Warehousing in the Context of Digital Supply Chain in the Oil and Gas Industry: Towards Conceptualization and Groundwork

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Abstract. The oil and gas industry is a complex industry with many stakeholders, risks, and monetary values involved. The supply chain of oil and gas companies is an aspect of oil and gas companies that has developed without major optimization measures along the way – it has simply had activities and concepts added as they have come along. One such activity in the supply chain in need of optimization is warehousing. A large amount of spare parts cost oil and gas companies extensive amounts yearly. With the introduction of the digital supply chain, the oil and gas industry is looking to add lessons and concepts to decrease costs, increase sustainability, and optimize warehouse activities. As this is a research field in which little specific work has been conducted, we use grounded theory to develop groundwork upon which companies can rebuild their warehousing and other supply chain activities. We conclude the work with suggestions for future research.

Keywords: Warehousing, digital supply chain, spare parts inventory, oil and gas, Industry 4.0

1 Introduction

The technological advancements of the last decades have, through industrial revolutions, advanced supply chains. Possibilities seem to be endless: increased availability of real-time data, optimization of various logistics practices, and increased transparency across the supply chain are among the listed benefits of the digital supply chain [1]. The oil and gas industry is characterized as a less digitally mature industry in comparison with many other large industries [2]. This is not due to a lack of digitalization needs – Lu et al. [3] note that the oil and gas industry needs to accelerate efficiency measures to meet governments' sustainability policies, for which Industry 4.0 technologies will be vital. Additionally, technology implementation in the industry is linked to cutting costs, optimizing production, and maximizing profits [3]. Literature goes far in

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suggesting that the heightened use of digital technologies leads to achieving higher value of both monetary and functional type.

Digitalization of the oil and gas industry is relevant across its entire operational spectrum. During the past few years, research has been conducted on the use of technology in the oil and fluids production phase [4], [5], [6]. Even still, literature on digitalization in the oil and gas sector is limited, regardless of specific application [7]. The component of the oil and gas supply chain we would like to focus on in this research is warehousing. Warehousing in the oil and gas industry serves several functions, one of which is spare parts inventory [8]. Spare parts for offshore production systems must always be available, sometimes for scheduled maintenance jobs and always in case of unpredicted malfunction. A combination of predictive maintenance planning offshore and appropriate technology implementation in warehousing can reduce inventory and its frequency of use. However, offshore oil production contains a high level of risk, and spare parts must always be available in some form in case of emergency.

Warehousing does not have to be a burden to the oil and gas industry. With appropriate optimization measures, its presence can be a catalyst for optimization and digital fluency across the whole supply chain. These types of initiatives – modernizing supply chains in industries as large and complex as the oil and gas industry – are vital. The industry's ability to renew themselves in a time when they are under great pressure due to high carbon emissions and longevity concerns will have great meaning in the long run. Modernization and digitalization in all areas of operation – offshore production, supply chain operations, sales, and other activities – will be of significance.

According to Mol [9], increasing visibility across the supply chain is key to eliminating many of the issues observed in industrial supply chains in the past years. Increasing visibility can be done through digitalizing the supply chain [10]. In this paper, we aim to outline the components of spare parts warehousing in the oil and gas industry in the context of digital supply chain. In essence, this means identifying the building blocks, mindsets, and technologies that should be included in the future. The work will be on the basis that both warehousing and other supply chain activities in the industry are in adherence with the concepts of digital supply chain as presented in recent literature. We perform this research using grounded theory. A paper on the data foundation and methodology is published separately. We start with introducing the background on the topic, presented in Section 2. Thereafter, we present the work from the grounded theory process in Section 3. Finally, we discuss our results and conclude by suggesting further research in Section 4.

2 Background

Supply chains relating to oil and gas production are complex [11]. The frequent use of single-source suppliers, great amounts of material warehousing, operational limitations, and non-resilient distribution networks consitute some of the main

challenges in the oil and gas supply chain [12]. However, some analysts claim that digitalization has the potential of eliminating challenges in the supply chain [13].

Spare parts warehousing in the oil and gas industry is a topic many supply chain workers in the industry work with. As the primary products from the industry are extracted from raw material rather than being manufactured in a factory, there is a uniqueness to warehousing practices and concepts compared to other classic manufacturing industries. The uncertainty relating to offshore production is rooted in function, safety, environment, and monetary considerations. The spare parts warehouse should go through optimization work to decrease inventory levels, yet there should be secure inventory levels in cases of emergency and unpredictable circumstances. Establishing clear practices in warehousing then is challenging – there is no foundation, criteria, or strategic groundwork to guide managers and decision makers. This is what our work wishes to address: a starting point for optimization of oil and gas spare parts warehouses in a disruptive era.

3 Results – grounded theory and resulting groundwork

In the belonging separate paper, we explained that the data would be coded. The coding is done in three steps: open coding, selective coding, and theoretical coding.

Open coding, which is to fracture data into larger categories, leads us to the categorization shown in Fig. 1.

Fig.1. Open coding. All data is deemed able to fit into one or more of these six categories.

The open coding categorization is rooted in the information gathered from all data presented in the belonging paper published separately. Open coding is meant to simplify and minimize information gathered from data to obtain a clearer understanding. The reasoning behind our open coding is the following: all data considered in our work can be placed in one or more of these six categories. In other terms: all aspects of warehousing in relation to digital supply chain can, according to our research, be placed in these six categories.

Selective coding, which is to limit code only to what is essential, further leads to the categorization shown in Fig.2.

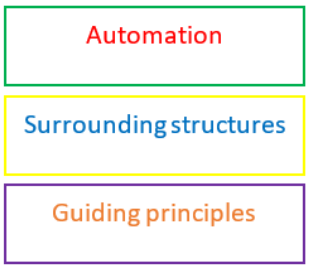

Fig. 2. Selective coding. Six categories reduced to three.

The selective coding categorization reduces the number of categories without reducing the content. The colors of the boxes and text in Fig.1 show that each box is a combination of two boxes from Fig.5: "automation" in Fig.2 is a combination of "digital infrastructure" and "technology" from Fig.1, "surrounding structures" is a combination of "strategy" and "planning", and "guiding principles" is a combination of "capabilities" and "actions". This simplification is intentional. Intuitively, we move away from technology as a description of a digital supply chain component. Technology's presence is established in industry and society, even before Industry 4.0. Computers, tablets, smart phones, sensors, and wireless tools are used in the oil and gas industry (including warehousing) daily, and have been for years. Although there are several newer technologies not currently in use which warehousing could benefit from, we choose to rephrase this as automation, as that is the ultimate capability and aim of the newer technologies. Automation then also includes digital infrastructure, which should also enable automation in cooperation with technologies.

Strategy and planning are rephrased as surrounding structures. The culture, built by leaders and managers and maintained daily by all employees, have a significant effect on both strategy and driving concepts as well as results. One synonymous term for culture, strategy, and planning is "surrounding structures", and thus this is the term we use.

Merging "capabilities" and "actions", we develop the concept "guiding principles". These are to be developed or derived from the culture one wishes to have at the core of warehouse operations, and these principles are then meant to contribute to shaping the strategy. The reason capabilities and actions are merged to become guiding principles is that such principles would affect and shape both capabilities and actions. The actions themselves are deemed unsuitable to include as a keyword in the final groundwork – exact actions are dependent on principles, strategy, culture, and automation levels. The same holds true for capabilities.

Theoretical coding is the final coding step, which is to recognize links between codes. Our selective coding is recognizing how automation, surrounding structures, and

guiding principles are related. The success of one would fuel the others, and the combination of all creates an adherence to the digital supply chain. Theoretical coding is thus the creation of the groundwork, presented in Fig.3.

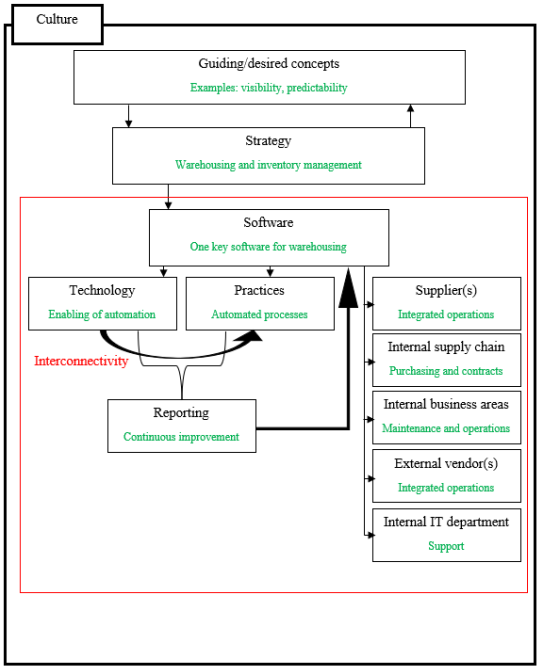

Fig.3. Conceptual groundwork for warehouse in the context of digital supply chain in the oil and gas industry.

The conceptual grodunwork of warehousing in context of digital supply chain in the oil and gas industry takes into account the components that will be necessary for implementation success. The oil and gas industry – unique in its nature and different to many other industries in culture, operations, and output – must first and foremost create a culture for innovation, creativity, and consistent development to succeed in warehouse and supply chain digitalization. A re-establishment of culture is highly likely to be necessary also in terms of the energy transition that is planned to occur during our lifetime. In an industry with many decades-long workers, culture altercations requires extensive work, particularly from management.

The desired aims of the warehouse and the digital supply chain should function as guiding principles in both implementation and eventual daily operations. These aims can be changeable, but should be established early in the process by leadership and teams. One of such aims should ideally be visibility. Digital visibility of products, processes, functions, and personnel realizes the digital supply chain's main functions. Additionally, principles like predictability, manageability and others can be added here.

Culture and guiding principles help form the strategy, which puts forth the specific aims of warehousing in the context of digital supply chain. The different components that are of relevance should have their separate strategies – the warehouse, the supply chain, the company, and the digitalization purposes. Ideally, there are links between these strategies, as digitalization is incorporated both in the supply chain and otherwise in the company.

Digital supply chain cannot be achieved without customized, interconnected software that can help personnel conduct relevant tasks. One overall software should enable and overview much of the work involved in the warehouse – this is a form of interconnectivity. Today, many oil and gas production companies use multiple softwares, applications, and programs for warehouse activities, many of which have no means of communicating with each other and therefore require more time from human warehouse operators. A customized, interconnected software is of great importance to warehousing. A combination of software purchase and company customization is likely to have to be conducted, as oil and gas companies conduct specific operations that external software developers can rarely cater to with ready-to-use products. Customization is not only beneficial, it is critical. Ready-to-use software that fails to function according to the specific oil and gas company's spare parts warehouse would result in being a burden rather than a digital supply chain tool, increasing expenditure and need of manpower.

Technologies are, as is evident from the data, an inevitable aspect of the digital supply chain. Their presence enables automation. Their appropriate use means incorporating them into daily warehouse operations to the point where they can conduct some of the warehouse activities without human involvement, other than occasional monitoring. For this reason, technologies and practices are linked in the conceptual groundwork. Certain technologies, like additive manufacturing and technologies that enable digital twin, may be of particular importance to the future warehouse. However, this is for management to determine – the conceptual groundwork shows that appropriate and suitable technologies must be implemented in the warehouse to achieve automation.

Suppliers, internal supply chain actors, relevant internal business areas, external vendors, and the internal IT department must be involved in softwares used for warehousing in an oil and gas company. The interconnectivity involves all relevant stakeholders having sufficient access to products, processes, and actions. This is for optimization in relation to time and communication. For this reason, several internal and external units are included in the conceptual groundwork.

Interconnectivity is the concept that runs as a common ground for strategy, software, technologies, practices, and stakeholders. Without this component, digital supply chain cannot be achieved. As Industry 4.0 and its technologies are strongly rooted in interconnectivity, the concept is given key space in the conceptual groundwork.

4 Conclusion

We used grounded theory to develop groundwork and present the relevant concepts of digitalization in the oil and gas supply chain, namely spare parts warehousing. Grounded theory constitutes gathering data to establish a foundation in areas which have not been extensively researched and requires the fundamentals before research of real-life implementation examples can be conducted. For future research, case studies are suggested. An extensive simulation study is recommended where an as-is case is compared to potential to-be cases. Such a study would be of further use to the oil and gas industry, to provide data on the exact differences between warehouse activities with and without automation technologies.

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