.641	0.670	0.410	0.649	0.596	0.486	0.552	0.492	0.688
Effectiveness Perception	0.641	1.000	0.645	0.479	0.547	0.696	0.505	0.645	0.575	0.664
Engineering and Procurement	0.670	0.645	1.000	0.412	0.654	0.599	0.468	0.556	0.495	0.692
Lifecycle Cost	0.410	0.479	0.412	1.000	0.485	0.455	0.322	0.453	0.527	0.424
Meeting Requirement Perception	0.649	0.547	0.654	0.485	1.000	0.705	0.511	0.654	0.582	0.673
Performance Guarantee	0.596	0.696	0.599	0.455	0.705	1.000	0.469	0.627	0.581	0.617
Plant Layout	0.486	0.505	0.468	0.322	0.511	0.469	1.000	0.434	0.387	0.426
Product Delivery Schedule	0.552	0.645	0.556	0.453	0.654	0.627	0.434	1.000	0.580	0.572
RAM	0.492	0.575	0.495	0.527	0.582	0.581	0.387	0.580	1.000	0.509
Studies and Strategies	0.688	0.664	0.692	0.424	0.673	0.617	0.426	0.572	0.509	1.000