Reduction of Late Design Changes Through Early Phase Need Analysis

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Abstract. Contractors in the oil and gas industry are experiencing an increased pressure to deliver projects at a lower cost and at a shorter schedule. Extensive requirements combined with strict governing documents restrict project designs. Therefore, contractors need efficient governing processes that capture customers' needs and ensure that system requirements relates to these customer needs.

In the execution phase of a project, the engineering degrees of freedom are limited. In the early project phase of concept and study, the basic design is established. The design freeze occurs in the tender phase, based on a best interpretation of customer needs. This causes any changes made in the execution phase to be costly and have the potential to impose severe subsequent consequences. Proper use of systems engineering ensures a minimal amount of late design changes. The most important systems engineering process in such a context, is the capturing of customer needs and definition of user requirements. We researched the processes used to capture system requirements today, and the potential impact of using systems engineering techniques for this purpose. We uncovered multiple gaps in the current process of capturing customer needs, which subsequently led to the definition of system requirements based on international standards and best practices, instead of actual needs. Our research also showed that with a process of capturing customer needs based on systems engineering techniques, as much as 92% of the costs imposed by late design changes are avoidable.

Introduction

Domain. We conducted the research in the subsea oil & gas industry. Subsea oil & gas production is mainly concerned with unmanned production systems for subsea oil & gas wells. Typical components for this industry are subsea valve trees or more commonly known as X-mas trees, subsea templates and subsea production manifolds.

The research has specifically been targeting light well-intervention equipment. Oil companies use this equipment to perform well intervention operations that increase the production ratio, and the lifetime of the producing well. Light well-intervention equipment functions as a barrier to the well, isolating it from its environment while the operators are conducting various operations on the live well. The research results apply to the global engineering procedures of the contractor.

Company. Aker Solutions (AkSo) is a Norwegian based supplier of equipment to the international oil and gas industry. AkSo has been delivering subsea solutions for 50 years. It has long experience with complex subsea systems and well intervention equipment. It has 25.000 employees in 30 different countries. The 2011 operating revenue was 36,2 billion NOK.

Problem statement. During initial design of the Light well-intervention system, the focus from system designers is solely on the requirements specified in the contract and in the governing documents. During design reviews, it is uncovered that the design will not meet all of the customer's operational needs. Consequently, the light well-intervention system design has resulted in a system that satisfies requirements, but is at the same time not designed according to the customer's actual needs and the systems operational environment. This gap between actual needs and system requirements cause late design changes on the system with resultant cost and schedule impact.

Research Methodology

Our research consists of an analysis of the existing SE effort in the AkSo organization. We performed a gap analysis of the current state of SE processes and methodology in AkSo projects, compared to SE Body of knowledge best practices. We conducted our analysis through a detailed review of AkSo internal procedures. In combination with the detailed review, we performed in-depth interviews of expert personnel from the AkSo organization. The research team performed the process review together with the interviews to confirm the findings and to achieve an insight into how the theoretical processes compare to the actual workings of the processes in an actual project. In addition to the internal review, we also conducted an in-depth interview with expert technical personnel from the Statoil project organization to capture the customer perspective. Capturing the customer perspective established a reference to what the customers intended concept of operation (ConOps) was for the system. Once we had a perception of the actual ConOps we were able to compare this with the actual output of the contractor processes. We benchmarked the internal processes against SEBoK best practices, and we benchmarked the SE Effort in the project towards the results of Honours' research. We recommended process improvements based on SE best practices, and analyzed the theoretical impact of these process improvements, through a detailed cost analysis of the variation orders on an actual AkSo project.

Systems Engineering Literature and Application

The methods and processes described in the Systems Engineering Body of Knowledge (SEBoK) [12] is the benchmark for our process review. In short, SEBoK describes Systems, SE, and the applications of SE processes and methodology. As we are researching the engineering processes resulting in a detailed design, we will refer to the SEBoK processes leading up to a detailed design. The specific steps in the fundamental SE process are:

- Identify needs
- Translate needs into requirements
- Generate, evaluate and select system concept
- Develop a functional architecture
- Detailed design

Eric Honour [9] has done extensive research on the value of SE. His research on the value of SE has resulted in metrics allowing systems engineers to benchmark the processes in the organization, and the amount of SE done in a project to assess if it is the quality of SE, or the amount of SE that limits the value of SE in the specific project. As a basis for his research, he references research at IBM and NASA. The research conducted at NASA showed that with an increased front-end effort in a project, fewer cost overruns were incurred [8] [9], and the

research conducted by IBM shows an increase in productivity improvement, cost savings and quality of design with an increased use of SE [8]. We show Honours findings in Figure 1.
In addition, Barrese [8] uses the research from NASA and IBM to justify the effect of the SEBoK fundamental SE processes.

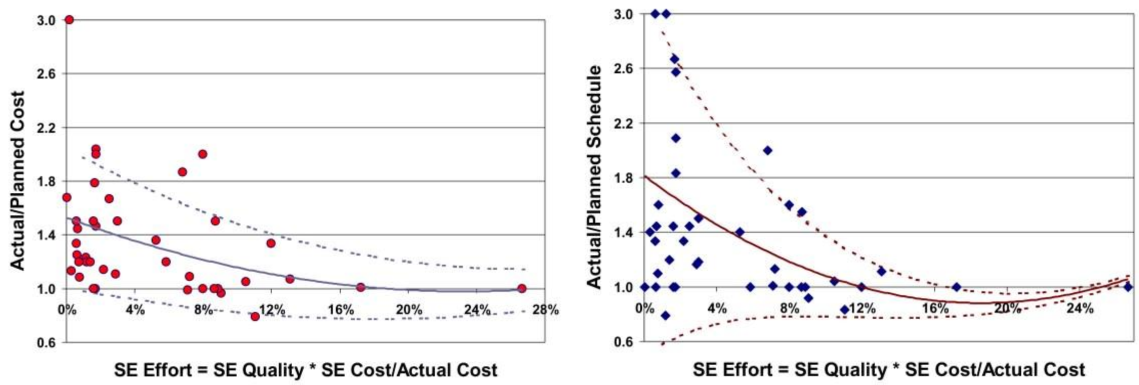

Figure 1 – SE Effort vs. Actual/Planned Cost and SE Effort vs. Actual/Planned Schedule [9]

Honour [9] shows a correlation between Systems Engineering Effort (SEE) and a projects cost and schedule performance. Honour introduces the following metric to measure SE effort:

*Systems Engineering Effort = SE Quality *SE Cost / Project Cost*

This definition shows that doing SE in a project is not enough to improve project performance. SE effort is dependent on the amount of SE done in a project, but it is also dependent on the quality of the SE performed. This implies that projects, which do not see the expected improvements from SE, are either doing too little SE or doing SE with the wrong quality.

Financial Analysis and Motivation for Research

In recent years the media [6] [7] have highlighted that Engineering, Procurement and Construction (EPC) projects on the Norwegian continental shelf are subject to large cost overruns. The Norwegian national budget has highlighted this [1] [2] [3] [4] [5].Although, there is a lack of academic research into why these cost overruns occur, the media articles and expert opinions all mention scope change and late design changes as important contributors [6]. Scope changes incur extra cost to the customer and it has the potential of adding schedule delay. This translates into a project risk, and the oil companies need means of mitigating this risk. The Norwegian government is partially covering the cost overruns of offshore EPC projects through tax reimbursements; we can thus expect continued focus on this issue from the Norwegian Department of Oil & Energy, the Oil companies and also the press and media. In 1999, the Norwegian government released the report "Analysis of the development of investments on the Norwegian continental shelf" [15]. This report analyses the cost overruns in the period 1994-1998 and reports the same overruns as the media is reporting for the recent years.

The oil companies transfer the risk of scope changes and schedule delay to the contractors who need methods to reduce the amount of late design changes and changes in scope. Systems engineering (SE) has shown value in this context [8]. We therefore focus on SE as a suitable tool for handling cost overruns and reducing late design changes and scope changes caused by poor initial design.

However, Contractors in the oil and gas industry are already using SE, and it is an integrated part of the industry governing documents [10]. In addition, some oil companies also include requirements for doing SE work in their contracts [16]. Regardless of SE being a part of the industry best practices, the cost and schedule overruns continues.

Historical data shows a consistent trend from 1994 through 2008 with EPC projects on the Norwegian continental shelf suffering from cost overruns [1] [2] [3] [4] [5] [6] [7] [15]. The investment committee's analysis [15] of the period from 1994 through 1998, points to a series of contributing factors. There is a strong incentive for the oil companies to reduce their investment cost. To achieve the goal of a reduced investment cost, oil companies invite several contractors to tender for the projects. If possible, they invite multiple contractors to tender for different subsystems of the development projects. While inviting several subcontractors to tender has the potential to reduce the cost of the individual subsystems and the total development cost, it also imposes a risk of increased cost due to challenges with cross vendor interfaces. When reviewing the pricing of the contracts in the period 1994-1998, the investment committee concluded that the pricing of risk was too optimistic. NORSOK, a Norwegian project initiated between the oil companies' interest organizations and the contractors' organizations with the goal of reducing cost and schedule for petroleum development projects, recommended using full range suppliers to reduce the risk of cost overruns and schedule delays, as this reduces the risk of interface issues. Despite the NORSOK initiative, oil companies do not follow this recommendation, and the risk calculations are the same. The committee also addressed the issue that due to a pressure of early start-up of development projects, there were often limited data of the field, which led to the use of insufficient data for technology and concept selection. At the initiation of a tender, communication between the oil companies and the contractors are limited, and the data collection halts.

For the period 1998 until today, independent researchers have not done a similar analysis. However, media articles by engineering journals have interviewed project personnel in the projects suffering from cost overruns and schedule delays. These interviews state that late design changes due to poor front-end engineering are the main contributor to the schedule delays. The same journals also report scope changes as a contributing factor. When comparing the projects in the period 1998 and until today with the analysis for the period 1994 through 1998, it seems like little has changed in the way that oil companies invite to tenders, and how the contractors are bidding. Although, we can conclude that due to an increase in the number of projects on the Norwegian continental shelf, the number of projects with cost and schedule overruns has also increased. As the trend of cost overruns and schedule delays is consistent throughout the whole period, and challenges related to scope changes and late design changes is recurring, we see a need for better processes for improved concept selection and efficient project execution. The investment committees' report [15] for the period 1994-1998, reaches the same conclusion.

The total costs of the overruns are severe. For the period 1994-1998, a total cost overrun of more than 4 billion Euros is documented [15]. For the period 1998-2008 the estimated total cost of the 10 projects with the largest overruns makes up for a total of 13 billion Euro.

Current state of SE in the researched company

In our research, we have analyzed parts of the AkSo internal procedures, also known as Project Execution Model (PEM). The PEM is a high-level model, which governs the overall processes in AkSo projects, and defines how they systematically move from a concept to win a tender and how we execute and complete a project; refer to model in Figure 2.

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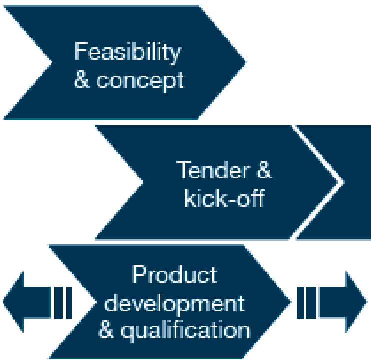

Figure 2 – Aker Solutions PEM top-level model [9]

The phases in the PEM describe in detail the individual activities and their timing in the project. According to the top-level PEM (fig 2) system definition takes place immediately following the tender phase.

The first phase is the feasibility & concept phase (F&C). This phase is the study phase where different concepts are researched and chosen dependent on how suitable they are for the concept of operations of the customer. Please refer to Figure 3 for the different stages of this process. Normally the customer initiates the F&C phase, and put few constraints on the contractor. Resultant concepts of this phase potentially influence which concept the customer chooses to invite to tender for.

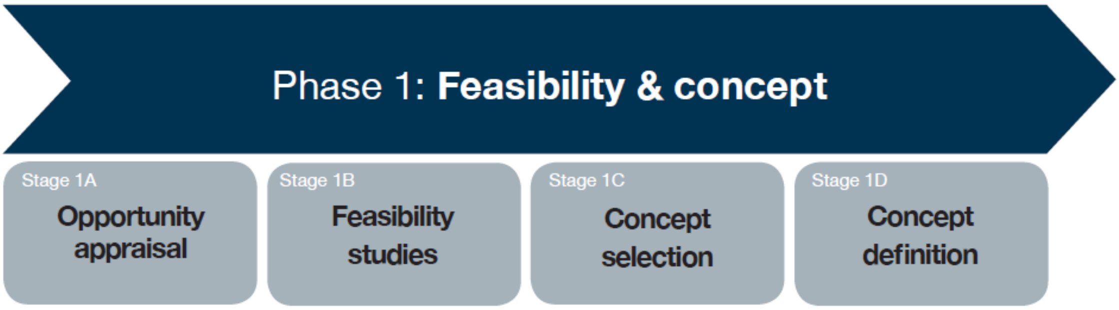

Figure 3 – Aker Solutions PEM – Feasibility & concept [9]

When AkSo receives an invitation to tender (ITT), this initiates the tender phase. During the tender phase, the contractor reviews the concept presented by the customer and develops a tender explaining how the contractor plans to meet the customer's specifications. This includes selection of specific components and a presentation of the system conceptual design. A successful tender culminates in contract award and the handover of the tender to the EPC organization The individual stages of the tender process is shown in Figure 4, while the EPC organization is covered by the last four stages shown in Figure 2, hereafter referred to as the project execution phase.

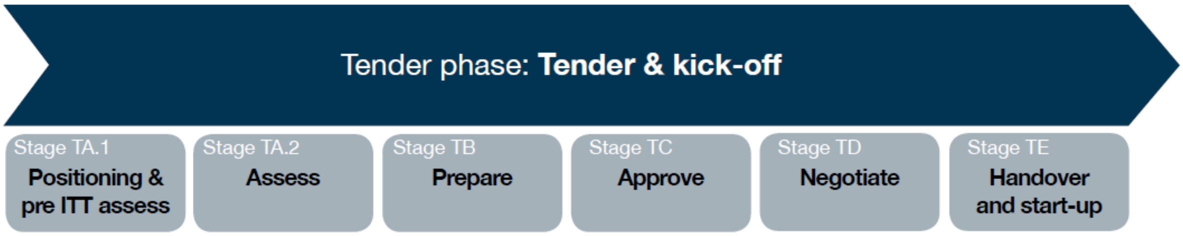

Figure 4 – Aker Solutions PEM – Tender phase [10]

Each of the stages for the individual PEM phases contains detailed activities, which the applicable team shall perform. Contractor keeps track of the status of the individual activities using checklists and individual stage-gate reviews. We do not show the individual activities in the illustrations in this section, but we will discuss them throughout the paper.

Identification of Root Causes

To identify the reason behind the lower than expected performance in projects, we needed to benchmark the SE performance and compare it to the project performance. Benchmarking SE is a challenging task due to the lack of quantitative output from the processes. This has in many organizations led to the misconception that more SE by itself should yield better project performance. We identified which of the parameters in Honours SEE equation the project organization is underperforming in order to identify the root causes of the lower than expected performance. The amount of systems engineering done in the project compared to the projects total cost was available in the project [14]. We examined the reported values and concluded that they were high enough to expect good results from SE according to the SEE equation. Historical data from the project also confirmed that the startup of SE activities aligned with the general project start-up, so underperformance due to late start-up of SE activities is not a root cause.

After establishing that the amount of SE and the timing of SE activities aligned with SE best practices, we performed a review of the performed SE activities compared to SE fundamental processes described in SEBoK. We reviewed our internal processes in three incremental steps. These three steps were:

- Capturing the customers perspective
- Capturing the state of the internal SE processes through detailed review
- Chart the actual process execution through interviews

Capturing the customers' perspective. By capturing the customers' perspective, we could assess if the initial system design covered the operational needs of the customer. By concluding on how suitable the system design was for its intended operations, we could establish a basis for evaluating the initial need analysis done in the project.

We performed an in-depth interview with the customers' technical lead to capture the customer perspective. The technical lead is a person with extensive operational experience and a long career as technical expert in various subsea developments and work-over systems projects. Thus, he has an insight in both the design and construction phase of such systems, and on the operational phase of the system.

He highlighted several of the technical challenges in the project. The interview allowed us to identify the root causes. The main root causes were:

- Cross vendor interfaces
- Mismatch between tendered design and operational needs
- Mismatch between requirements in governing documents and operational needs and the physical limitations of interfacing systems and stakeholders

Cross vendor, interfaces are interfaces between equipment from different vendors. We will not discuss the causes related to cross vendor interfaces specifically, as this does not relate to customer needs and we do not deem this as relevant to our research.

We identified several mismatches between the design that were the basis for the tender and the operational needs of the customer. We established that the requirements derived from the tender phase were generic instead of application specific. This in turn led to over dimensioning of subsystems compared to the actual operational need.

We also identified several operational needs regarding the limitation of the operational vessels, which the requirements in the governing documents did not cover. This also reflected on how the different requirements interacted with each other. Requirements in governing documents [10] [11] define the set-up of the system and limits the opportunity to transport it in separate parts or sub-assemblies. These requirements impose weight restrictions on the system. This additional weight makes the system exceed the maximum allowable lifting weight of the offshore vessels that will interface the system, if the delivered system bases itself on the design presented in the tender for the project. I.e. the design that won the tender is not suitable for the actual operational need for the customers' operational organization.

Review of early phase Systems Engineering

The in-depth interview with the customers' technical lead revealed that the projects systems engineering processes had been unsuccessful in capturing the customers' operational needs. According to SE best practices [12], Systems engineers shall perform the initial capturing of needs before system design, and from the captured needs derive the system requirements. We initiated a review of the AkSo internal governing processes to identify if the processes were according to the SE best practices. As we have already established that the projects systems definition phase does not capture the customers' operational needs, we had to investigate how the tendering processes worked in order to define a system and its requirements. Studying the PEM model also allows us to identify if the model causes the limitations in SE Effort, and we can determine where implementation of improvements are advisable.

The Tender Phase. The review of the tender phase processes showed that the theoretical processes were in accordance with the actual processes in the tender. What we were surprised to see was the fact that any forms of need analysis or requirements definition were not a part of the tendering process. During the in-depth interview, we challenged the tender engineer on this, and asked if this would not be a beneficial part of the tender. Although he agreed that a need analysis and a requirements definition would be beneficial, he argued that the tendering process does not allow for this. The reason for this is that a tendering process is a public process where all communication between a potential bidder and the client is subject to disclosure. This means that a potential bidder exposes itself to the risk that the customer will communicate detailed SE efforts during a tender, to the competing tendering parties. Consequently, any attempt to assess the customers actual needs and get the subsequent requirements implemented into the design, must take place before initiation of the tender. In most companies in general, and AkSo in particular, this means that the research & development (R&D) or feasibility & concept phase of a project must assess the customer needs. The Norwegian Government report "Analysis of the development of investments on the Norwegian continental shelf" [15] supports this conclusion as it also addresses the challenges with little to no communication and the subsequent consequences of the current tendering regime. When contractors enter into a tender, it is normal that essential operational data is missing. In our research, we have identified Meteorological and oceanographic data, field data, soil data, together with fluid data and information of the installation vessels to be typical missing information. These findings correlate with the findings in the investments committees' report [15].

The Feasibility & Concept Phase. As our review of the tender phase concluded with limited design space and limited amount of communication with the customer, we initiated a review of the F&C Phase to identify to what extent AkSo could chart customer needs before initiation of a tender. We interviewed the vice president of the F&C department. He has extensive experience and has participated in both the tender and execution phases of several projects, before he started working with F&C activities. During our interview, we got confirmation that during the F&C phase there are more degrees of freedom for design. At the startup, neither the contractor nor the customer has chosen any single concept, and the F&C organization has the freedom to tailor the solutions to the specific field and customer needs. However, no structured need analysis takes place. Similar to the tendering phase, AkSo partially assumes that the initial documentation and information received from the customer sufficiently describe what the customer needs.

The interview confirmed our assumption that this phase allows for more customer interaction, without foreclosing the details to contractors' competitors. This allows for in-depth interviews with the customer, to identify the underlying needs that the customer provided documentation not necessarily documents. By fully understanding the customer needs, the contractor gains the opportunity to tailor the concept to the actual needs of the customer, and not least to the contractors' available technology. Should the F&C phase lead to a tender between competing contractors, the contractor that performed the F&C study may possess an advantage. During our interview with the tender team, the tendering team stated that it is not unusual for a tender to clearly be influenced by competing contractors in such a way that their technology is more likely to suit the customers' preferences. A contractor that uses need analysis during the F&C phase will have the opportunity to tailor the study to the customer needs, and adapt it to the contractors' available technology. As we have already established, competing tendering contractors will not identify customer needs during the tender, and will not be able to customize their bid proposal accordingly. A contractor that uses the F&C phase to identify needs not stated in customer F&C documentation or ITT, will therefore both potentially gain a competitive advantage to win the contract and to execute the project with less design changes. Executing a project with less late design changes will increase the profitability potential of the project for the contractor and gives the customer a more predictable project cost [8].

PEM specific findings. In addition to the findings for the tender and F&C phase best practices; we identified gaps in the current PEM procedure. The PEM procedure used in all AkSo projects does not reflect the need for a need analysis at any stage during the project. As stated by both Barrese [8] and SEBoK [12], understanding the customer needs is essential to define good requirements. The AkSo F&C PEM has an activity of defining requirements [13], but does not include a need analysis. The tender phase and the execution phase have no requirements definition activities, no need analysis and there is no system for tracing the product specific requirements. The consequence is that the requirements found in international standards and customer specific documentation is the only external requirements considered during design. Subsequently the project will not know if the system requirements are reflecting the customers' needs, or if there are unknown customer or third party needs that would benefit from different requirements. According to Barrese [8] and SEBoK [12] poorly defined requirements will generate late design changes. Based on the above there is a potential for a reduction of late design changes in the AkSo projects.

Analysis of Cost and Potential Impact

To assess the value of need analysis, we had to determine how many late design changes were avoidable if the contractor had been aware of the customer needs. We decided to analyze the Variation Orders (VO) to determine the potential impact of an early phase need analysis. VO's are changes to the contractual delivery or scope of work. Unless the change is due to an error made by the contractor, the customer will cover the cost of the change. There are several types of changes in a project, but we focused on VO's, as this is a type of change, that has a financial, and a potential schedule, impact on a project.

Vigdis NE findings. The Vigdis NE WOS project gave us full access to their VO registry. This included the cost of each change and the technical details leading to the actual change.
The analysis reviewed a total of 23 VO's. This amount of VO's adds up to several million euros in extra cost for the customer. Customer rejected VO's are not included. By analyzing the technical details that lead to a design change, we could determine if the change was avoidable by a need analysis in the early phases. The lead systems engineer, to ensure quality of the analysis, reviewed the results of the analysis. Our findings were as follows:

- 74% of the late design changes could have been prevented by need analysis
- 92% of the cost incurred by late design changes came from those preventable by need analysis

The finding that 74% of VO's were preventable by early phase need analysis was higher than initial expectations. It is worth noting that the lead systems engineer revised this number up from 70% after the quality control. The finding that the preventable VO's made up for 92% of the cost of all the VO's is also a high value. However, when we review the details of the VO's we see that the VO's that are preventable by need analysis are design changes to the actual products, which are incurred due to mismatches between project requirements and operational needs. The analysis covers the billed costs towards the customer, as this is the cost reflected in the cost overrun data, described in our financial analysis. In addition to this cost, there is the hidden cost of additional labor and schedule delay incurred by the scope and design changes.

Example of Preventable Design Change

Of the 74% of the late design changes that were preventable by an early phase need analysis, we present one example of the importance of need analyses to discover all customer needs. The Vigdis NE project is the first light well intervention project where a contractor will deliver a lower work-over riser package (LWRP) to interface the production structure, called a template and X-mas tree, of a different vendor (third party). Based on the information provided for the tender, contractor designed a conceptual LWRP with a cross over component to interface the third party X-mas tree. The client accepted the proposed design, based on similar systems for earlier deliveries. Approximately 6 months into the execution phase, contractor discovers an interface clash between the template structure surrounding the X-mas tree and the side panel on the LWRP. Remote operated vehicles use this side panel to perform different tasks during a well intervention operation, and thus it is important that they have clear access to the panel. The undiscovered need was the height between the X-mas tree and the template structure, and the size of the structure itself. This led to a need for a higher than normal frame size on the LWRP. This information was unknown to the contractor, but the oil company's operational organization would be familiar with this. The effect was extra cost and an unknown amount of schedule delay. The added cost of this one change made up for 27,5% of the total cost of the VO's.

Recommended Process Changes

We have established a lack of a process to capture customer needs in the internal procedures of AkSo and we have suggested need analysis as a suitable tool. For a need analysis to be implemented as a standard PEM activity we had to determine if this is an activity which will yield results equivalent to, or greater than the effort necessary to perform the analysis. The cost analysis of the VO's in the project provided this basis. Due to the lack of communication during the tendering phase, any implementation of need analysis must happen prior to the initiation of a tender. As the tendering regime is universal within the industry, and the contractual terms for the EPC projects are similar across the industry, we can assume that the findings in this research are applicable to all contractors, if the contractors adapt their own governing procedures accordingly. In Figure 5 we show the SE process with its input from the governing documents throughout the process. The governing documents will contribute to requirements definition and guide the necessary trade off decisions in a project, until the detailed design is frozen. Our diagram show the most relevant industry standard, ISO 13628, where ISO 13628-7 is the standard concerning Light well intervention equipment. We have also shown one customer-specific governing document, which is applicable to the Vigdis NE project, where we have done our research.

While the governing documents provide input throughout the process, the need analysis will provide input during the two first stages of the SE process. As different contractors have different processes, we cannot make a general recommendation of where to implement need analysis, but we have established that for need analysis to have an effect on the design; contractors must perform the need analysis before the initiation of a tender.

In an actual SE process used in an organization, there will be iterations throughout the SE process. The organization will evaluate requirements and concepts, and it will go back to the previous process step and revise the requirement, revise the design or agree on a tradeoff. We have not included the arrows showing the iteration in order to increase the focus on the role of the governing documents and the need analysis.

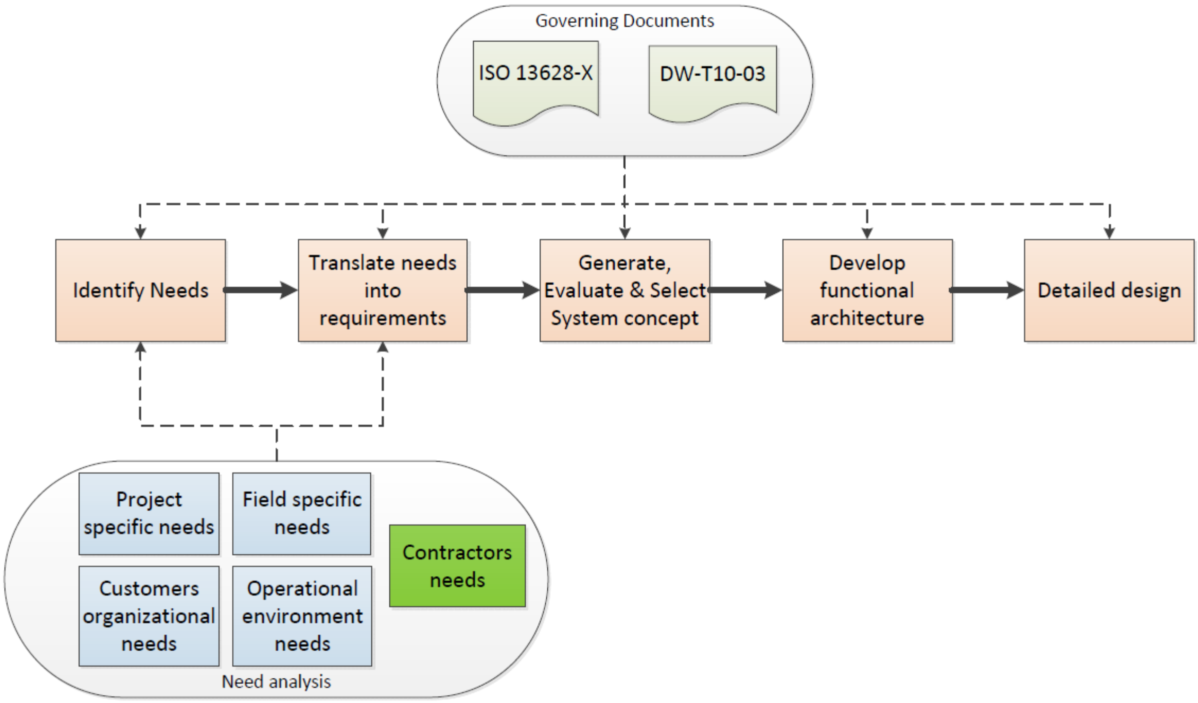

Figure 5 – Process diagram

Summary

The challenges with cost and schedule overruns on EPC projects on the Norwegian continental shelf are partially incurred by existing tender and project execution processes. The current industry standard for executing projects is dependent on requirements defined by governing documents. By implementation of need analysis as a basis for system requirements definition, there is a potential for reducing project's late design changes by 74% and the cost of late design changes with as much as 92%. Oil and gas companies want to see their investments yield profits as early as possible, which have led to a trend of increasingly shorter project execution times. This leaves little time for system definition in the project execution phase, and the system requirements are already defined when the project execution phase starts. For need analysis to have the desired impact, implementation in the pre-execution phases is required. As the existing tendering regime restricts the flow of information between the contractors and the oil companies, it is not possible to perform an efficient analysis in this phase. The F&C phase has the necessary amount of open interaction between the project parties and the necessary degrees of engineering freedom required to develop need based system requirements.

Future Research

Throughout our research, we continuously find data showing a conflict between the customers' operational needs and the technical solutions that the invitation to tender's are based on. As we have shown, the existing tendering regime restricts the engineering processes and its outcome. From the contractors perspective it results in changes to scope and additional work, which the oil companies partially reimburse. Research on the effects of the schedule delay for the oil companies will give an insight of the tendering regime's effect on the value chain as a whole. Both oil companies and contractors might benefit from an alternative approach to today's tendering regime.

There is a need for more research on the hidden costs connected with late design changes from the contractor's perspective. A common attitude towards scope changes is that they represent added profitability for a project. However, our research finds indications of otherwise. Contractors should investigate this in order to more accurately calculate and estimate project cost.

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Author Biography

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Eldar Tranøy is a Systems Engineer in Aker Solutions. He has 5 years' experience from the Norwegian offshore industry. His project experience includes EPC projects for semisubmersible drilling vessels and EPC projects for subsea light well intervention equipment. He is currently holding the position as the Lead Systems Engineer in the Vigdis NE work over systems project. He has education as a Subsea engineer from Bergen University College and as a Systems engineer from Stevens Institute of Technology and Buskerud University College. This report is the result of the research done for his Master's degree in Systems Engineering.

Gerrit Muller.

Gerrit Muller, originally from the Netherlands, received his Master's degree in physics from the University of Amsterdam in 1979. He worked from 1980 until 1997 at Philips Medical Systems as a system architect, followed by two years at ASML as a manager of systems engineering, returning to Philips (Research) in 1999. Since 2003 he has worked as a senior research fellow at the Embedded Systems Institute in Eindhoven, focusing on developing system architecture methods and the education of new system architects, receiving his doctorate in 2004. In January 2008, he became a full professor of systems engineering at Buskerud University College in Kongsberg, Norway. He continues to work as a senior research fellow at the Embedded Systems Institute in Eindhoven in a part-time position.
All information (System Architecture articles, course material, curriculum vitae) can be found at: Gaudí systems architecting http://www.gaudisite.nl/