Application of system thinking to frame the problem in a subsea development projects with high-level business requirements

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***Abstract*—The oil and gas industry are continuously performing development projects to improve their offerings. In this industry the typical input to the development project is high-level business requirement mixed with specific solutions. The stakeholders setting the requirements and dictating the solutions are often more concerned with the business needs and are lacking a holistic view of how this affect the technical systems solution through its life cycle. In this paper, we apply systems thinking to understand the impact of the high-level business requirements and gain a deeper insight in how to tackle them to meet the target of the project. We apply systematic analysis to an actual development project in a supplier company to understand the problem and the forces acting on it. Using a systemigram we model the problem and then apply the system principle of openness to understand what parts of the problem we can affect. Based on the analysis we propose three focus areas for the project development to move forward and meet the project target**

Keywords— Systems thinking, systemigram, high-level business requirements, openness, problem framing, oil and gas

I. INTRODUCTION

In the oil and gas industry, a development project often starts with a single high-level business requirement, like reduce cost with 50% or reduce lead time with 6 months. In [1] the authors claims that the stakeholders driving these requirements may be completely disconnected to how the target should be reached, or even worse, that they have a given solution in mind, but lack the understanding of how the implementation of such solution will affect the system. The focus of the stakeholder is often on short-term business need and profit, lacking the understanding of the long-term effect on the system life cycle. The challenges for such development project is to understand the effect of these high-level business requirements and proposed solution. There is a need to understand how we can meet the short-term targets and still have a development strategy that also is sustainable. To gain such understanding the development team need to have a holistic view on the problem.

In this paper, we investigate the use of systems thinking to understand the problem and systematic analyze how external forces affects the target of the development project. To illustrate the approach, we apply it on an ongoing development project in the oil and gas industry. We use Gharajedaghis system principle of openness [2] and define the context for the project both in its developing and operating context. Further, we investigate the stakeholders to the development project and their interest and look at the external forces that has evolved the problem to its current state. Next, we analyze the problem using the systemigram as proposed by Boardman [3], to gain a deeper understanding of what affects the problem and development project. We then apply the principle of openness to the systemigram to understand what part of the problem the development project can affect. Using this approach, we conclude on three high-level guidelines for how the development project should focus their efforts to succeed.

The case. In this paper we follow a development project in supplier company the oil and gas industry. The company started the development project as a direct response to the fact that the company were losing their market share. The high-level business requirement given to project was "develop the next generation configurable subsea system to regain the company market share on the Norwegian Continental Shelf by using standard product and building blocks. The project shall challenge existing solutions and find new ways to reduce size and weight, to reduce schedule and installed cost of the subsea system to meet a target cost per well of XX MNOK".

Company of research. The company being target for this research is a global supplier of equipment to the oil and gas industry. We have conducted our research within a Norwegian department specializing in subsea production systems. To avoid confusion of terms, we hereby call the global supplier of subsea equipment the "supplier", and the oil and gas companies that are the customers we hereby call "oil company". The project development team in the company we hereby call "the team".

II. BACKGROUND

Barry Richmond was the first to introduce systems thinking as a term in 1994 [4]. He defined systems thinking as the "*art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure*". Since the literature has presented several definitions of systems thinking. Arnold and Wade [4] is giving attempt of one common definition, stating "*systems*

thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects. These skills work together as a system". Edson [5] states that systems thinking provides a way of looking at the problem situations and an approach to problem solutions. He gives two simple steps for approaching the problem systematic, first look at the problem as a whole system in a larger world, and second, approach problem investigation and assessment in a systematic way.

Gharajedaghis [2] introduced in his work five system principle to define the characteristics of a system, namely openness, purposefulness, multidimensionality, emergent property, and counter intuitiveness. He states that "no problem or solution is valid free of context". To define the openness of a system, he defines three boundaries; *control* – the part of the system we to some extent can control, *influence*, the part we cannot control, but only influence, also called the *transactional environment*, and *appreciate*¸ the environment the system is operation in that we cannot control or influence, the *contextual environment*.

A systemigram is a systems thinking tool introduced by Boardman [3], with the purpose to "bring context to the meaning of togetherness". Systemigram is a way to visualize a problem, using nodes and links, to understand the interrelation in the problem. Mansouri, Sauser and Boardman, [6] claim that systemigrams can support learning about each other's perspectives and identify organizational and communicational bottlenecks and enable effective and efficient decision making.

III. The Problem Context

To define the context for the problem we need to understand the system of interest for the development project and define the context for the system both in the development and in the operational environment. To define the context, we use Gharajedaghis definition of system boundaries, [2]. In the following, we present the system of interest for the development project and the system context both for the development context and the operational context.

A. The system of interest for the development

Before setting the context, we introduce the subsea system, which is the system of interest for the development project. The purpose of a field development is to extract the oil and gas in the reservoir and bring it topside. The role of the subsea system in this development is transferring the oil and gas from the bottom of the sea and to the topside facility. Fig. 1 shows a simplified sketch of the main components in a subsea system. The wellhead acts as a pressure containing interface to the well. The Xmas tree is a collection of valves that is installed on top of the wellhead to control the flow and well pressure. Its main function is to control flow and to act as a well barrier during operation. The Xmas trees connect to a manifold. The main function of the manifold is to collect oil and gas flow from all the individual valves and distributing electrical signals and fluids from the topside to wells. The manifold has a connection system to connect the subsea system to the flowline, which transfer fluids and signals from topside to the manifold and oil and gas flow from the subsea system to topside.

B. The system boundaries – operational context

In the operational context, we consider the subsea system the system we can control. The subsea system is a part of the complete field development, which is the system we can influence. This includes drilling, topside facility, subsea umbilical, risers, and flowlines (SURF) and the vessel used for installation. The field development has an operational environment, which is the system we need to appreciate. The key factors in the operational environment are the met ocean, such as data, waves, current, wind, temperature etc., the seabed and soil condition and the reservoir.

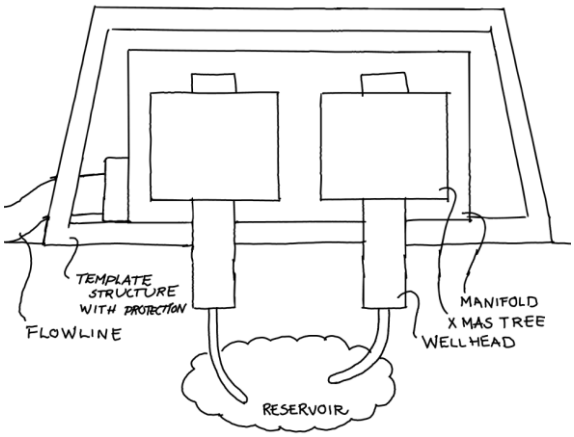

Fig. 1. Subsea system

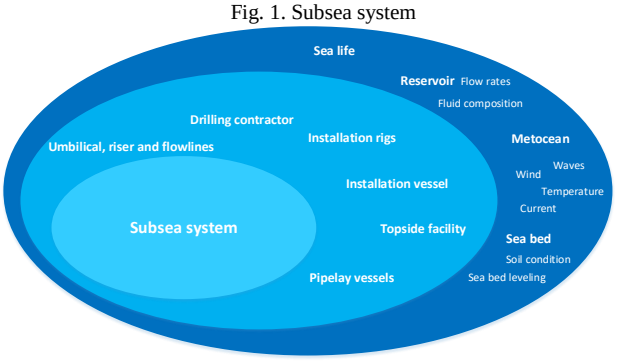

Fig. 2. The system boundaries in operational context

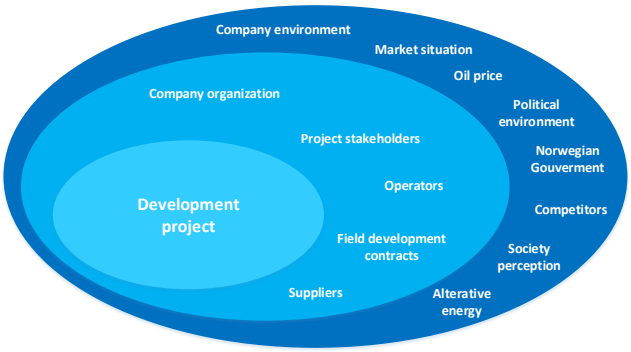

Fig. 3. The system boundaries in development context

Fig. 2 shows an illustration of the system boundaries in the operational context.

C. The system boundaries – developing context

Fig. 3 shows the system boundaries for the development context. The development project team is in the inner circle, within what we can control. Within the area we can influence, we have the company organization, including several different entities such as the sponsors, project teams, product group,

management teams, etc. In the area of influence, we also have the oil companies, suppliers, and the other field development contractors. Finally, in the boundary for what we must appreciate, we have the current market situation. This is strongly dependent on the world situation, affecting the oil price and the political environment. We also included the society perception of oil and gas industry, as this influences the political environment, and alternative energies, as that can affect both the society perception and the political environment. Finally, we have included the competitors and the Norwegian Government.

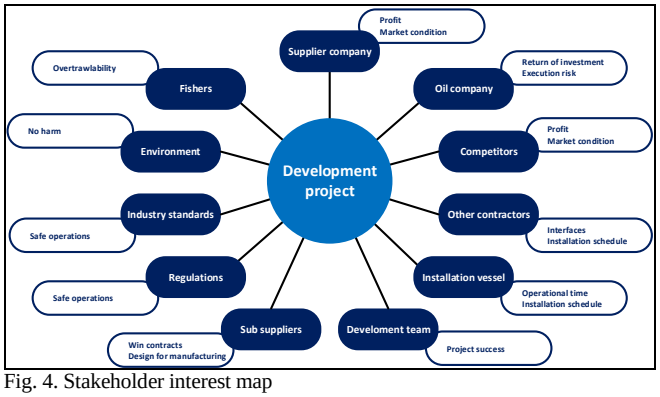

Fig. 4. Stakeholder interest map

IV. Stakeholder Interest Map

Having defined the context for the problem, we can define the stakeholder to the development project and their main interests. Fig. 4 shows the stakeholder interest map for the development project.

An important stakeholder is the company, and their main interest is to maximize its profit and to regain its market share. On the left-hand side are the stakeholders that are directly involved in a field development, the oil companies, competitors, installation vessels, sub suppliers and the other contractors, such as drilling and topside facility. They share the interest connected to maximize the profit of their investments in a field development. To achieve this, the customer is interested in low cost solution with low execution risk, while the contractors and installation vessels are more concern with the installation schedule and interfaces. The sub suppliers are interested in getting manufacturing contracts from the supplier. They are also interested in that the product development adhere to the principle of "design for manufacturing", to reduce complexity of manufacturing. The competitors have the same interest as the company, maximize profit and gain market position. On the right-hand side are the stakeholder affected by the system, the environment and the fishers, and the stakeholder affecting the system, the regulations and industry standards. The main interest of the two latter is to ensure the safety of people and environment. Owertrawable systems is the key concern for the fishers. The interest of the environment, is no harm from operations or spills.

Fig. 4 shows the high-level stakeholder overview; behind each of these are several stakeholders, which could have other needs. Internal in the company there are many individuals and organizations which all have their own interest in the project, not only to support the project, but also to strengthen their position in the complex company organization. For the oil company, the interest depends on if it is a large or small company, if it is a Norwegian company or not. In addition, inside the oil company organizations, there could be different stakeholder needs, depending on the stakeholders' location in the organization, their background, and their personal agenda etc.

V. How the Problem has Evolved

Previous sections show the context and the stakeholder which affects the problem today. To gain deeper understanding of the problem, we also need to understand how the problem has evolved to its current state. The supplier has historically had a dominating market share in the industry. However, over the last years, it has experienced a decline. In this section we consider how the market transformed, shaping a problem for the supplier.

A. The market upturns and downturns

The oil and gas development on the Norwegian Continental Shelf (NCS) started in the 1970ties. It has been a major contributor to the Norwegian wealth. Still there is a great amount of reserves available in the area, which is a potential source for future wealth. In early 2000, the Norwegian oil and gas industry went through a period of growth. In this period, the industry developed a high volume of fields, and the oil companies and suppliers experienced economic growth. In this period, the cost level increased rapidly, and for the subsea deliveries, the cost tripled in the period 2005-2013. The increase in cost was significant compared to the activity increase [7].

In 2014, the oil prices dropped significantly, and the industry faced a down turn. Combining low oil prices with cost increases made it challenging to develop profitable fields [8]. During this period several field developments were set on hold since they were not profitable, and the activity on the NCS dropped significantly. This downturn effected the whole industry, and the oil companies and their suppliers all had several rounds of downsizing.

To recover the industry there was a need to reduce the cost level significantly. The focus for the oil companies and the suppliers the last years has been to develop low cost solutions. This has given a more acceptable cost level in the industry and combined with a slowly increasing oil price, the market is currently picking up and the activity is increasing. Going forward in the new market, the industry maintains the focus on the low-cost solution, to avoid having the same increase as they had before the downturn.

B. The change of the game

Historically, horizontal Xmas trees (HXT) has been the dominating subsea solution on NCS. In 2012, there came a shift in the industry when Equinor, the major player on the NCS, announced the new standard for the subsea XT should be vertical (VXT). Changing from horizontal to vertical XT effect the complete system solution, both for the engineering and the installation scope. The reasoning for the change was to reduce the operational cost. In the past, the oil companies measured the offerings in the subsea industry mainly on the capital expenditure, CAPEX, that is, all the cost of producing the system and putting it into operation. However, a subsea has a minimum lifetime of 25 years. During this time there is a need for service, meaning the operational expenditures, OPEX, are equally important. From the shift in 2012, the industry tends to be focusing on the both CAPEX and OPEX, measuring the offerings on the Total Cost of Ownership (TCO). The supplier has a field proven solution for a HXT system. It has delivered this with a sustainable margin. The

shift to the VXT system required the supplier to develop a new system. Initially, they did this on a project basis, successfully securing them the first large contract on VXT systems for NCS. However, for the next contracts the suppliers VXT solution was no longer competitive, and the need for developing an improved offering arose.

VI. The Systemigram

Using the analysis and discussion in the previous sections, we developed a systemigram to graphical represent the problem, see Fig. 5. The upper corner is our system of interest

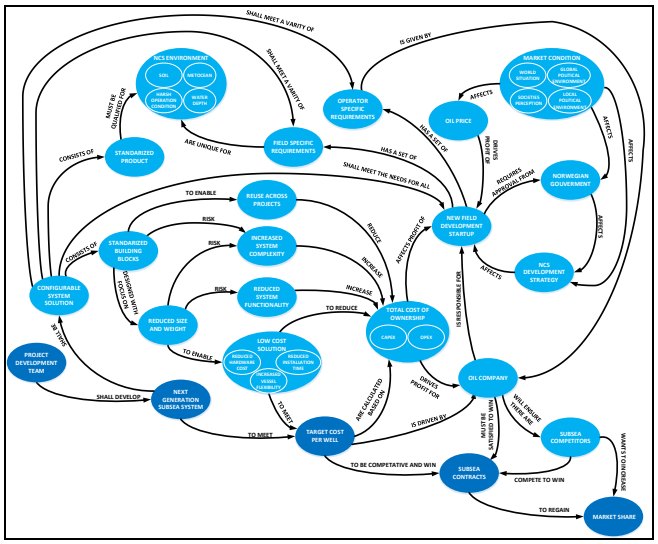

Fig. 5. The systemigram

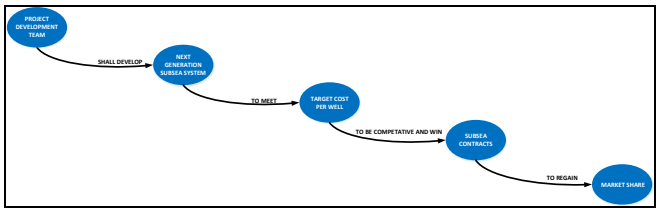

Fig. 6. The mainstay

in this context – the development team. In the lower corner we show the "utopia", the state we want to achieve with the development project. In this problem "utopia" is to regain the company dominant market share on the Norwegian Continental Shelf. In the following sections we look in more detail of some of the stories found in the systemigram.

A. *The mainstay – the purpose of the project*

The mainstay as shown in Fig. 6 tells the sole purpose of the development project. We can read this story as "the *project development team* shall develop the *next generation subsea system* which meets a *target cost per well* in order to be

competitive and win subsea contracts to regain minimum market share at NCS". The mainstay is the path for how the team can go from where they are today to where they need to be in the future.

B. *The story of "oil company"*

The story of the oil company, Fig. 7, shows the extent of the influence the oil companies has on a supplier's internal development project. The oil company are operating the fields, deciding when to start a field development and put out the contracts to the suppliers. To win the subsea contracts the supplier is dependent on the customers satisfaction. The oil companies want to optimize the profitability of the field, and they are driving the cost reduction in the industry. A reduction in the TCO of the subsea system will increase the oil companies profit and thereby make the supplier more competitive.

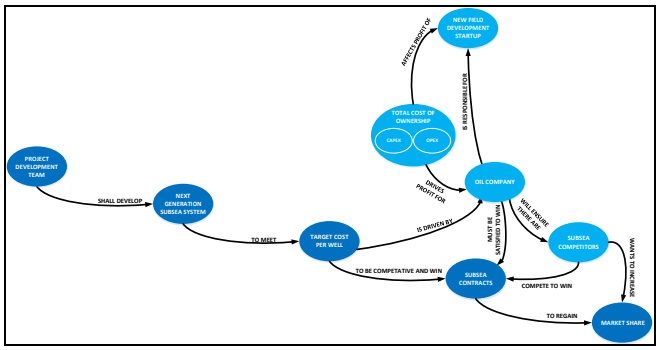

Fig. 7. The story of oil company

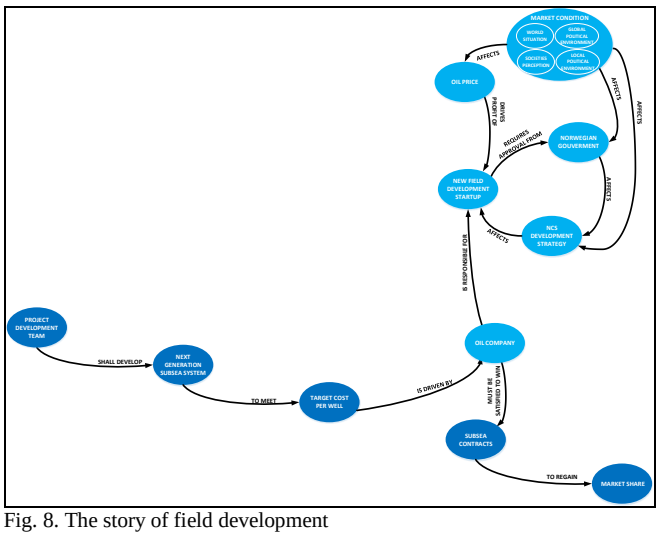

Fig. 8. The story of field development

C. *The story of "field development"*

Fig. 8 shows the story of the field development, and the drivers for a startup. A new field development is dependent on approval from the Government before starting up. This is depending on the development strategy for the NCS. The market situation is affecting both the acts of the government and the development strategy. With permission form government, it is the oil company that makes the final decision to start the field development based on the expected profitability of the system. The expected profit of the field depends on the value of the reservoir and the oil price. The market is driving the oil price, while the value of the reservoir depends size and quality of the reservoir and is estimated based on results from exploration drilling and seismic analysis. Based on the expected value of the reservoir and the oil price the oil company set a cost target to make the field development profitable.

D. *The story of "Configurability"*

The last story of the systemigram is the story of configurability, which is a collection of several stories. The first story, shown in Fig. 9, tells a story of the variability of needs a configurable solution should meet. To regain the market share, the next generation subsea system must meet the need for all the new field developments. All field developments have large sets of requirements, both field specific and oil company specific. The environment is driving

the field specific requirements. In the NCS harsh conditions are characterizing, which gives strict requirements to operational conditions, and making the needs for the system in NSC unique compared to the global market. The oil

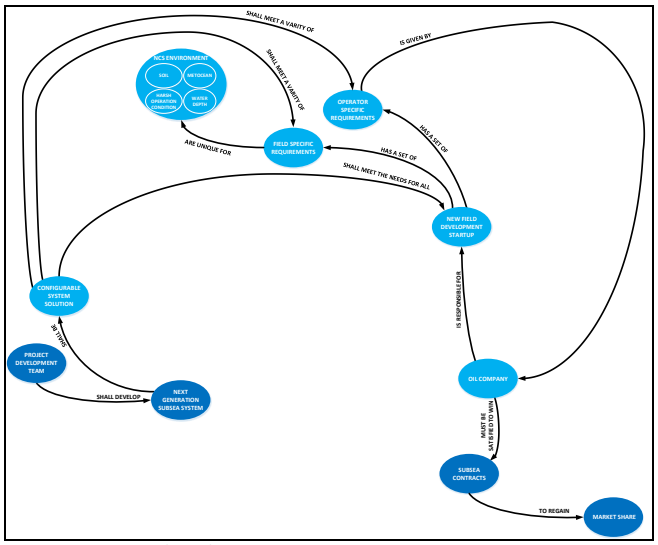

Fig. 9. The story of configurability – the need

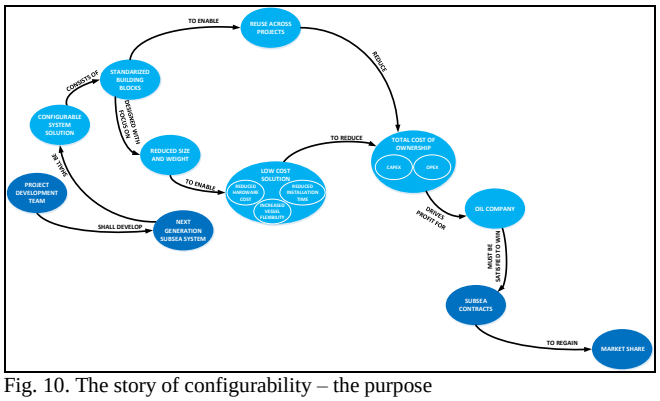

Fig. 10. The story of configurability – the purpose

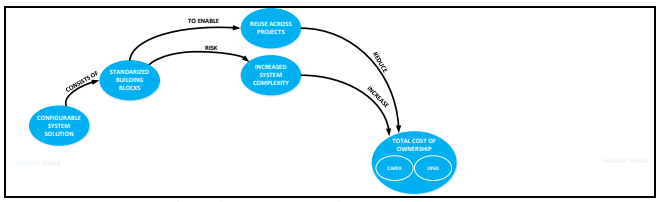

Fig. 11. The story of configurability – first contradiction

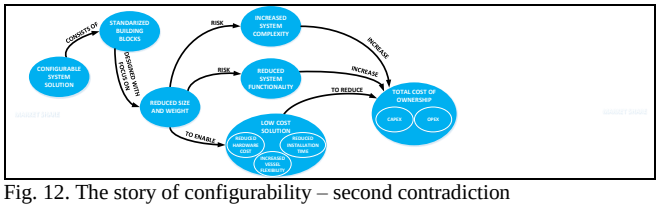

Fig. 12. The story of configurability – second contradiction

companies are all providing their set of company specific requirements, and the extent of these requirement are strongly dependent on the type of company, as discussed in section IV. The configurable system solution must fulfill both the field and the oil company specific requirements to satisfy the oil company. The next story, Fig. 10, shows the intent of the supplier when introducing the configurable solution. This story reads “the next generation subsea system shall be a configurable system solution consisting of standardized building blocks to enable reuse across projects to reduce total cost of ownership”. The story also tells the intent behind the focus on reduction of size and weight, namely “configurable system solution consisting of standardized building blocks designed with focus on reduced size and weight to enable a low-cost solution to reduce total cost of ownership”. These stories also introduce two contradictions, Fig. 11 shows one of them. The intent of building blocks is to enable reuse. However, designing building blocks to fit the variety needs as shown in Fig. 9 carries the risk of increasing the system complexity. This could result in over specifying the system for its purpose and increase the total cost of ownership. Fig. 12 shows the second contradictions. Designing building block with focus on reducing size and weight, carry the risk of reducing the system functionality or increasing the system complexity. Both of this would increase the cost of total cost of ownership.

VII. How to Tackle the Problem?

The systemigram gives us a good visualization of how several forces are acting on the development project. To move forward with the development project, we need to understand where the team have the power to influence and should invest their effort and what are outside the teams control. In Fig. 13 we apply the system principle of openness to the systemigram, and categorize the nodes into control, influence and appreciate.

A. *Appreciate*

As shown in Fig. 13, a large portion of the nodes are in the area of appreciate, meaning we have no way of influencing or controlling them. But being aware of these is important for the project team to succeed in their mission. The main forces outside that the team need to appreciate includes;

- the market conditions which is the major driver for the oil price and the NCS development strategy, which again are drivers for the startup of the field development
- the NCS environment which are a very harsh environment compared with other regions, and which set strict requirement to the technical solution

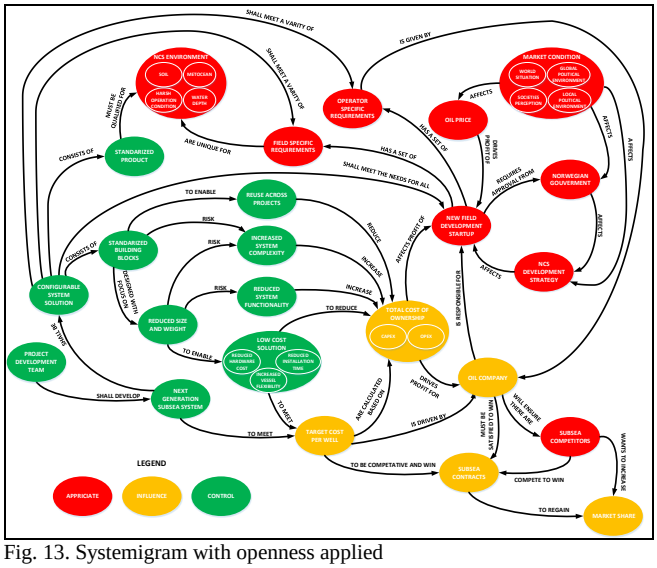

Fig. 13. Systemigram with openness applied

B. *Influence*

In the category of what the project team can influence, the most important actor is the oil company. In "the story of the oil company" we saw that the oil company satisfaction is key to win contracts, and that the oil companies is driving the requirements of a field development. The other important aspect the team can influence is the total cost of ownership, by developing the low-cost solution with this in consideration.

C. *Control*

In the area of what the team can control, it is the nodes defining the technical solution and most of the story of configurability. The team cannot control the drivers for the system needs, the field and oil company specific requirements are outside our control. But the remaining of nodes making up the story of configurability is within the teams control.

D. *Guidelines for tackling the problem*

From systemigram combined with the system openness principle, we can extract three high-level guidelines on how the development team should tackle the problem, namely

- **Understand** the market needs and drivers
- **Influence** the oil companies
- **Control** the system solution, balance the opportunities and risk

Understanding the market needs and drivers, are important in all development projects. This is key to make a long-term plan for the development project. The team needs to ensure focus on the future market prospect and not just on the short-term wins. Influencing the oil companies are important to gain trust on the system that the team are developing. Having good collaboration with the oil companies during the project and introducing them to the technology as it is developing, are important to ensure acceptance of the final delivery when

introduced to the market. Concept visualization and prototyping are important tools to support this communication. Finally, the team must control the system solution. Even if it is important to meet the market need and keep the oil companies satisfied, the team must not forget that they are owning the technical solution. Within this area of control, it is key that the team evaluate risk and opportunities in the choices that they do. Architectural reasoning and conceptual modeling will be important tools in this work, supporting them in exploring several viewpoints and balance out the design solutions.

VIII. CONCLUSION

Oil and gas industry developments project often starts with high-level business requirements. The stakeholders giving these requirements may focus on the business need and underestimate the influence this can have on the technical system solution throughout its life cycle. To understand the impact of such high-level requirements the problem, we suggest applying systems thinking, to understand the problem as a whole. We use systemigram to graphically represent the problem and understanding the shaping forces. By applying the system principle of openness to the systemigram we gain understanding on how to tackle the different parts of the problem, by defining what need to be appreciate, influence and control.

In the paper we are applying this to an actual development project in oil and gas industry. From the stories in the systemigram and the categorization of openness, we found some high-level guidelines of how the team should tackle the problem.

Systemigram are an efficient tool for representing the problem, facilitating understanding of several viewpoints and to identify the bottlenecks. The stories pulled out from the systemigram support the team in understanding the influence of the most important actors to the problem. In the case study we found that applying the principle of openness to the systemigram was efficient to categorize the problem and to understand how to tackle the problem.

In this problem we have showed the application of the systems thinking to a case study in the oil and gas industry. In this domain, we believe that using systems thinking are key to avoid unsustainable short-term wins, and to focus on building an understanding of the larger picture by analyzing the challenge in a holistic perspective.

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