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Transferring Needs and Operational Experience from Life-of-Field to Engineering functions - a case study from the Subsea Industry

Severin Myhre
University of South-Eastern Norway
P.O Box 235, NO-3603 Kongsberg, Norway
+47 95139905
severinmyhre@outlook.com

Siv Engen
University of South-Eastern Norway
P.O Box 235, NO-3603 Kongsberg, Norway
+47 416 25 503
siv.engen@usn.no

Kristin Falk
University of South-Eastern Norway
P.O Box 235, NO-3603 Kongsberg, Norway
+47 97586909
kristin.falk@usn.no

Abstract. This paper investigates how a company in the subsea industry are transferring needs and operational experience from Life-of-Fields functions to Engineering functions, to allow for more holistic life cycle design and to improve engineering solutions. The subsea industry is changing, putting more emphasis on total life-cycle cost. In order to improve their offerings, suppliers within this industry see the need for more effective utilisation of Life-of-Field's needs and operational experience. Challenging communication between Life-of-field and Engineering affect transference of needs and operational experience, hindering engineering for life cycle. To research this problem, we investigated the operational process and made in-depth interviews of relevant personnel at both the Engineering and Life-of-field functions of a global subsea supplier. We discovered that suboptimal transference of needs and operational experience between the Life-of-Field and Engineering functions results in added work, repetitive design issues and operational inefficiencies from project to project. We found an insufficient organisational process, low prioritisation of cross-functional feedback together with formal tools not fit for purpose to be the predominant causes for ineffective transferring of needs and operational experience between Life-of-Field and the other functions. Suggestions for improving the transference of needs and operational experience are presented based on the findings and analysis.

Introduction

As technological advancements continue to increase the capabilities of modern industrial systems, the complexity of these systems also increase. The offshore petroleum industry is no exception, with systems that are expected to operate for extended periods of time in harsh environments, whilst meeting higher expectations for capability and accounting for environmental and safety concerns. Ensuring that subsea systems are designed in a holistic perspective with the life cycle in mind is a monumental challenge.

One of the challenges is the transference of needs between the Engineering and Life-of-Field functions. Subsea systems are more likely to be successful if the design accounts for critical Life-of-Field elements like inspection, testing, integration, and maintenance. Failing to properly transfer needs from the Life-of-Field function to the engineering function will in a best-case scenario lead to increased project cost and delays and may potentially result in environmental accidents or risk to human health and safety.

Increasing the engineering team's understanding of Life-of-Field's needs can lead to shorter inspection and installation times, more easily maintainable systems, shorter time to market and overall cost efficiencies. This is of great importance for financial and resource utilisation gains, especially in light of increasing pressure to reduce project costs in the offshore petroleum industry (Engen et al, 2018).

Furthermore, the subsea market is increasingly transitioning to a business model where the operators lease tools and equipment from the suppliers, instead of purchasing the equipment. The market transition to leasing presents an opportunity for resource utilisation improvements, with tooling potentially getting increased lifespan spread across several projects. Reversely, failing to make efficient use of existing and forthcoming tools or equipment is likely to incur significant logistical cost and lead to suboptimal resource utilisation. Ensuring that the company integrates Life-of-field and Engineering functions well is likely to become more important as operators transition from a business model of purchasing equipment to a business model of leasing equipment.

Domain/Company. The company is a supplier of subsea, onshore, offshore, and surface systems to the oil and gas industry. The company is active in the entire life cycle of Field development, including concept and planning, execution and installation, Life-of-Field services and strategic planning solutions. We are conducting our study in the subsea segment. Figure 2 depicts the company's subsea project development model, as defined in its Global Business Process Management System.

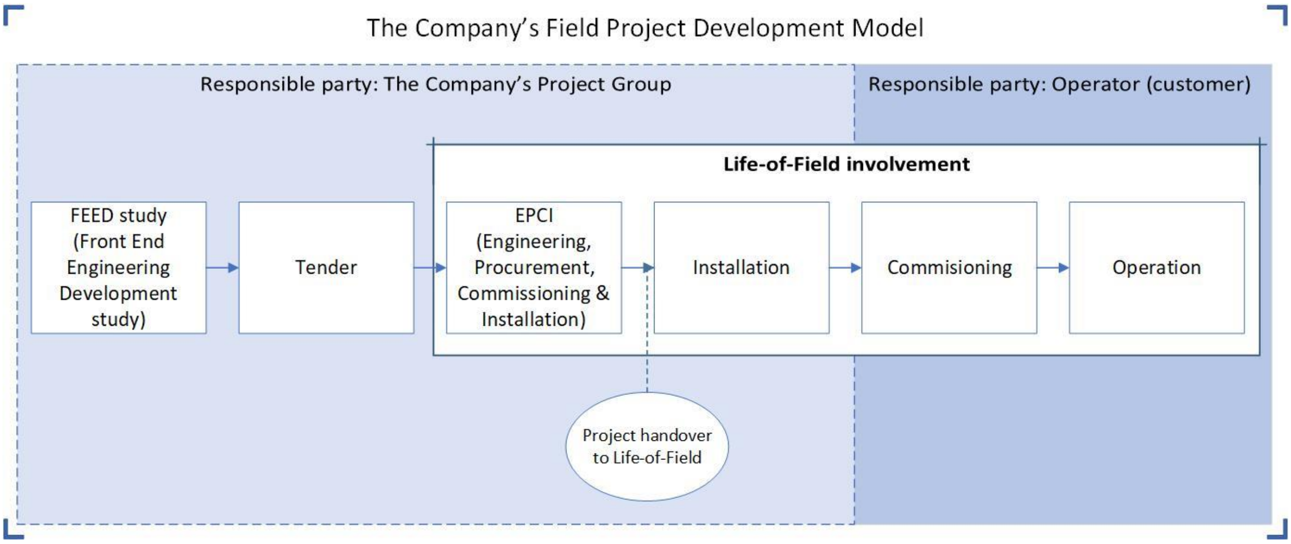

Figure 1: The Company's Field Project Development Model

Disambiguation.

- **Life-of-Field.** Life-of-Field (Life of Field) is the supporting function for the company's projects internally and the field operators externally. Life of Field is located at a port facility for close proximity to the fields and performs final assembly, sub-system integration, inspection and testing of new systems before they send the equipment offshore. Life of Field preforms the installation and commission the systems offshore, on behalf of the engineering fucntion. Life of Field also provides servicing, maintenance and refurbishment of existing hardware once the fields become operational. Life of Field assists in the development of new and existing fields and can be considered the “Service” function, acting as the servicing agent to the field Operator. Life of Field is not the party responsible for a project and instead acts as a supporting element to the company's engineering function to and the operator.

- **Engineering.** Engineering (engineering) is the function responsible for defining, designing, engineering, constructing and installing systems and field solutions. For the purposes of this paper, Engineering is a collective term including the EPCI (Engineering, Procurement, Commissioning and Installation) and Tender functions as well as the Project and Product Groups.
- **Field Operator.** Field operator is the company responsible for operating the field. There may be many owners of a field, but only one field operator. The field operator is responsible for safe operation of the field and complying with any regulatory agencies.
- **Project.** Project is an industry term for a field development or service project. “Project” in this paper pertains to the company's part of a field project and may include several systems, involve any or all functions from Tender to maintenance and last over an extended period of time. The company's Project Group is responsible for the completion of the Project. The Project Group consist of personnel from the engineering function and assumes responsibility of a project until the responsibility is handed over to the operator. Hand-over of responsibility from the company's Project Group to the operator occurs after field commissioning.
- **Product.** Product is an industry term for a subsea system, such as a Christmas Tree or a Template. The company's Product Group is responsible for designing and building the Products and support the Project Groups with the systems they require.

Problem. The subsea oil & gas supplier industry is highly competitive. When a field operator opens a new field or makes changes to an existing one, supplier companies such as the company are invited to tender. If the tender is accepted and the company wins the supplier contract, the architecture of the system to be delivered is defined. Engineering then makes the final definitions and construct the system(s). Life of Field then inspect, test, install and commission the system(s) before responsibility is officially handed over from the company's Project Group to the operator. Life of Field gains valuable operational experience about the system during testing, installation, commissioning and operation, experience engineering could use as needs for the next time they define and design a similar system.

However, transferring these needs from Life of Field to engineering is a challenge. The company is not able to transfer needs and operational experience from Life of Field to engineering in a timely manner that allows engineering to take them into consideration. Suboptimal feedback between the functions results in unexploited potential for optimisation in a range of areas. Optimisation from improved transference of needs and operational experience can yield reduced workload at Life of Field, reduced installation times, reduced maintenance times, reduced operational downtime and improved life cycle costs and value proposition.

Research question. We have investigated the **cooperation and integration** between the Life-of-field and Engineering functions in the company. We wanted to research how engineering could better utilise the needs and experience of Life of Field at early projects phases for a more holistic engineering approach. The main research question is:

How can needs and operational experience from Life-of-Field be more effectively exploited to improve the company's subsea offerings?

Sub-questions in this paper are:

- *What is the current operational model in the company, and how does it affect transfer of needs and operational experience?*
- *How does the company currently use Life-of-Field's needs and operational experience in Projects and Products?*
- *How can the company improve transfer of needs and operational experience between Life-of-Field and Engineering?*

This paper is organised as follows. The next section presents the research method. Then the literature section gives a very brief status of relevant literature on needs elicitation and knowledge management. The results and analysis sections present current state at the company. The paper ends with a discussion and conclusion.

Research Methodology

In the paper we are presenting a case study where we are identifying causes for poor transfer of needs in the company. To collect data about the issue, we preformed semi-structured interviews with resources in the company. In total we conducted ten interviews of resources from both the engineering and Life of Field functions, to shed light on the issue from multiple viewpoints. We selected the personnel for participation in this study based on their position and experience. All interviewees had more than ten years' experience at the company.

This type of interview allows the interviewees to go in depth and discuss the issues from their perspectives. Semi-structured interviews give the interviewees freedom to explain their thoughts and highlight their area of interest while keeping focus on the broader issue at hand (Macve, 2004). During the interviews we did audio recordings, which we later transcribed to enable analysis of the causality factors.

To get a deeper understanding of the current situation we looked at the company's execution process and studied technical company documents such as installation procedures and system documentation. We also conducted an in-depth interview of a resource from the Quality Department, to gain further understanding of the existing Quality Notification system.

To analyse the findings in the interviews we were using a Current Reality Tree (CRT) (Goldratt, 1994). We chose to use the CRT as it relates multiple causal factors and creates a basis for understanding complex systems (Dettmer 1997). The CRT shows causal interdependencies, has a high ability to find systemic causes of effect (Doggett, 2005), and is effective at finding specific root causes (Doggett 2004).

Relevant Literature

Systems Engineering. According to (INCOSE, 2014) systems engineering is defined as "an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholder's needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system's entire life cycle."

According to (Armstrong, 2001) engineering projects, regardless of their scope or complexity, should apply a holistic approach to view the system from all relevant perspectives. One of the responsibilities of the systems engineer is to steer the project in such a way that emerging properties can properly flourish. Having a holistic view of the project and understanding all stakeholder's needs assist in creating emerging properties (Defense Acquisition University, 2001). Systematic exchange of design information between coherent design activities can greatly contribute to the overall success of product and service design in regard to developing integrated product-service systems (Aurich, Fuchs & Wagenknecht, 2006).

A design is freezed after 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 subsequent severe 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 (Tranøy & Muller, 2014).

Needs. Understanding the needs is vital for overall project success (Callister & Andersson 2016). However, the oil and gas industry are immature in implementation of system engineering and design knowledge is not properly documented (Falk, Ulsvik, Engen & Syverud, 2019), increasing the risk of poor design choices and subsequent cost overruns and schedule delays.

Communication in engineering. A recurring problem in many design domains is communication between personnel involved in different project stages (Nasr & Kamrani, 2007). Lack of a common language and background for multiple engineering disciplines is one of the main reasons for poor design choices (Heemels & Muller, 2006). Decision making and communication are also critical issues for multi-disciplinary development in the conceptual phase (Haveman & Bonnema, 2013; Tomiyama, D'amelio, Urbanie & Elmaraghy, 2007).

Knowledge and Project Value Streams. Figure 2 displays an operational model with knowledge and product value streams. These value streams illustrate how knowledge from different projects should float back to the knowledge value stream, to be used in the next project. The knowledge value stream is used to establish and maintain knowledge of a project. The purpose of the captured knowledge is to solve challenges and streamline the other value stream, namely the project-execution (Ulonska &Welo, 2014).

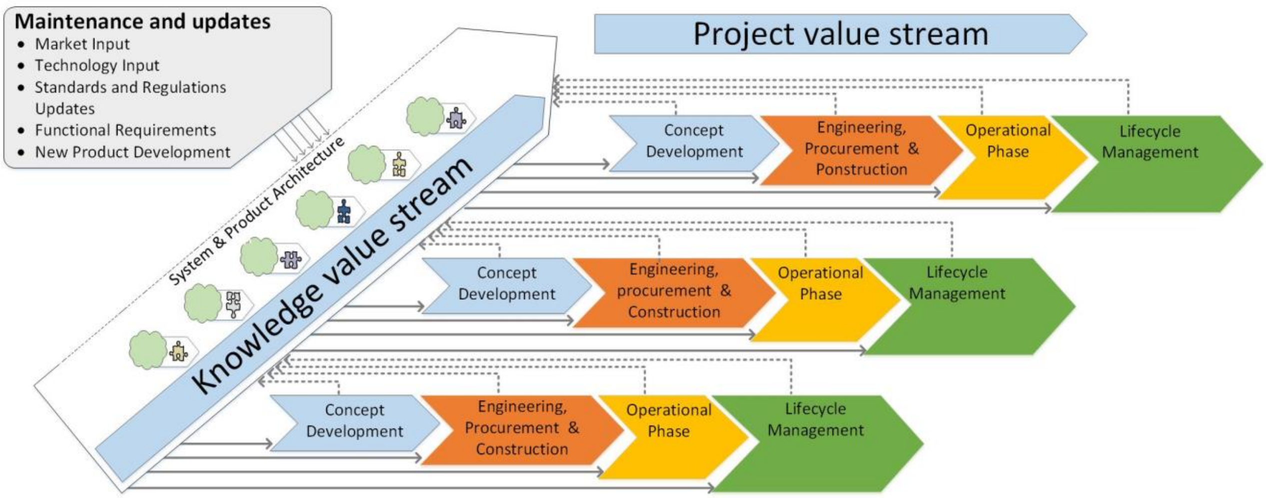

Figure 2: Value streams; Knowledge and project execution. Adapted from Ulsvik and Falk (2018).

The two value streams in Figure 2 use a common system architecture. The knowledge value stream architecture includes all variants and variance. The project-execution value stream architecture configures specific variants based on content in the knowledge value stream

The knowledge value stream is populated by variants developed, tested, and verified during the full life cycle. At the initiating point of a project, the project will use the most recent configuration available from the knowledge stream. Designs and life cycle data updated during the project will be fed back to the knowledge value stream. The knowledge value stream serves as the configuration repository which contains the technical design data as well as the lessons learned during project execution and operation. (Falk, Ulsvik, Engen & Syverud, 2019).

Results & Analysis

This section presents the results from our studies of the company tools and processes and the in-depth interviews with company resources.

Existing Tools

The company is aware of the importance of having needs and operational experience from Life of Field transferred to engineering. The company has several processes and tools in place for trying to identify Life of Field's needs. These include:

- ***Quality Notification (QN)*** is an element in the company's Business Management Software, and is used to register, document and track issues. The Quality Notification system allows personnel across the company to look at previous reports and notifications about specific parts, systems or deliveries. The company uses several different categories of Quality Notifications, and one of the categories is specifically for improvement proposals (Improvement QNs).

- ***Design Review (DR)***. The company performs Design Reviews (DR) at several stages throughout a project, including during system specification, product concept, product detailed design, procurement and installation. The Design Reviews are technical meetings for discussing a project, and both engineering and Life of Field are involved in the Design Reviews. The Design Reviews are meant to identify potential project issues, and engineering makes a report called Design Review Minutes (DRM) after each Design Review.

- **Lessons Learned (LL).** The company's Lessons Learned can be both documents and workshop. They are made after each Project in an effort to document lessons made during the course of the Project. Engineering makes Lessons Learned documents after the project has been shut down. They do not include operational experiences, and there is no defined standard for how detailed or thorough they should be.

The experiences still show that it is challenging to transfer back experiences from Field of Life to Engineering. The problems relate particularly back to Quality Notification, but also to Design Review and Lessons Learned as displayed from our semi-structured interviews.

Results from semi-structured interviews

A core of this research are the semi-structured interviews. These interviews were based on the questions as presented in Table 1.

Table 1: Questions for semi-structured interviews with company resources.

Questions for Life of Field function	Questions for Engineering function
• What are your experience of working with early phase engineering and product development • Which problems have you met in this work? • Are Life of Field sufficiently accounted for in early phase? • What are your thoughts on communication between Life of field and Engineering function? • Are the suggestions from Life of Field received and understood of Engineering? • How could Life of Field contribute better in the early phase?	• Do you feel that you receive the feedback you need from Life of Field? • Do you have any examples of feedback? • Which, if any, tools and methods were used in providing this feedback? • Which problems have you met in this work? • How do you go about understanding the operational needs? • Does the quality notification system work as intended? • How could Life of Field contribute better in the early phase?

Table 2 displays some of the key quotations we extracted from the interviews. In the following we will discuss the findings in more detail.

Table 2: Quotations from semi-structured interviews with company resources

No	Quotations	Role
[A]	*There is no defined process for how the cooperation between the functions is to be done in projects. For two projects, with two different Life of Field personnel acting as engineering's point-of-contact, the engineering-Life of Field integration is done in two different ways.*	Specialist Systems Engineer Project
[B]	*I do not feel feedback to engineering yields results.*	Specialist Life of Field
[C]	*I might feel it is difficult to get Life of Field to take responsibility in projects. Cooperation can become too low-level in the hierarchy. We need managers at engineering and Life of Field to be on the same wavelength.*	Specialist Systems Engineer Project
[D]	*Life of Field does often not have a defined mandate, so they lack authority. Engineering is the authority.*	Specialist System Engineer Product
[E]	*I cannot remember the last time engineering asked 'why do you do this, what are your concern.*	Senior Project Engineer at Life of Field
[F]	*In a perfect world, the experiences from Life of Field should come back to the Product Groups. Then they could take the experiences into account and update the products. This would create a feedback-loop and we would know the products are fit for purpose, including offshore usage, procedures and maintenance. This is not the reality. I don't know if a link back to the products exist, and if it does, it is a weak link.*	Specialist Systems Engineer Project
[G]	*Involving Life of Field is the exception, not the norm.*	Specialist System Engineer Product
[H]	*Feedback often comes too late. Well, Life of Field is involved late.*	Specialist System Engineer Product
[I]	*We enter the projects so late that everything is defined. The scope has been made and almost nothing can be changed.*	Specialist Life of Field
[J]	*In my world, Life of Field enters the project too late. They should optimally enter in tender, so they can be part of defining the project.*	Specialist Systems Engineer Project
[K]	*To me, it is totally strange how lead-engineers and product-engineers are not more offshore.*	Specialist Systems Engineer Project
[L]	*I think it is about interaction. Also, us being there more and them coming here more.*	Specialist System Engineer Product
[M]	*Life of Field's involvement depends on if engineering wants to involve them. But there is no real process for it, it entirely depends on if the people at engineering involves them.*	Specialist System Engineer Product
[N]	*Life of Field are not always considered as a stakeholder*	Specialist Systems Engineer Project
[O]	*I don't think the value of the interaction with Life of Field is clear to many of the people in the organization. Many because we don't know what we can influence.*	Specialist System Engineer Product
[P]	*For the customer, total cost of ownership is vital. We have lost contracts due to total cost of ownership calculations before, based on installation time and cost. Inputs from Life of Field is vital!*	Specialist Systems Engineer Project
[Q]	*I cannot recall improvement Quality Notifications from Life of Field occurring*	Specialist System Engineer Product
[R]	*I don't get Quality Notifications*	Specialist Systems Engineer Project
[S]	*Involving Life of Field in design review provides no benefit in my opinion. We need to have some pre-meeting. Pre-meetings never happen.*	Specialist System Engineer Product

Quotes [A] and [B] in the table indicate that the company's organisational model does not sufficiently support the transfer of needs. The personnel at both functions experience a lack of a defined organisational process for transferring needs, and there is no automatic process for getting the needs from Life of Field to Engineering that works as intended.

Quotes [C] and [D] illustrate that Life of Field generally lack a defined role is during the EPCI phase of projects. As a result, there is a lack of ownership to the operational needs.

Quote [E] indicates that there is currently no efficient process for transferring operational experiences back to engineering. Life of Field is involved in the installation and commissioning of the projects, and understands, to a greater extent than engineering, operational lessons and experiences. The company's projects end when the systems become operational. Then the Project Group reduces its activity level and resources. Thus, a delivery project is not an efficient channel for giving operational feedback back to engineering.

Quote [F] relates to **products.** Personnel at Life of Field are usually allocated as a supporting role to a Project, but rarely directly to a Product. This combined with the organisational issues limits interaction between Life of Field and the Product Groups. As a result, Product Groups do not have a proper feedback loop with Life of Field. The missing feedback loop is especially pertinent as operational experience and needs from Life of Field often are directly related to Product design.

Quote [G] refers to **Projects.** Some recent Projects have been observed to have a better communication loop between Projects and Life of Field. The improved communication loop is regarding keeping Life of Field informed about project developments and testing activities in an effort to avoid confusion during project handover from engineering to Life of Field. The observed improved feedback loop is the result of relevant personnel taking the initiative to communicate more often. The initiative comes from the relevant personnel’s own volition, and the improved project-Life of Field feedback loop is person dependent. The consensus at both functions is that the feedback loop between Life of Field and engineering has a large potential to improve.

Quotes [H], [I], [J] relate to **timing of the integration between engineering and Life of Field.** Needs and suggestions for system improvements from Life of Field arrive too late to have a significant impact on projects. The integration between Engineering and Life of Field ramps up in the transition period when a project is handed over from engineering to Life of Field, and engineering identifies many of Life of Field’s needs in this phase of the projects. Engineering has constructed the systems by the time project hand-over occurs and can no longer implement design changes based on feedback for Life of Field. Even if Life of Field successfully transfers relevant needs engineering, time and cost constraints make it challenging to act on the needs, particularly if meeting the needs do not impact the fulfilment of the contract with the operator. We find that Life of Field in many instances falls out of the loop about project developments, so feedback arrives late and the feedback does not necessarily translate into design improvements.

Quotes [K] and [L] relate to **Communication.** The current organisational process relies to a large extent on each person’s contact network to sufficiently transfer needs and experiences. In practice, personnel use phone calls or emails to transfer needs or concerns to colleagues at different company functions. We also found the contact network to be lacking in some areas, especially pertaining to cross-functional visitations. Engineering and Life of Field have different backgrounds and understanding of the system operations, creating a potential pitfall in design decisions (Heemels et al, 2006). Meeting in person is an effective way of ensuring common understanding of system operations.

The above points also have to be viewed in light of tight schedules and cost constraints. Project and product teams work within pre-defined time and cost constraints. As illustrated by Quotes [M], [N], [O], needs transferred outside of the organisational model will, by definition, be outside of the pre-defined budgets and schedules, limiting engineering’s ability to act upon Life of Field’s needs.

There is a consensus at both the engineering and Life of Field functions that the engineering and Life of Field functions are separated both in location and people, and feels like two different entities. This perception stems from insufficient processes for cross-functional cooperation and a lack of understanding of what the other function’s needs and concerns are. Still, we find that personnel at both functions are self-reflected in that they believe they themselves have some responsibility for taking the initiative in making sure other company functions understand their needs and concerns.

The interviews reveal that transferring needs and operational experience from Life-of-Field to Engineering is a complex task. The current methods for identifying Life of Field’s needs and transferring them to engineering are not perceived to be effective by any of the interviewed personnel. Furthermore, extracting Life of Field’s needs and operational experience such that compnay's project- and product groups effectively can use it is particularly challenging.

As exemplified in Quote [P], engineers at both the Life of Field function and engineering see significant benefits of involving Life of Field at an earlier stage. For instance, decisions made by engineering can inflict unforeseen or avoidable added work to Life of Field. Closer cooperation between the functions at an earlier stage could in many cases resolve added work at Life of Field. All personnel interviewed thinks better transferring of needs and operational experience from Life of Field to engineering is highly beneficial to overall system performance and company competitiveness.

Quality Notifications (QN). A problem with assigning personnel to a Quality Notification is that it is not always possible to assign the correct person to a Quality Notification due to individually defined permits and privileges. Improvement Quality Notifications can then become a container that is created and forgotten. Another problem with the Quality Notification system is the link between Products, systems and Projects to a part number. If a component is handed over from engineering to Life of Field and Life of Field discover something to be corrected, they register the issue through the Quality Notification system. However, when engineering one or two years later make a similar component, but with minute alterations, the Quality Notification system will register the altered component with a new part number. The alterations may be significant, or they may be inconsequential. The previous Quality Notification reports about the component will not necessarily follow over to the new component due to the new part number, and the engineering team may repeat the original design issue. We found that the Quality Notification system contains a Bill of Materials-structure for keeping track of part numbers across projects, but poor user-friendliness makes it challenging to use.

The bureaucratic structure of Quality Notifications is in itself a problem, as a Quality Notification brings paperwork with it to the receiver. Sometimes an improvement Quality Notification is considered unnecessary, as they often are not clear on what should be improved. If the end goal or result is not clear, then the improvement Quality Notifications are not very beneficial and are considered a nuisance. Another finding from our study is that the Quality Notification system previously was part of the company’s KPIs and management added a budgetary cost to each Quality Notification. The result of this policy was an aversion by the personnel to report Quality Notifications, and this aversion still lingers within the company, Quote [Q].

Additionally, a Quality Notification is typically linked only to a product. There is no automatic link from the Product Groups to system designers or relevant projects, making Quality Notifications unsuitable for providing feedback from Life of Field to the system designers. *“I don’t get Quality Notifications,”* claimed one of the project engineers, Quote [R].

Design Reviews at the company are technical in nature, involves both engineering and Life of Field and are performed repeatedly throughout the course of a project. The Design Reviews are therefore a potential arena for cross-functional needs identification. The technical nature of Design Reviews requires participants to come prepared to the meetings in order to have an impact. We discovered that having Life of Field come prepared to the Design Reviews is difficult as Life of Field is not adequately kept in the loop regarding project developments during the Engineering phase. This is illustrated by Quote [S]: *"Involving Life of Field in design review provides no benefit in my opinion. We need to have some pre meeting. Pre-meetings never happen."*

Lessons Learned documents are usually without input from Life of Field personnel. In addition, personnel find the Lessons Learned document structure to have poor search functionality, making traceability challenging.

Three Cases

This section presents three cases obtained by in-depth interviews. First, we present incidents that occurred due to lacking transference of needs and operational experience. The third case is the project development that shows very good interaction between Life of Field and engineering.

Tubing Hanger Case: The company is a major supplier of Tubing Hangers (TH). Field operators and Life of Field use THs in the completion of oil and gas production wells. THs are set in the tree or the wellhead and suspends the production tubing and its casing. The THs are designed and constructed at the engineering function, and the customer also purchases a skid for transporting the TH. The TH is then transported to Life of Field for final assembly and testing before transportation offshore. Life of Field extends the THs with additional tubing when they arrive at the port Life of Field's port facility. As a result of this extension, the skid built for the TH no longer fits the TH assembly. The immediate consequence of this is that the TH cannot be transported offshore, unless a suitable skid can be obtained or constructed. Such a scenario may very well lead to delayed delivery of the TH assembly to the customer and with added cost, particularly if the TH assembly requires a special skid design.

In addition to the potential delayed delivery to the customer, Life of Field is also left with a skid that cannot be used for the final transport offshore. This may seem trivial, but it turns out that this situation has occurred multiple times. There are currently more than 50 TH baskets registered in Life of Field's inventory. The cost of such a basket is in approximately 25.000 USD. Quality Notifications about this issue were reported as early as the year 2013, serving as an example of the Quality Notification system's deficiencies.

Hydraulic Oil case: In one of the current projects, an engineer had to specify which hydraulic oil to use in subsea equipment. A suitable hydraulic oil was selected based on relevant requirements and operational considerations. The standard procedure in the company is for equipment to be specified, designed and built at engineering, and then send the finished equipment to Life of Field for final testing, inspection and eventually installation and commissioning.

In this instance, Life of Field discovered that the hydraulic oil used in the equipment was different from the hydraulic oil used in their testing tools and instruments. As a result, the testing-equipment at Life of Field had to be flushed and the specified hydraulic oil injected instead, increasing project cost and resource usage. Similarly, the hydraulic oil in the testing equipment had to be flushed again at the next test, reverting to the standard hydraulic oil. Engineering decisions such as defining hydraulic oil happen on a project by project basis and the company has no process in place to avoid repeating similar inaccuracies in the future. In this case the additional work related to this decision was approximately 70 manhours.

Field Development Project: The company was the primary contractor of subsea systems to ta field development project. No significant unforeseen issues occurred during project handover from engineering to Life of Field and personnel from both functions were satisfied with the trans-functional cooperation.

The distinguishing factor between this project and other projects is that Life of Field was integrated into company's internal project at project initiation. A clear contact network was then established before the project was fully defined, assisting communication across functions. engineering used the contact network and exploited Life of Field's knowledge pool actively for input during the engineering phase. The decision to involve Life of Field early on came from personal initiative and was person dependent.

Project size and resource pool usually are reduced substantially after project handover to Life of Field, as engineering personnel is allocated to new projects. The project differed in that a fraction of engineering was kept in a supporting role after project handover to Life of Field. The engineering support to Life of Field was used actively during installation and commissioning. The company got the supplier contract for this field development at a time when the subsea market was in a downturn and the project was prioritised throughout the organisation.

Current reality

Using the findings from the interviews and the analysis of the company tools and processes, we established a Current Reality Tree (Figure 3). The figure illustrates the causal factors we observed that lead to a ***suboptimal transference of needs and operational experience*** from Life of Field and back to Engineering.

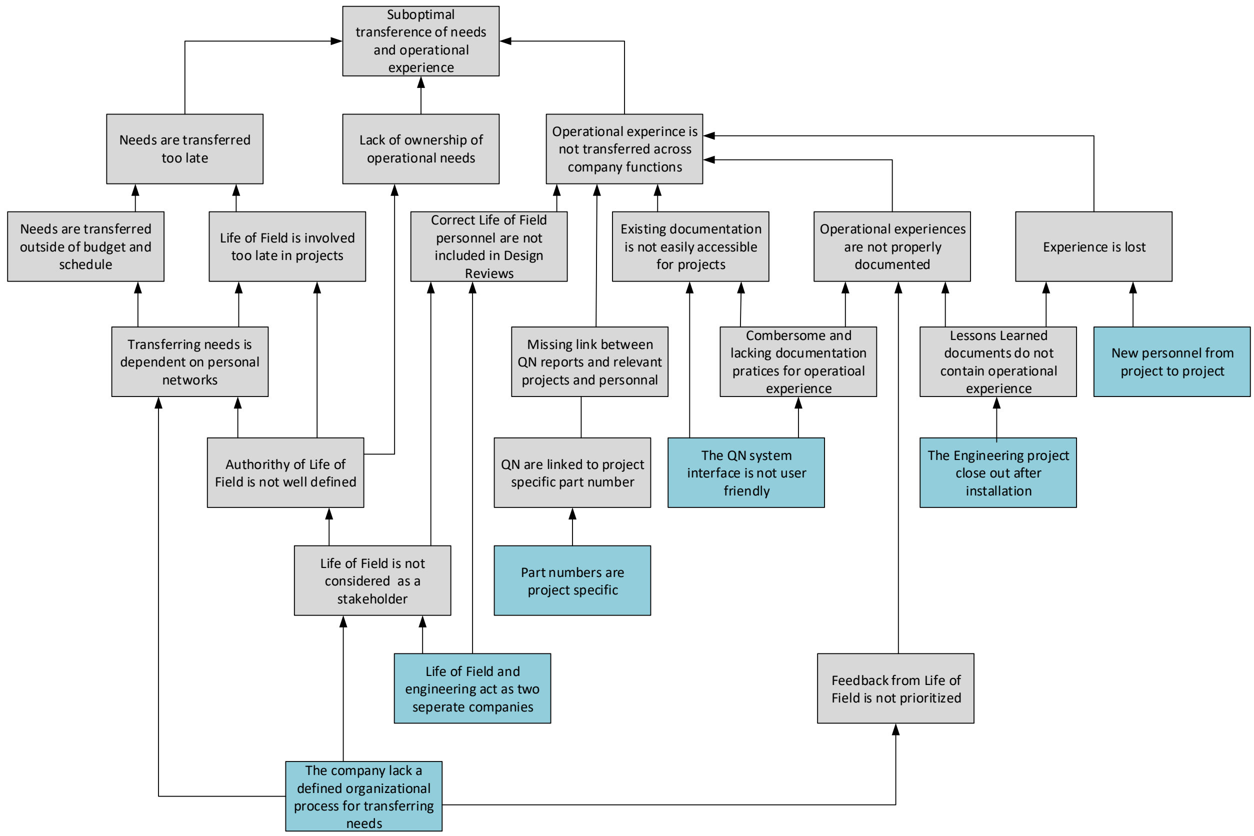

Figure 3: Current Reality Tree of transferring needs between Life-of-Field and Engineering in the company

The Current Reality Tree organizes causal factors and the relationship between them in a concise visual manner, making it easier to understand complex causal systems and reveal initial causes. The Current Reality Tree has six initial causes. These are:

1. The company lack a defined organizational process for transferring needs
2. Life of Field and Engineering act as two separate companies
3. Part numbers are project specific

4. The QN system interface is not user friendly
5. The Engineering project close out after installation
6. New personnel from project to project

Suggestions for improvements

In this section we make suggestion for improvements based on the analysis of the current situation.

Overall, our research indicates that operational needs is not efficiently collected, and there are no official channels for integrating the experience from operation into new projects. A fundamental issue for transferring needs and operational experience from Life of Field to engineering in the company currently is that such transference is not adequately supported in the organizational processes, as depicted in Figure 1. In order to take Life of Field's needs and operational experience into account in a manner that allows for system improvements without inflicting significant consequences to project budget and schedule, the needs and operational experience must transfer to engineering at an earlier project phase.

Closer integration of Life of Field and Engineering will make the company more able to optimise projects and systems for installation time and reducing added work through early phase needs transfer. Projects are to a large extent defined during the tender and study phase (Tranøy & Muller, 2012), and the cost of changes increases rapidly with each Project phase (Buede, 2009).

In the interviews we find that in the current process model, the informal communication between the Engineering and Life of Field is important method to transfer needs. Personal contact networks allow the company's personnel to discuss technical issues unrecorded, allowing for a great degree of honesty and openness. However, transferring needs and operational experience outside of official processes makes them challenge to document and dependent on the personal relationships between the involved parties. This creates pitfalls in interpretation, division of responsibility and traceability. Based on this we suggest

- Altering the company's organizational process so that Life of Field is involved in all stages of the development, giving them the opportunity to provide feedback to engineering during system and project definition. The purpose of this is to allow engineering to account for the feedback early in projects and prevent late phase design changes, as late design changes are costly and mostly avoidable (Tranøy & Muller, 2012).
- Implement an effective, official process for transferring operational experiences across the functions. When engineering and Field-of-life communicate properly, Life of Field's needs are more likely to be identified
- Allocating a resource from Life of Field as supporting personnel to the product development projects. This will strengthen the company's ability to improve product designs based on operational experience by encouraging cross-functional interaction and discussion.

Beyond official communication channels for operational experience, we recognize that the informal communication will continue to be important to transferring needs. The company relies on personal contact networks for everyday operations and communications. To keep continue building these networks we suggest

- The company should encourage more travel between Life of Field and engineering. Furthering cross-functional travel builds the personal network and improve the understanding of the different functions' needs.

The current tools in the company to support the need transfer, include a quality notification system and design reviews. We have found that the Quality Notification system have a potential to contribute to the transfer of operational experience, but currently it is not working as intended. To improve the system, we suggest:

- User-friendliness of Quality Notifications should be improved, including the ability to link QN's to several resources and possibility to link the QN to a general product, not just a project specific product number.
- A resource from Life of Field should be allocated to every improvement Quality Notification they report to improve traceability

Regarding the design review we found that in the current process, the company is not successful in including Life of Field, as they are not kept sufficiently in the project loop. To mitigate this, we suggest:

- Include a pre-meeting between engineering and Life of Field in the Design Review Process. Having a pre-meeting will enable the inclusion of relevant personnel form Life of Field function and give the possibility to get up to speed on the design.

Discussion

Petroleum operators are expecting equipment suppliers to create field development concepts from scratch. Furthermore, it is expected that the concepts are integrated with one holistic solution for both subsea and surf systems (Engen & Falk, 2018). Making sure operational needs and experience are adequately understood and taken into and account when designing new subsea systems is vital for system improvement and for creating competitive systems. We investigated this in three research questions.

The first research question: “What is the current operational model in the company, and how does it affect transfer of needs and operational experience?” The company's operational model specifies that a resource from Life of Field shall be designated as supporting personnel to engineering in projects. However, the role of this resource is not clearly defined. Support for transferring needs and operational experience from Life of Field to engineering is included in the company's operational model through Design Reviews and Quality Notification reports. Our interview series displayed that the support is unsubstantial in practice. Existing tools for needs transfer between the functions are not effective, and resources are not allocated for preparing Life of Field for Design Reviews. In practice, the primary role of Life of Field is to avoid misunderstanding and unforeseen incidents during project handover from engineering.

The second research question: “How does the company currently use Life-of-Field’s needs and operational experience in Projects and Products?” As engineering-Life of Field integration primarily serves to avoid misunderstanding during project handover, needs transfer for the purpose of system design improvements and project optimisation is a lesser priority. Cross-functional transference of needs and operational experience for system definition and project planning does occur, but predominantly by virtue of personal initiative, making the transference person dependent.

The third research question: “How can the company improve transfer of needs and operational experience between Life-of-Field and Engineering?” The current Reality Tree reveals that the primary causes of suboptimal needs transfer are the company organisation not prioritising feedback from Life of Field, lack of a defined organisational process for needs transfer and suboptimal documentation practices. Furthermore, needs and operational experiences that do transfer successfully to engineering arrive too late in the project to instigate design changes.

This study has several limitations. We made the findings in this study from data predominantly originating from interviews. Findings from interviews are subject to bias since the interviewees can interpret the questions differently based on their experiences and frame of mind. Similarly, the interviewer may interpret the answers differently than the interviewee intended. The semi-structured nature of the interviews allowed the interviewees to focus on the relevant details and clarify misunderstanding. We found that the responses from the interviewees were not contradictory and that there was a companywide consensus for many of the questions.

Additionally, the findings are based on four interviews from Life of Field and six from engineering. This selection is too small to draw generalised conclusions. Still, the interviewees each have between 10 to 25 years of experience in the company and we are confident the selection is representative for the challenges of transferring needs and operational experience. Our findings and analysis are in accordance with what we have heard in informal conversations at the company.

We found that the current reality tree was of great use, both as a tool for documenting the causal relationships and as a tool for analysing them. We conducted this study from a systems engineering perspective. Many of the issues and causal effects identified are complex with both technical, personal, interpersonal and cultural considerations. Studying the problem from only a systems engineering mindset leaves room for causal relationships to remain unidentified.

Application in the company. The focus of this study was to analysis the challenges with transferring the needs and operational experience and identify means to improve the transfer. Implementation in the organization is outside the scope. However, we have observed that the company have ongoing initiatives to implement improvements consistent with our findings, such as improving the lessons learned system.

Further studies. The problem of transferring needs and operational experience across functions is complex and multidimensional. Our study is company specific and not necessarily directly relatable to other companies, domains or industries. Further studies are needed to create a more generic approach to improving cross-functional transference of needs and operational experience. It might also be interesting to research the problem further with expertise from other relevant fields of study, such as for instance psychology. Expanding the study to understand the problems in greater detail is also of interest. We have based our analysis and proposed solutions on data from interviews, literature and company processes. However, we have not tested the solutions in practice. Further research is needed to observe cross-functional communication and test the solutions applied at the company or other comparable entities.

Conclusion

In this paper, we have studied how a supplier company in the subsea industry more effectively can exploit the needs and operational experience from Life-of-Field to improve their subsea offerings. We conducted interviews of personnel at both Engineering and Life-of-Field, studied relevant technical company documentation and made a Current Reality Tree depicting the causal relationships of suboptimal transfer of needs and operational experience. We found that the company's current operational model does not sufficiently support transference of needs and operational experience from Life-of-Field to Engineering, and the personnel feels the two functions act as two separate companies. Currently, the needs and operational experience are being transferred from Life-of-Field to Engineering outside of organisational models, without support in budgets or schedule.

To meet these challenges, we suggest that the company alter their operational model such that Life-of-Field is involved in projects already from the tender phase. This way Life-of-Field’s needs can be identified by the project group before fully defining the systems. Other industries have implemented Integrated Product and Process teams to ensure involvement from all stakeholders. The company is currently testing out such operational model in one of their development projects and have seen clear benefits from having multidisciplinary teams, (Engen, Falk, and Muller 2019). We also recommend allocating a resource from Life-of-Field to every Quality Notification report, to give Life-of-Field the responsibility and mandate to follow up on product improvement. Physical travel between the functions is also important to build personal networks and improve understanding. These steps are important to improve transferring needs and operational experience, resulting in more holistic engineering with improved life cycle cost and capabilities.

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References

Armstrong, S.C. 2001. *Engineering and Product Development Management: The Holistic Approach*. Cambridge University Press.

Aurich, J.C., Fuchs, C., Wagenknecht, C. 2006. 'Life cycle oriented design of technical Product-Service Systems', Journal of Cleaner Production, 14 (2006) 1480-1494.

Bailey, J. 2008. 'First steps in qualitative data analysis: transcribing. *Family Practice'*, (pp. 127-131).

Buede, D.M. 2009. *The Engineering Design of Systems. Models and Methods*. John Wiley & Sons. Second edition. New Jersey.

Callister, P. S., Andersson, J. 2015. 'Evaluation of System Integration and Qualification Strategies using the Technical Debt metaphor; a case study in Subsea System Development'. INCOSE International Symposium, (pp. 1016-1028).

Defense Acquisition University. 2001. *Systems Engineering Fundamentals*. U.S. Department of Defence. Systems Management College. Defence Acquisition University Press. Fort Belvoir. Virginia.

Engen, S., Falk, K. 2018. 'Application of a System Engineering Framework to the Subsea Front-End Engineering study'. *INCOSE*. 28th Annual International Symposium.

Engen, S., Falk, K., Muller, G. 2019. 'Architectural reasoning in the conceptual phase - a case study in the oil and gas industry'. SOSE 2019.Falk, K., Ulsvik, O. K., Engen, S., Syverud, E. 2019. 'Systems Engineering Principles to Enable Supplier-led Solutions', *OTC*.

Dettmer, H. W. 1997. *Goldratt's Theory of Constraints: A Systems Approach to Continuous Improvement*. ASQ Quality Press.

Doggett, A.M. 2004. 'A Statistical Comparison of Three Root Cause Analysis Tools'. *Journal of Industrial Technology*. Volume 20.

Doggett, A.M. 2005. 'Root Cause Analysis: A Framework for Tool Selection'. *The Quality Management Journal*. 12, 4; Health Management Database pp. 34.

Goldratt, E.M. 1994. *It's not luck*. 1st edition. North River Press.

Haveman S.P., Bonnema G.M. 2013. 'Requirements for high level models supporting design space exploration in model-based systems engineering'. Procedia Computer Science, vol. 16, pp. 293–302.

Heemels, M., Muller, G. 2006. *Boderc: Model-based design of high-tech systems: A collaborative research project for multi-disciplinary design analysis of high-tech systems*. Eindhoven.

INCOSE. 2014. What is system engineering. Retrieved from Incose.org: http://www.incose.org/practice/whatissystemseng.aspx

Løndal, S., Falk K. 2018. 'Implementation of A3 architectural overviews in Lean Product Development Teams; A case study in the Subsea Industry'. *INCOSE*. 28th Annual International Symposium

Macve, R. 2004. ‘Qualitative research: experience in using semi-structured interviews’. *Elsevier*. ISBN: 0-08-043972-1, (pp. 339-357).
Muller, G., Wee, D., & Moberg, M. 2015. ‘Creating an A3 Architecture overview A Case Study in Subsea Systems’. *INCOSE* International Symposium, (pp. 448-462).
Nasr, E.A., & Kamrani A.K. 2007. ‘*Computer-Based Design and manufacturing: An Information-Based Approach*’. Springer Science.
Tranøy, E., & Muller, G. 2012. ‘Reduction of Late Design Changes Through Early Phase need Analysis’. *INCOSE* International Symposium, (pp. 570-582).
Tomiyama, T., D’amelio, V., Urbanic, J., Elmaraghy, W. 2007. ‘Complexity of Multi-Disciplinary Design’. Ann. CIRP, vol. 56, no. 1, pp. 185–188.
Ulonska, S., and Welo, T. 2014, ‘Product Portfolio Map: A Visual Tool for Supporting Product Variant Discovery and Structuring’, Springer-Verlag, Berlin, Heidelberg.
Ulsvik, O.K. and Falk, K., 2018 ‘Developing a Configure-to-Order Product in the Subsea Oil and Gas Domain’, 28th annual INCOSE international symposium, Washington DC, USA, July 7-12, 2018.

Biography

Severin Myhre. Severin Myhre is currently a Mechanical Systems Engineer working with industrial packaging machines and automation systems. He holds a Bachelor in Mechanical Engineering from the University College of Southeast Norway and a Master of Science in Systems Engineering from the University of South-Eastern Norway. This report is the result of the research done for his M.Sc. in Systems Engineering with Industrial Economics.

Siv Engen. Siv Engen is an Industrial PhD candidate at University of South-Eastern Norway. Siv holds a Master of Technology in Engineering Science and ICT, with specialization in Marine Constructions from NTNU, Trondheim. She has more than 10 years of experience from a major supplier company in the oil and gas industry and is doing her PhD research within the company. The focus of her research is on system architecture and conceptual modeling in early phases.

Kristin Falk. Professor Kristin Falk has lead technology teams in start-ups, SME and large corporations, primarily in the energy industry. She has been in the industry for more than twenty years. She is teaching Systems Engineering at the University of South-Eastern Norway. Her research focus is 'how to create systems fit for purpose in a volatile, uncertain, complex, and ambiguous world'.