Developing the Stakeholder Requirements Definition Process – A Journey of Customization

Simon Aasheim  
Department of Production  
HENT AS  
Oslo, Norway  
simon.aasheim@gmail.com

Yang-Yang Zhao  
Department of Science and Industry Systems  
University College of Southeast Norway  
Kongsberg, Norway  
yangyang.zhao@usn.no

Abstract—Although high oil prices have attributed bad habits in a matter of “doing things right” rather than “doing the right things” in subsea productions, a continuous price drop renewed the need for cost cutting in recent years. This has been the case for subsea companies, where previous research found significant cost and schedule overruns due to late design changes. A large amount of these late design changes has been a result of poor understanding of stakeholder needs in the early phase of the requirement engineering. To address this issue, we firstly investigated the case subsea company’s current practices and found no formal governing process for capturing stakeholder needs and defining them as requirements. We then adopted the systems engineering theory from requirement engineering, agile engineering and associated ISO 15288 and ISO 29148 standards to customize a stakeholder requirement definition process within the company context. In consideration of the company’s existing best practices, we further illustrated the customization in a complex system development using advanced subsea product development as an example.

Keywords—requirement engineering; late design changes; stakeholder requirement definition process; advanced subsea products

I. INTRODUCTION

Domain. The research that forms the basis of this paper is conducted in the oil and gas industry, within the subsea domain. This is an industry where it is important to develop a product or system that works as intended from day one, and have the reliability and quality to work as intended for the rest of its operational life time. Traditionally, subsea systems aim to have a life time of 20-25 years. Subsea process systems as the core product of the industry are installed at the sea bed with the intention of increasing the oil and/or gas production of the field and make the production more efficient. This research focuses on advanced subsea products (ASP), such as actuators, separators, pumps, compressors, filtration systems and coolers. ASPs are products that process the well fluid to increase recovery of oil and gas fields. They are untraditional subsea products that are often complex in regards to technology.

Motivation. The low oil price over last couple of years has posed challenges to the subsea companies. The price per barrel of oil dropped from 114.81 to 28.94 [USD/bbl] from Jun. 2014 to Jan. 2016, approximately 75% in one and a half year [1]. Since then, oil companies stopped most of their field investments and subsea contractors that were forced to largely lay off their employees and restructure the organizations.

Many subsea contractors have been used to relatively high oil prices and thus defined the according project cost. According to the Norwegian Petroleum Directorate [2], there exist major cost and schedule overruns in the oil and gas industry whereby high quality work in the early phases for the project success is crucially required. The drop of oil prices has urged subsea companies to cut waste and improve efficiency in the daily work. The cost overuns and late design changes as a main cause thus have Raised a growing need to redesign requirement engineering (RE) to ascertain stakeholders needs and value creation from the start.

Project of Interest. This research is initiated by the management of the ASP department in the contractor X¹, aiming to improve the RE process for the development and qualification of ASPs. A real-life subsea compression project² is used as an example which project consists of most ASPs for contractor X by far. The subsea compression project is owned by the oil company, while the contractor X has been awarded the engineering, procurement and construction contract.

Problem Statement. During the initial phase of a product development project, the designers exclusively focus on the functional requirements in the contract and associated governing documents. However, not all requirements can be met as they are not clearly stated initially, and the contract may not be completed to fully capture the stakeholders needs [3]. The consequence is that the system can be designed to fulfill the requirements available but not necessarily to meet actual needs in its operational environments and different phases of its life cycle.

Former research [3][4] identified a lack of understanding of stakeholder needs and stakeholder interaction in the early phase of the project, which can be prevented. Contractor X’s

¹ Contractor X, a top global provider of subsea solutions to the oil and gas industry from Norway, has 10,000+ employees globally and operates in 20 different countries over the past 50+ years.
² The subsea compression is a gas compression station located at a water depth of 300 meters and operates in a 200-km field outside the coast line of Norway, which increases the recovery rates (20-25%) from the reservoir.
Project Execution Model (PEM) needs to perform the activities in the regard to early phase requirement engineering (RE), however, it has been split up in different activities that are not systemic managed or seen as one coherent process. The main problem of the lack of understanding of stakeholder needs causes late design changes and therefore cost overruns.

**Goal.** As the main problem is the lack of understanding of stakeholder needs, our goal is to: 1) confirm the relevancy for development and qualification of ASPs; 2) identify gaps between current practices of an early phase RE in Contractor X and SE standards and best practices; 3) develop the customized early phase RE process for product development and qualification of ASP for Contractor X.

## II. RESEARCH METHODOLOGY

Former research [3][4] posited the early phase RE could be improved. This early phase is often known as: stakeholder requirements definition process (SRDP) [5]. The process mainly is related to eliciting stakeholder needs, transforming them into requirements and defining clearly-stated stakeholder requirements. Firstly, we enhanced the understanding of the impact of poor early phase RE, and how it may provoke late design changes and cost overruns. Further, we analyzed existing RE efforts in the early phase of product development and qualification of ASPs in Contractor X. The data of analysis were collected from internal procedures, the project execution model (PEM) and interviews of internal experts in Contractor X. An in-depth customer interview was also performed to capture their perspective. In this way, we can investigate the current state of SRDP. Through gap analysis between RE literature and current processes in Contractor X, we were able to identify areas of improvement for the way the case company works with SRDP. As a result, a proposed process to resolve the identified areas of improvements was derived. In summary, the research process of this study is outlined in Figure 1.

![Research Methodology Flowchart](image)

**Fig. 1. Research Methodology Flowchart**

1 We conducted interviews with 22 employees, who are as experts in the field and serve important roles in ASPs development and qualification.

2 The customer is the oil company’s engineering manager of ASPs project with over nine-year experience from advanced subsea projects.

### III. SYSTEMS ENGINEERING KNOWLEDGE APPLIED

**Requirement Engineering.** To ensure a good understanding of stakeholder needs, proper requirement engineering should be reflected in the PEM. RE is an interdisciplinary activity that is central in Systems Engineering Body of Knowledge (SEBoK) [6]. The main activities within RE are: to discover, elicit, develop, analyze, determine, verify, validate, communicate, document and manage [7]. The final goal is to establish requirements to be met by the system to be developed, which mediates between domains of acquirer and supplier. Proper RE, resulting in a complete hierarchy of requirements that are validated towards actual needs, should enable the consensus among stakeholders and provide the basis of the system design verification.

**Systems Engineering Standards.** The two standards—ISO/IEC/IEEE 15288 [5] and ISO/IEC/IEEE 29148 [7]—have been widely used as they describe the relevant part of RE in a lucid way. Both these standards and SEBoK have the conservative view on how RE shall be performed. ‘Conservative’ in this regard means the standards propose activities to be performed under the assumption of the success of the activities. This is not always the case in practice of ASPs that needs agile engineering in place [8].

**Agile Engineering.** Agile engineering supports the requirements definition in an agile way rather than the requirements freeze upfront which can posit big risks from invalidated requirements or their changes during the development process [8]. It has been a good response to a general challenge in the industry where the product life cycle is split to different contracts by the oil companies. The contracts awarded at different stages of the development process is difficult to elicit information from all phases of the life cycle. To include the agile perspective in practices is thus induced to the more conservative RE sources. It is needed to be customized to specific industrial context, which does not mean that oil and gas system and service providers are exempted from RE standards.

**Stakeholder Requirements Definition Process.** The SRDP, in regard to the early phase of the requirement engineering management, is the focus of this study which contributes the root causes of late design changes and cost overruns in previous product developments of ASPs. This process can help capture all stakeholders needs, transform them into requirements and define them as high-level requirements. It can be seen as a trade of between [8]:

- Defining high-level stakeholder needs that reflect the entire life cycle of the project and its environments.
- Avoid getting too detailed compared to what knowledge that are available for the project group at that specific moment in time.

Based on the above, we aim to derive a customized SDPR for Contrator X. The RE standards and related literature have been used to fill in the gaps that are uncovered during the gap period.
analysis. The data capture and analysis from the current state of Contractor X are presented in the following sections.

IV. STAKEHOLDER REQUIREMENTS DEFINITION PROCESS

A. Current State of SDRP

Base on the literature, experts’ interviews, analysis of PEM, we uncover the insights of how Contractor X performs RE.

**Project Execution Model (PEM)**. The main PEM is a high-level model that governs the process on how Contractor X executes subsea projects. In addition, there is a PEM for studies and for technology qualification program (TQP) for product development and qualification (shown in Figure 2). This study focuses on the TQP PEM, which is used for development and qualification of ASPs in Contractor X. The phases of the PEM are further divided into sub-phases that describe all activities and their timings in detail.

![Technology Qualification Program](image)

**Technology Qualification Program.** This is a high-level description and illustration that governs the process of how product development and qualification are performed in the company. The idea with this process is to increase the Technology Readiness Level (TRL) [7] from zero or another low value to 4 out of 7. The overall goal of this process (shown in Figure 2) is to ensure a consistent and predictable execution platform based on the industry’s best practices. Each of the sub-categories in the flowchart consists of concrete objectives that should be performed.

![Existing Technology Qualification Program](image)

The TQP is an iterative process where the idea matures for each iteration. Q1 and Q2 are stages for capturing ideas based on collected opportunities from all levels of the organization. These ideas often are derived from needs in other projects or from development and upgrades of existing products. The subsea compression is an example of such a project.

Stage QA and QB are more or less the same, except QB is more detailed in each activity. Stakeholders’ requirements are important inputs to define system requirements and thus at the latest stage of QB before closing projects. If following the timing in the TQP PEM, we finalize a complete list of system requirements before the engineering, procurement and manufacturing which is relative late to RE literature [5][6].

Some activities in TQP can be stakeholder requirement definition related, but not be included in SRDP. Those activities are typically stated as short objectives rather described how to be performed. The in-depth interviews with several managers and engineers in the field confirmed not only the need of the inclusiveness of activities but the focus of RE and stakeholder needs in that extent. However, there does not exist such a consistent process to guide engineers through the eliciting and defining stakeholder needs properly which may cause late design changes and cost overruns.

B. Challenges of Eliciting Stakeholders’ Needs

“The purpose of the SRDP is to define the requirements for a system that can provide the services needed by users and other stakeholders in a defined environment” [7]. Based on the interview of needs-finding, we highlight some challenges.

**Customer Perspective.** The interview with Engineering Manager for the subsea compressor project in the oil company (i.e. customer) disclosed capturing the customer’s perspective was about how they think Contractor X understood their needs at the early stage of the project. As the project represents a typical need for ASPs to occur, it is relevant to investigate what kind of stakeholder requirements captured for the system to be developed can be transformed to the high-level stakeholder requirements for a specific ASP.

Customer often pose a challenge of needs uncertainty while awarding a contract. They knew most of the intended functionalities except the details of needs. This is the case found in the subsea compressor project and most projects where lots of ASPs and technology developments are in need. The customer’s intention was that Contractor X should have freedom to develop possible solution(s) together with them. A problem with some ideas was presented to Contractor X, but what the customer actually needed was still not ascertained in detail. Moreover, since ASPs, such as subsea pumps and compressors, are complex systems in terms of technology and scope, SE and RE by SEBoK [5][6][7] may be difficult to follow directly. However, many elements from their early phase RE, also known as SDRP, are valuable while being referenced and adjusted to Contractor X’s standards and industry’s best practices. The adjustment can enable a fit with the existing PEM which governs the process on how the case company executes their projects. On the other hand, it can make the SDRP more agile than the conservative standards.

**Detail Level of Stakeholder Requirements.** Almost every development project in Contractor X shared the challenge of specifying the level in a defined SRDP. Based on interviews, we even found none RE process in this regard. A primary task is then to understand the stakeholders’ needs fully. To capture all available information without unnecessary boundaries at the first place is important that it may save the project for major design changes later. For instance, to require a specific instrument for pressure readings might limit the product designs without any particular reason from the requirement.

**Agile Engineering.** Both interviews with the internal experts and customer of ASP projects, such as the subsea compressor
project, posited the need of being agile [8]. The customer said they wanted to take part in the work to define the solution. It also means that not all stakeholder requirements are in place as early as we would hope in a traditional product development.

C. Identified Gaps

The gaps between Contractor X’s current way of handling the SRDP and the RE theory and standards are identified by in-depth analysis from the PEM, associated documents, and expert interviews.

Need for a Coherent Process. The in-depth study of the TQP PEM in Contractor X and associated internal documents was performed. It is found several activities of TQP PEM were closely related to typical RE activities. Though the PEM did not explicitly highlight the RE process, they had plenty of shared objectives. It did not suggest how to perform it, but show as high-level outcomes, such as: “receive customer input, create design basis, evaluate market need and evaluate test requirements...”. How these activities were performed have been more or less depending on each individual engineer. Interviews with engineers, project leaders and product line managers confirmed the need for a specified process to highlight the importance of eliciting customer needs and defining them as clearly-stated stakeholder requirements.

Timing of the SRDP. The SRDP is described as part of the RE process in theory, however what Contractor X usually performs now focused on the life cycle as a whole. The design basis of Contractor X is found to be summarized as the design requirements and described as technical equipment specification, so that the PRM can be issued [9]. The current design basis template often reflects issues that cover most of the life cycle. Thus, a common understanding of applicable documents and the relation between the them should be included. Part of the problem is that the design basis might be written after most stakeholder requirements are in place. In this case, the aspect of reflecting upon the whole product life cycle is arriving too late, according to RE standards [5][6].

Product Life Cycle. The PEM is found not to reflect upon the product life cycle according to its theoretical description. Based on the interview with Contractor X’s Systems Engineering Lead of the subsea compressor project, the challenge is identified as a complete life cycle view at the early phase of the project. There has been little or no knowledge about some of the phases of the life cycle. The reason why this project is more challenging than usual is its involvement of new technologies that needs to go through a qualification process. It thus leads to a more focus of the operational aspect of the products. We identify where a knowledge gap can be in regards to development of ASPs in the subsea compressor project.

The installation contract was awarded to a third party company at a later stage, it did in the ÅSC project. These knowledge gaps may result in the mentioned cost overruns and late design changes. Therefore, this introduces AKSO, tended to development of ASPs. At least, this was not focused on the life cycle as a whole. The PEM does not reflect upon the product life cycle to the challenge, but designs almost completed when presenting the installation philosophy by the third party. The installation philosophy is a typical phase to be brought in the later development of the projects, and late design changes has thus become necessary in order to fulfill the installation requirements. If one can narrow the knowledge gap of the life cycle at an early stage, it is more likely to provide what the customer needs and thus with less costly changes. The Contractor X can contribute to elicit such information by asking questions and force the customer and themselves to reflect upon the entire life cycle.

The fact that oil companies award contracts from different phases of the life cycle at different stages in the project time line can be a problem. This is not only the case in this study, but a global problem in the industry. It can raise difficulties to get information from the various stakeholders at different life cycle stages. Problems like this with huge impacts on the execution process and stakeholders need to be highlighted.

Understanding Stakeholders. In order to elicit stakeholder requirements from all phases of the life cycle and their environments, it is crucial to understand our stakeholders: who they are; what they care about; what impacts or interests they have. This is not mentioned directly in the PEM or the associated documents, but the interviewees and RE literature both confirm the importance of understanding these stakeholders. Customers, users, fabricators, transportation companies, operators, etc. are examples of stakeholders associated with the product in the development life cycle. Therefore, to gain a thorough understanding of what needs and concerns they have early is important. Since some stakeholders may have more interest and/or power of the product development than others, it could be beneficial to map their relevance to the product/system. An example of how the stakeholders can be mapped is shown in Figure 5.

The diagram shows that stakeholder interest is not necessarily consistent across the product’s life cycle. This can be particularly relevant to the engineering process, where the focus may shift between different phases of the project. For instance, at the early stages of development, the focus might be on understanding and defining the product requirements, whereas at later stages, the focus might shift to implementation and testing.

PEM as an Engineering Tool. The PEM is seen as a tool for managers and engineers to manage the project execution in Contractor X. It consists of relevant work tasks that are helpful at all stages throughout the project. According to early study
[10], some employees treat PEM as an overall guideline for management and project control, but do not know how to use it themselves. The PEM is developed by experienced employees, but it turns out to be difficult to understand by new employees.

D. Customized Stakeholder Requirements Definition Process

A good systemic overview of the theoretical SRDP can be achieved by studying the RE standards [6][8] and SEBoK [7]. This overview is used as inspiration to develop the Contractor X’s SRDP for ASPs. Using the SE theory as a baseline, the gaps are highlighted between the Contractor X’s practices and conservative RE literature and standards. The need for closing the gaps is confirmed by experienced ASP developers before implementing the derived SRDP. There is an additional need to be agile while developing ASPs as the complexity to acquire information from all stakeholders for all life cycle stages at once. This study at the first time confirms the need for a coherent governing process of eliciting stakeholders’ needs. Based on the former research [3][4], Contractor X’s practice, investigation of PEM, customer’s perspective, SE literature [6][8] and standards [5][7], a high-level presentation of the developed process is presented in Figure 6. The flowchart illustrates this process in six main stages.

**Goal of the Process.** The main goal of the process is to illuminate the importance of understanding our stakeholders needs within the development context of complex systems. The standards [5][7] are the contributors to the process. This new process has been customized to fit existing way of working with ASPs and not to introduce many changes. It is not favored for the engineers to use specified tools, as every ASP development process is different. Therefore, the process should be used as a guidance where it highlights importance and suggests ways of solving issues. A well-performed SRDP facilitates easier requirement handling throughout a product development and qualification program. As a result, a well-executed process includes [5]: 1) Stakeholders of the system are identified; 2) Required characteristics and use of capabilities and concepts in the life cycle stages, including operational concepts, are defined; 3) Constraints are identified; 4) Stakeholder needs are identified; 5) Stakeholder needs are prioritized and transformed into clearly defined stakeholder requirements; 6) Critical performance measures are defined; 7) Achieved agreement with stakeholders that their needs and expectations are reflected adequately in the stakeholder requirements; 8) Traceability of stakeholder requirements to stakeholders and their needs are established.

**Defining the Life Cycle of the Product.** Most RE literature has confirmed the product life cycle knowledge enables the understanding of what stakeholders we are dealing with. However, the TQP PEM and supporting documents are not reflecting upon the life cycle in detail. Thus, the SRDP goal is set not to know everything about every phase of the life cycle, but to be aware of them and reflect upon them during elicitation of stakeholder needs.

**Identifying Stakeholders and Prioritization.** At first, we need to know who are the stakeholders. Different stakeholders have different interests and influences in a project. As it is nearly impossible to fulfill all stakeholders’ interests and needs, it is important to find out what kind of interest or power they have in the product development. The proposed process suggests mapping the stakeholders according to the power/interest grid (illustrated in Figure 5). The idea of mapping stakeholders is derived from the RE standard — ISO/IEC/IEEE 29148 [7].

**Eliciting Stakeholders’ Needs.** The TQP PEM has activities that can be associated with customer needs capture. An illustration of its flowchart in the beginning of phase QB is shown in Figure 7. The flowchart and activity description state an open and wide exchange of information between customer and contractor. It assumes the Contractor X should receive a precise specification from the customer. It also assumes that customer surveys and interviews should be performed and that the requirements should be reviewed. This is a good RE practice according to several standards [5][7] and SEBoK [6], which is thus kept in the newly-derived SRDP. However, according to the interviews, a precise specification provided by a customer is a rare case. In this regard, it is beneficial to have close contacts with the customer and tools to elicit information about their needs. Suggested tools in the standards are CONOPS\(^5\), OpsCon\(^6\) and Use Case\(^7\). It is also recommended to identify needs by functional analysis and to prioritize needs for what is important. Other activities facilitating close interactions with relevant stakeholders include: structured workshops and brainstorming, review meetings, simulations and modelling. All these activities are referenced from standards [5][7] and proposed in the derived SRDP.

\(^5\) CONOPS—A verbal and graphic statement, in broad outline, of an enterprise’s assumptions or intent in regard to an operation or series of operations [7].

\(^6\) OpsCon—A verbal and graphic statement of an enterprise’s assumptions or intent in regard to an (a series of) operation(s) of a (set of) system(s) [7].

\(^7\) Use Case—The ways of using a system to achieve a particular goal for a particular user [11].

---

![Fig. 6. Stakeholder Requirements Definition Process](image)

![Fig. 7. Existing Activities of TQP PEM](image)
relevant disciplines or linked to tests. It is also suggested to identify constraints and functions related to critical quality characteristics, as these requirements are critical for projects.

Analyzing and Prioritizing Stakeholder Requirements. The requirements should be analyzed according to a predefined set of characteristics. The derived process suggests to use the characteristics defined in ISO/IEC/IEEE 29148 [7]. Critical performance measures shall be defined to enable the assessment of technical achievement. During this phase of the SRDP, a close stakeholder contact shall be maintained to ensure they agree a complete set of stakeholder requirements.

Obtaining Explicit Agreement and Traceability. The intention of this last stage of the SRDP is to ensure the agreement and traceability are obtained. Any problems in the set of requirements need to be solved before they will be a part of the system solution. Comprehensibility needs to be confirmed and there should be no conflicts in the set of requirements. Validating the set of stakeholder requirements shall make sure that it defines the right system, i.e. the system that the stakeholders need [5].

Application of the SRDP on ASPs. The SRDP should be applied in an early phase of development. It is an iterative process that should take place between the end of the idea capture and the end of phase QB (shown in Figure 8). The reason to place the SRDP at that specific place is the fit of the current TQP PEM in regards to the timing of stakeholder interactions in the current PEM. It can be discussed whether it is too late in the development process or not, but the intention is to fit the existing PEM without restructuring the timing of other development activities. It would be beneficial to establish close stakeholder interactions even from the idea phase, but previous experience has shown that fictive base cases and other inaccurate information are used as input at these fuzzy front stages. Part of the reason is that oil companies want to see possible products and solutions before sharing accurate information about future plans and field developments.

Based on the real-life data in Contractor X, this study firstly confirms the poor understanding of stakeholders’ need is the core reason for late design changes and cost overruns. Thereafter, the gap analysis between the extant practices and RE literature and standards forms the basis for the development of the SRDP. Several gaps regarding SRDP are identified through in-depth study of the PEM and associated documents, together with expert interviews of managers and engineers within ASP development and qualification. The key finding is the existing TQP PEM consists of activities in Contractor X that are closely related to RE, but are not structured in a coherent process. These activities together with findings highlighted in the gap analysis forms the basis of the customized SRDP development. In the end, the developed process is customized for product development and qualification of ASPs within the context of Contractor X.

The identified gaps in this study between Contract X’s way of eliciting and defining stakeholder requirements may provide practical implications in managing late design changes to other companies. The customized SRDP to be used for development and qualification of the ASPs may serve as a beneficial tool in the similar complex system development context. By referencing the customization journey in this study, a further customization based on SRDP is enabled to help the broad yet specific applications. In addition, it is worthy mentioning though the need of the content in the developed process is confirmed with the interviewees and the customization journey of SRDP itself is complete, it is yet to be introduced as part of the governing procedure for actual use in Contractor X. To introduce the SRDP into the day-to-day governing process for development and qualification of ASPs requires further investigations such as the interfaces between SRDP and existing governing process in practices.

REFERENCES


[4] M. Moberg, and G. Muller, “Need analysis and requirement handling in Oil & Gas industry with complex systems and tight schedules; Mitigation of late design changes”. Internal Report, 2014.


