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MASTER THESIS REPORT

Which IoT & data-driven solutions have contributed to optimizing supply chain performance for midstream oil and gas companies?

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Abstract

The oil and gas industry is one of the most important industries in the world due to its contribution towards the global economy and energy supply. Despite the industry's challenges related to sustainability and the environment, its historical importance and current energy demands makes it a critical part of the global economy and energy landscape. In our paper, we have focused on midstream companies operating in the oil and gas industry. They play a pivotal role in transportation, storing, and processing oil and natural gas, as well as forming a link between extraction and distribution.

Industry 4.0 has drastically changed how many industries operate by integrating advanced technology and automation solutions in different processes. These changes have made their way to the oil and gas industry and are changing the way companies operate. Through previous literature and interviews with industry representatives we have gathered relevant data with the aim of identifying which IoT and data-driven solutions have contributed to creating more optimized supply chain performance in the midstream oil and gas industry.

Part 1: Introduction

1.1 The oil and gas industry in Norway

The Norwegian petroleum industry arose in 1969 when Ekofisk in the North Sea was discovered. This marked the beginning of what has become the largest industry in Norway. The industry is of high importance to the Norwegian economy and financing of the welfare state. Measured in terms of all value added, government revenues, investments and export value, the oil and gas sector is the biggest in Norway (Regjeringen.no, 2021).

In addition, the industry creates many important job opportunities for the Norwegian people. It is estimated that around 156 900 of the Norwegian people were directly or indirectly employed in the petroleum industry and petroleum-related industries in 2020, which corresponds to almost 6 % of total employment in Norway (SSB, 2022). Figures that highlight the importance of the oil and gas industry in Norway are provided in the figure below (Figure 1).

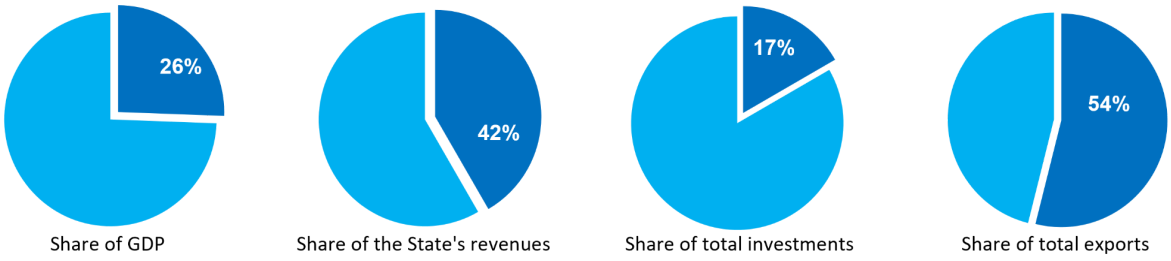


FIGURE 1: *Macroeconomic indicators for the petroleum sector, 2023 (Norwegian Petroleum, 2023).*

These percentage figures highlight the economic importance of the petroleum sector, and that there is no doubting its importance for the Norwegian economy, although we also know that the oil reservoirs will eventually meet their end. However, since the Norwegian production of petroleum started in 1971, only 52 % of the expected recoverable resources on the shelf have been

produced. This is illustrated in the pie chart on the right of Figure 2 below. We can also see that 24 % of the overall resources have yet to be discovered. In addition, we can see that 17 % of the overall resources are reserved, which is the same number as the year before. In 2022, the authorities approved eight plans for development and operation (PDOs), and five PDO exemptions (Oljedirektoratet, 2023).

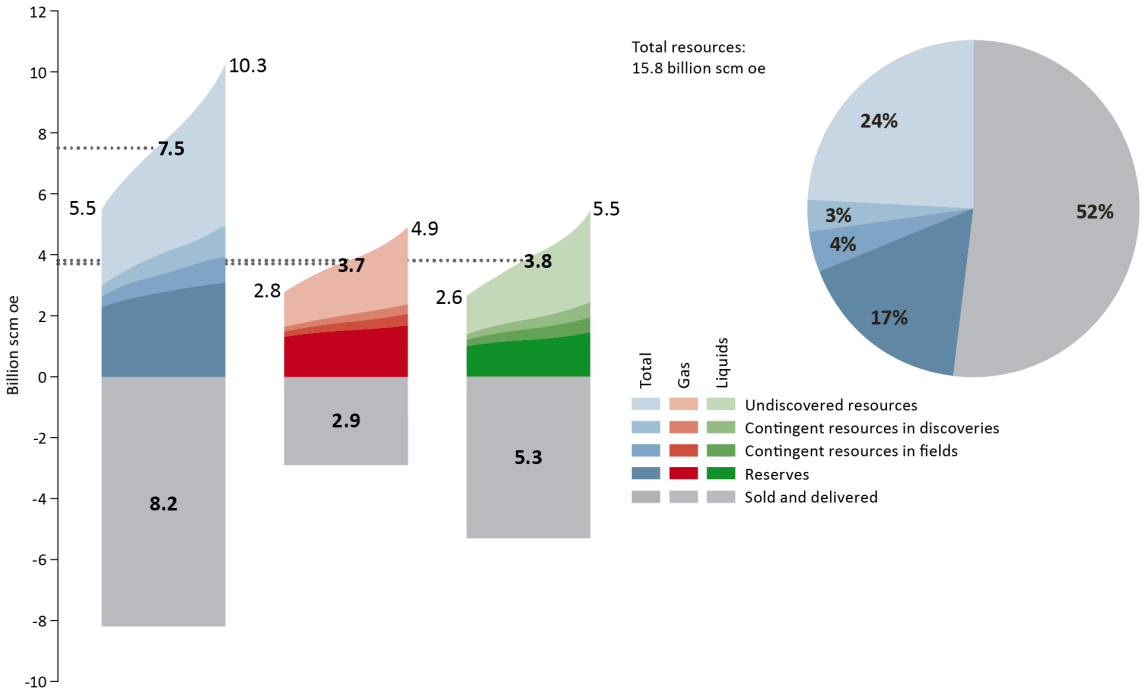


FIGURE 2: *Petroleum resources and uncertainty in the estimates as per 31 December 2022 (Oljedirektoratet, 2023)*

These numbers prove that the recent reviews done by the Norwegian Petroleum Directorate (NPD), which state that the current recoverable volume of oil in fields and discoveries are still huge (Oljedirektoratet, 2023). In addition, the NPD's production forecast for oil and gas shows that the production will remain high in years to come, which is further highlighted in Figure 3 below.

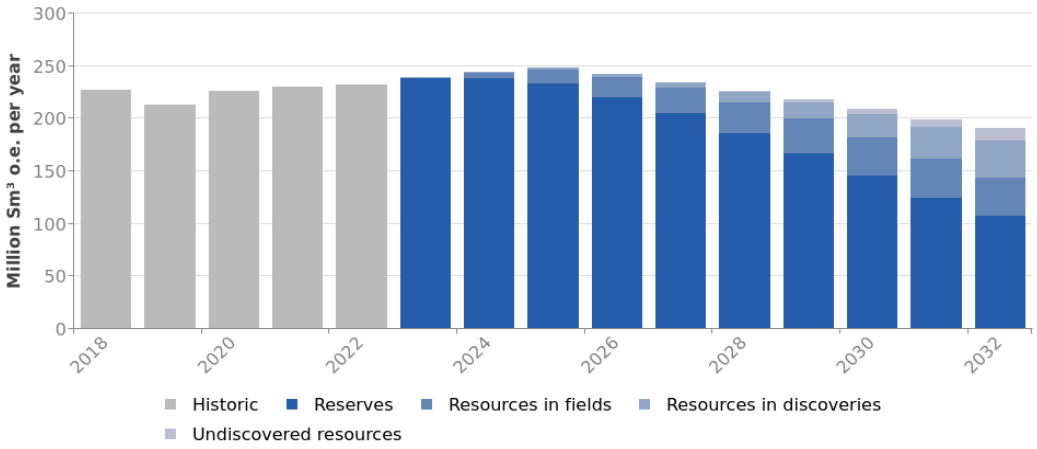


FIGURE 3: *Production history and forecast distributed per resource category, 2018-2032 (Oljedirektoratet, 2023)*

With the petroleum sector being this important for Norway's economy, and research showing that it still will be for many years to come, we wanted to look further into how the technological developments of recent years have helped to streamline the supply chains of oil and gas companies.

When discussing technological developments it is now difficult to do so without mentioning the term; Internet of Things (IoT). The IoT term has been used since 1999 when Kevin Ashton wanted to put RFID chips in products to be able to track them (Guth, 2022). Since then, the IoT term has been widely used and the developments have been many. The oil and gas industry was one of the early adopters of IoT, and one of the benefits from the emerging technologies is that companies can monitor their internal systems and be able to react quicker than they were previously (Matuszak, 2022).

Seeing the potential in the technological developments of the last decades, technology has become an important pillar in most supply chains, including the oil and gas industry. This made us intrigued to look further into how modern technology has improved the midstream oil and gas supply chain, which is responsible for storing and transportation of oil and gas to distributors.

1.2 Problem statement and research question

The aim of this master thesis is to explore some of the opportunities created by IoT and data-driven solutions for the midstream sector of the oil and gas industry. Oil and gas transportation has been constantly evolving, and pipeline transportation is the primary means of moving petroleum products to the consumer market, and one of the main areas of which IoT has been implemented. Therefore, the research has been primarily done on this method of transportation, and we will be looking into how the technological developments have influenced the midstream sector of the industry in recent years. This will show how transportation of oil has become very advanced to create the most effective supply chain. To sum this up we developed the following research question:

Which IoT & data-driven solutions have contributed to optimizing supply chain performance for midstream oil and gas companies?

In order to investigate the research question we have used an exploratory research design, with a focus on qualitative data and a deductive approach.
Through semi-structured interviews with industry representatives we explore the oil and gas supply chain network, how it has improved, as well as some of the challenges it has overcome. While conducting the research we gradually found the need to include the dangers the use of IoT has brought with it in our discussion, as the research has provided some interesting downside aspects.

1.3 Value of the research

The purpose of this thesis is to provide knowledge on how IoT and data-driven solutions have been utilized to optimize and develop the most cost-effective supply chain operations in storing and transportation of oil and gas. We believe the research conducted is highly relevant because of the developments in the industry in recent years. The results from this study can be used to initiate discussions on further improvements of the current midstream supply chains. We believe our research fits its purpose as an initial research tool that can be taken further, by providing theory on the opportunities and the solutions related to our research question.

There seems to be less documentation and literature specifically on the implementation of IoT in the midstream petroleum sector. Through our paper we want to strengthen the academic foundation on what benefits the implementation of new technological solutions has given this sector of the industry. However, we believe much of this research is also transferable to other industries as IoT and data-driven solutions are being implemented for optimization in most industries.

1.4 Thesis Structure

The thesis is divided into eight parts. After the introduction, we will introduce the different elements of the thesis in the background description in Part 2. It will bring some important background information and knowledge about the different elements discussed in the paper. In Part 3, we will look at all the relevant literature and previous research that has contributed to laying the basis of our research. Part 4 will go through the methodology of the thesis, the reasoning for why we choose this methodology, and an evaluation of the research.

The next part of the paper, Part 5, will contain our findings and discussions. They are built by a combination of the previous parts of the paper, which includes collected literature, interviews and data. We will use the research and information gathered to discuss our research question. Part 6 will suggest some ideas on how future research can further use our findings and discussions to conduct deeper research into the field of IoT in oil and gas transportation. Part 7 will include some limitations of our research study, while lastly, the concluding remarks will be provided in Part 8.

Part 2: Background

In this chapter, we will provide the background information considered to be relevant to the thesis, and introduce the main topics. Firstly, in section 2.1, we will provide a brief introduction to the petroleum supply chain, and how we can distinguish the midstream of the oil and gas supply chain. This section will also include a section about pipeline transportation, the most important aspect of the midstream oil and gas sector. This will be followed by section 2.2, which provides an overview of the most important elements of supply chain management in the petroleum industry. This will also include some of the challenges that are faced by the supply chain. Finally, we will introduce the two main topics of the thesis through the oil and gas 4.0 era in section 2.3. Here we will introduce both the IoT and data-driven logistics concepts, which we later will use to present solutions to many of the supply chain challenges introduced. They are all solutions created to strive toward an optimized supply chain in the midstream petroleum industry.

2.1 The Midstream Supply Chain

When we refer to the midstream supply chain of the petroleum industry this includes the part of the supply chain that is responsible for transportation and storing supplies of oil and gas to the distributors. However, there can be instances in which the midstream sector also includes some elements of both the upstream and downstream sectors, for example when it comes to oil refining which could be part of the midstream sector. The upstream sector could also include some storage functions, and downstream will in some cases have transportation solutions that overlap into the midstream sector (Gabrielson, 2015).

Companies specifically working in the midstream sector are intended as an intermediate link between the downstream and the upstream sector of the supply chain. This includes all of the processes and operations between when the product is produced to when it is distributed to the end user. Specifically, the two main areas of responsibility are related to storage and transportation.

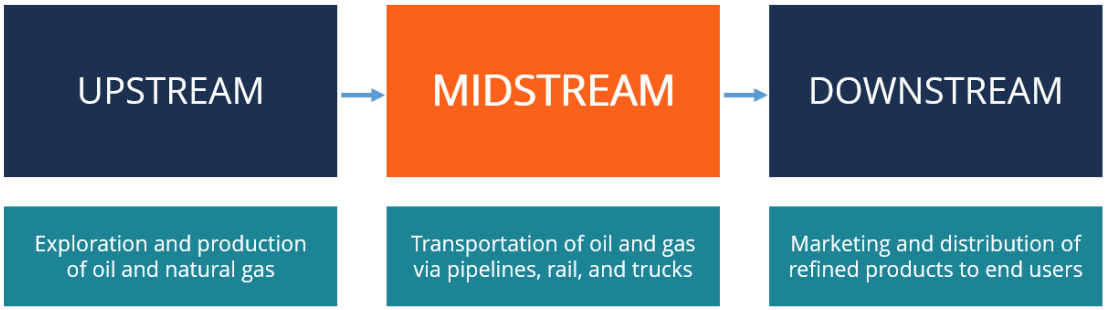


FIGURE 4: *Petroleum Supply Chain (CFI, 2023).*

When it comes to storage, this can be done in several ways, but the most common in the petroleum sector is done through major oil tankers. The most important capability of storing is the balancing of supply and demand. A big part of the storing is also the preparation of distribution equipment, as the equipment needed to do so is heavy machinery that requires a lot of maintenance.

However, the logistics stage starts when the crude oil and natural gas is extracted from underground reservoirs. After the product is extracted the oil and gas has to be stored either on oil tankers or barges, before being transported and distributed throughout the country (or sea) using pipelines. Using extremely high pressure, the product is transported through these pipelines to its designated destination. Because of the economic scale of the oil and gas product, this process has to be highly predictable, safe and secure. When pipelines cannot be used, the best current alternative option of transportation is LNG (Liquified Natural Gas), where gas is liquefied by cooling it below –161.4 °C. This makes gas easier to transport and export because its volume is reduced (Hofstad, 2020).

No matter which form or what method of transportation is used, in the end the supplies have to be delivered to a warehouse, facility or plant, for the final product to be refined and distributed to the end customer. The midstream sector may seem more straightforward than the upstream sector which deals with oil drilling, extraction and exploration. However, the reality is that the transportation flows can be far more complex than they seem at first glance. This is because there are strict safety guidelines, government regulations and several layers of bureaucracy that all impact storing, transportation and logistics of petroleum products.

There is no doubt that there are many factors influencing the midstream supply chain, but their role in the supply chain is clear. Ultimately, the essential focus of the midstream operations is to transport and store natural gas, crude oil, and petroleum products efficiently, and ensure safe delivery to the downstream markets.

2.1.1 Pipeline Transportation

As briefly mentioned previously, pipelines are used to transport oil from different oil wells to refineries and storage facilities. Pipelines are viewed as the most cost efficient way to move oil on land (Karangwa, 2008). Pipelines are also built as underwater pipelines, which are much more expensive, even as much as ten times the cost of on-land pipelines of the same length, and are naturally limited by the underwater terrain they have to traverse (Wang et al., 2009). Nevertheless, underwater pipelines are a necessity because much of the oil and gas extraction is done at sea.

To include an example of how a natural gas pipeline can look, we have provided a figure below (Figure 5). As illustrated in the figure, the supply sources of natural gas are imported into a pipeline. The sources could be from another pipeline, LNG, gas processing plants, and gas gathering systems (Wang et al., 2009). Depending on needs, demand and what season of the year we are in, some of the gas products can transfer to underground natural gas storages or for LNG peaking, which is used for managing energy demand during different seasons (Admin, 2023). The gas can then be transported very long distances before eventually reaching the consumer markets.

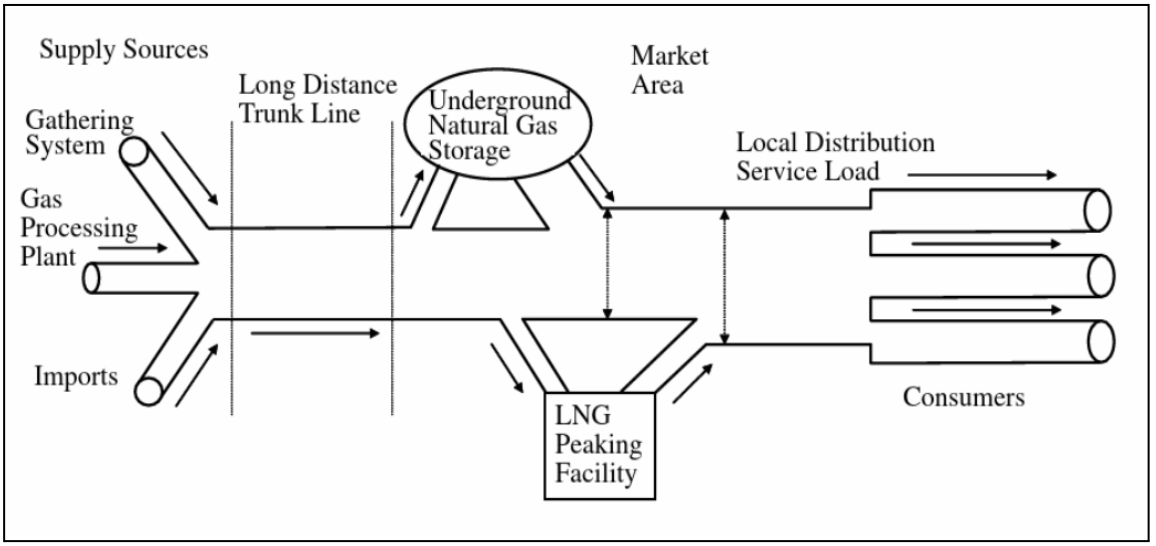


FIGURE 5: *Basic pipeline design concept (Wang et al., 2009)*

The pipelines have become the most important factor of the midstream supply chain, and are currently the best way to move energy products both quickly and protected, and will most likely be so for many years. In fact, Norway has together with Poland, committed to creating the Baltic Pipe pipeline, which began its operations to transport fuel in 2023, and has the capacity to transport up to 10 billion cubic meters of natural gas per year. This pipeline has been developed as Norway and Poland seek to move away from dependence on Russian gas (CE Noticias Financiera, 2022). Seeing that we still develop new pipelines is proof that the government of Norway believes it will still be a reliable means of transportation in the coming years.

Norway has become Europe's largest supplier of gas, following sanctions that led to the drop in Russian gas flows, and the Norwegian pipeline network stretches almost 9,000 km (Fouche, 2023). The pipeline distributes to the Norwegian coastline, the European continent and Great Britain. An overview of the pipelines on the Norwegian continental shelf can be seen in Figure 6 provided below.

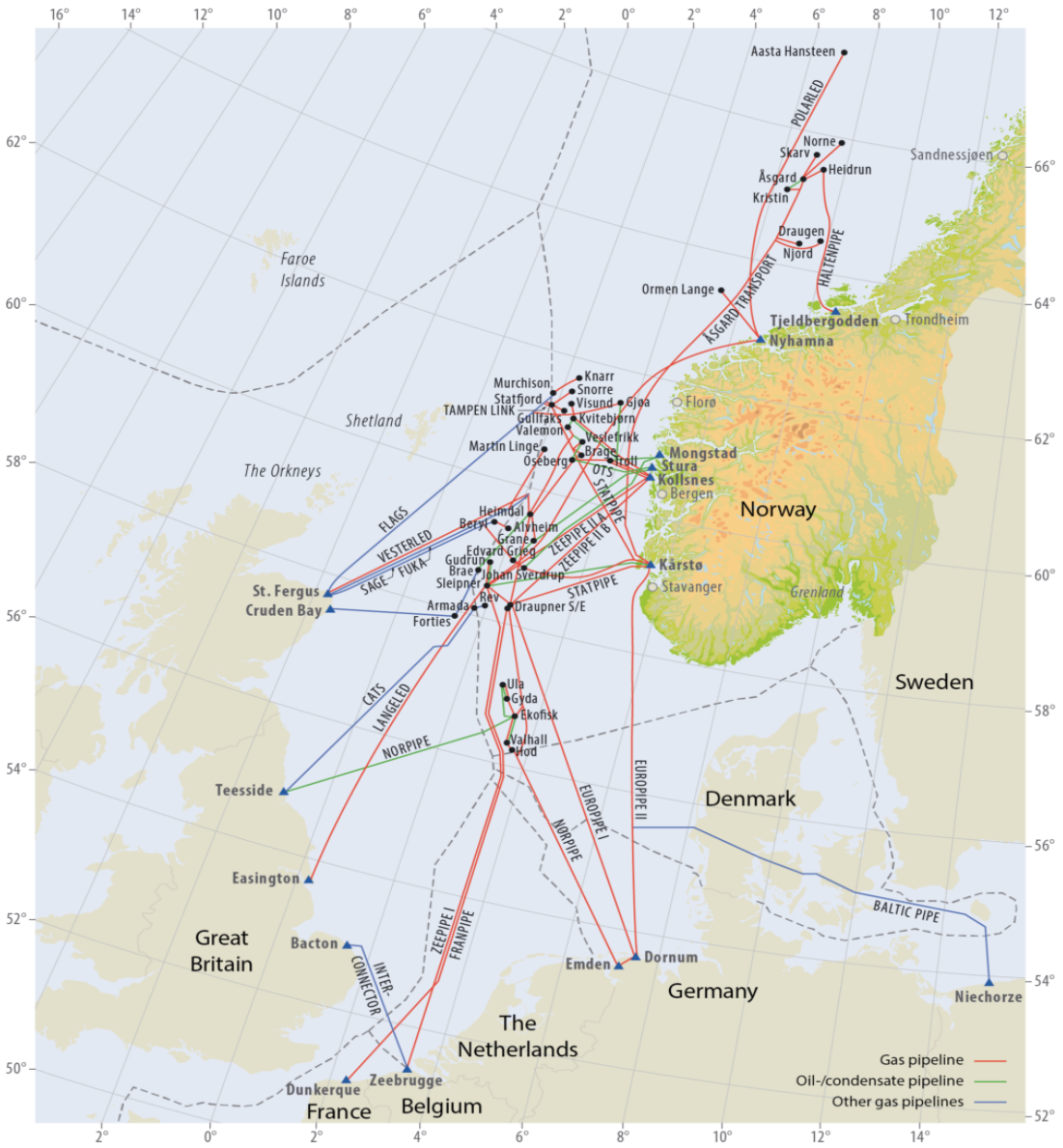


FIGURE 6: *Overview of gas pipelines (red) and oil pipelines (green) on the Norwegian continental shelf (Oljedirektoratet, n.d.).*

As of December 2020, there were at least 2,381 operational oil and gas pipelines distributed across 162 countries in the world. The length of these pipelines is more than 1.18 million km combined, which is enough to circle the Earth 30 times (Hussein, 2021). Just above 305 000 km of these pipelines are located in the US (API, n.d), and is connected to the Canadian pipelines which is the US biggest source for crude oil imports (EIA, 2022). According to the CER (Canada Energy Regulator), 88% of all crude oil exports from Canada is transported through pipelines as of 2020 (CER, 2023).

As seen in Figure 7 below, pipelines have been the choice for transporting crude oil for many decades in the US, and have also shown an increase in recent years.

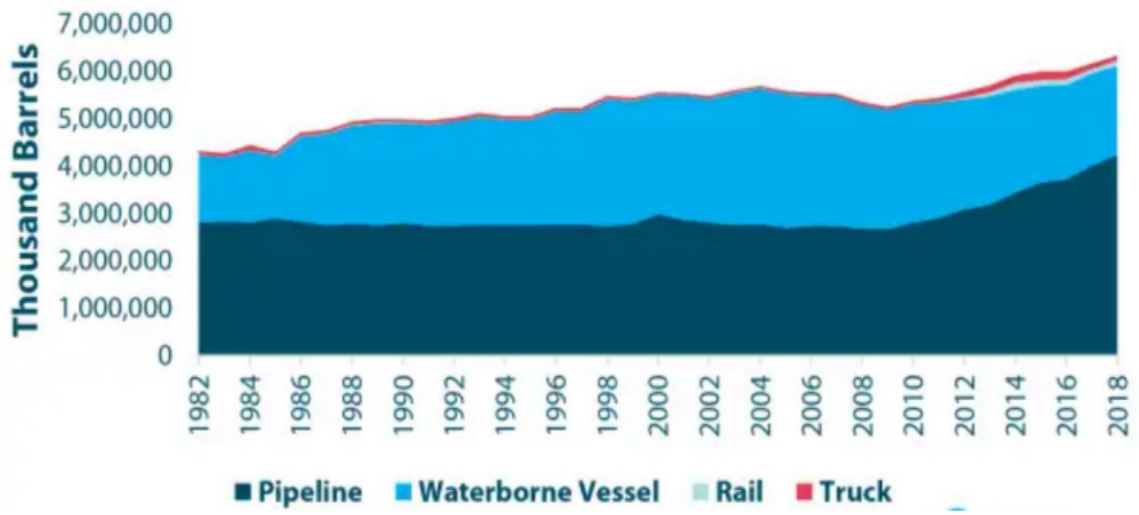


FIGURE 7: *Crude oil transportation by mode in the US (Ahmed, 2023).*

It is not surprising that so much of the transportation of petroleum products has been turned toward pipeline transportation. Pipelines have the lowest carbon footprint of the different modes of transportation (Ahmed, 2023). In addition, studies have shown that pipelines are the safest way of transporting oil and gas as it rarely breaks down (Fan & Feng, 2023). The Fraser Institute in Canada did a study where they compared pipelines to railways. Looking at data from 2003 to 2013, they found that pipelines experienced fewer occurrences (accidents) per million barrels of oil transported. Overall in that period, rail transport experienced 0.227 occurrences per million barrels of oil transported, while pipelines had 0.049 occurrences. This means that rail transport is more than 4.5 times more likely to experience an occurrence or accident compared to pipelines (Green & Jackson, 2015).

However, even though it is suggested to be the safest way of transportation, pipelines are not without accidents, and when they do happen they can potentially cause spills that can be devastating for the environment if not dealt with quickly. This is why solutions to detecting and managing such scenarios is very important, and is something we will be looking at later in this paper.

2.2 Supply Chain Management and Integrated Logistics

The petroleum industry is dependent on a comprehensive supply chain. This is because of the vast amount of different actors needed from upstream to downstream in order to explore, extract, store, transport and refine the product before it is ready for the end customer. To make the supply chain efficient all the way through to the end customer, substantial supply chain planning and management is needed to create better visibility in the supply chain.

In this section we will first go through some of the challenges faced in the petroleum supply chain, the importance of supply chain planning and then how integrated logistics plays a role in creating visibility in the petroleum supply chain.

2.2.1 Challenges in Petroleum Supply Chain Management

The logistics of petroleum face several challenges, many of which are not present in most other industries. However, these challenges can be addressed through wellworked and efficient planning, and in this section will discuss some of the key challenges of supply chain management in the petroleum industry.

Complexity in shipping

More often than not, a shipment of products has to be carried through multiple transportation modes before reaching the final customer. The distances between different supply chain partners present significant variability of transportation times, which can hurt suppliers in terms of service levels, and final customers because of safety stock costs. The transportation process is carried out either by ships, trucks, pipelines, or railroads (Al-Husain et al., 2006). The senior manager at the consulting firm Accenture, Doug Houseman, stated that “Very few industries deal with that kind of complexity in shipping,” (Morton, 2003, p. 31).

Visibility, quality and shipping speed are important components of an efficient oil and gas supply chain. Bottlenecks and blind spots in transportation of oil and gas can result in costly delays and consequences with huge impacts on the business, the environment, and the entire market (Read, 2023).

Geographical and Environmental challenges

There will always be risks associated with the transportation and logistics of petroleum. Companies working with the transportation of crude oil and gas operate in harsh environmental conditions that are challenging and pose significant risks to both people and infrastructures as well as to the environment (Rahman et al., 2019). The long distances, both offshore and onshore, mean that there will be longer lead times, and therefore increased costs associated with inventory and transportation.

We know that Norwegian geography is distinguished by the many mountains and long stretching fjords which makes the onshore transportation challenging. This requires major investments in transport infrastructure to be able to handle the needs. The transportation capacity of the Norwegian pipeline network is currently about 120 billion Sm^3 dry gas per year. The three onshore gas processing plants – Kårstø, Kollsnes and Nyhamna – are integrated with the pipeline network which has a total length of approximately 8 800 km (Norwegian Petroleum, 2023).

Lack of information and visibility

Because of the global nature of the industry and the involvements of a wide array of different stakeholders, information and visibility can often be limited. Since the industry involves multiple companies and entities operating in different parts of the supply chain, with their own systems, data formats and information sharing practices, the supply chain can easily be fragmented, which is a challenge that can be very hard to overcome (Javaid, 2023).

The petroleum industry is a critical infrastructure of the Norwegian economy. There are security concerns related to sabotage, theft and even terrorism. This

can limit the sharing of sensitive information and access to other data as they want this to be confidential. Examples of such data can be volumes, storage capacity, transportation routes, or inventory levels. The reasoning behind this confidentiality might be both for competitive and security reasons.

The Colonial Pipeline in the USA is a great example of a security breach in the midstream sector of the petroleum industry. In May 2021, the pipeline, which is one of the biggest and most vital in the U.S., was a victim of a ransomware attack. This was a cyber attack that brought the pipeline to a standstill, and president Joe Biden declared a state of emergency (Kerner, 2022). The incident caused jet fuel shortages, panic buying, and a spike in prices at gas stations (Kerner, 2022). This showcased the importance of security and the impact the petroleum industry has on society.

Lack of technology adoption and outdated systems of data management and communication can be a threat to both security and a hindrance to efficient data exchange and real-time visibility in the supply chain. Collaboration and information sharing represent a crucial factor for supply chain efficiency, parsimony regarding collaboration and sharing demand or cost information can waste opportunities for cost saving also in the petroleum industry (Al-Husain et al., 2006).

2.2.2 Integrated Logistics

In their book from 1999, “Global logistics and distribution planning: Strategies for management”, Fabbes-Costes and Colin used the term “integrated logistics” to describe the co-ordination of inbound supply, production, and distribution. They differentiated later phases in the supply chain process, where logistics extends its influence from upstream into product development and downstream into after-sales service. They called the culmination of this process “total logistics” (McKinnon, 2017).

In the 2017 article "Integrated Logistics Strategies", McKinnon wrote about the role of freight transport with integrated logistics strategies. He stated how freight transport is an integral part of logistical systems and supply chains. This was also illustrated by the table seen below (Figure 7).

	Quantity of freight	Mode choice	Vehicle type	Vehicle utilization	Routing	Scheduling
Product development						
Product design	•	•	•	•		
Packaging	•	•	•	•		
Product range	•	•	•	•		
Marketing planning/sales acquisition						
Market area	•	•	•		•	
Marketing channels	•	•	•	•	•	
Sales strategy/promotion	•	•	•	•		•
Order fulfillment						
Location of production and distribution facilities	•	•			•	
Sourcing of supplies	•	•			•	
Production system	•		•	•		•
Inventory management	•	•	•	•		•
Materials handling	•	•	•	•		
After-sales service	•		•	•		•
Recycling/reverse logistics	•	•	•	•	•	

Key: •, a direct relationship exists.

FIGURE 8: *Table of interrelationship between strategic decisions and freight transport parameters (McKinnon, 2017).*

McKinnon created the table as an attempt to map the interrelationships between a set of six freight transport parameters and areas of strategic decision-making grouped in relation to the three core business processes: product development, marketing planning/sales acquisition and order fulfillment. The table showcases how transportation decisions affect many parts of a business, and influences several areas of the supply chain. To obtain "total logistics" as Fabbes-Costes and Colin referred to it, companies need to be able to integrate and create fluent relationships between the different areas of the supply chain. "The process of integration has transformed the way that companies manage the movement, storage, and handling of their products" (McKinnon, 2017).

The company DHL, which is one of the world's biggest logistics providers, did a case study on integrated logistics solutions for oil field service markets in 2015. They implemented a Lead Logistics Provider (LLP) setup which was integrated to increase efficiency, reduce costs and improve service. The LLP services combine a carrier-neutral decision making approach, with the assets of a strong global network. The setup is powered by what they refer to as the Supply Chain Integrator (SCI), a comprehensive IT solution that provides visibility on shipments and workflows (DHL, 2015).

2.3 Oil and Gas 4.0

There has been much talk and discussions regarding “Industry 4.0”, also known as the fourth industrial revolution. McKinsey defines Industry 4.0 as; “Digitization driven by new trends such as analytics, artificial intelligence and connectivity” (McKinsey, 2022).

The same trends that have influenced many different industries have also made their way to the Oil and Gas industry. “Oil and Gas 4.0 is where the industry meets the Fourth Industrial Revolution, an era where digital innovation is catalyzing economic progress and driving demand for everything that depends on the humble hydrocarbon molecule- from power, to fuel and the countless products that enable modern life” (Alrawi et al., 2018).

The Oil and Gas industry is one of the industries that has faced the most critique when it comes to environmental questions. Therefore it is pivotal that this industry takes advantage of new possibilities and solutions in order to become more efficient, environmental and productive. There is an increased amount of companies within the industry that have started to create digital partnerships, especially within the supply chain. “Between 2013 and 2018, the proportion of announced partnerships with a digital emphasis, between the oil and gas industry and the supply chain, grew from 22 percent to 55 percent” (Alrawi et al., 2018).

With numerous possibilities brought to life by IoT, the industry is changing rapidly. However, changing the mindsets of those who work within it is just as crucial as new technologies when it comes to developing the industry as a whole, as human resources play a crucial part when implementing new solutions.

2.3.1 IoT (Internet of Things)

The term Internet of Things has been in use since 1999. It began when computer scientist Kevin Ashton wanted to put RFID chips on products which made sure that they could be tracked (Greengard, 2023). Since then, the term has been used frequently in many different contexts. In the 2000`s, IoT became huge when more and more connected devices were introduced in international markets.

How one defines IoT may vary from different sources. One possible definition is: “The Internet of Things makes everyday devices “smarter” by enabling them to send data over the internet, communicating with people and other IoT-enabled devices” (Velazquez, 2022). One of the most important reasons why IoT is so important is that it allows products and different aspects of industries to connect. The IoT allows in many ways different products or software to communicate and speak with each other with little to none human intervention.

The IoT has been able to develop due to a number of various reasons. Some of them are: Access to low cost, low power sensor technology, connectivity, cloud computing platforms, machine learning and conversational artificial intelligence (Oracle, n.d.). Industrial IoT, which refers to different industries starting to use IoT, has also increased over recent years. One of the industries that have taken advantage of technological developments is the oil and gas industry.

“There are a lot of innovations that are shaping the renewable energy sector. New energy technologies are becoming increasingly popular. With technological advances, more things can be monitored and measured” (Matuszak, 2022). This is one of the solutions midstream oil and gas companies have taken advantage of to monitor pipelines and control them in real time. In addition, the technology minimizes risk by allowing people to control these massive systems in a better way and can contribute to tracking emissions. The last part is something that has become highly relevant for the energy industry as IoT has helped companies in becoming more sustainable.

2.3.2 Data-Driven Logistics

According to Oxford Languages, if something is data-driven it is “determined by or dependent on the collection or analysis of data”. This means that instead of personal experience and intuition, the activity is determined by the use of data. For example, if a company employs a data-driven approach, it would imply that they make their strategic decisions based on data analysis and interpretation. Today, this term can be carried over to so many activities and industries, from data-driven learning to marketing, programming or security. In this paper we will be looking at data-driven logistics.

Supply chains today are very different from those of a few years ago and continually change in a highly competitive climate. Because of the competition, investing in technology that can handle the complexity of dynamic supply chain operations has become a necessity (Detwal et al., 2023). With the technological evolution that we have seen in the last decades, most industries are being optimized through the IoT, and new technology involving the use of data. Data-driven logistics can be utilized in many different ways across multiple industries. In the midstream petroleum industry, we refer to it through the use of data analytics, automation, and technology to optimize storage, movement, and transportation of petroleum products between the upstream and downstream sectors. It involves leveraging data from various

sources to make informed decisions, improve operational efficiency, and reduce costs.

Agistix, a company working from the US, develops data-driven solutions for supply chain optimization. They provide software that creates end-to-end visibility in the supply chain. They state on their homepage that “You’re under constant pressure to reduce your freight spend. But that’s tough to do when you can’t see the decisions partners are making on your behalf until well after the fact. A great challenge is that suppliers and carriers don’t have a way to connect to you through their own systems and processes - severely limiting your end-to-end supply chain visibility” (Agistix, 2022).

There have become more and more companies involved in the development of innovative data-driven solutions for supply chain management. Siemens, Emerson Automation, Mecco, and Agistix are just a few, and they all have a focus on data-driven solutions, contributing to traceability, management and visibility in the supply chain. It is a long way from oil reservoirs to a sellable product. The process includes many steps throughout the supply chain, spanning from extraction, transferring products for transportation through pipelines or ships, and to oil refining. This makes it difficult to keep track of all the steps and retrace the product and its information. Traceability software makes it easier to view the products history, origin and status. Nevertheless, achieving transparency and visibility across the entire supply chain remains a very complex task, and requires coordination and cooperation from all the parties involved.

Part 3: Literature Review

In this part of the paper we will review previous literature that has been written on relevant subjects for our paper. In addition to IoT technologies, and the petroleum industry itself, it is all related to supply chain management. Our topics are closely connected and therefore it is important to review them all. We will also look at previous literature regarding "Oil and Gas 4.0", a term that has come to use as a consequence of "Industry 4.0". With increased use of technology and digitalization of the petroleum industry, cybersecurity has become increasingly important. Even though the oil and gas industry is reaping the benefits of technological developments, it also becomes more vulnerable to digital attacks. Literature regarding cybersecurity and incidents like the Colonial pipeline attack is therefore something we found relevant and have looked into. We will start Part 3 by reviewing the literature regarding supply chain management.

3.1 Supply Chain Management (SCM)

Supply chain management is at the core of logistic operations and its goal is in many ways to optimize the flow of materials and information. There has been increased interest regarding SCM and similar terms in recent years (Croom et al, 2000). Many researchers believe that the supply chain should be considered as a crucial part of the business (Croom et al, 2000).

SCM may be defined in different ways depending on who you ask or what types of sources you use. One possible definition is; "Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model" (Stadtler, 2014).

In our paper we are focusing on logistics and a different definition of supply chain management is the following: "Supply Chain Management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the

right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements" (Simchi-Levi et al., 2008.).

Industry 4.0 has affected many different industries and changed the way businesses think. Supply chain management is an area that is constantly changing and the newest trend is SCM 4.0. This era focuses on the interaction between digital technologies and supply chain management (Bentaher et al., 2022). Even though technology has made it possible to develop supply chains, change does not happen by itself. "Successful firms must establish appropriate digital projects that are linked with their goals, learn quickly from trial implementations, and be determined and capable of scaling (Bentaher et al., 2022).

Even though it was published in 2006, Hussain et al. published a paper we find very relevant to our thesis; "Supply chain management in the petroleum industry: Challenges and Opportunities". In the paper they claim that SCM faces many challenges, particularly regarding logistics (Hussain et al., 2006). However, the paper also states that there are many opportunities and given that it was released in 2006, it is natural to believe that these opportunities are even bigger today.

3.1.1 Supply Chain Management in the Oil and Gas industry

As mentioned above, Hussain et al., wrote a paper where they identified challenges and possibilities within SCM in the oil and gas industry. They concluded that more efficient and cost effective supply chains were important factors in order to reduce lead times, costs and create more efficient logistical operations (Hussain et al., 2006). One of the reasons why developing SCM in the oil and gas industry is of importance is described very well in their paper. "The supply chain of the petroleum industry is extremely complex compared to other industries. It is divided into two different, yet closely related, major segments: the upstream and downstream supply chains. (Hussain et al., 2006).

Since this paper was written we might even argue that it is even more complex now as we consider a third segment as well: midstream supply chains. In addition, there have been multiple developments within the field since it was published. However, it is worth mentioning that they suggest that the next steps, to strengthen SCM in the industry, should be to investigate opportunities for new technology and for companies to cooperate to a greater extent.

In a paper written by Christopher Chima in 2007, he discusses the challenges and issues of SCM in the oil and gas industry. As he mentioned in the paper, the oil and gas industry is responsible for huge logistic operations, both foreign and domestic. Therefore supply chain management plays a pivotal role in the industry, and the paper's objective is to investigate the role of SCM within the oil and gas industry (Chima, 2007).

One of the challenges in the industry is that companies are very competitive and information sharing can be limited. As previously mentioned this is also something Hussain and his co-writers discuss. Or at least they suggest that cooperation should be an area of focus. Chima also addresses the topic when he states the following: “One of the weaknesses of a supply chain is that each company is likely to act in its best interests to optimize its profit. The goal of satisfying the ultimate customer is easily lost and opportunities that could arise from some coordination of decisions across stages of the supply chain could also be lost” (Chima, 2007).

Even though both papers focus on challenges within the supply chains in the oil and gas industry, they both highlight opportunities and possibilities for the future. Given that they were written more than 15 years ago, we know that there have been a lot of developments that have contributed to creating more efficient supply chains. Chima also stated that there were lots of possibilities for companies during the time period this paper was written: “Today, there are more opportunities for coordinating activities across a supply chain even in such complex operations as oil and gas, because of improving information systems and communication technologies. Integrating operations management

with other functions of the operation allows all functions to be involved in the supply chain management decisions" (Chima, 2007).

One of the things that have changed the most over the past decades is the technological advancements that have been made. New organizational structures and the need for new management strategies are some of the effects that are creating new business environments for supply chains (Aslam et al., 2021). Given that the oil and gas industry is of high importance in regards to the world's economy, companies within the industry must take advantage of these developments to strengthen their supply chains.

3.1.2 Supply Chain Resilience in the Oil and Gas industry

Because of the dynamic nature of operating environments so prevalent in twenty-first-century systems, oil and gas supply chains have become more global and complex (Hosseini et al., 2019). In light of Covid-19, Russia's invasion of Ukraine and the increased focus on creating a sustainable climate, the resilience within the oil and gas industry has become more important. In a paper written by Erik Hollnagel, he presents four cornerstones of resilience: (1) responding to what is happening; (2) flexible monitoring to identify critical problems; (3) anticipating potential problems, and; (4) learning from experience (Hollnagel, 2009). Resilience within the oil and gas industry has become very relevant, given both external and internal factors.

Previous research on organizational resilience has largely focused on safety (Bergström et al., 2015), which of course is natural given the consequences if something goes wrong on oil platforms or during oil transportation. However, in addition to safety and other internal aspects, one must take external ones into consideration. One important external factor is the increasing social and political pressure to a change in profile from oil and gas to energy companies expanding their portfolios to renewable sources (Bento et al.,2019). This transition will certainly require adaptation and learning at different levels.

A transition described as the one above, will without a doubt require adapting and learning.

The implementation of integrated operations represents a major change in the business model of oil and gas companies enabled by the use of real data-sharing through ICT(Information and Communication Technology) developments and increasing collaboration across disciplines, companies and geographical areas (Bento et al., 2021). In a paper written by Hepsø in 2006, it is claimed that integrated operations are forms of common information spaces that enable multidisciplinary collaboration and knowledge creation (Hepsø, 2006). Therefore there is a need to understand the relation between resilience and integrated operations. (Bento et al., 2021).

Bayesian models facilitate the analysis of the relationship between available information and uncertainty in complex systems. The models usually consist of networks of causes and effects (Bento et al., 2021). Bayesian networks are another important aspect when approaching studies within the field of resilience. “They are probabilistic models that have often been used for decision-making and risk assessment in areas such as software development, safety management and traffic accidents” (Hossain et al., 2019).

“The analysis of findings reveals a variety in terms of conceptualization of resilience in organizations studies in oil and gas. The studies conceptualize resilience either as an outcome of different organizational strategies or assets of specific capabilities” (Bento et al., 2021). However, some articles conceptualize resilience as processes and capabilities.

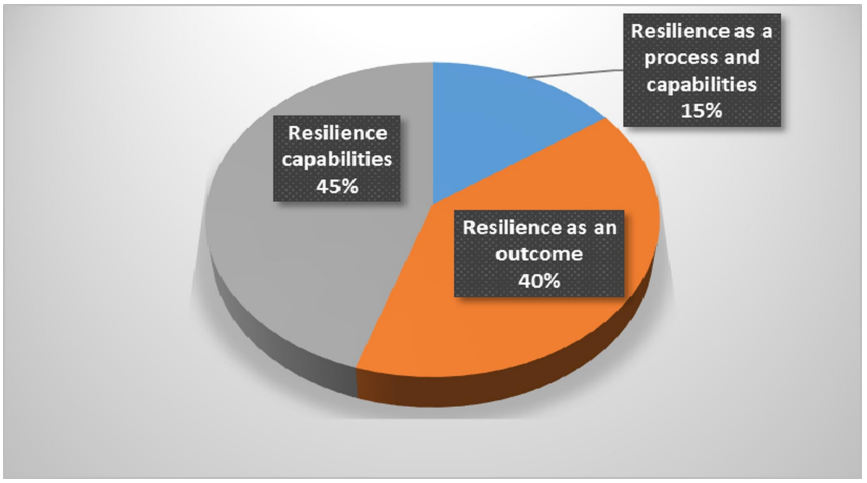


FIGURE 9: Conceptualization of Resilience (Bento et al, 2021).

Throughout our research of relevant literature, we have discovered that many of the papers have quite optimistic perspectives when it comes to resilience in the oil and gas industry. How IoT and data-driven solutions have contributed to optimization through resilience will be discussed in Part 5.

3.2 The Midstream Sector of the Oil and Gas industry

Some of the papers we previously introduced mainly focus on upstream and downstream activities. In our paper we have chosen to look closer at the midstream sector. This sector may be defined as: “Midstream involves infrastructure used in transporting crude oil and petroleum products. As its name implies, the midstream oil and gas segment encompasses facilities and processes that sit between the upstream and downstream oil and gas segments. Activities can include processing, storage and transportation of crude oil and natural gas” (Lisitsa et al., 2019).

The figure below shows the typical activities that are characterized in different sectors within the oil and gas industry, as illustrated in Lisitsa et al. (2019).

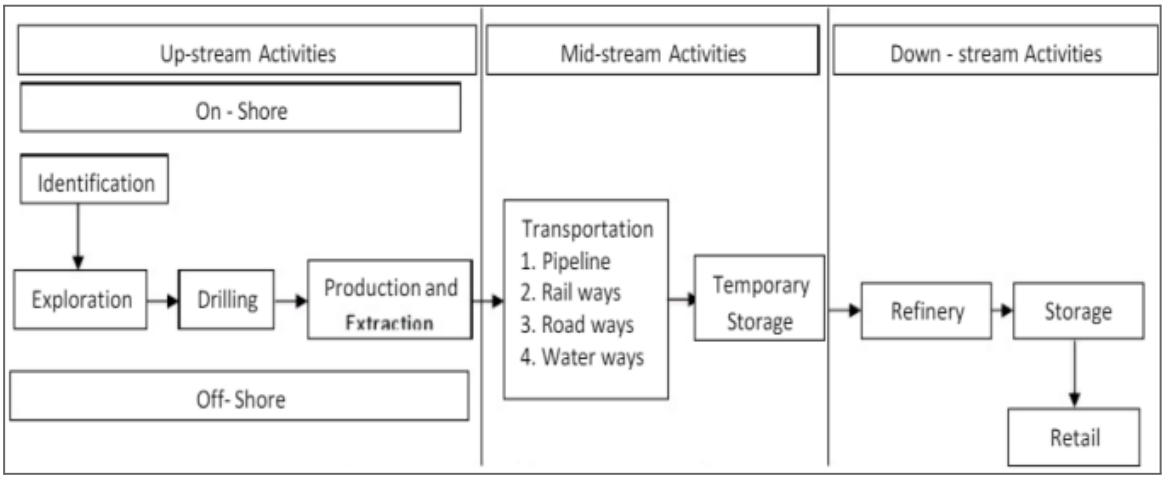


FIGURE 10: *Various Segments Of Oil Supply Chain (Lisitsa et al., 2019).*

Haidy Eissa has written a paper where she discusses how big data analytics, which we will introduce later in our paper, can give opportunities to the midstream sector within the oil and gas industry. As we have discussed previously there is no doubt that new technology and developments within the field have created new possibilities for companies in the industry. These developments and the technological evolution, industry 4.0, are aspects Eissa addresses in her paper. Eissa also states the following: “Data is the foundation of digitalization, and to get on the right digitalization path, data silos that are streaming at very high rates from diverse sensors and systems, shall be first sorted out. Big data analytics helps in creating a bridge between raw data and knowledge” (Eissa, 2020).

In terms of the midstream sector, Eissa focuses on how technological developments and implementation of big data analytics can be a source to reduce nonproductive time and increase both efficiency and profitability (Eissa, 2020). Another paper written by Heba Kadry draws similar conclusions; “Blockchain has opened a series of possibilities for blockchain-based innovative applications that are extended to the midstream Oil and Gas industry” (Kadry, 2020). Throughout the paper Kadry, like Eissa, addresses how new technologies have become a crucial part of the industry.

Opportunities related to environmental, operational and economic aspects are huge. The paper concludes that new technology, in this case, blockchain, might enhance efficiency and profitability for companies who operate in the midstream sector. (Kadry, 2020).

Jalali et al. wrote a paper where they review strategic capabilities in the midstream sector. “Findings showed that gaining competitive advantage in the midstream of the oil and gas industry is rooted in both inward capability of productivity and value-addition and outward capability” (Jalali et al., 2019). Based on their results one can say that it is important to have a balanced approach in order to gain competitive advantages.

Companies located in the midstream sector play a pivotal role in transportation of oil and gas. As stated in the papers above, new technology such as data analytics and new software solutions have the potential of enhancing efficiency and profitability. This might strengthen supply chains and be a source to gain competitive advantages.

3.3 Data-driven logistics

Supply chains as we know them today are very different than they were in the past. Increased competition and new technologies are two of the most important reasons why. Because of the competitiveness, investing in technology that can handle the complexity of dynamic supply chain operations has become a necessity (Detwal et al., 2023).

Odero et al. performed a conceptual analysis before writing their paper; Towards Big Data-Driven Logistics Value Chains for Effective Decision Making and Performance Measurement. They state the following: “What is evident from the analysis is that various data analytics methodologies and techniques that have been in existence are now being used as part of the repertoire of BDA used in analyzing, measuring and monitoring logistics value chain functions” (Odero et al., 2017). Furthermore, they discuss how data

analytical maturity can assist companies in making better decisions related to understanding, measuring and monitoring.

Yuxia Guo and Heping Ding wrote a paper on coordinated development of data-driven logistics and digital economy. Even though their paper is a case study of the Anhui Province, there are general points that can be collected from the paper. The logistics industry as a whole started to use new technologies, such as IoT, block chain and big data after the global Covid-19 pandemic. By applying these technologies, companies have been able to meet demand quickly and accurately, this again maintains normal economic and social development (Guo et al., 2022).

Some of the research regarding data-driven logistics is not directly applicable to our paper, as it does not focus on data-driven logistics in the oil and gas industry. However, Muehlbauer et al. wrote a paper where they state that: “the growing amount of digital process information helps to expand the existing process understanding to determine weaknesses in the process landscape. Due to the extensive complexity within production and logistics systems, a comprehensive approach is required to ensure a systematic analysis”(Muehlbauer et al., 2022). The results of Muehlbauer and his co-partners’ research showed that data oriented approaches are applicable when it comes to internal logistic operations.

The papers share many of the same thoughts regarding data-driven logistics and how it may change logistical operations. Through new technologies, companies are able to meet demand, enhance performance, conduct precise analysis and continuously monitor logistic operations.

3.4 Oil and Gas 4.0

The Industrial Revolution 4.0 driven by digitization has also affected the oil and gas industry. As mentioned previously, the industry was one of the early adopters when it comes to using new technology.

"Oil and Gas 4.0 is where the industry meets the Fourth Industrial Revolution, an era where digital innovation is catalyzing economic progress and driving demand for everything that depends on the humble hydrocarbon molecule- from power, to fuel and the countless products that enable modern life" (Alrawi et al., 2018).

Lu et al. wrote a paper reviewing the Oil and Gas 4.0 era. In the paper they state that; "Companies have increased beliefs that this era could potentially change the whole industry. New technologies, digitalization and intelligentization offer possibilities that one has not had before" (Lu et al., 2019). The oil and gas industry is an industry that has been subject to many changes and developments over the past decades. New technologies such as; automated drilling, fiber monitoring, pipe robots and geographic information systems are all new technologies which have been presented at different times (Lu et al., 2019). Some of the most crucial developments within the industry are shown in the figure below.

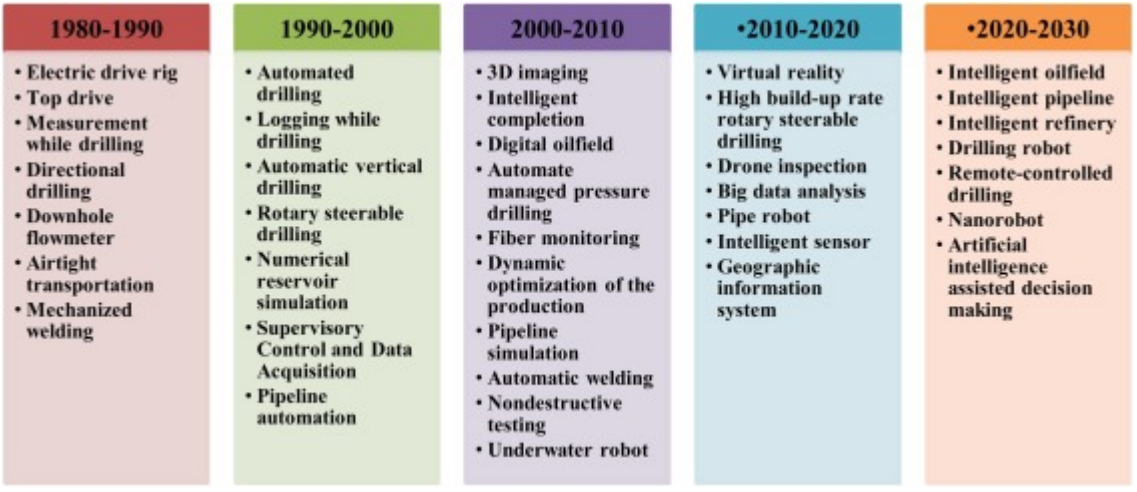


FIGURE 11: *Development course of the world's oil and gas technology (Lu et al., 2019).*

The paper analyzes scenarios in the industry and looks closer at intelligent pipelines. This is very relevant in regard to our research. The paper states that pipelines are the most important carrier of oil and gas, transporting it worldwide with lengths increasing 3-4% per year (Lu et al., 2019). If a pipeline has sustained injuries or any other incidents have taken place, it has been difficult to track where it occurred. Technology is developing rapidly which has led us to the digitization of pipelines, furthermore the intelligent pipeline.

"The intelligent pipeline is an integrated system that integrates technologies such as IoT, cloud computing, big data analysis, automation and intelligent control with pipelines based on the life cycle data of pipelines and the surrounding environment, it is observable, controllable and adaptable" (Lu et al., 2019). Intelligent pipelines are something that is a mix of multiple technological developments. They have improved quality, reduced lead time, created higher automation and efficiency, enhanced safety and created data-driven decision making.

Similar to other papers that are previously mentioned, the authors focus on future possibilities and options within the industry as a result of continuous development in regard to technology. "Therefore, with the wave of "Industry 4.0", the development of "Oil and Gas 4.0" is an inevitable trend driven by various opportunities. Through a variety of advanced technologies in "Oil & Gas 4.0", the oil and gas industry can greatly improve efficiency and save costs" (Lu et al., 2019). However, the authors also include difficulties or things that may interfere with the development. Some of these are lack of overall planning and the governments need to change the way they are thinking to reap the benefits.

Other challenges are presented in the paper *Analyzing the Roles and Competence Demand for Digitalization in the Oil and Gas 4.0 Era*, written by Georgiou et al. In the paper they state that: "The digital transformation is also hindered by other non-technological aspects related to both organizational structure and human capital. Generally, resistance to change constitutes a cultural obstacle that each organization must face in all levels of the

management hierarchy" (Georgiou et al., 2021). In addition to writing about these challenges, the authors state that even though the oil and gas industry has developed and taken advantage of new technologies, there are still many opportunities in the future.

The papers discussing the oil and gas 4.0 era share many of the same thoughts. The industry has drastically changed over the last decades following innovations, primarily in terms of technology. However, there is still a lot that can be improved and the opportunities to increase efficiency, automation and profitability are very much present, even though the industry still faces various challenges.

3.5 Colonial Pipeline Attack

In 2021 the Colonial Pipeline in the US was attacked, which affected consumers alongside the east coast of the United States. "The Colonial Pipeline is one of the largest and most vital oil pipelines in the U.S. It began in 1962 to help move oil from the Gulf of Mexico to the East Coast states" (Kerner, 2022). How is it possible that a pipeline becomes a victim of a cyberattack? This was a question that many people asked themselves in the aftermath. As Joe Tidy states in an article published on BBC; "The type of modern operation Colonial Pipeline runs is extremely digital" (Tidy, 2021). When operations are run more digitally, companies are also more vulnerable to digital attacks.

The attack was initiated by a hacker group that accessed the pipeline's network and infected it with ransomware. The attack showed how vulnerable digital systems can be and especially those of this magnitude. In the aftermath of the attacks, the government alongside the oil and gas industry started to find solutions to prevent similar incidents in the future (Kerner, 2022). Some of these solutions will be presented in Part 5 of our paper.

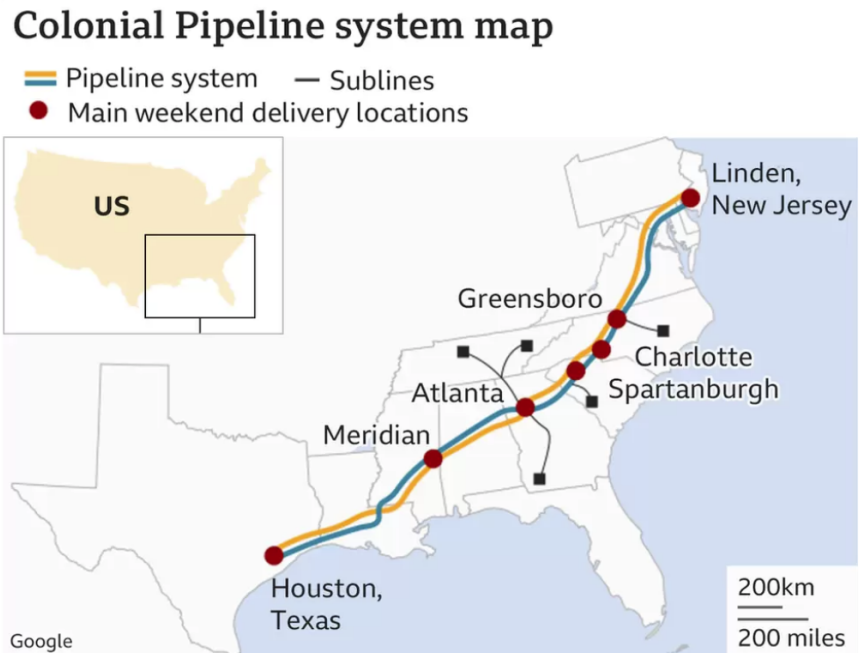


FIGURE 11: *Map of Colonial Pipeline (Tidy, 2021).*

In a paper written by Stephanie Smith, she focuses on communication and relations more than the technology and why it happened. Even though Smith focuses her paper on crisis management it is interesting and of important value to companies operating in the industry to understand how and why it happened in order to prevent it from happening again. Similar to what Kerner (2022) discussed in his article, Stephanie Smith also highlights the importance of learning from such incidents: "Through an examination and understanding of what happened during the Colonial Pipeline cyberattack, we can learn how to be more prepared for a crisis and how to effectively respond when one inevitably occurs" (Smith, 2022). This relates to the fourth cornerstone of resilience from Erik Hollnagels paper, (4) learning from experience, which has been an important factor in optimizing the oil and gas supply chain.

Allegra Hobbs wrote a paper discussing the Colonial Pipeline, where she focuses on cybersecurity and how seriously this has to be addressed. Even though her paper revolves around cybersecurity in the United States, many of the points remain valid in other parts of the world as well. For example, the

paper discusses vulnerabilities in cybersecurity and the focus that must be pointed at diminishing infrastructural weaknesses (Hobbs, 2021).

The reason why these articles and papers are relevant to our research is that they show that even though digitalization has contributed in creating more autonomous, efficient and profitable pipelines, the amount of technology has also made them vulnerable to new threats. In the modern era, most attacks and break-ins occur online, and not physical as we have been used to in the past. Awareness regarding these threats and creating countermeasures is of high importance. This is something we are going to review further in the next part of our paper.

3.6 Cybersecurity in oil and gas

Cybersecurity is more relevant than ever with technology becoming a bigger part of most industries. “Cybersecurity is important because it protects all categories of data from theft and damage. Without a cybersecurity program, your organization cannot defend itself against data breach campaigns, which makes it an irresistible target for cybercriminals” (Tunggal, 2023). As you implement IoT solutions, cybersecurity becomes equally important and should be developed in line with the technology, as it has become a bigger part of the midstream oil and gas industry. Even though the Colonial pipeline attack raised additional awareness towards cybersecurity, the topic has also been addressed previous to the attack, nevertheless, it was a big wake up call to these kinds of threats.

Angharad Lock wrote an article where he addressed the changing threat landscape in the oil and gas industry. Lock mentions the Russian oil company, Rosneft, which also has experienced cyber attacks in the past and that the digitization of the industry introduces new threats. The oil and gas industry is very lucrative and as Lock states in his article; “The high-value and high profile nature of the Oil & Gas Industry, together with its complex layers of supply chains, processes and industrial controls, makes it a high-value target

for hackers" (Lock, 2017). Lock suggested, even before the Colonial Pipeline attack, that companies should invest in cybersecurity experts and train their operational teams with this in mind (Lock, 2017).

Onyeji et al. have also written a paper regarding the same topic. Their paper focuses on cybersecurity and critical energy infrastructure. They share many of the same thoughts as Lock and highlight the fact that as oil and gas companies become more technical and increase the usage of technological systems, they are also more vulnerable to attacks (Onyeji et al., 2014). In the paper they discuss similar events to those mentioned previously and that creating smarter solutions, also brings more vulnerability. Given that the paper was published in 2014, it is only reasonable to assume that the following statement is even more important at the present date; "The threat on critical energy infrastructures from cyber attacks is significant and growing as energy system operations become more electronically interconnected" (Onyeji et al., 2014).

In addition to the papers described above, there are multiple others that focus on different aspects of cybersecurity within the oil and gas industry. Pete Mohammed et al. have written a paper where they discuss challenges related to cybersecurity in the offshore oil and gas industry. Many of the challenges they introduce in their paper are similar to the research mentioned above. "There has been significant interest within the offshore oil and gas industry to utilize Industrial Internet of Things (IIoT) and Industrial Cyber-Physical Systems (ICPS)" (Mohammed, 2022). With the increased use of IoT, one becomes more vulnerable to digital attacks. Potential consequences of these attacks are many, as the authors state; "A successful cyberattack against an oil and gas offshore asset could have a major impact on the environment, marine ecosystem and safety of personnel. Any disruption to the world's supply of oil and gas can also have an effect on oil prices and the global economy" (Mohammed, 2022).

The papers introduced in this section are of relevance to our research as we want to investigate how IoT has created a more optimized supply chain in the midstream oil and gas industry. Even though there are many opportunities in

regard to automation and technology, it has been important to consider the possible threats these developments bring. As stated by Lock;
"As cyber criminals become more sophisticated, the energy industry must develop a stronger and more responsive defense" (Lock, 2017).

Part 4: Methodology

In this section we are going to present the methodological approach of the paper. We will introduce our research strategy and design, in addition, we will discuss ethical considerations that must be recognized.

4.1 Research Strategy:

Research strategy refers to a plan of which steps and methods one chooses when conducting research, and sets a direction for the work. It is a framework that can help researchers through the process, from collecting and analyzing data to concluding the paper. Which strategy is correct, depends on the research question, what amount of time you have and what type of data that is possible to collect (Wedawatta et al., 2011).

When conducting research, one often separates between qualitative and quantitative research. Qualitative research is a method that does not focus on numerical data. The idea behind it is to find relevant people's experiences, thoughts and perceptions. Data collection is done through interviews with open questions, surveys or similar sources of information. Instead of focusing on how much, qualitative research focuses on how and why. One of the advantages of choosing this type of research is that it allows feelings and thoughts, which is a challenge in quantitative research (Tenny, S. et al, 2022).

On the other hand, quantitative research focuses on collecting and analyzing numerical data. This type of research is often used to find averages, test causal relationships and generalize findings to a wider part of a population. It is often

used in biology, chemistry and economics (Bhandari, 2020). After collecting numerical data and numbers one analysis the findings often using
tools such as computational analysis, mathematics and statistics. This is a great way for testing hypotheses and theories (Bryman et al., 2015).

Qualitative and quantitative research are not necessarily opposites. In some cases, qualitative research may give a deeper understanding of the numerical data one has collected in the quantitative part of the research. If you have discovered a correlation in the quantitative part, the qualitative part may help in understanding why there is a correlation (Tenny et al., 2022). Often one uses a mixed method approach, which combines the two previously mentioned methods. This is a method that might allow you to see results that can not be uncovered by only using one of them (Bryman et al., 2015).

When we started to work on this paper our initial thought was to use a mixed method approach. However, due to challenges in collecting numerical data from companies and on the internet, we have had to focus on qualitative research. As we discussed earlier in our paper the global nature of the industry and involvement of a wide arrange of stakeholders, information and visibility can often be limited.

We have conducted interviews with industry representatives in order to better understand how the oil and gas industry works. By conducting these types of interviews we have also been able to get their views on challenges and possible solutions to the topics we have chosen to focus on in our paper. By interviewing two representatives from Equinor we have been able to get first-hand access to experience and thoughts from someone working in Norway's biggest oil and gas companies. We have not been able to receive any numerical data from Equinor and therefore we have had to focus on qualitative research.

In our paper we have used a deductive approach. This means that we will come up with a hypothesis based on existing theory. Deductive approaches are often preferred to avoid risk and when there is lesser time to complete a study. It also allows us to generalize our findings (Dudovskiy, n.d.).

4.2 Research Design

The research design will provide an overview of the overall strategy for how we conduct our research. This means it will explain the strategy for how the research question will be answered through the various options of research design methods. The choice of design, however, will depend upon the fundamental objective implied by the research question.

Silver et al. describes the three categories of research designs: causal, descriptive, and exploratory. If the objective of the research is to attribute cause and effect relationships among variables to better understand and predict the outcome of one variable when varying another, a causal research design is fitting. However, if the objective is to describe an event, or a population in a precise manner where we can attach numbers to represent the extent to which something occurs, or determine the degree two or more variables vary, a descriptive research design is required. Lastly, if you want to conduct a general exploration of an issue, gain some broad insights, and achieve a better “feel” for the subject, the exploratory research design is best suited (Silver et al., 2012).

Since we have limited access to past data, and only a few interviews with industry representatives, the exploratory research design is natural for our research. We use a variety of sources such as existing research, literature and discussions with industry representatives to provide insights and information, and search for ideas and clarification. We believe our research fits its purpose as an initial research tool, and provides theory for the opportunities we believe the solutions related to our research question provides.

4.3 Data collection

4.3.1 Qualitative sampling

The sampling gathered for our research has consisted of a mixture of industry insight through interviews with representatives in the oil and gas industry, and the collection of information from previous research articles on our topic. It was important that we got to talk to industry representatives with different responsibilities within the field of oil and gas transportation. Through direct communication both face-to-face, and through frequent messaging and questions through emails with a representative from Equinor, we gathered valuable information.

We expected it to be quite challenging to gather the desired information from the right people, however, our contact managed to get us in touch with another representative for a semi-structured interview. We wanted to conduct a semi-structured interview to be able to gain knowledge and reflect on relevant problems and potential solutions that are being developed for the industry. This could for instance be how much digital solutions have impacted pipeline transportation, or how we cope with the dangers of implementing IoT solutions because of cyber attacks, as we have previously seen in the US.

Because the nature of the oil and gas industry can be highly complex, it is difficult to conduct a fully structured interview approach. Instead, we saw this as an opportunity to gain knowledge about the topic, and also leave room for flexibility in our interviews. One of the interviews went through Microsoft Teams, but we did not feel this impacted the interview in a negative way.

4.3.2 Interview approach

To get the most out of our interview a vast amount of research had to be done beforehand. We had to be well prepared because of the complex nature of our research, and to not delve into areas we could not comprehend. The first interview was conducted in a more informal manner with an industry

representative from Equinor we knew beforehand. This would allow us to be guided in a direction that would fit our research, and to ask the right questions in our next interview which would be conducted with a more formal approach.

4.3.3 Interview considerations

We had to take into consideration that the people we interviewed and spoke to had their own incentives and views, which could very much differ if we spoke to other industry representatives. Some might have a negative attitude towards the technological solutions that have changed the industry in recent years, while others might have a completely different viewpoint. This might promote participants into promoting certain solutions or perspectives, and de-emphasize others. This can also potentially mean that some information is withheld, which is important to keep in mind.

When conducting interviews we had to make sure of having informed consent. This means that all participants have received and understood all the information they need to decide whether they want to participate (Bhandari, 2021). We need to let the participants know what we intend to do with our study and how their information might benefit us in what we want to achieve.

4.3.4 Issues of achieving access and ongoing cooperations

Through our research we experienced some hesitation in information sharing, and we acknowledged the fact that there was a possibility that we would experience a problem with a lack of response or even no response from the people we tried to contact. Lack of knowledge-sharing practices in the oil and gas industries as well as other industries is because of a number of limiting factors (Ali et al., 2019). Organizations in the oil and gas industry operate in a highly complex and turbulent environment, because of globalization, outsourcing, government rules, and rapidly changing technology (Denicolai et al., 2014). This creates the potential issue that the actors we contact would be concerned about unwanted leakage of information. It is understandable that

inquiries from two students are easy to downplay or postpone because of these reasons, and also restrict what information and data we get access to.

4.3.5 Data utilization and secondary data analysis

The data collection process includes, in addition to the interviews conducted, a gathering of theory and information from previous research on the topic. This implies conducting secondary data analysis, which refers to the use of existing research data to find answers to our research question (Szabo et al., 1997). By doing so we had to avoid potential harm to individual subjects and issues of return for consent. When it comes to data that is found freely available on the internet, in books, or in other kinds of public forums, further use and analysis are implied. However, we need to acknowledge the ownership of the original data. The same also implies to the interviewed representatives, their information and identity. In our case, the interviewees wanted to remain anonymous for the questioning and interviews.

4.3.6 Data management and protection

When doing data analysis, and especially when using secondary data, it is important to recognize who owns the data and under what circumstances it should be used. Different countries may have different legislations and laws when it comes to data protection and storage of data. Because new technology is continuously being developed, the potential of processing and utilizing large data volumes have been made easier through IoT, A.I., and machine learning. The Norwegian government has an ambition for more data to be shared in industry and between the public and private sectors (Regjeringen.no, n.d.).

As an EEA country, Norway is bound by EU legislation in the area of data protection (Regjeringen.no, n.d.). This is why we have General Data Protection Regulations (GDPR). When doing research we have to acknowledge GDPR, and also make sure that this does not become an issue for the people we talk to.

To mitigate the risks we had to establish an understanding of who is in control of the data and information we receive and respect the rights of privacy.

Informed consent

Informed consent is one of the main principles of research ethics, and was required when doing interviews for our research. The principle requires that participants are provided with sufficient information about the research they are being invited to participate in, and information should be accessible for their decision about whether to take part to be considered informed (Crow et al., 2006). Gaining informed consent from people being researched has come to be regarded as a central element of the ethical conduct of research (Tinker & Coomber, 2005).

4.4 Evaluation of Research

When evaluating research there are some criteria that has to be considered. Mårtensson et al. (2016) found that there are four main aspects that emerged from their workshops as part of their research project, and they are largely consistent with earlier research. Previous research done by Mårtensson (Mårtensson, 2003; Mårtensson and Mårtensson, 2007) has pointed out the first three aspects, credible, contributory and communicable. However, these three aspects did not take into consideration to what degree the research is aligned with regulations, ethics and sustainability. To add these three outlooks as well, they added the fourth aspect named conforming. (Mårtensson et al., 2016). This aspect is also something we had to take into consideration when conducting our research, which is why we will focus on the four aspects found by Mårtensson et al. (2016) for our evaluation of research.

4.4.1 Credible

Mårtensson et al. (2016) states that credible research refers to research that is coherent, consistent, rigorous and transparent. This means that the method we use has to be appropriate for the research question we look into, and we believe it is due to the nature of our research. If the research we do shall be rigorous and reliable it has to be described so that others who use our procedure would obtain similar results. Since the industry we look into can be very complex, we rely on obtaining knowledge through people of experience, lots of literature and reliable sources. Without this, our research would be difficult to consider fully credible.

4.4.2 Contributory

The second aspect mentioned by Mårtensson et al. (2016) is contributory. This refers to research that is original, relevant and generalizable. We believe the research conducted is highly relevant because of the developments in the oil and gas industry in recent years. Technological developments and IoT are becoming more and more important in almost every industry, and since the oil and gas industry was one of the early adopters of IoT (Moore, 2021), there is now a lot of literature and research on the topic to look into. We believe that by investigating some of the potential of IoT in the industry, and how some of the solutions have helped its optimization, we can contribute to further research.

4.4.3 Communicable

When evaluating whether or not the research is communicable, Mårtensson et al. (2016) define this as to what degree the research is consumable, accessible and searchable. Most of the data and information we have collected are searchable online and are based on a wide array of different sources of information and knowledge. While conducting the research we have strived towards making it structured and understandable, since we found that IoT and data-driven logistics can be very complex.

4.4.4 Conforming

The final aspect from Mårtensson et al. (2016) in evaluating our research is to what degree it is conforming. This means that we will evaluate if the research is regulatory aligned, ethical and sustainable. The research we have conducted is dependent on conforming with previous literature and research done in this field, which is what we have made sure of throughout our research.

Part 5: Findings and Discussion

As we highlighted in our introduction, the oil and gas industry will continue to be important for many years to come. With the technological developments of the last decades, it has been crucial for the oil and gas industry to be able to follow in the footsteps of the fourth industrial revolution and implement IoT and data-driven solutions. The aim of this master thesis is to explore some of the opportunities created by IoT and data-driven solutions for the midstream sector of the oil and gas industry. This brought us to the research question that will now be explored in our findings and discussion:

Which IoT & data-driven solutions have contributed to optimizing supply chain performance for midstream oil and gas companies?

This part of the thesis will present the theoretical findings of our qualitative analysis and research, as well as discussions of solutions. We have focused on analyzing and evaluating the knowledge gained from representatives from Equinor, previous literature on the subject, and data found throughout our research. As we have seen, pipeline transportation is the primary means of moving petroleum products to the consumer market, and the main area in which IoT solutions have been implemented. Therefore, the research conducted and solutions found have been primarily for this method of transportation.

Through the findings and discussions, we will also be looking at how the data-driven solutions contribute to the four cornerstones of resilience found by Hollnager, as mentioned in our literature review: (1) responding to what is happening; (2) a flexible monitoring to identify critical problems; (3) anticipating potential problems, and; (4) learning from experience (Hollnagel, 2009).

5.1 The start of a pipeline evolution

More than 50 percent of the US pipeline network was constructed during the 1950s and 1960s, as the interstate pipeline network was built in response to the huge demand for energy resources in the growing post World War II economy (U.S. Department of Transportation, 2011). Similarly, the first Norwegian petroleum pipelines were built in the 1970s (Gassco, n.d.).
The pipelines being several decades old can create challenges for pipeline companies. Modernizing the pipeline operations has helped optimize the supply chains through better flexibility, security and data management.

The operations across all oil and gas sectors present lots of data. For every 150,000 miles (241 000 Km) in the midstream sector, the transportation of crude oil produces approximately ten terabytes of data (Ahmed, 2023). This data has the potential to be utilized in the optimization of supply chain performance. GE and Accenture launched the world's first “Intelligent pipeline solution” that enabled the implementation of monitoring with data visualization, real-time risk management and context awareness of the pipelines (Lu et al., 2019). This was first implemented by the Columbia Pipeline Group in 2016, and since then pipeline solutions have developed exponentially, with many IoT companies jumping on the technological bandwagon. One of these companies is Rockwell Automation.

Rockwell Automation has also taken advantage of the rapid advancement of information technology and developed what they refer to as “The Smart Pipeline”. As stated by Rockwell Automation on their implementation of IoT in their pipeline, “a data-driven approach can potentially reduce annual downtime by 70% and bring down the unplanned cost to 22% of the total, compared to 50% currently” (Rockwell Automation, 2019). In the end, the objective of these new pipelines introduced is the same, creating IoT and data-driven solutions to optimize the midstream supply chain. The Smart Pipeline introduced solutions that are part of what we have looked closer at in our findings and discussion.

5.2 The IoT and data-driven solutions contributing to optimization

5.2.1 Real-time remote monitoring in pipelines

The first technological solution we will look at is “Real-time remote monitoring” in pipelines. “Pipelines are the main, global, and distinguished tools for transporting water and petroleum products. They are usually suffering from some natural phenomena (e.g., corrosion) or some external effects” (Abed, 2022). Pipeline safety is extremely important in the oil and gas industry. In order to ensure this, it is essential to monitor and control them (Vanek, 2023). Real-time remote monitoring takes advantage of new technology and has a lot of advantages compared to traditional systems. Since there is continuous monitoring it is now possible to react quicker to incidents and it is more cost efficient since the technology completes tasks that were previously done by human resources.

Giro et al. presented a predictive maintenance strategy. A pump is tracked by using standard measurements and record points along the pipeline (Giro et al., 2021). They have used historical pressure data, collected by the energy company Eni, to compute statistical indicators. “These indicators are then fed

to an unsupervised clustering procedure, based on a Gaussian Mixture Model" (Giro et al., 2021). The algorithm used in their research had a mean silhouette score of 0.83. "Silhouette score is a metric used to calculate the goodness of a clustering technique. Its value ranges from -1 to 1." (Bhardwaj, 2020). With a score of 0.83, this indicates that the patterns in the data collection are credible. The robustness of their monitoring strategy has also been validated on separate datasets. Giro et al. managed to predict all pump failures which were reported from maintenance logs (Giro et al., 2021).

"The unsupervised clustering analysis has provided four distinct operational statuses of the pump and the definition of a reference model, parameterized with Gaussian Mixtures" (Giro et al., 2021). From their research, it shows that vibrations can be shown from remote locations, but they decrease if the distance is big. Multiple sensing stations in each pipeline is a solution, and they have validated that it is possible to detect failure up to 100 km away from the pump. Remote monitoring can be very effective, especially since direct access is often resource-demanding. Furthermore, clustering techniques based on gaussian mixtures can be used for real-time monitoring of pumping machinery (Giro et al., 2021). Historical data can be used to train algorithms and create more advanced pipeline integrity methods. As mentioned above the authors managed to predict and detect pump failures correctly.

Francis Idachaba & Minou Rabiei analyzed current technologies within leak detection, not only by looking at pressure monitoring. Leak detection is an important area within oil and gas operations. Creating robust leak detection and localization systems is something that is becoming increasingly important for companies operating in this industry (Idachaba et al., 2021). "Data analytics provides an opportunity for the application of intelligent algorithms for the analysis of the data acquired from the sensors located in the field for the detection and localization of pipeline oil and gas leaks. The pipeline network and the governing equations enable the simulation of oil flow in the pipeline and predict the pressure distribution along the pipe with or without leak under specific flow conditions" (Idachaba et al., 2021).

The research of Idachaba et al. showed that digital solutions for real time monitoring can replace old systems. Different mathematical models and software can account for similar results to experimental data with high accuracy. In addition, these systems can contribute to developing warning systems for pipeline leakages by analyzing vibrations. This allows companies to react before events such as pressure failures or oil spills (Idachaba et al., 2021). Furthermore, Idachaba et al. discovered the following: “The use of machine learning has been shown to play a critical role in the detection of leaks” (Idachaba et al., 2021). Some of the models used in their research need high volumes of training data. However, combined with machine learning algorithms, one can create robust leak detection systems (Idachaba et al., 2021).

These findings suggest that we are now close to being able to detect and prevent failures in the pipeline from remote locations. This means easier forecasting of transportation and less unpredictability of lead times. Remote monitoring of pipelines improves control and overview of the entire pipeline, compared to the old fashion ways of monitoring, which had to be done by physically inspecting them. In addition, technological developments save costs and require less personnel as the technology solves tasks that have had to be done manually in the past.

In relation to Hollnagels cornerstones of resilience (Hollnagel, 2009), real-time monitoring will contribute to (1) responding to what is happening; by continuously monitoring status and allowing for quicker responses than before. It contributes to (2) flexible monitoring to identify critical problems; by allowing monitoring to be done from remote locations and not just by physical visits on site. (3) anticipating potential problems; with continuous monitoring, it is easier to predict and forecast what will happen in the future, similar to the warning systems we mentioned above. When companies use newly developed technology solutions and AI, these systems will be able to learn from previous experiences and understand patterns. In addition, with aid from technology, human resources can learn more than before which contributes to the fourth

cornerstone; learning from experience. Increased resilience is something that creates more robust pipelines.

5.2.2 HyDiLLEch as a leak detection solution

As mentioned above, leak detection is a very important area within the oil and gas industry. In addition to the technology researched by Idachaba et al. there are several other technological solutions that have improved detection of leaks, and by doing so; optimize supply chain performance. Ahmed et al. proposed using a HyDiLLEch technique. This stands for: Hybrid Distributed Leakage detection and Localisation tEchnique, which is based on a fusion of different leak detection techniques (Ahmed et al., 2021). The authors of the research paper state that standard leak detection techniques often create false alarms, and therefore can only be trusted to a certain extent.

In order to assess the effect of the HyDiLLEch technique, they implemented it and compared it to separate leakage detection techniques, in regards to leakage detection and localization accuracy (Ahmed et al., 2021). Their findings show promise for this type of technological solutions: “With HyDiLLEch, the number of nodes detecting and localizing leakages increases by a maximum of four to six times, thereby eliminating single points of failures. In addition, we improve the accuracy of localization in nodes physically close to the leak and maintain an average of 96% accuracy with little to no communication overhead” (Ahmed et al., 2021).

In addition to the solutions we have mentioned above, Fung et al. have researched other advances in technologies within pipeline leakages. The different methods they have looked at are: Exterior methods, visual/biological methods and interior-based methods (Fung et al., 2019). Given that their research is from a while back, we must take into consideration that there have been technological advancements made since then. However, in their findings, they conclude that each of the mentioned techniques has merits and drawbacks. The various techniques and solutions we have presented regarding pipeline

leakages have optimized the supply chain performance, but there are still gaps that need to be filled in order to find one common solution.

5.2.3 APM Software

APM, or Asset Performance Management, is a strategy and a set of different software tools used for tracking and managing a company's assets. Where companies in the past have had a break-fix approach, they can now focus on a proactive approach, which leads to reduced costs and less downtime (Bernard, 2023). These are critical factors if one wants to optimize the supply chain. Oil and gas companies that are involved in the midstream, are highly dependent on their assets and need to manage them if they want to succeed. APM software has made it possible to develop solutions such as: predictive maintenance and asset tracking and management.

Predictive Maintenance

As many of the petroleum pipelines are decades old, several challenges are created for pipeline companies. One of which is the amount of maintenance needed to avoid harm to the products, breakdowns, or other problems that could potentially hurt the supply chain. In order to avoid such problems before they occur, what is referred to as “Predictive Maintenance” can be implemented. By implementing predictive maintenance in pipelines or terminals for storing, companies are now able to reduce costly emergency repairs by detecting problems early, and turning unplanned downtime into scheduled downtime.

South Hook LNG Terminal is one of the largest LNG terminals in Europe and supplied by the UK’s largest gas pipeline. The terminal stores and distributes gas to the UK, and has the capacity to meet close to 20% of the UK’s daily gas needs (South Hook LNG, n.d.). The terminal implemented the APM software developed by General Electric (GE) and has proven to give positive results. According to GE, their APM software eliminated 17% of South Hook

Terminals maintenance tasks and optimized 73% of the remaining proactive maintenance tasks across the facility (GE, n.d.).

Deloitte did a study in 2017 on the benefits of predictive maintenance on an industrial scale. As showcased by the implementations in the South Hook Terminal, and the Columbia Pipeline Group, this is also applicable for the oil and gas industry. The Deloitte study showed that “predictive maintenance increases equipment uptime by 10 to 20% while reducing overall maintenance costs by 5 to 10% and maintenance planning time by 20 to 50%” (Deloitte Analytics Institute, 2017). Predictive maintenance allows for the optimization of equipment lifetime and minimizes unplanned downtimes. In order to be implemented, similar to detection of leakages, sensors are required that can be connected to track important process parameters (Deloitte Analytics Institute, 2017). Even though it requires investments upfront and expert knowledge to implement, the cost savings are substantial for the oil and gas industry.

Asset Tracking and Management:

Managing assets is challenging in every industry, but especially in the oil and gas industry given that they are often expensive and heavily regulated (Saha, 2023). Implementing strategies for asset management can be difficult and often requires much planning. Even though this might be time-consuming and costly in the short run, asset management has been proven beneficial in the long run by studies.

A study from IDC, International Data Corporation, has discovered that digitization of asset management can reduce organizational costs by 20% and improve asset availability by 20%. In addition, it can extend the lives of a company's machines. AI and machine learning are contributing to making this possible (Chawla, 2021). “These savings can free up resources to invest in profit-seeking opportunities while also improving productivity and reducing downtime. Critically, they also can help advance sustainability goals” (Chawla, 2021).

Veson is a company that was founded in 1979 and is a digital transformation company that develops and supports solutions within maritime commerce. With over 38 000 users present in 75 countries, they are continuously expanding their market reach (Veson, n.d.). The company has developed the Veson IMOS Platform, which is: “An integrated maritime operations system that delivers a comprehensive suite of connected solutions that can be adapted to your unique workflow” (Veson, n.d.). During the interview with an Equinor representative, it was revealed that this is the software they use for asset tracking and management of their freight transport. As stated by the interview object, Equinor and other companies operating in the industry are investing more in technologies that contribute towards better maintenance, tracking and management of their assets. By integrating various systems, communication with suppliers and customers is more seamless.

In regards to Hollnagels four cornerstones of resilience, solutions that improve asset performance, such as predictive maintenance and asset management, have contributed by monitoring assets and anticipating maintenance. By tracking and monitoring a company's assets, it is possible to identify potential problems and respond before failures or incidents occur. In addition to increasing its resilience, companies can reduce costs and reinvest what is saved elsewhere. All important parts of optimizing the midstream supply chain performance.

5.2.4 Big Data Analytics

Companies within the oil and gas industry handle enormous amounts of data every day. As stated in an article by Bharani Kumar; “The oil and gas industry is one of the largest sectors in the world in terms of dollar value, making an estimated $5 trillion in global revenue as of 2022. To deal with this magnitude of data, it is always important to find new solutions” (Kumar, 2022). Big data analytics aims to process and analyze these increasing amounts of data (Mohammadpoor, 2020). In the previous decades, there has been both

increased interest in finding solutions that handle data efficiently, as well as actual solutions being developed.

In 2018 a survey was conducted by General Electric and Accenture on executives in the oil and gas industry. 81% of them had big data analytics as one of three priorities of their companies. This is a drastic change from 2012, where a survey by IDC Energy, revealed that 70% were not familiar with big data (Mohammadpoor, 2020). This proves that executives within the industry view data analytics as an integral part of optimizing their companies and furthermore their supply chains.

With huge data sets being delivered continuously, it is crucial to have technologies capable of handling them. Some of the technological solutions that have been developed and are available for big data analytics are; Hadoop, MongoDB and Cassandra (Mohammadpoor, 2020). Which script these technologies are written in varies, but they are all capable of handling huge amounts of data. After data is processed it needs to be analyzed in order to extract the information one seeks. In recent years there have been multiple processing tools developed and some of them are; R, Datameer and BigSheets (Mohammadpoor, 2020). These solutions allow companies to improve their data analyzes and by doing so assist them in strengthening their supply chains.

We have previously mentioned Rockwell Automation, who creates IoT solutions for several industries. One of the software systems they have created for their smart pipeline is FactoryTalk. “FactoryTalk software from Rockwell Automation collects the control data from each compressor station and converts it into easy-to-comprehend visual graphics” (Bradley, 2016). One of the key tasks of data analytics is to give meaningful insights and knowledge from large and complex datasets, in addition, it is an advantage if it is presented in a way that people understand. Solutions and software such as the one presented above have contributed toward more company insight and knowledge.

Big data analytics plays a pivotal role in supply chains for oil and gas companies. This is due to the increasing complexity of the supply chains and the huge volumes of data being generated. As described above there are new solutions that have been implemented successfully within the industry. As stated by Mohammadpoor et al. “Big data has also been successfully used in the oil and gas industry in areas such as oil refining, oil and gas transportation, and HSE” (Mohammadpoor, 2020). Big data analytics has contributed to optimizing supply chains in the industry and it is a tool that strengthens supply chain resilience.

5.3 Benefits of the technological solutions

The oil and gas industry has and will continue to reap the benefits of new innovations and implementations of new technological solutions. The oil and gas 4.0 era is in its early stages and as described previously, many companies are starting to see improvements that lead to optimization of their supply chains. Even though it is natural to look at the benefits from an economic point of view, we must also take into consideration how these new technologies have and will continue to prevent accidents and save lives.

Developments within pipeline monitoring have made it possible to inspect them from remote locations, which allows human resources to work on different tasks and save time. By monitoring and controlling a company's assets, it is now possible to act proactive and tend to them before they are damaged and have to be replaced. These are some of the new solutions that contribute to reducing costs and lay the foundation for improved margins and results. As stated in an article by Georgiou et al. “Based on findings, the digital transition into the new “Oil and Gas 4.0” era is estimated to unlock approximately 1 trillion of value for the industry and 640 billion for its customers and wider society, during the decade 2016-2025” (Georgiou et al., 2021).

During the last decades, there have been numerous incidents in the oil and gas industry. “Incidents at oil and gas pipelines in the United States resulted in 339.72 million U.S. dollars of reported total costs in 2020” (Aizarani, 2023). Another paper that presents findings related to how much incidents have cost is written by Fung et al. who state that “Over the past three decades, pipeline accidents in the USA damaged property which cost nearly $7 billion” (Fung et al., 2019). Even though these papers focus on incidents occurring in the US, it is reasonable to assume that the costs of incidents in other countries have been sizable as well. Another aspect is incidents regarding cybersecurity, Beato et al. claims the following of the costs related to this; “the average energy sector data-breach cost has risen more than 13% since 2019, to $6.39 million” (Beato et al., 2021). This is another example of how important solutions regarding cybersecurity are in order to optimize supply chains.

Many of the incidents in the oil and gas industry have also led to human casualties. “For example, the incident of pipeline explosion in the community of San Bruno, California, USA on September 6, 2010 killed eight people, and injured more than fifty” (Fung et al., 2019). By implementing IoT and data-driven solutions, human risk related to working in the oil and gas industry has been reduced. As we see from the figure below, 43% of incidents during the period 2009-2018, occurred as a consequence of material/weld or equipment failure.

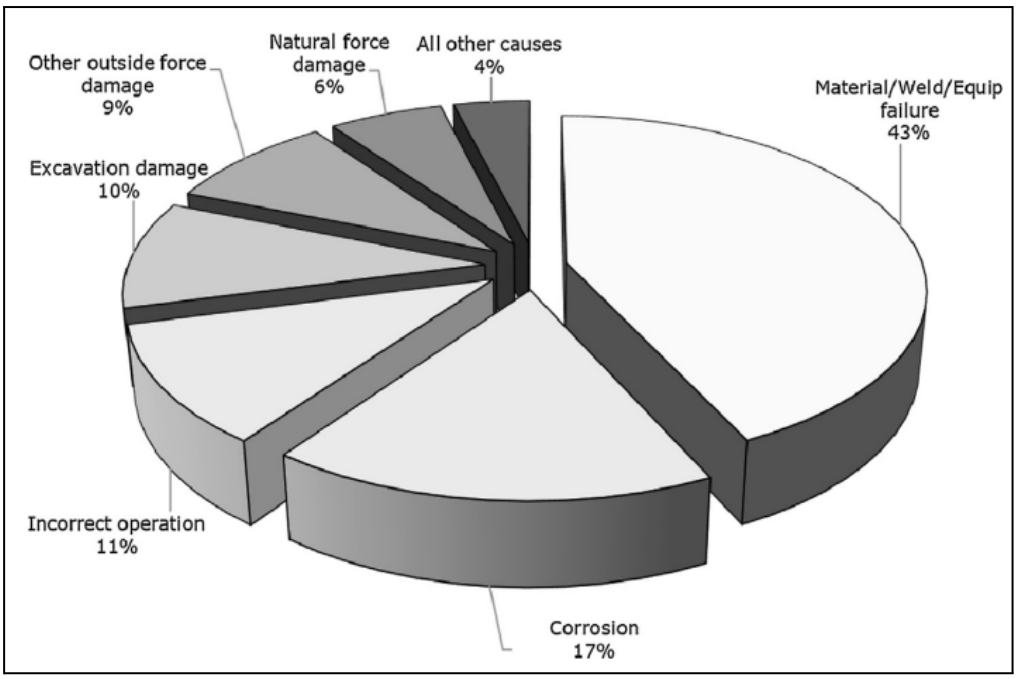


FIGURE 12: *Oil and Gas Pipeline transportation incident distribution per cause 2009-2018 period (Biezma et al., 2020).*

The technological developments have transformed the industry by optimizing operations, reducing costs and use of automation. In addition, they have played a pivotal role in making the industry a safer place to work. Technological developments will continue to shape the industry in the future, leading to even greater efficiency and safety.

5.4 Cybersecurity

The Colonial Pipeline incident brought a lot of attention to cybersecurity in the oil and gas industry, and since the incident occurred there have been several changes in laws and regulations for the industry. In the US, the Department of Homeland Security's Transportation Security Administration (TSA) implemented a new security directive to enable the department to better respond, identify and protect against threats to pipeline companies (DHS, 2021). Since then, it has been required to report all cybersecurity incidents to the DHS CISA (Cybersecurity and Infrastructure Security Agency) and have a designated coordinator of cybersecurity in pipeline companies operations

(DHS, 2021). One of the reasons for this is that it will provide data for DHS to make a better case for more funding to Congress in order to prevent something like this to happen again (Collier, 2021).

In collaboration with Siemens Energy and Saudi Aramco, the World Economic Forum has developed what they refer to as a “Playbook for Boards and Corporate Officers" in the oil and gas industry. To provide a framework for cyber security in the industry, they brought together a group of more than 40 oil and gas senior executives. Creating a blueprint for evaluating cyber risk and enhancing cyber resilience (Beato et al., 2021). This included different case studies and a set of principles for the oil and gas industry to follow.

Cybersecurity has been an important factor in the IoT and data-driven solutions optimization of the midstream oil and gas industry. The growing technological developments in the industry have proved that investments in new security measures have been required for the optimization of the supply chain. This will further be highlighted by some of the industries responses to what areas oil and gas companies now invest in.

5.5 Industry response to IoT and data-driven solutions

Surveys from the industry have shown that companies see the benefits of the new technologies, as the numbers show that companies are increasingly investing in IoT and data-driven solutions. The 2023 Gartner CIO and Technology Executive Survey asked CIOs (Chief Information Officers) from the oil and gas industry questions about changes in technology and digital investments. One of the questions in the survey was:
“What are the technology areas where your enterprise will be spending the largest amount of new or additional funding in 2023 compared to 2022?”
Out of the sectors most relevant for our paper, it was revealed a 66 % increase in investments in cyber/information security, 60 % increase in business intelligence/data analytics and a 26 % increase in IoT funding (Kusznir, 2022).

This highlights the growing understanding of the importance of cybersecurity in relation to the still growing investments in IoT and data-driven solutions.

In regards to the objectives of digital investments over the last 2 years, the survey asked:
"How would you describe the primary objectives of your enterprise's digital technology investments in the last two years?"
Through this question, we found some interesting numbers in regard to our research. 71 % of the oil and gas respondents included "improve operational excellence" as the objective, while 31 % included "ensure business continuity and resilience" as their primary objective (Kusznir, 2022). This is another proof of the expanding focus on IoT and data-driven solutions in the oil and gas industry, towards optimized supply chain performance.

However, there is still much more to be done, and there has been a relatively slow transition of digitalization in the oil and gas industry. This is related to human capital and the lack of a skilled workforce able to fulfill emerging digital job positions (Georgiou et al., 2021). An article in Deloitte Insight has also highlighted this by pointing to the fact that the workforce in midstream oil and gas companies "affirms that the digital "concepts" have not yet translated to changes at the grassroots level - 90 percent of new midstream jobs in the last eight years have been in the field of construction, maintenance, and materials movement, compared to a couple of hundred jobs added in the digital and operation experts field" (Slaughter et al., 2018).

One of the senior executives at Emerson Automation also stated in 2018 that "it is extremely important for the midstream industry to foster digital transformation - rethinking outdated business models and strategically applying technology to change them - rather than focusing on simply cutting costs." (Cahill, 2018). This is just another example of industry representatives who emphasize the importance of focusing on IoT and data-driven solutions in the midstream oil and gas industry.

Part 6: Future Research

New IoT and data-driven solutions are seeing rapid growth in the midstream oil and gas industry, as well as in other industrial sectors. The potential of these solutions is huge. Real-time monitoring, APM software and leak detection are some of the most impactful innovations on supply chain performance in the industry. The aim of future pipeline monitoring should be to design an even better real-time intelligent pipeline leak detection and localization system that can be universal for all pipeline networks.

We have not focused on the environmental benefits these solutions have and potentially can bring in the future. We believe this is something that should be researched further. We also acknowledge that further research can be conducted for each of the different solutions we have looked at, and investigate deeper into how each of them individually has helped optimize the midstream oil and gas supply chain.

We know that studies in relation to the effect of leakage parameters on flow mechanisms are still being conducted, and we believe there is still a lot of research that could be done on the potential the solutions we investigated can have for the future of oil and gas transportation. Solutions like APM software can be implemented to create visibility in all three sectors of the oil and gas industry. Creating visibility and traceability from upstream all the way to downstream will greatly enhance the performance of the whole supply chain, as we have seen in the midstream optimization. Creating a common framework of how the implementation of such software can be done for the supply chain, could further optimize supply chain performance. Similarity to the blueprint developed by Beato et al. in 2021 for the implementation of cybersecurity in the oil and gas industry.

Part 7: Limitations

The aim of this study was to research how the solutions had optimized the supply chain performance of midstream oil and gas companies. In doing so we contacted a handful of oil and gas companies, as well as companies working with IoT and data-driven solutions for oil and gas, and industrial industries. Even though we sent inquiries to stakeholders throughout the oil and gas supply chain, we found that actually gaining access to numbers and data on how the solutions had impacted the specific companies and sectors was very challenging.

We filled out forms on company websites and sent emails to many departments of the different companies, but got close to zero responses. This made it difficult to find actual cost savings and economic value of the optimization solutions. For this reason, we had to depend on lots of previous literature on the different aspects of the research question. Some of the articles and data found are from some years ago, and we are aware that a lot has happened in this field of research in a short period of time, with the booming developments of new technology.

On the other hand, we were lucky enough to have a contact at Equinor that could provide some valuable data and confirmation of our theories. But some of the data collected from the interview could potentially also be limited. This is because of the fact that Equinor does not necessarily want to provide data that could eventually negatively impact their position or be of benefit to their competitors

Part 8: Conclusion

In conclusion, it is clear that IoT and technical solutions have been important tools for optimizing supply chain performance within the midstream oil and gas industry. Real-time monitoring allows companies to make informed decisions and identify bottlenecks prior to incidents. In addition, it is cost-efficient as tasks previously performed at offshore sites now can be done remotely. Utilizing data analytics allows midstream companies to optimize their maintenance. Through predictive algorithms, they can monitor the health status of equipment and detect failures at an early stage. Proactive maintenance reduces a company's downtime and ensures a smooth flow of operations. IoT and data-driven solutions have led to reduced lead times, improved communication and increased supply chain responsiveness, by integrating various systems and platforms that lead to seamless communication with suppliers and customers. In addition, the solutions mentioned above contribute to creating supply chain resilience, which in the oil and gas industry is crucial to resist uncontrolled outside forces or incidents like leakages and material breakdowns.

Even though these IoT and data-driven solutions have contributed to creating more optimized supply chains, one must address the fact that the successful implementation of data-driven solutions in the midstream oil and gas industry introduces a new set of challenges. Security concerns, such as data breaches and cyber-attacks, must be dealt with to protect sensitive information and maintain the integrity of the supply chain. However, since the Colonial pipeline attack in 2021, there have been changes in laws and regulations within the industry. Among these is the requirement to report all cybersecurity incidents to the DHS CISA, and frameworks created as a blueprint for evaluating cyber risk and enhancing cyber resilience.

There will of course be more solutions than those we have mentioned throughout our paper. However, they are ultimately solutions to the same challenge of optimizing the supply chain performance of the midstream oil and

gas companies. Overall, the technological developments powered by IoT have transformed the oil and gas industry. Real-time visibility, integrated logistics, optimization of operations and enhanced safety measures are some of the benefits brought by the digital transformation. Companies in the oil and gas industry can now reach new levels of efficiency and competitiveness in a landscape that is continuously evolving. As technology continues to evolve, it is important that companies embrace the innovations and are able to adapt to them.

Appendix:

Appendix I:

Interview Guide for Equinor interviews

1. The Midstream supply chain
- What do you define as the midstream sector of the oil and gas supply chain? - What do you see as the biggest challenges in transportation of oil and gas? - What is the most important mode of transportation for Equinor? - Are there any best practices in the industry when it comes to improving the midstream supply chain optimization?
2. IoT & Data-driven solutions

- How would you define IoT in the context of pipeline gas transportation?
- What kind of software does Equinor use to monitor and track transportation of oil and gas?
- How do pipeline operators monitor and detect leaks or other integrity issues in real-time?
  - What measures are in place to prevent these leaks in pipelines?
- How do pipeline operators ensure the security of oil shipments and protect against different types of security threats?
- Has the company invested more in IoT and data-driven solutions and technologies in recent years?
  - If yes, what kind of technologies are the company investing in?

- Are there any alternative pipeline technologies being explored that could improve the safety or efficiency of oil transportation?
    - If yes, how do these technologies contribute to creating more effective pipelines?
- Are there any challenges or concerns associated with implementing IoT in oil and gas transportation?

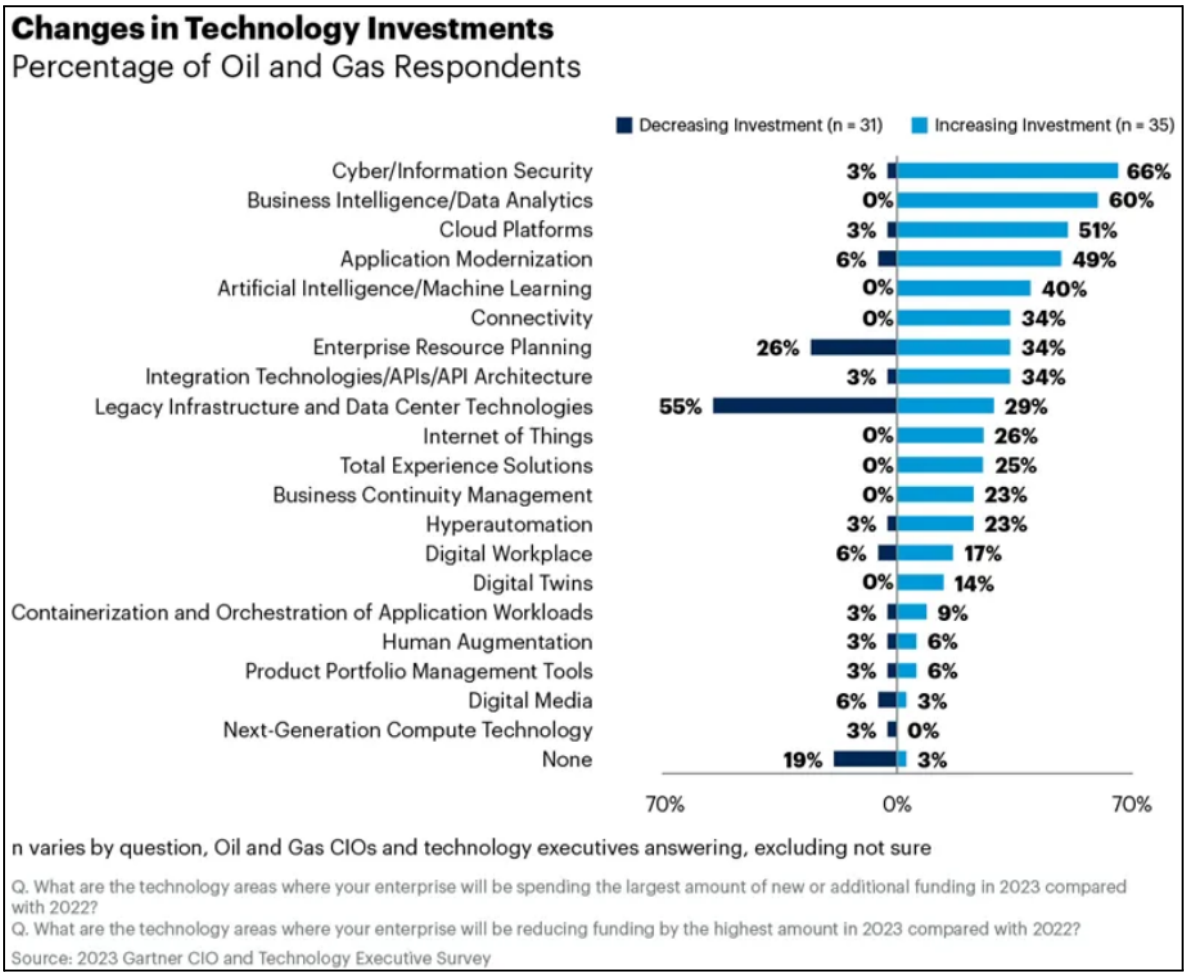
3. Impact on supply chain optimization

- What do you think are the main benefits IoT brings to pipeline gas transportation?
- What solution do you feel has been most important for midstream supply chain optimization?
- Do you feel the implementation of IoT solutions has improved visibility and transparency within your midstream supply chain?
    - If yes, do you have some specific examples?
- Can you discuss the benefits and/or cost savings your company has achieved by implementing IoT and data-driven solutions in transportation and logistics operations?

4. Other

- What do you think is the future of oil and gas transportation? (eg. Pipelines / Freight transport)
- What are the key factors influencing investment decisions in the oil and gas industry, and how are they expected to evolve in the future?
- What role do you see oil and gas playing in the overall energy sector in the coming decades?

Appendix II:



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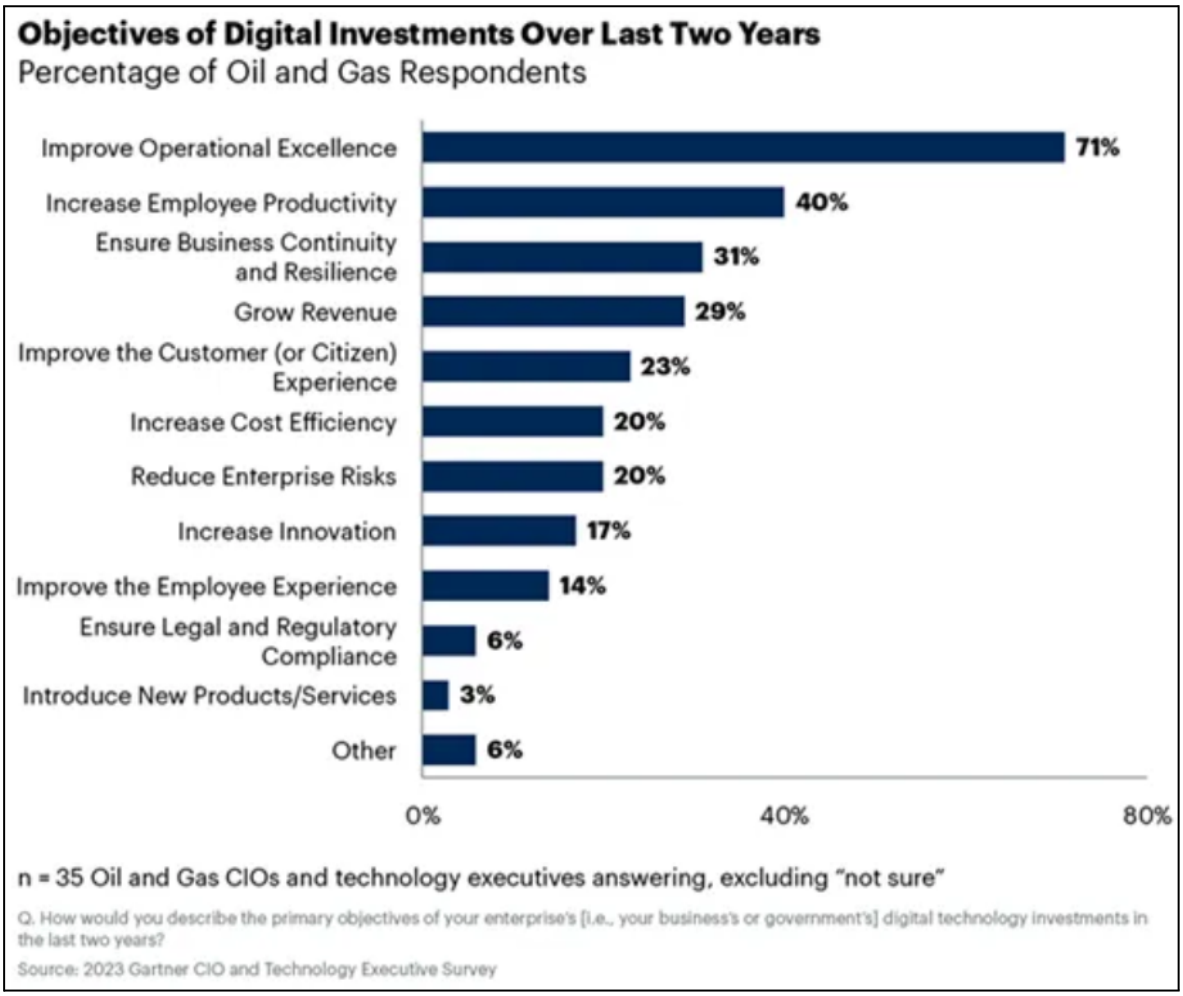
Appendix III:



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