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Implementation of tailored requirements engineering and management principles in a supplier to the oil and gas industry

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Abstract. This article investigates the implementation of a tailored requirements management system. Requirements management is becoming increasingly important, due to the growing complexity of umbilical systems coupled with efforts to reduce both project duration and project cost. We have investigated the use of a new system for requirements engineering and management, by interviewing stakeholders and analyzing the as-is state of the company. Based on the findings, this paper proposes a requirements template and tailored functionalities to aid with requirements engineering and management. Results indicate that the use of requirement elicitation increased by 62 % through implementation of the proposed system. A survey with stakeholders reveals that they are positive to future implementation of the proposed system. In conclusion, the tailored requirements management system will be a step in the right direction for management of requirements and better control for members of the project teams.

Introduction

All around the world, the offshore oil and gas industry develops new or expansions of existing oil fields (NPD, 2019). These companies often divide the scope of work to several subcontractors. The subcontractors receive an invitation to bid for a contract award; a tendering phase. These tendering phases can often last several years before contracts are awarded. Tender invitations are issued to several subcontractors, and each subcontractor must show that they can provide a cost-efficient solution to be eligible for the contract award. During the tender phase, the companies and the subcontractors go through several iterations of clarifications to solve questions and possible misunderstandings before the contract is signed.

Company. This research was performed in a company which is one of many subcontractors for the oil and gas industry.

The company specializes in subsea umbilical systems, performing all life cycle stages related to the completion of a subsea umbilical system; including feasibility, design, engineering, manufacturing, testing, installation and commissioning. Umbilical systems are used as an all-in-one solution to connect the main components in a subsea environment, such as floating platforms, fixed platforms, and subsea installations. An umbilical system is a multi-purpose connection tailored to each use case. It provides functionality such as fluid transfer, hydraulics, electric power, and fiber optics. Figure 1 illustrates an example of an umbilical system between a fixed platform and equipment at the seabed.

The company manufactures the umbilical cables, while the associated accessories are provided by the company's subcontractors.

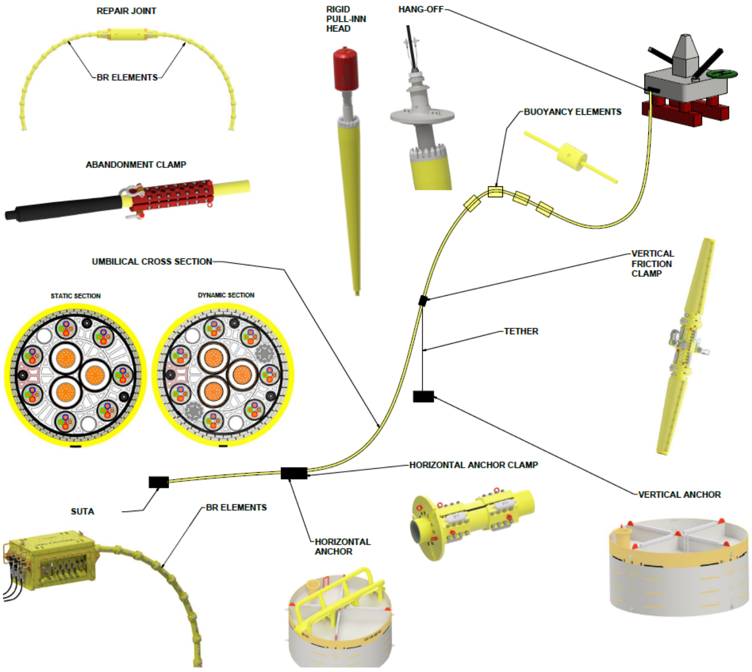

Figure 1 System overview of an umbilical system

Systems engineering in the company. The competition for contract awards in the offshore energy market is high. Companies within the industry push hard for lower cost and tighter schedules, even as the projects grow in complexity. Thus, it is inevitable for the companies to seek methods that lower cost and increase efficiency, and keeps time spent to a minimum. To apply systems engineering methodologies in the oil and gas industry, tailoring of the systems engineering methods are necessary. Requirements management methods that may work in projects which have a lifespan of several years may not work in the oil and gas industry; where it is more common to have a tight schedule and further strive for a lower cost. As well as additional requirements that must be considered. There are often technically competent people at the other end and high expectations from the customers in the industry. The company often finds themselves in a time critical situation where they are forced to not to prioritize requirements engineering and management; proper eliciting of requirements and management of changes in requirements. This is due to an excessive amount of inputs to the project requirements, such as industry standards, company requirements, and client-specific requirements. Further, to the extreme focus on cost reduction, the balance of the amount of input and a tight schedule and low cost has become skewed.

Problem statement. The umbilical system projects have grown more complex over time. As a result, requirements will change; new requirements will appear, while others become outdated; at any phase of the product life cycle. The company relies on an informal requirement engineering process to tackle this, based on the experience and effort of the team members, and it leads to incomplete sets of project requirements. Likewise, the company relies on an informal process of dealing with changes to the requirements at the various parts of the lifecycle, such as a verification and traceability process. This provides several challenges, especially for personnel entering a project at a later stage in the project life cycle, as information is stored widely across several platforms, and thus accessing the requirements and its historical changes are difficult to trace.

Proposed solution. This paper investigates the tailoring and implementation of a new system for requirements engineering and management in the company. It is expected that a tailored requirements management system shall improve the engineering and management of requirements, and further reduce the time spent searching for project-related requirements. The company has adapted the product lifecycle management (PLM) vision as a starting point, utilizing Siemens Teamcenter (Siemens, n.d.) as a system to support project execution. Design basis documents (DBD) will be the starting point to gain control over requirements in projects. By combining synergies from previous design basis documents, requirements template in Teamcenter is designed for use in future projects.

Rationale for solution and goal. The company started implementing the PLM vision and Teamcenter, so it is natural to explore the functions within the system that could potentially aid requirements management in the company. Requirements management is one of the mitigation strategies that can help ensure that this information is maintained through the distinct phases of the project. Teamcenter has a work package called "requirements management", and by using these functionalities it is possible to tailor the system to fit the needs of the company. The enabling potential for the company is that the users can find data with minimum time spent, change management, and collaboration of requirements are all found in one place.

Research questions. This research aims at implementing a tailored requirements management tool based on Teamcenter functionality in a company. The research also seeks to investigate the value of implementing a requirements management system in an oil and gas company, and determine to what degree systems engineering principles are possible to implement.

The research questions are as follows:

- What are the key challenges when implementing requirements engineering and management in the company?
  - What value can a tailored requirements and management system provide to the company?
  - How to mitigate the key challenges found?

Literature review

The process of requirements engineering can be described as the process of eliciting, analyzing and verifying the requirements (ISO 24766). These steps involve, inter alia, identifying the stakeholders, formulating requirements, and validating requirements. Requirements management is the process of dealing with the proposed changes to a set of accepted requirements, including control and monitoring of the approved change proposals (Sols, 2014). If combined with change management, requirements management ensures that requirements are aligned with the product (ISO 24766). Both engineering and management of requirements last throughout the entire lifecycle of a project.

Requirements engineering and management in oil and gas. Projects in the oil and gas industry have a short project execution duration and a limited time to establish the project baseline after a contract award. When the projects have a short project execution duration the requirements elicitation often suffers. Usually, in a project, there are countless documents, specifications, and standards that the engineers need to review and often little time to do so. Wee and Muller (2016), states that in their system of interest, the workover of a subsea system, there were 112 unique documents that were the base of requirements and requirements management. Within the context of oil and gas, their system is characterized as a more extensive system, with more subcomponents, than an umbilical system. However, a chosen umbilical system in the company has 86 unique documents. The number of documents that the system needs to comply with makes up an extensive number of requirements to elicit for umbilical systems.

Muller & Falk (2018) has conducted a study on how much of systems engineering there should be in a subsea system. They state that the problem with systems engineering and requirement management lies in that the oil and gas industry often has mediocre quality of requirements, it does not adhere to the systems engineering theory related to requirements engineering. Further, Muller and Falk highlight some of the challenges with systems engineering concerning subsea systems. They emphasize several points where the oil and gas industry is failing, with an example being that every engineer has their way of managing their product and lack traceability from requirements to the finished product. These requirements are often fuzzy and ill-defined. Requirements tend to be inadequate in the oil and gas industry, and it is highlighted by Tranøy & Muller, 2014, that when capturing of the customers' perspective there tends to be mismatches between the design made in the tender and the operational need. They found that the requirements in the tendering phase were generic instead of application specific.

Standards review. Mjånes et al. (2013) reviewed the use of ISO 15288:2008 as a guideline for product management in a subsea system. They used this standard on a subsea system project and extracted essential items from this standard. Their research concludes that the use of standards can help analyze current situations and can aid in the development of a tailor-made approach in future improvements. Requirements are rarely static, instead they tend to evolve during the lifecycle of a project. The final revisions of requirements are likely to be late in the lifecycle (ISO 29148).

Two applicable standards for the process of tailoring systems engineering methods into the company are ISO 29148:2018 and ISO 24766:2009. Both standards are based on the principles from ISO 15288:2015 but are targeted to requirements. ISO 24766:2009 is a guide for the systems engineering tool capabilities. The proposed tool should facilitate and support the systematic management of requirements throughout the life cycle of a project. The tool needs to address requirement elicitation, analysis, specifications, validation and verification, and requirement management. Furthermore, requirement management should be done in conjunction with change management, to ensure that the requirements remain aligned with the developed product. It is essential to adopt measures to mitigate the effects of change. All changes should go through a defined impact assessment, review, and approval process, and by applying precise requirements tracing and version management (ISO 29148).

Research methodology

The research method uses an industry-as-laboratory approach; described as taking a hypothesis and applying the method in an industrial setting, in this case the tailored requirements structure. As part of the methodology, one must observe and evaluate the results of the hypothesis (Muller 2018). For this study, the authors took inspiration from the work of Thygesen (2019) and Damien Wee (2016).

Exploration and understanding, analysis, development, and verification, are the four main phases in this research, as shown in Figure 2.

Exploration and understanding. The exploration and understanding phase involved exploring the needs of the company and identifying the stakeholders.The identification of the stakeholders is important not only to gain an understanding of the problem situation, but also to involve them in the process of creating a system that shall fulfill the needs. The results are illustrated in Figure 3. Four of the stakeholders were considered as "active" and provided in-depth interviews. Table 1 lists these stakeholders. The interviews provided input to "key challenges" for mitigation in the system, and an understanding of the "as-is" state in the company related to the process with design basis documents and requirements.

Analysis. The study analyzed three design basis documents from three different projects. Guidelines and parts of the standards (ISO 20184) and (ISO 24766) were added to define the required capabilities for the system and the process of requirements engineering**.** These analyses contributed to the knowledge on how to build foundation for the requirements template, and what to change in the new method of working. This phase provided key insights into challenges related to requirements management and shaped the foundation of the requirements template.

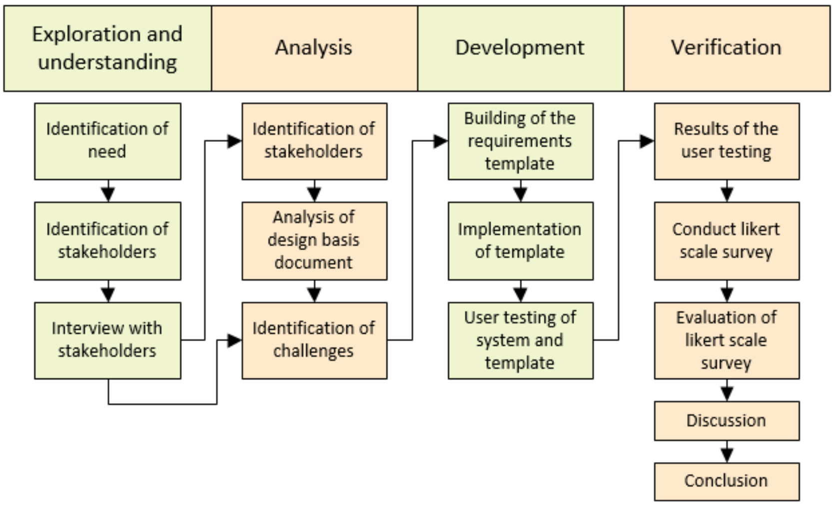

Figure 2 Research methodology flowchart

Development. All tailoring and building of the requirements template were performed in the development phase, with the basis being a template made in Microsoft Office Word. In tailoring the template to suit the company needs, the two earlier phases served as input. The guidelines found in the standards that were analyzed helped in determining the capabilities of the system. Lastly, the template built in MS Word was imported to Teamcenter and had a user acceptance test to validate the functionalities set for the system.

Verification. A requirement structure of an already finished project was used to test the hypothesis determined in this research. Unfortunately, the authors could not test the requirement structure throughout a whole lifecycle of a project due to the long timespan of projects in the company. We reviewed all the documentation available for the selected projects and used it to populate the requirements structure. This would simulate the work of a user in a project. The test format was a questionnaire in Google forms containing five questions related to the project. The participants answered the questionnaire two times; first time when using old method, and second time when using the new requirements structure. The time the participants spent on each question was measured. After the testing, the same participants were asked to fill out a Likert scale survey to measure the how satisfied they were with the new requirements template and structure.

Exploration and understanding

Identification of stakeholders. A context diagram can often help to identify the stakeholders and can be useful in finding/establishing the boundaries of a system. The context diagram in Figure 3 maps out the stakeholders, passive and active, and the boundaries for the requirements management system. All the identified stakeholders should be taken into consideration when creating a requirements management system. The active stakeholders, marked in orange, are the ones that will interact from a user point of view and are believed to use the system more often. The passive stakeholders, marked in blue, are the ones that has a saying regarding the system, but will not extensively use the system. The system boundaries are marked in green.

Interview with stakeholders. Active stakeholders were identified in the context diagram and representatives from the active stakeholders were engaged in prepared interviews. The questions asked during the interview invited the interviewees to express their use of the design basis. This gave a broader understanding of how the different stakeholders use the design basis document, as well as how the process of eliciting and managing the requirements throughout the lifecycle is conducted, and what challenges the new system needs to mitigate.

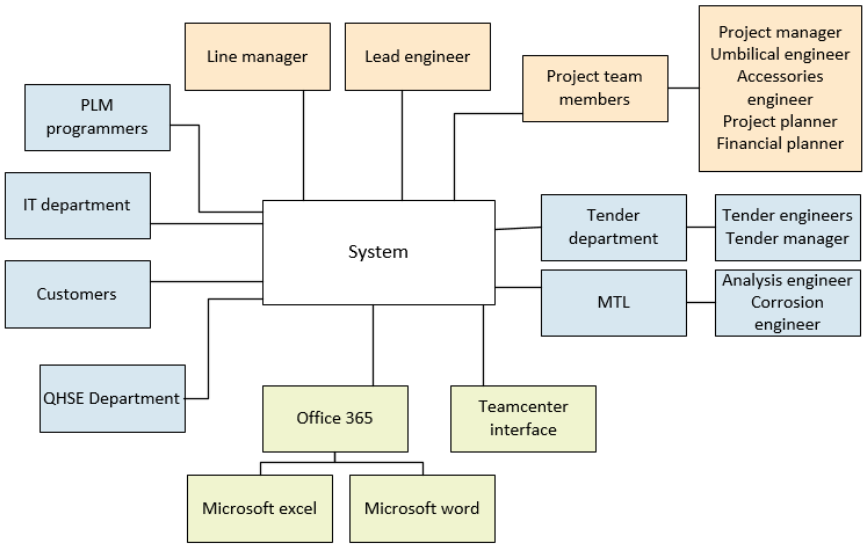

Figure 3 Context diagram of stakeholders

The lead engineer has the technical responsibility in the project. The workflow in Figure 4, is based on input from the interviews, and is shown from the perspective of a lead engineer, as they are responsible for the design basis document. All projects are initiated by establishing a Master Document Register (MDR) following the contract award. The MDR is a register, usually in an MS Excel spreadsheet, listing all documentation the project team will deliver to the customer during project execution. The design basis document is in the MDR and is often the first document that needs to be issued to, and approved by, the customer. The period for issuing and approving the design basis document is often short and stressful.

Table 1 Stakeholder interviewees

Stakeholder	Experience in company	Responsibility
Project manager	10 + years	Holds the responsibility of the project
Line manager	10+ years	Keeps an overview of all projects
Lead engineer 1	6-10 years	Technical responsibility in projects
Lead engineer 2	6-10 years	

The design basis aims to confirm that the company has understood the scope of work and is a counter-response to the contract. At the beginning of a project life cycle, the design basis serves as an "easy access" guide for the project team members to get to know the project in the establishment phase of a new project.

The lead engineer starts by preparing the design basis documents. The document layout is a blank word document, except for project details on front page and in headers. In most cases, lead engineers starts with blank sheets when making the design basis, the document must be tailored to each project/contract. They will then elicit requirements from sources such as the contract, clarifications, standards, and company best practices, before writing them into the design basis document. Thereafter, the lead engineer initiates an interdisciplinary check, from which they will receive feedback on the document. The lead engineer reviews the feedback and updates the document accordingly, before issuing the document to the client for review. This is an iterative process to get the document approved if the customer has any comments or new input.

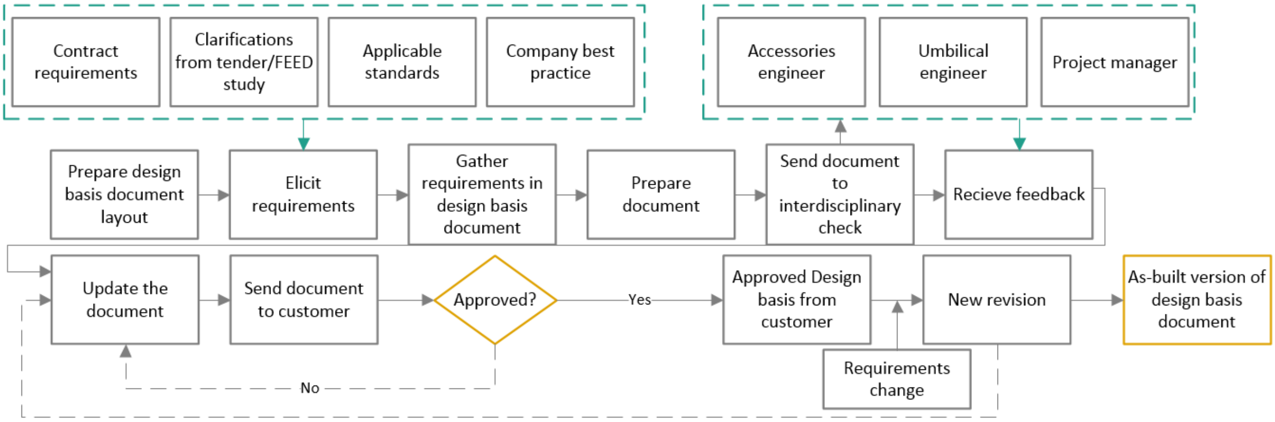

Figure 4 Workflow of current process

When the customer approves the document, it will be left unchanged until there is a formal requirement change from the company. There are no clear guidelines on when the "working file" should be issued to the customer. When the project reaches the end of the life cycle from company perspective, and the umbilical system is ready for delivery to customer, the lead engineer creates an as-built revision of the document. This as-built revision should contain a complete and correct requirements set.

Analysis of design basis document. In this research, the authors analyzed the as-built revision of the design basis documents for three different delivered projectsand compared to an actual as-built version of the umbilical system. The definition of as-built of an umbilical system is: when the company delivers the physical system and associated documentation to the customer. For the analysis, all requirements in the as-built design basis has been compared to other documentation that was confirmed correct for the system. The output was several requirements deviations between the as-built design basis to the as-built umbilical system. The recommendations by Sols (Sols, 2016) for measuring the deviations and pitfalls in the requirements was applied throughout the analysis.

For the analysis, there is one small, one medium, and one large project. The value of the contract award and the number of engineering hours estimatedin tender phase of the projects were used as classification of size.

Project 1 had a contract value of 170 MNOKunits; categorized as a medium project. The project had a project duration of two years between signing the contract and delivery to the customer. Three revisions of the design basis were sent to the customer, and the project had a total of 18 requirements deviations. This is a high number of requirement deviations considering it being a medium-sized project, compared to deviations found in the other projects. The reason for the high number could be that the design basis had only three revisions.

Project 2 had a contract value of 23 MNOKunits; categorized as a small project. The project had a duration of one year. The company sent four revisions of the DBD to the customer and has a total of eight requirements deviations. Here, the requirement deviations are defined as low compared to the other two projects.

Project 3 had the highest number of deviations among the three projects, with 19 deviations. The project had a contract value of 529 MNOKunits; categorized as a large project. The project duration was two years. The design basis had the highest number of revisions, six revisions.

Analysis of requirements deviations. The categories for the pitfalls in requirements engineering and management according to (Sols, 2016) are:

- *Fuzzy or ill-defined requirements*
- *Unnecessary requirements*
- *Wrong requirements*
- *Infeasible requirements*

The analysis revealed a total of 45 requirement deviations: 18, 8 and 19 for Project 1, Project 2, and Project 3, respectively. From these 45 requirement deviations, Table 2 presents few selected requirement deviations.

Table 2 Requirement deviations categorization

Categorization	Project	Requirement	Correction
Unnecessary requirement Wrong requirement	Project 1	Max average attenuation shall be [db/kM] <0.25 @1550nm of fibre optical element.	Wrong requirement, max average attenuation [dB/kM] <0.22 @ 1550 nm of fibre optical element. This requirement is stated in three other documents and are stated in the acceptance specification as an acceptance criterion for testing.
Fuzzy requirement	Project 2	Tensioner pads for verification testing is 1 set.	Not stated what “1 set” of tensioner pads is.
Wrong requirement	Project 3	The fibre optic element shall consist of 24 off ITU-T G.654 C fibres.	G.654C type of fibre is not stated to be used in the contract. In the umbilical specification document, it is stated that either 652.D or 654.A are approved for use. The company had clarified in early stages of the lifecycle that they used 654.A in the umbilical. No documentation could be found that explains why it is stated 654.C in the design basis.

Errors in requirements can propagate throughout entire life cycles of projects and as the project progress, the consequences magnify (Sols, 2016). For the company projects, this appears to also be true. The discovery of errors late in the lifecycle of a project will significantly raise the cost and re-work.

Analysis of standards

This paper used ISO 20184 as basis for the process of requirements engineering, and ISO 24766 for defining what capabilities the system should have. The standards provided information that was deemed relevant for the company and was integrated into the system. The standards served as guidelines for advice and guidance on which capabilities a system should have. In the following section a few of the key functionalities and aspects derived from the standards are presented.

Documentation of change
One of the essential aspects of requirements management is documenting changes. All changes within the requirements must be traceable in the system, back and forth. The software shall be able to track the history and traceability of the requirement. One essential aspect of requirements management is traceability of change. The software shall be able to keep track of every version of the requirement. Every version of the requirement must be uniquely identifiable and easy to find, and every transition between versions must be documented: Who changed it, when was it changed, and why was it changed. It should be capable of keeping a history of requirement changes: who changed it, when was it done, and why was it done.

Collaborative working
Project members, who have a field of expertise, should be able to participate in the elicitation of

requirements. The software shall have a function where the owner of the requirements structure can distribute ownership of requirements.

Complete set of requirements
The requirements need to be in a complete state. The system must make it easy for the user to gain an overview of the requirements. Therefore, it must be possible to extract the structure to a document specification.

Traceability
Traceability is the knowledge of where requirements have their origin and the verification of requirements. The traceability shall be able to go in both directions. The company documentation, standards, and clarifications from tender shall be linked to the high-level requirement structure.

Verification
The verification methods of the requirements must have a relation in the structure. The verification methods (e.g. documents, drawings, analysis, reports) must have an attachment status to the belonging requirement.

Identification of challenges to mitigate. To ensure full functionality, the authors defined four key challenges for the new requirements management system to handle:

- The company treats the design basis document as a static document
- There is no formal traceability of requirements
- There is no formal change management of requirements
- Lack of ownership at the beginning of a project for project members

Building and implementation of the requirements structure

Tailoring of requirements management system. Requirements in the oil and gas industry may change rapidly and generating lot of documentation to where the requirements are elicited. The quality of requirements and the deviation from the systems engineering theory are therefore in need of improvement. The key challenges listed in the previous section are higlighting the need from the company. All the projects in the company are of different nature, but the product and their functionality are the same. The common requirements from all projects can be found in the design basis document, which lists all requirements and the understanding the company has towards the customer. The structures of several design basis documents from different projects and customers were analyzed to find the synergies within these documents.

Requirements template. The idea behind a requirements structure template is that it will be easy for future projects to enter the Teamcenter system and pick a standard template with requirement categories, which the projects themselves must populate. The requirements template is a requirement structure in Teamcenter that has categories of requirements. The requirements template consists of requirements that will help to address one section at a time in the process of eliciting requirements. According to (Robertson & Robertson, 2013), it is practical to categorize requirements into several types, so that it is easier to structure the requirements and locate them in a structure. The requirement template has categories based on requirement type attributes such as; functional and performance, design requirements, interface, and reliability requirements.

To make requirements management more efficient, all requirements that apply to the same element, e.g. steel pipes, is included in a single requirements item. A requirement item can be related to other items in Teamcenter, and requirement items can be revised individually to facilitate traceability.

Figure 5 shows the highest level of requirement categories and a few sub categories in the template. Under each of these requirement categories, several requirements are found.

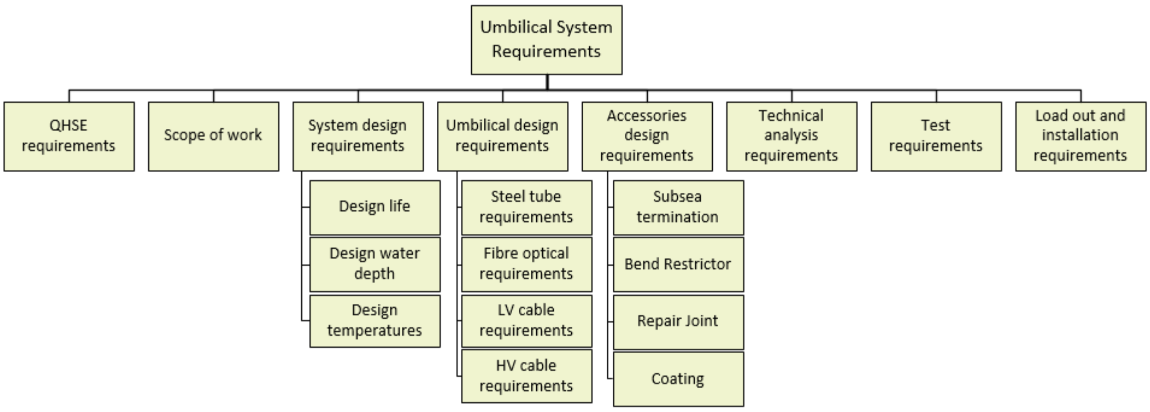

Figure 5 High level categories of the requirements template

The verification method of all requirements will be linked back to each requirement. This can be e.g. drawings, reports, analyzes, and/or mechanical tests. By using the relation function that already exists in Teamcenter, it is simple to link requirements and verification methods together. A relation is a dependency between two items in Teamcenter, e.g. the requirement item will be the defining, and the corresponding part in the product structure will be the complying. Teamcenter will then create a connection between the requirement item, product structure item and the verification method.

Results

User testing of system and template. Due to the long timespan for most projects in the company, the authors created an experiment based on an already delivered project to simulate the requirements structure in a project. All documentation of the projects was collected and reviewed, and the results were populated into the requirement structure in Teamcenter to simulate the flow of a real project. Changes and updates found throughout the project for the requirements structure was implemented. The authors made a questionnaire for testing using Google forms; containing six questions about a selected few changes in the project. The testing had two scenarios, one where the participants used their old way of working, where all tools that they usually have (e.g. company server, Teamcenter, email) were allowed. Each participant measured the time spent on each question in both situations.In the other scenario, they used only the requirements structure to find the answers. Of the ten people receiving the questionnaire, six responded; one line-manager, one lead engineer, two accessories engineers, and two umbilical engineers. The participants had moderate to little experience with Teamcenter beforehand i.e. they all have been on an introductory course on Teamcenter functionality. These participants received no training for the requirements management system beforehand. The intention was to measure the intuitive and user-friendliness aspect, the first time the participants used the structure.

The questionnaire included the following questions:

1. *Which optional deliverables were exercised by the customer?*
2. *How many connectors in total were delivered in the project?*
3. *Which technical analyses had been conducted in the project?*
4. *The customer had a request for a new operational bending radius below the one provided by company. What was the new operational bending radius?*
5. *How many and which changes has been done in the umbilical length?*

Figure 6 represents the average time spent in minutes, for all six participants. All participants used more time on the old method than the new method, on all questions, except question no. 4. In total, all participants spent an average of 23 minutes and 30 seconds on the old method. Using the new requirements structure, they spent 8 minutes and 51 seconds, which indicates that the process of collecting requirements is improved 62 %. However, 62 % is only an estimate and may not entirely represent the reality of the requirements management in the company.

All questions in the old method, represented as orange in Figure 7, were answered wrong. Four out of the five questions had three errors each. In the new method, represented as green in Figure 7, question number 3 and 5 were answered wrong. Question number 5 had tracking of changes implemented and the participants had to review earlier changes of requirements, a lack of training beforehand may be a possible source for the wrong answers given.

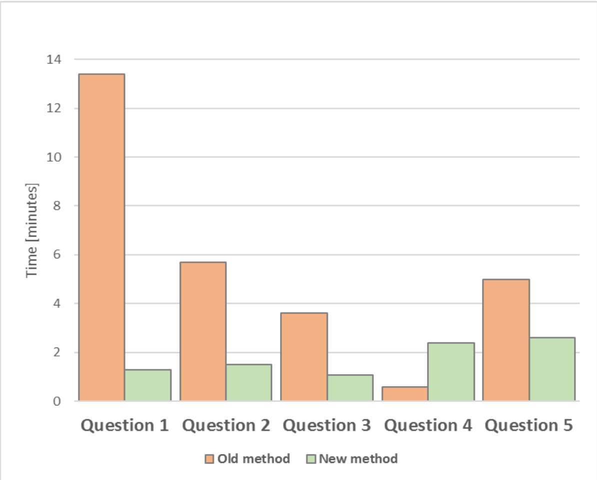

Figure 6 Time spent by participants on old and new method.

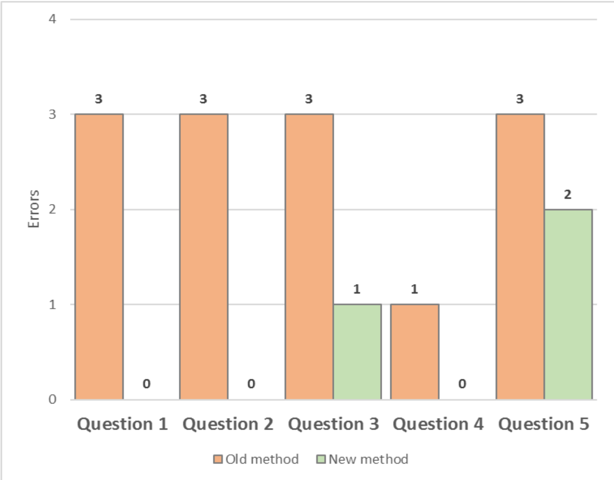

Figure 7 Error identification in the experiment.

Only one participant answered all the questions correctly. This person was part of the project team simulated in the test. Often when working in projects the project members know and remembers where they have stored information. For people who have not worked with the project it may be difficult to know where all information about projects located; especially as the this tends to be done differently across projects. This participant was faster than the others using the old way, confirming the theory that they already knew where information was located.

There were six participants and five questions for each, which gives a total of 30 questions in each of the situations of the questionnaire. Using the old method, 13 of these were wrongly answered giving an error percentage of 43 %. Using the new method, there were 3 errors, giving an error percentage of 10 %.

For the questionnaire, we have taken several possible sources of errors into account:

- *We have created a requirements structure based on a finished project. When the structure integrates with new projects in the future, the requirements structure must be updated frequently and be the source for requirements management and information eliciting.*
- *The questions that we asked in this test may differ from what people need to know about a project.*
- *Six people and five questions may not be enough to represent all stakeholders.*

Survey. After the experiment, the participants received a survey, which thereafter was sent to Net Promoter Score (NPS) (Muller, 2013) to analyze the answers. The promoters were the ones who answered, “Strongly Agree” and the detractors were “Neutral” and below. The intention with this survey is to investigate the user friendliness of the system. Also to obtain feedback from the participants regarding the structure.

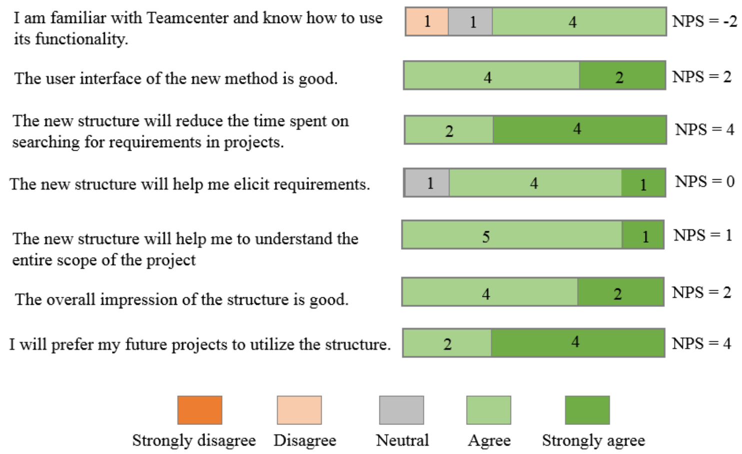

Figure 8 Results from survey

In the survey, we observe a positive aspect, as there were few detractors. Some observations from the results of the survey:

- The question “whether the participants are familiar with Teamcenter” received a NPS = -2. This indicates that some of the users need training and feel insecure about the functionalities that Teamcenter has.
- “The new structure will help me elicit requirements.” This assertion received a NPS = 0. This can be explained by the lack of systems engineering methods currently used in the company. The participants are not used to systems engineering perspective of the eliciting of requirements.
- Two survey questions received a NPS = 4: “The structure will reduce time spent searching for requirements in projects.” indicates that that they would spend less time searching for requirements using the structure in a project setting. “I will prefer my future projects to utilize the structure” gives an indication that the participants are quite positive to adopt the new structure into their work.
- The overall impression of the participants observed is that most have a positive aspect to the new requirements structure that. This is concluded based on the low portion of respondents answering “disagree and strongly agree” on the questions concerning the interface, usability and the overall view of the requirements structure.

The participants were allowed to write feedback, and is given below:

- *I do not use Teamcenter that much, but I found the answer incredibly fast in the new structure.*
- *The new requirements structure looks good. I hope that it will be implemented in future projects.*
- *Very straightforward. It is easy to find different things. In addition, it could have been possible to search for single words.*
- *The system seems really good, and it will require rigid maintenance of the content during the course of the project in order to have everything up to date.*

Discussion

The following sections will discuss the key challenges of implementing requirements engineering and management for the company, and how these are mitigated through the system. It also describes whether a tailored requirements engineering and management system proves to be suitable for the company, and what value the system can bring to the company.

Key Challenges. The key challenges of implementing requirements engineering and management in the company, mostly depend maturity of the organization regarding change. This article has focused on stakeholders and users of the system and defined four key challenges for the new requirements management system to handle.

Systems engineering theory that works for projects with lifecycles lasting several years may not work in the oil and gas segment, where the schedules are increasingly tight and there is a constant strive for lower cost. Proper eliciting of requirements and management of changes in requirements are often skipped due to the nature and urgency of these types of projects. Oil and gas projects have high amounts of inputs to requirements which often see changes throughout the lifecycle; especially in the beginning of a new project.

Mitigation strategies. As stated by (Muller & Falk, 2018), the requirements found in oil and gas industry are often fuzzy and ill-defined, and a similar claim could be made for the company (these are still part of the challenge). Unfortunately, requirements are often fuzzy and ill-defined, leaving room for errors later in the project's life cycle. This problem and the need for standardization defined a need for the requirements structure, which will aid in the process of eliciting and the traceability later in the projects. The difference in earlier phases, such as tender with generic requirements, as opposed to application specific (Tranøy & Muller, 2014) amplifies the urge for the user themselves to see the value added into doing the eliciting of requirements thoroughly. There must be an effort in eliciting the requirements in to the structure.

Value added to the company. The idea of a requirements template for standardization and requirements structure for the product can provide many benefits. It will collect all requirements applicable for projects in one location, which again enable easier collaboration between users to create the structure. Additionally, relations can be built between requirements items, the product, and the verification methods. Further, the templatecan provide a structured view of the project with a sole source of requirements. As an example: project teams often find themselves asking for additional resources, and as a result, new project members are assigned to assist in the project. These new project members must review documents spread widely to get acquainted with the project. This is unfortunate, as the reason for adding new project members often is a lack of time available in the project.

Systems engineering theory. One can say that this method differs from the systems engineering theory claiming that every requirement shall have a verification method (Sols, 2014). However, every requirement has a verification method in the structure, but they are compiled into groups of requirements within the same verification method. The use of categories shortens the time spent on requirements engineering and management by combining the requirements that applies to the same product element. As a result, the categories will enable structure when eliciting the applicable requirements. The users shall be familiar with the category set up, which give the structure an advantage in usage. The verification method will be specified for each category, related to the requirement item, through the product structure; and to the verification document through trace linking in Teamcenter.

Credibility of results. A small group of participants who have tested the functionality and the requirements structure. It is uncertain if this is group can represent all the users of the system. Individual users have different knowledge level of Teamcenter and requirements engineering and management. It requires an effort from the users to maintain the requirements structure in projects; if not conducted, it is deemed plausible that the system will not be used as intended. To avoid this, the users need training, and assistance to see the benefits of the requirements management system throughout the lifecycle of a project. Since, the new method's questions were to be answered right after the questions using the old method, there is a risk that they could remember the answers. Therefore, we stated that they had to find the answers to the questions in the new requirements structure and not write the answers from memory.

Conclusion

This study presents research on the implementation of a tailored requirements management system in an oil and gas company. One of the main challenges found during the analysis was that the company relies on an informal way of eliciting and managing requirements, and further, that the same applies to change management or traceability of the requirements. By implementing a tailored requirements structure, there is a strong possibility of reducing the time spent on searching for requirements, to gain control in projects, and the requirements management. This will create value for the company. The requirements structure received positive feedback from the users, and the results from the testing was that the average time spent on answering the questionnaire in the structure was reduced by 62 % than the old method. During the testing, the intuitiveness and the user friendliness reveal that the new innovative tool was easy to use, and it gave encouragement to work with requirements. The participants are willing to utilize the new system in future projects. For the new system to be optimal, there should be a collective understanding that this is a new way of working and needs maintenance and structure in future projects from the project members.

Future research

Future research should look into the implementation of the tailored requirements management system and requirements structure in a new project. The company should analyze the use throughout the entire lifecycle. Furthermore, the company should continue the work to improve the eliciting of requirements. In addition, the tracking of changes in requirements throughout the life cycle should serve as a basis for the change management method in the company. Lastly the company should work to further mature the requirements structure towards verification activities, so that it can monitor the progress of projects.

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Biography

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