Machine Learning Effects on the Norwegian Oil and Gas Industry

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Abstract

Title: Machine Learning Effects on the Norwegian Oil and Gas Industry
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The downturn in the Norwegian oil industry in recent years has led to a revaluation of the sector. Out of this turmoil, a new surge of innovation appeared. This paper explores the innovation effects machine learning (ML) technology has brought to the Norwegian oil and gas industry (NOGI) using a qualitative approach through conducting semi-structured qualitative interviews.

These interviews focus on five unique perspectives within the industry. These perspectives represent the unique interplay between private and public actors on the Norwegian continental shelf (NCS). The interviews discuss the value of big data, the use of ML in optimizing extraction processes and finding more sustainable approaches to detecting oil and gas. After presenting the five perspectives in the analysis, similarities and differences are discussed in light of the role the actors i.e. the companies play on the NCS.

Interviewees expressed their enthusiasm and aversions about using new technologies to secure competitive advantages, despite most companies developing similar uses of ML. Throughout the analysis, background information from website searches and analyses are used to provide context for the interview data. The results show that the use of data, advanced analytics and various forms of ML create opportunities to fundamentally reimagine how and where work gets done and that there are possibilities of finding safer, more cost efficient and more sustainable approaches to the work currently being done through ML in the NOGI. The study shows that ML has brought disruptive innovation to the NOGI that enhances competitive advantages.

Research question: What innovation effects has ML brought to the Norwegian oil and gas industry to enhance competitive advantages?
Key words: Norwegian Oil and Gas Industry (NOGI); Innovation; Technology; Digital Transformation; AI; Machine Learning (ML); Competitive Advantage
Players in focus: The Norwegian Petroleum Directorate (NPD), Petoro, Shell Norge, Lundin Petroleum, Aker BP/Cognite

Resumo

Título: Efeitos da aprendizagem de máquinas sobre a indústria Norueguesa de Petróleo e Gás
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Esta dissertação explora os efeitos que a inovação de machine learning (ML) trouxe à indústria Norueguesa de Petróleo e Gás (NOGI), concentrando-se em cinco perspectivas únicas dentro da própria indústria cujo objectivo é fornecer uma compreensão dos efeitos de inovação que o ML trouxe à NOGI. Para responder à pergunta de partida colocada, uma abordagem qualitativa é utilizada através de cinco entrevistas qualitativas semi-estruturadas.
Estas cinco perspectivas representam a interacção única entre actores privados e públicos na plataforma continental norueguesa (NCS). As entrevistas mostram que o valor de big data, o uso do ML na otimização dos processos atuais através de estratégia e tecnologia, e as possibilidades de encontrar abordagens mais seguras e sustentáveis para o trabalho que é feito atualmente através do ML. Os entrevistados expressam que novas tecnologias podem assegurar vantagens competitivas, apesar da maioria das empresas desenvolverem usos semelhantes de IA e ML. Após a apresentação das cinco perspectivas na análise, sobreposições e divergências são apontadas e analisadas. Ao longo da análise, são fornecidas informações retiradas dos websites para fornecer o contexto necessário aos dados obtidos através das entrevistas. Os resultados mostram que o uso de dados, análises avançadas e várias formas de IA criam oportunidades para reimaginar fundamentalmente como e onde o trabalho é feito no NOGI. O estudo mostra que o ML trouxe inovação disruptiva para o NOGI que aumenta as vantagens competitivas.

Pergunta de partida: Que efeitos de inovação trouxe o ML para a indústria Norueguesa de Petróleo e Gás para aumentar as vantagens competitivas?
Palavras-chave: Indústria Norueguesa de Petróleo e Gás (NOGI); Inovação; Tecnologia; Transformação Digital; IA; Machine Learning (ML); Vantagem Competitiva
Empresas estudadas: The Norwegian Petroleum Directorate (NPD), Petoro, Shell Norge, Lundin Petroleum, Aker BP/Cognite

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1 Introduction

The oil and gas industry has experienced many cycles of transformation over the years. The industry developed at a time when resources were scarce, and the available technology was not nearly as advanced as it is today (Handscomb et al. 2016). In addition, there is tension concerning management of natural resources and industrial development given the global emphasis on sustainability and the environment (Andersen et al., 2018). Countries with "black gold" have seen their economies rapidly transform. At the same time, the industry has come under fire for practices deemed to be unsustainable, unsafe or corrupt.

Norway discovered oil in 1969 and started developing oil in 1971. In the years since, Norway has gone from being a poor fishing and farming nation, to quickly becoming a significant global oil and gas producer. Today it is the 3rd largest gas exporter and the 10th largest oil exporter in the world (Overland, 2018). Norway today provides 20% of the EUs gas demand (Arctic Economic Council). The exploration of mature petroleum regions such Norway, where most of the 'easy oil' has been extracted, requires increased investment in advanced production technologies. This demands innovation.

Today, Norway has three main fields in production: The North Sea, the Norwegian Sea and the Barents Sea. Of these, the North Sea was where the first oil exploration started as this region still has the highest number of producing fields and the highest production numbers annually.

Despite the turmoil that oil and gas often bring to an economy (known as the "resource curse"), Norway has been able to remain politically and economically stable through the years. With its small and relatively homogenous population (5.2 million people), Norway has been able to use the resources for the good of the country. As a constitutional democracy, Norway is often used as a prime example of a country that has had a successful economic development strategy, effectively investing oil and gas revenues through its Sovereign Wealth Fund. Ultimately, the Norwegian welfare state has been a success story due to the fund's support.

Following the 2015 crash in oil prices, the Norwegian oil industry was forced to reconsider itself. The crash caused significant job losses and called into question the viability of oil and gas as Norway's most valuable and lucrative export. The crash was also a catalyst for the major oil and gas companies to invest in machine learning technologies (ML). This capex was an innovative move,

undertaken in the hope that ML tools would help minimize risk, assist in predicting wear and tear, and that it would streamline processes to make these companies more cost and time efficient and ultimately more competitive. In addition to innovation contributing positively to improving the industry, innovation is also needed to attract new talent to the sector. A depressed oil price was thus a net positive for innovation in the P&P industry (Meehan et al., 2015). While in good times workers were focused simply on continuation of their various activities, in more difficult times teams need to innovate for the companies to stay afloat.

We are in a time of significant digital transformation where artificial intelligence and machine learning are reshaping businesses. Machine learning, a subset of AI, uses statistical techniques to give computers the ability to learn from available data sources and apply this knowledge to new situations. In the oil industry today, ML is used for analytics and modelling, for drilling and subsurface characterization, for predicting maintenance needs, optimizing supply chains and for optimizing financial resources thereby improving productivity in the industry. Improving these processes adds value to the industry as a whole (Davis et al. 1990).

This study explores innovation effects of machine learning on the NOGI that enhance competitive advantages looking at how machine learning is used, how it effects the companies′ competitive advantages and what innovation effects accrue.

2 Literature Review

2.1 Innovation

Due to geopolitics and price volatility within the oil and gas sector, recent developments have made the industry technology dependent (Pillai, 2006). Technology and innovation are becoming more important in the process of sustaining and reinventing the industry. Due to economic pressures after the oil crisis, the industry needed new ways to grow (Kleinschmidt, 2016).

Innovation is a complex concept that is considered the source of growth for companies and economies. It can involve products, processes or services, technologies or administrative factors that have the ability to evolve (Cooper, 1998). Organizational innovation is defined as the development of new products or services (Jackson, 2011). Schumpeter (1947) states that innovation is simply "doing things that are already being done in a new way." Innovation as a process is based on thorough initial research, then developed from there, repeating the process until a problem is solved. As innovation can be both the development and the implementation of new ideas. And innovation has historically been used to characterize processes that used new technology and knowledge to improve processes and products (Porter, 1990). If done right, business model innovation can help companies become more resilient during times of change and innovation processes which have been developed can contribute to growth (Christensen et al., 2016). Innovation is also defined as transforming an idea into a viable product/service (Hassani et al., 2017).

Christensen (2004) stated that there are two types of innovation: sustaining and disruptive. Sustaining makes current products and services better and disruptive innovation brings about a paradigm shift. Later, he added a third category, efficiency innovation, which entails measures such as cost cutting where a firm can achieve more with fewer resources. (Christensen, 2016). In the oil and gas industry, sustaining innovations tend to be preferred leading to improvements in existing product lines, so most innovations in the sector are not disruptive. Many of the most important and most profitable innovations take a good product or service and make it better (Christensen et al. 2004). Innovation is the way that businesses improve and develop processes, services and products. This is important for an industry to grow and remain competitive while not becoming stagnant. Digital transformation has in recent years been the most significant source of sustaining innovation in the NOGI, improving and transforming digital processes using artificial intelligence and machine learning to transform the way people work (Tabrizi et al., 2019).

A company′s values determine how it prioritizes opportunities. Most mature companies tend to favor innovations that improve its ability to service important customers and avoid activities that destroy significant revenue streams (Christensen et al., 2004). Only incumbents who control large portions of an industry's value chain can introduce radical innovations. These integrated companies can master the various interdependencies associated with compatibility, interoperability, and legacy issues (Christensen et al., 2004). Bers et al. (2009) claim that radical innovations lead to technological revolutions. This is relevant as we are currently in what is known as the Fourth Industrial Revolution, characterized by the coming together of various technologies that blur the lines between the physical, digital, and biological spheres (Xu et al., 2018).

The current low levels of fuel prices are expected to result in further innovation-driven differentiation within the industry (Evans, 2016). With the concept of peak oil now rejected, technology is even more important for upstream growth (Mitchell et al., 2012).

An idea becomes an "innovation" when it has the possibility of being accurately repeated on a meaningful scale at practical costs (Senge, 2004). Innovation is about solving problems in a more efficient manner than they are currently being addressed. Innovation has positive effects such as increasing efficiency, improving safety, making processes more sustainable etc. But the most important contribution from innovation is that it provides strategic insights about the future and promotes growth and improvements (Jong et al., 2015). Innovation is taken to be the fundamental source of significant wealth generation within an economy. Because high-tech industries offer higher growth potential, the best way to spur job creation and economic growth is by facilitating more efficient migration of innovations from the knowledge economy into the commercial sector (Jackson, 2011).

A study by Anzola-Roman et al. (2018) showed that external innovation practices increase the chances of developing technology-based innovation. The authors suggested that organizational innovation also improves the likelihood of spillover innovation effects generating technological innovations as well.

Schumpeter (1912, 1939) makes the distinction between economic growth and economic development. Economic growth represents progressive change in the economic system whereas

economic development is generated by innovation. The economic growth model developed by Schumpeter further proposes that competition through innovation promotes economic growth, a claim supported by empirical studies (Aghion et al., 2005, 2009).

Norris, et al., (2010) found that innovation has a major impact on the financial performance of companies. The positive effect of innovation on productivity is significantly higher in countries with developed capital markets.

2.2 AI and machine learning

Technology and insight used in the oil and gas industry, can contribute to diversification of the economy as a whole (Mäkitie et al. 2018). The Norwegian oil and gas supplier industry has been crucial in developing innovative technologies that have contributed to everything from extraction technology, to contributing to the offshore wind power industry (Steen and Hansen 2014).

AI can be defined as "the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable." (McCarthy 2007) Russel and Norvig (2009) define artificial intelligence as machines (or computers) that mimic "cognitive" functions that humans associate with the human mind, such as "learning" and "problem solving". These definitions are not far off the first definition of artificial intelligence explained by John McCarthy in 1956 as "the science and engineering of making intelligent machines."

Machine Learning is an application of AI "concerned with the question of how to construct computer programs that automatically improve with experience" (Mitchell, 1997). Machine learning studies algorithms and statistical models used by machines to carry out tasks automatically making "decisions" based on patterns and inference. Machine learning is ultimately a machine or program performing human-like tasks that automatically learns from its own data.

Many companies across multiple industries will have to adopt machine learning as a matter of survival in the coming years (Barro et al., 2019). Andrew Ng, cofounder of Google brain and

former VP of Baidu states that the use of AI and ML allows a company to compete more effectively . ML will become a key component in a cost-efficient business strategy creating a strong competitive advantage. (Ng, 2018)

As in many other industries, ML technologies are replacing workers in the oil and gas sector. Jobs that remain require increased human–machine interaction and often computer engineering skills. As data generation continues to grow, every physical piece of equipment will connect to a larger network. The use of data, advanced analytics and various forms of AI create opportunities to fundamentally reimagine how and where work gets done (Handscomb et al. 2016).

The oil and gas industry is developing new technologies inspired by software-development methods . They have used a "scrum" approach to simplify drilling standards. Statoil (now Equinor) encouraged innovation activities by giving technical employees the option to build their own work schedules and locations where they worked. This led to innovations, such as the creation of the prototype of Statoil's new Cap-X subsea system, which decreased development and operating costs by 30 percent (Handscomb et al. 2016). This is only the beginning of development and adoption of AI and ML in the Norwegian oil and gas sector.

2.3 The organization of the Norwegian oil and gas industry (NOGI)

According to experts, the Norwegian oil and gas industry is a model for the global industry (Ryggvik, 2015) (Reve et al., 1992). What truly sets the NOGI apart from other international oil and gas industries is a strict government control, a unique interplay between private and public actors, along with a successful long-term investment strategy (the Norwegian Sovereign Wealth Fund). The Norwegian Ministry of Petroleum and Energy (MPE). The MPE reports directly to the Norwegian government. Under the MPE we find four main institutions and companies who relate closely to the Ministry, securing public interests and optimal use of oil and gas resources.

The major regulatory players are as follows:

The Norwegian Petroleum Directorate (NPD) (est. 1972), is responsible for overseeing all activities on the Norwegian continental shelf (NCS). They maximize the number of oil drilling sites while minimizing environmental mishaps. The NPD also ensures that companies fulfill their contracts extracting oil on the shelf.

Petoro (est. 2001), has the main objective of managing the State′s Direct Financial Interest (SDFI) to maximize state revenues from the portfolio, i.e. the total of oil and gas related shares and stocks.

Equinor (est. 1972), former Statoil, is an oil and gas production company that makes up 70% of the production on the NCS. The Norwegian state owns close to 70% of the shares in the company.

Gassco (est. 2001), is an independent operator of the gas transport system and is responsible for operating infrastructure, such as pipelines on behalf of other owners.

In addition to these four main government bodies and semi-governmental companies, there are a myriad of private companies supplying and operating the activities on the NCS (Vega-Gorgojo et al ., 2016)

In the decades following discovering of oil off the Norwegian shoreline, the complex dynamics of the oil and gas industry include, but are not limited to, price volatility, the complicated politics of petrochemicals and rising sustainability concerns. The need for improved communication technology has resulted in greater collaboration between suppliers and oil companies (Al-Kasim, 2006). The relationship between petroleum companies and their suppliers has become increasingly important over the years (Pellegrini et al., 2012).

Overall, there are three major actors in the system. These are the upstream petroleum companies (oil companies or operators), the petroleum supply companies (also sometimes referred to as oil service companies) and the public sector organizations which regulate and support the industry (Thune et al., 2018). Overall, successful innovators have the ability to establish strategic partnerships within their specific industry supply chains, and as a result develop close relationships with lead customers and key suppliers, as well as with third-party resource network partners such as banks, venture capital suppliers and providers of new technology (Cook and Wills, 1999).

External factors like international events, also play an important role in the industry. Events like China′s devaluation of its currency, sanctions on Venezuelan and Iranian oil exports, and US presidential policies are resulting in uncertainty around oil prices and the future of oil (Sen, 2019). OPEC and its allies are currently cutting production by 1.2 million barrels per day to support oil prices. Top producers, like Saudi Arabia and Russia have both pledged to lessen supply to rebalance oil markets. (Rahman, 2019) In the world of oil and gas, unknowns play a very significant role in how the industry performs as a whole.

The oil and gas industry has had a rough decade. The per barrel cost of production was 60% more in 2015 than in 2005, and oil prices dropped by approximately 70% since peaking in 2014 (Decker et al., 2016). New advanced-analytics programs are able to analyze and normalize data and identify opportunities for cost savings that can be leveraged across future operations (Ward 2016).

2.4 Innovation, ML and oil and gas

Developing the oil and gas sector in Norway has required an innovative industry culture, flexible in adapting as times and technologies change. The Norwegian government has been effective in using oil revenues to support social goods such as education and healthcare. Thus, values and preferences of the broader society are fundamental for understanding natural resource-based development (Ranestad, 2018).

From its inception, NOGI has been structured differently from other oil and gas producing countries . In addition to environmental expectations and regulations there has been a carbon tax and permanent gas flaring has been outlawed (Gavenas et al., 2015). The oil and gas sector in Norway is both a success story and it has also transformed innovation models within the global petroleum industry (Sæther et al., 2011).

Norway has specific policies and programs to support development and deployment of new oil and gas technologies, often based on collaboration between suppliers, knowledge providers and oil and gas companies (Engen, 2009). The industry collects immense amounts of data through hundreds of sensors. There is therefore considerable potential to improve processes and develop innovative

solutions taking advantage of all the valuable data. At the same time new talent is needed in every aspect of the industry (Norskpetroleum.no).

The oil and gas industry plays a key role in Norway today, directly or indirectly employing 170000 people (number from 2018) and continuing to building the Sovereign Wealth Fund (Government.no).

2.5 Key take-aways from the literature

The literature states that:

- A low oil-price leads to increased need for innovation.
- Norway has been able to avoid the resource curse by keeping the industry attractive to private companies, while at the same time imposing strict regulations and heavy taxation on oil revenues.
- Due to the immense amounts of data that the industry collects, there are opportunities to use this data to improve processes, increase cost-efficiencies, safety and sustainability.
- New technologies can lead to securing sustainable competitive advantages if companies are able to execute appropriate strategies accordingly.

3 Methodology

This project employs semi-structured qualitative interviews to explore the innovation effects of machine learning (ML) in the Norwegian oil- and gas industry (NOGI). Other methods could have been used, including large scale surveys covering all involved actors. However, given the time frame and the amount of resources available in a master′s project, expert interviews were the more sensible, feasible, and optimal solution (Horton et al., 2004).

Qualitative semi-structured interviews give the interviewer direct access to informants, maintaining a structured list of questions while allowing for the flexibility when interviewees introduce new pieces of information that are worth probing (Doz, 2011). As an outsider interviewing experts in the oil and gas industry in Norway, there were bound to be unexpected topics that would arise during the interviews. A fixed survey or fully structured interview guide would not have captured these valuable pieces of information.

With a limited number of informants, it is important to be conscious of the composition of the sample. Who are included determines the perspectives that are presented and can skew results. In qualitative studies, the question often arises of how representative the data is. In this study, five experts from different positions in the industry were interviewed. The goal was not to give a complete map of all the perspectives that exist on the topic, but instead to present examples drawn from a variety of actors and perspectives (small/large companies, government/private sector). The voices and positions which are included, must therefore not be taken to represent the industry as a whole, but can be seen as key examples of major perspectives.

3.1 Access

To get access to the right experts, the structure of the industry was carefully studied. The aim was to secure experts who represented different perspectives within the industry. A list of people was drawn up, either from organizational charts on the companies′ websites or through management overviews on LinkedIn. Depending on accessibility, participants were reached by LinkedIn messaging or by email. The focus when reaching out was to find experts who were leaders in the field. The author′s network was also used, reaching out to people who might be in positions to recommend experts who would be willing to schedule 30 minutes for a chat. Often the CEO was first reached and he or she then referred the author to someone within the company they deemed

appropriate. All experts who responded were enthusiastic and forthcoming. However, they needed reminders and active follow up to make each interview happen. The final experts accessed are representative sample, dependent upon who was reached out to and who responded, and who was able to make room to schedule the interview.

3.2 Informants

The final experts presented different perspectives from within the industry. Getting two experts representing the state or the government perspective, NPD and Petoro, provided insight into how the industry is structured and what the state thinks about technological innovation in the sector today. Two experts representing Shell and Lundin Petroleum, a smaller oil company, were also interviewed for their thoughts on ML in the industry and where they think the industry is headed in regard to automation and use of data. Lastly, there was an expert representing data companies discussing why both state-run and private oil companies are investing in ML technology. The final strategic sample revealed divergent views within the industry and yielded insights.

Table 1. Overview informants

Name of institution/ company	Type of institution/ company	Informant′s position
NPD	Government	Former Director
Petoro	Government	Chief Digital Officer
Shell	Big oil	Business Lead Architect Projects & Technology
Lundin	Small oil	Director of Production
Cognite	Data company	Software Engineer

3.3 Preparing for the interviews

As a background for interviews and the analysis, each company′s online presence and other parties′ comments were studied. Even though specifics about their AI and ML strategies were often not shared online, this background research was valuable for understanding the actors′ priorities. Practically, this information made it possible to formulate an adequate interview guide and follow-up questions.

Further, the background information made it possible to put the responses from the interviewees into a relevant context. It also provided insight about what interviewees would be willing to share. The online information also assisted in forming and adjusting the questions.

3.4 Interviews

The interviews were semi structured, with both prepared questions and follow up questions (see full interview-guide in Appendix p. 39-47). There was also room for opinions and casual conversation to get additional personal insight. Throughout the communication with the informants, a key consideration was to build trust in the project and in the interviewer to have the subjects open up and provide as much candid information as possible. Some of the experts requested the questions prior to the interviews while others wanted to do them on the fly. The option of receiving the questions before the interview was offered in the initial email/ message.

As four of the informants were in Norway and one was in the Netherlands, the interviews were done over video chat and other communication happened over email. The interviews that were conducted with Norwegian experts were done in Norwegian, while the interview done with the informant in the Netherlands was conducted in English.

The interviews were short and conversational (around 30 minutes) to achieve pointed answers to the questions. The goal was to get an understanding of what the various companies in the Norwegian oil industry are doing in regard to digitalization, technology focused innovation, specifically machine learning and what has played a role in making the decisions to invest in machine learning. The overall focus is understanding what is being done in ML, what the innovation effects are, and to gain insight as to where the weak links were in the supply chain prior to innovation efforts made.

Notes were taken during interviews that were filled in and translated within the hour to ensure accuracy. Throughout the analysis, notes of the five interviews were compared, looking for common traits, patterns, variations in use of concepts, contrasts between perspectives, and more, as will be described in the next section.

4 Analysis

4.1. The perspectives and interviews

In the following section, the interview material is presented along with analysis of the material focusing on overlapping topics. First, we present the perspectives of the two governmental institutions, the Petroleum Directorate and Petoro. Next, there are the two different corporates; the large oil company, Shell, and Lundin, representing smaller corporations. Finally, there is the data company perspective through Aker BP′s Cognite.

After presenting the five perspectives, overlaps and divergencies are pointed out and analyzed. Throughout the analysis, background information from website searches and analyses are used to provide context for the interview data.

4.1.1. NPD – The government perspective I

Since Norway assumed sovereignty over exploration and production on the Norwegian continental shelf (NCS) in 1963, the government has played an important role in NOGI (Janicke, 1984). After the first oil was produced in 1971, the state established the Norwegian Petroleum Directorate (NPD). The NPD to this day recommends licenses on the NCS and is responsible for long-term technological and geological analyses as mandated by Norwegian law (NPD). The Directorate also manages the frequency of exploration and production per field. With the government playing a significant role in the Norwegian oil industry its perspective is important to take into consideration for understanding the state of the industry. Government policy also has bearing upon innovation in the industry and how it will be shaped in the future.

The diversity of companies creates competition, and this promotes efficiency and value-creation in both the exploration and production phases. Collecting and making data available has given the Norwegian Shelf a competitive advantage compared with other areas of the world.

The former Director of The Norwegian Petroleum Directorate (NPD) who was interviewed spent the past 20 years working in the oil industry. He has a master′s degree in resource technology and geology and after graduating he worked offshore and was then brought into the NPD and has since had a variety of roles including the past 7 years as Director of the NPD.

Technology as fuel for accelerated development in NOGI

He observes that the main trend today in NOGI is to focus on accelerated development, with an emphasis on using technology to reduce costs and improving the supply chain by making each process more productive and effective. According to him:

> All steps within the oil extraction, production and distribution processes are costly there is a huge focus on reducing said costs, the technology that is being developed and explored today show that that the technology available is not only accelerating processes but helping explore more possible oil wells. The cost efficiency of the new technology allows the companies to find more natural resources and extract more efficiently (The Former Director of NPD, December 2019).

He notes that there always is room for development as the nature of the industry makes it important to innovate constantly as falling behind can lead to big losses. Finding new opportunities and improving the supply chain will not only move the industry forward, but also simultaneously move technology "forward". As oil extraction is an expensive process, making processes more cost efficient is important.

The exploitation – environment nexus

It is often stated in the media that there is a trade-off between oil exploitation and sustainability (Ferns et al., 2017). The former director states that technology and ML have the potential to make oil extracting more efficient, while at the same time respecting environmental concerns:

> Machine learning (ML) can help increase oil finding, improve analyzing seismic data, improve extracting methods and make them more efficient. A big issue the oil industry is facing today are environmental challenges that come along with extracting and producing oil. The hope is that with improved methods through technology, we can make the various processes more environmentally friendly (The Former Director of NPD, December 2019).

The former director stated that the NPD views the environment as the number one challenge with respect to improving supply chain processes. Processes need to keep up with government sustainability requirements and the NPD treats sustainability as a priority. NPD's role is to give advice to make sure that companies are extracting and producing oil in a "smart way". NPD approves sites and is in charge of licenses. Its priority is to ensure that companies operating on the NCS extract both the oil that is easily available and also resources which are more difficult to get to. The goal is that this is done with minimal environmental damage and the lowest possible number of

accidents. The former director sees an important role for new technologies such as ML for finding the balance between profits and environmental sustainability.

> In the future they are going to have to focus on balancing profits and the environment and will have to close down fields and open new ones. How will this be done well? What does that entail? What has to change? Ultimately, new technologies can lead to finding new resources without digging (The Former Director of NPD, December 2019).

AI and ML – sustaining or disruptive innovation?

The former director of NPD believes that AI and ML can be both sustaining and disruptive innovations. In the case of improvements in ongoing activities, such as improving the process of digging wells and the use of seismic data, AI and ML are definitively sustaining innovation. At the same time, examples such as systems for coping with wind speeds, show that AI and ML can create disruptive technologies, they can be game changers for the industry as a whole.

4.1.2. Petoro – the government perspective II

Petoro is a government owned company, established in 2001, that manages the Government's portfolio of exploration and production licenses for petroleum and natural gas on the Norwegian continental shelf, known as the State's Direct Financial Interest.

Petoro plays a central role in NOGI as their main tasks are to manage the state′s interest in all ventures that state is involved in, to monitor Equinor′s marketing of petroleum and to make sure these are all within the guidelines of the Norwegian Ministry of Petroleum and Energy, and, lastly, to keep the accounts of the state′s direct participating interests.

On Petoro′s website they state that they are a driving force for increasing competitive advantage -- creating certainty about reserves, promoting sound operations, as well as optimizing cost effective solutions across the board (Petoro). They aim to create honest interactions and transparency around other licenses, suppliers, technology providers, the authorities and the community. Technology and innovation are not words that are often repeated on their website however the importance of d igitalization is mentioned a few times.

Digitalization and changing the operations model

The Chief Digital Officer at Petoro worries about potential conflicts that may arise between active companies on the NCS because of the heavy focus on competitive advantage and on having the "edge". He holds that:

> It is about finding a balance between competing and working together to have the best technology and using the research available to its full potential. The operations model has to improve drastically, overall new technology is going to change the principle of leadership. The culture, the mindset and the structure is changed (CDO of Petoro, December 2019).

Going forward, he believes that development is going to have to focus on the agility of processes. New technology being introduced changes the overall structure, which is going to result in a paradigm shift. Digitalization's main challenge, according to him, is that it is easy if a task previously done by a person is now performed by a machine. However, because of what he regards as overall lack of trust in the system, he believes that people whose job tasks change due to machines make the transition challenging because they have to change the way they work. He puts it simply: "It is just more difficult to get people to change" (CDO of Petoro, December 2019).

The CDO believes employees' reactions to change are 70% about the culture of the company they work for. The biggest mistake companies make is that they put data ahead of business. Strategy and culture, he states, will ultimately play a larger role in how change will be received. In changing times, business intelligence has to come before artificial intelligence and the companies have to have a clear strategy in communicating what problems need to be solved.

ML's potential

Petoro works with Schlumberger to use data to its fullest potential. Ultimately, they work with technology that helps oilfields planning wells and processing construction sites communicate with each other. Mainly they are developing ML to help with seismic data and search. He states that:

> ML and AI can help with reservoir models, the parameters and create innovative solutions on use and execution of generating large amounts of data. There is so much room for development- in this industry it is incredibly important to innovate or to "think new". In finding new opportunities and moving technology "forward". However, ML and AI has its limits; It cannot think like a business-

and regard full circumstance and effects. Full transparency is key (CDO of Petoro, December 2019).

The final reflection comes down to the disruptive role ML and AI are going to play. The CDO believes that technology can help give accurate readings of the surface for exploration rather than having to drill holes which is a huge game changer for costs and the environment. He concludes that ML has the potential to disrupt the industry as a whole.

4.1.3. Shell – the big oil company perspective

Shell states on their website that AI will be used to drive efforts in predictive maintenance and will powered applications across the company (Shell Global). Online content shows that the company is making efforts to innovate and to be on the forefront of new technologies. Shell′s goal is to make ML and other tools widely available by developing and deploying AI applications at scale. Main efforts include specific sensor technology and Microsoft assessors predicting when maintenance is needed on compressors valves and other equipment. The goal with this is to help steer drill bits through shell deposits, improve safety and assist with anomaly detection. Shell also uses AI tools from Bonsai (a software company bought by Microsoft in 2018) in order to build software that runs autonomously.

The goal is to cut costs, boost production and more efficiently manage assets by making better use of the data flowing through corporate systems and equipment. This will also help with image recognition video analytics to alert gas station managers when a customer does something unsafe. Sensor technology applications will also help with predictive maintenance fraud detection and supply chain optimization.

Shell also has a version of a digital ″Centre of Excellence″– to facilitate the company′s digital strategy deploying cutting-edge digital technologies. Shell separates the tasks of innovation and operational execution of completed digitalization applications, with the latter tasks performed by Shell′s Business Service Center. The key point with such separation is that innovation is often disruptive and brings value in the long run, whereas ongoing operations naturally seek out continuity and proven best practices.

ML and the supply chain

The Business Lead Architect Projects & Technology (BLAPT) at Shell, who is in charge of all projects and deliverables within digital technology for Shell, shared that the company′s heavy investment in innovation is exactly why he enjoys working there. According to him, Shell′s innovations can be placed into five categories: AI and ML (in different capacities, robotics (visual inspections, drones and robots on platforms); IOT (sensors using data); blockchain (increasing traceability of oil and gas); and cameras (using AI and robotics, cloud based). Blockchain technology provides producers with an overview of where the oil and gas originates from, where it was extracted, where it was refined and what borders it has crossed. This allows the company continuously to share data with customs and other government bodies.

BLAPT understands that ML can play a role in helping improve many components of the supply chain. At Shell there is about 9 million data points collected per second. Utilizing this data, optimizing it and building optimization models is important for ongoing innovation and improving the supply chain. He states that;

> We are not so brilliant at tapping into the right data to optimize processing, so it′s important to bring this data into the right hands (Business Lead Architect Projects & Technology at Shell, December 2019).

According to BLAPT there is data sufficiency but to make efficient use of the data companies need models to train in order to fully automate the oil rigs. There seem to be few limits to what the interviewee believes ML can accomplish as he states that 90% of present tasks in the supply chain can be done with machine learning.

Technology to attract talent

New talent is important in order to innovate. Fresh people bring energy and ideas. Shell is ultimately a tech company, where they use data to improve the value chain. But it is important to hire talent. Despite the increased use of ML, decisions will always require some level of human intervention in certain circumstances. There are some things ML just cannot do --

> Final decisions will always have to be made by humans (Business Lead Architect Projects & Technology at Shell, December 2019).

Even though Shell considers itself an oil and gas technology company, BLAPT also knows that they are not Microsoft, Amazon or Google. Specific knowledge and experience is important as are strong collaborations in order to develop as a company. Currently Shell has a 25-year strategic partnership with Microsoft Azure, and they are also working with geological data in a partnership with Amazon . BLAPT acknowledges that when it comes to internal versus external innovation, Shell cannot simply rely on a partner to achieve competitive advantage, as core capabilities always need to reside inhouse. That is where new talent and innovation are required at Shell.

4.1.4. Lundin – the small oil company perspective

Lundin Petroleum is a development and production company that is smaller employee-wise. It has been active on the Norwegian Continental Shelf since 2003 (Lundin Petroleum). Today they are one of the largest operated acreage holders in Norway. On their website they claim to have a proven ability to "discover, develop and produce oil and gas resources and hope to continue as one of the strongest players able to capitalize growth going forward". Their site says little about AI and ML, but Lundin Petroleum outsources their efforts to the Norwegian data company Cognite.

Where ML can save lives

The Director of Production at Lundin Petroleum believes that innovation and ML in the NOGI is especially important because of the license to operate and HMS known as "helse, miljø og sikkerhet" (Health, environment and safety)**.** The main aim is to automate as much as possible in order to have fewer people offshore as this can be a liability with regard to HMS. Anomaly detection, cost and production efficiencies are a focus to maximize safety. Offshore, HMS has to come first, as the Director bluntly put it, and trial and error is not an option. If mistakes occur on platforms, people die. She therefore emphasizes that there really is no room to fail:

> When it comes to ML, everyone is doing similar things, but it's just about doing it fast. At Lundin, due to smaller size we can make things happen faster. We can produce fast, make decisions fast and the fact that we can run the system fast gives us a competitive advantage (Director of Production at Lundin Petroleum, December 2019).

She believes that it is important to invest in innovation and, in addition, to create valuable partnerships, and to encourage innovation in-house among employees. With the decreasing oil price and pressures around the industry Lundin realized they had to innovate and bring in a company that could help with big data and ML. Categorizing innovation effects, she shared that:

> ML and the maximum utilization of big data will disrupt the industry and change the sector, the processes and supply chain drastically (Director of Production at Lundin Petroleum, December 2019).

Realizing the potential of the data they had available, Lundin decided to outsource ML efforts to the data company Cognite. The hope was that in combining Lundin′s small company structure and innovative mindset with Cognite′s data expertise they could digitalize the supply chain quickly and efficiently.

4.1.5. Cognite – the data company perspective

In addition to Lundin, Aker BP outsources their machine learning innovation efforts to Cognite as well. Cognite works with both Lundin and Aker BP in Norway to deliver digital solutions tailored for oil platforms. The core of what they do is to collect and organize all active data in one place. They gather information from any industrial application and improve maintenance procedures by seeing data sources in relation to each other (Cognite). They state that this production optimization removes unnecessary constraints and increases production by advancing efficiency and automation of parts of the supply chain. Lundin also provide a digital worker where relevant information connects work orders to related data which supports key workflows.

At the 2018 ONS conference, Aker BP′s CEO, Karl Johnny Hersvik, was on stage with Google′s Daryl Willis, VP Oil, Gas and Energy in Google Cloud (Aker BP ASA, 2018). They demonstrated Cognite′s industrial data platform. Willis stated that the goal of working with Aker BP and Cognite was to helping the company become more efficient, effective, safe and clean. According to Willis, there are two options for companies in the industry. The first is to be a catalyst of change, or to be a causality of change. ″Evolve or expire″ he stated. The company praises the value of partnerships which they say will be critical for the future, the more unusual the partnership the better because ″we can do more together than apart″. AI is fueled by data, deeper insights and faster outputs to ultimately improve performance and efficiency. They concluded with a simple motto: Fast beats slow.

The leaders agreed that data will be critical for creating innovation by digitalizing all operations because it will reduce the time spent on processes, it cuts down on waste and improves safety. In securing the right partners, oil companies can leverage the full suite of data at their disposal which

will create efficiencies within each company, and eventually within the industry at large.

The specifics of what ML does

One of the lead Software Engineers at Cognite served as an informant for this part of the study. He confirmed that they use many forms of new technology: Photogrammetry**,** Machine Learning (Computer vision) (Regression) (Classification)**,** Physics Simulators**,** AR**,** Game Engines / Unreal Engine, Lidar Scans. He believes that ML is especially important in the oil industry because of computer vision with photogrammetry for automatic construction of 3D models and object detection to be able to detect rust, leaks, cable breakage and the like. Yield optimization gives the ability to use live sensor data to optimize production.

> What is important to us is that we constantly develop products that deliver value to customers. That′s why we spend a good amount of time identifying that greatest needs of customers. In the next phase, we map how long it would take to develop a solution to those problems. Finally, we select number of ″use cases″ to focus on based on a cost/ benefit assessment (Software Engineer at Cognite, December 2019).

The software engineer shared that Aker BP, like many other industrial companies, experienced great challenges when it came to digitalization. Data was originally stored in different source systems and in several different formats which was not an optimal way for use in applications. Over a period of about a year, the management of Aker BP in collaboration with John Markus Lervik mapped the needs and concluded that a cloud-based data platform could solve several of the challenges that were constantly encountered. In the startup phase of Cognite, John Markus brought in Geir Engdhal, a former Google employee as CTO.

Utilizing the data

The biggest competitors seem to use ML in similar ways. Ultimately, it is about using ML in a smart way (and on the right projects).

> In order to place ML in one of the two segments, I think it is important to look at the scope of ML. A good portion of the various uses of ML will serve as small improvements in overall performance, but also a good portion can radically change the way a product performs and functions and am therefore somewhat uncertain as to whether ML as a whole fall into one or the other category (Software Engineer at Cognite, December 2019).

He shared examples of disruptive innovation: computer vision where the intention was to classify images and extract information from images or video, ML has helped to radically change the performance and basis for building models. This also applies to OCR, reading text and symbols in images and other models that require large data bases for training.

4.2. The takeaways

Following a steep decline in oil prices and a decade where new technology was no longer just a possibility but an expectation, all the companies that participated in this study have committed to developing AI and ML. These types of new technologies have disrupted the industry as they make use of data available to automate processes and have opened up possibilities for the industry to become more sustainable and more production and more cost efficient.

4.2.1. The value of big data

All informants pointed out the value of data and that is has not necessarily been used to its full potential. The informants did, however, differ in what they emphasized with regard to data exploitation.

Both NPD and Petoro made the point of ML being able to help with analyzing seismic data. Petoro is currently outsourcing data management to help organize data to communicate between oilfields and shore, and for well planning and processing construction sites.

The informant from Shell made a point about the importance of bringing data into the hands of the right people to utilize the rich data that is already at available. At Shell there are about 9 million data points collected every second. Utilizing this data and building an optimization model will be important to keep innovating and improving the supply chain.

Lundin stated that big data will disrupt and change the industry and the processes and supply chain drastically. Cognite makes it clear that data is the main competitive advantage. Identifying partners that one trusts to leverage date will create efficiencies within the company.

It is clear from the interviews that a large amount of data is collected across the industry and that the actors sense the potential in the available information. This data can encourage innovation.

According to the informants, ML is expected to help solve the situation of data overload. The ML analytical model building is automated and through this technology, the value of data will have a substantial effect on the NOGI and provide it with a competitive advantage. As Lundin stated, "Taking advantage of Big Data and ML will change the industry."

4.2.2. The effect of optimization

Three of the experts interviewed mentioned that different forms of AI and ML can help optimize the supply chain, despite the word not being used in the interview questions.

Petoro talks about increasing their portfolio's competitive advantage by creating certainty about reserves and sound operations, as well as optimizing cost effective solutions across the board. Shell emphasized that predicting maintenance fraud detection can help improve the supply chain utilizing available data. At Cognite they gather information from any industrial application and improve maintenance procedures by seeing data sources in relation to one another. This production optimization removes unnecessary constraints and increases production efficiency.

ML automates processes, making each step of the supply chain more efficient and less dependent on variables susceptible to human error.

4.2.3. Health, environment and safety

Health, environment and safety, known in Norwegian by the acronym HMS, is a topic all experts mentioned in some form. The industry as a whole has often come under fire for practices deemed to be unsustainable and unsafe. The media also at times paints a questionable picture. All the experts gave the impression that this stereotype is something they are trying to change. The health aspect based on employees living offshore was couched as a liability and guaranteeing health and safety was recognized as a challenge.

Shell, Lundin and Cognite, in particular showed concern for health and safety. They claimed that new technology could assist in improving health and safety concerns. More automation means fewer people offshore which can improve HMS. Anomaly detection, cost efficiency and production efficiency have to be in focus to maximize safety and security. Offshore, HMS has to come first, as trial and error is not an option.

The governmental experts, NPD and Petoro, put more emphasis on environmental issues. NPD stated that environmental issues are currently the number one challenge holding back processes and improvements in the supply chain. Processes need to keep up with sustainability and an environmentally friendly supply chain is a priority.

ML can help improve analyzing seismic data. Petoro supported these claims by seconding that technology can help give accurate readings of the surface rather than having to dig. This can be a huge game changer for both costs and the environment.

4.2.4. Innovation efforts – in house or outsourced?

The companies operating in the NOGI have to decide whether to fulfill their ML efforts in house or to outsource ML operations to external providers.

Petoro works with Schlumberger, while Shell has a combination of data scientists in house (about 200 with the title data scientist have been hired in the past years), but also have a 25-year contract with Microsoft Azure. Lundin and Aker BP have decided to outsource their data management and development to the partly Aker-owned company, Cognite, and to Google Cloud.

Overall, these efforts show that investments in ML have brought important innovation effects into play in the industry.

4.2.5. The dynamics

All the parties interviewed ultimately want oil out of the ground in the safest, cleanest and most cost and production efficient way possible. The Petoro interviewee showed concerns about production companies that operate on the NCS because of the heavy focus on competitive advantage and because he worried about the companies sacrificing standards in order to competitive. Once NPD assigns competitors a drilling site, the game is quite simple, which is to make the most profit, while staying in line with regulations. NPD′s constraints concern being mostly focused upon sustainability and the environment.

NPD understands that the oil sector has a reputation for only maximizing profit. They recognize the power of data and share seismic and other data. NPD wants to use seismic data and machine learning to have better understanding of drilling sites, while production companies use ML for different parts of the supply chain such as for automation on oil rigs.

The Cognite interview showed that ML and AI are being used to make production more efficient. If a machine fails due to an anomaly, it does not directly affect the NPD. However, this is a liability for the production companies who care about losing time and money.

5 Discussion

5.1 The influence of ML

The analysis confirms that the use of data, advanced analytics and various forms of AI create opportunities to fundamentally reimagine how and where work gets done in the Norwegian oil and gas industry (NOGI). In the case of NOGI AI, and specifically ML, there is considerable potential to bring about paradigm shift that enhances competitive advantages across the industry and also improves current processes.

When this study began, the conclusion assumed was that ML is a disruptive element in the industry. However, after reading the literature, talking to the experts, and analyzing the effects, this is not certain. Through the interviews, it seems that big data and being able to train models and automate parts of the supply chain and that it will change the way the industry operates day to day. Knowing this, it is the data companies who are entering the market with advanced ML technologies that are disrupting the industry and changing the way people work. Maybe the ML technology itself is not the change agent?

As in many other industries, ML technologies are replacing workers in the oil and gas sector. The interviews showed that this can ultimately benefit the industry as it will automate processes that are hazardous, unsafe and unsustainable, as well as increasing cost and production efficiency through anomaly detection and seismic processes. This can also provide strategic insights about the future and promote growth and improvements (Jong et al., 2015). The literature also confirms that digital transformation is a significant source of sustaining innovation in the NOGI because of its ability to improve and transform digital processes using AI and ML, changing the way people work (Tabrizi et al., 2019). All these effects contribute to optimizing processes through reimaging the supply chain.

The results showed similarities between the interviewees′ five perspectives. The government actors had different concerns and priorities than the oil and data companies. Their concerns focused on seismic data, to take full advantage of all resources and sustainability. On the contrary Shell, Lundin and Cognite focused on how and in what ways ML could change processes to increase cost

efficiency, safety and security. The literature shows that Norway has maintained attractiveness of the industry for private companies, while at the same time imposing strict regulations and heavy taxation on oil revenues. This has been done through clear tasks and responsibilities divided between the government, production companies, supply companies, and now the data companies within the structure of NOGI.

5.2 The oil price downturn and innovation

The literature shows that low oil prices lead to increased need for innovation. This observation fits the case of the NOGI very well. The Norwegian industry has been able to overcome the downturn in 2015 and the lower prices in the following years due to constant innovation and the development of new technology.

Due to the amount of data that the industry collects, industrial actors are active in utilizing opportunities to use data to improve processes, increase cost-efficiencies, safety and sustainability. These new technologies can lead to sustainable competitive advantages if companies are able to execute appropriate strategies accordingly, which they have done here by a mixture of hiring for in-house innovation projects and outsourcing tasks to specialized companies. Based on information from the experts shared, the conclusion is that most players outsource ML efforts.

The interviews further showed that each expert either believed that ML is a source of disruptive or sustaining innovation in the industry. These results build on existing evidence and are in line with the literature (Handscomb 2016, Decker 2016 and Hassani 2017). Innovation based on ML is possible because of the large pools of aggregated data the industry collects to create learning algorithms. There are opportunities to use this data to improve processes, increase cost-efficiencies, safety and sustainability. New technologies lead to sustainable competitive advantages when companies execute appropriate ML strategies. As stated by Andrew Ng, ML will become a key component of cost-efficient business strategies creating a strong competitive advantage (2018).

5.3 The disruptive role

According to Christensen, disruption describes a situation where a smaller firm with few resources has the ability to challenge established incumbent businesses. In the NOGI the disrupter is the data

companies that have entered the market and created partnerships with larger oil production companies. The technology companies and the data companies, like Microsoft Azure, and Cognite are bringing about cost efficiencies and optimization through automation. Specifically, incumbents, I.e., the large oil corporations, used to focus simply on improving their products and services for their most demanding customers, prioritizing what was the most profitable. However, incumbents came to realize that change needed to happen, and they started outsourcing big data development to tech companies. Disruption followed.

When asked whether ML is a sustaining or disruptive innovative force, all informants answered either disruptive or both. They agree that this is due to the possibilities presented through use of big data and building predictive ML models. Through these forms of new technology currently being developed and explored, the new data companies, with the advances ML technologies, are bringing about a paradigm shift while also improving current processes across the industry with innovative business practices.

6 Conclusion

6.1 Conclusion

We live in a time of radical digital transformation. A key element of this transformation is artificial intelligence and machine learning. These technologies are reshaping businesses, including the Norwegian oil and gas industry (NOGI).

This study examined the innovation effects that ML has brought to NOGI to enhance competitive advantages. ML, itself a new concept, proved to be important for the ways that the industry is developing and innovating. As the literature showed, new technologies can lead to securing sustainable competitive advantages if companies are able to execute appropriate strategies accordingly. Similarly, the interviews all discussed the value of big data, the use of ML in optimizing current processes through strategy and technology, and the possibilities of finding safer, more cost efficient and more sustainable approaches to the work currently being done through ML. Interviewees also expressed that new technologies can secure competitive advantages, despite most companies developing similar uses of AI and ML.

ML technology is represented throughout industry through partnerships between data companies and experts and the original oil and gas companies. Companies seek specific solutions to become more effective, safe and sustainable, an ambition also of the industry as a whole. The study ultimately showed that ML has brought disruptive innovation to the Norwegian oil and gas industry that enhances competitive advantages.

6.2 Limitations

A limitation of this study is that it was conducted under time constraints of 4 months and had limited resources. The study was performed from Lisbon, which made communicating in person with Norwegians difficult, however, video-chat worked fine. The informants who took part in the study proved helpful, despite the limited amount of people interviewed. Even though they represented five different perspectives within the industry, the five experts interviewed did not constitute a diverse group and could not provide a comprehensive view of the industry as a whole. The five people worked for different companies within NOGI.

A further limitation is that ML and AI are relatively new topics and the technology is advancing at a fast pace. What the companies are actually doing and developing is more often beyond what literature has had time to capture and comparing results from this study to the literature might not be accurate.

6.3 Recommendations

To develop this research further, complementary methods can be used, including large-scale surveys covering all involved actors. A larger sample would help to map the prevalence and scope of ML in in the Norwegian oil and gas industry (NOGI) today.

In addition, more comprehensive qualitative studies would increase the knowledge about ML technology in the sector. Studies should include samples of informants, covering several levels of government and different positions within major private stake holders.

Further, comparative research, comparing the NOGI with national and regional oil and gas industries in other regions of the world would add to the knowledge of the impact of ML on oil and gas globally. One could also interview more experts within the same companies and divided the actors′ opinions by area of expertise.

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8 Appendix

Questionnaire

1. What advanced technological innovations do you use?
2. Why do you believe ML is important? Where do you think there are ML opportunities in your company?
3. What can ML improve in the supply chain? What can it not do?
4. What gives your company competitive advantages related to tech? Does ML do this? How?
5. Are your company's ML efforts internal or external? What were the important factors that played a role in creating partnerships? Or why did you make the decision to make an effort internally?
6. How do your competitors use ML? Is this different from you?
7. What do you believe are the innovation effects of developing ML within your company?
8. Academics describe two types of innovation: sustaining which makes current products and services better and disruptive which brings about a paradigm shift. Which of these do you consider ML to be?

Interviews

Interview 1

Tomas Mørch- Former Director of The Norwegian Petroleum Directorate (NPD)

Tomas has spent the past 20 years working in the oil industry, with a master′s degree in resource technology and geology. After graduating he spent a few years offshore and then was brought into the NPD and has since had a variety of roles including spending the past 7 years as the Director of the NPD.

1. **What are trends you see in the oil industry today?**
    - It is all focused on accelerated development, with the focus on using technology to reduce costs and make each process more effective.
    - All steps within the oil extraction, production and distribution processes are costly there is a huge focus on reducing said costs, the technology that is being developed and explored today show that that the technology available is not only accelerating processes but helping explore more possible oil wells. The cost efficiency of the new technology allows the companies to find more natural resources and extract more efficiently.

2. **Why do you believe innovation is important? Where do you think there are AI/ ML opportunities?**

    - There is so much room for development- in this industry it is incredibly important to inn ovate or to "think new". Finding new opportunities and moving technology "forward".
    - What ML can do, is to help increase oil finding, improve analyzing seismic data, improve extracting methods and make them more efficient.
    - A big issue the oil industry is facing today are environmental challenges that come along with extracting and producing oil. The hope is that with improved methods through technology, we can make the various processes more environmentally friendly.
    - As oil extraction is an expensive process, making the processes more cost efficient is important. Also, there is opportunity in building better processes and equipment.

3. **What can ML improve in the supply chain? What can it not do?**

- Environment is #1 thing that is holding back processes. We want to create and develop processes that are sustainable. Which is difficult, but that is the main thing in the supply chain that needs to improve.
- ML can help improve analyzing seismic data.
- Technology has few limits and can do a lot.

4. **I see that NPD is responsible for all data from the Norwegian continental shelf. How do you utilize this data and other technology to gain competitive advantage over other established companies in the industry? Is this the use of ML? If so how?**

    - We have immense amount of data available that we use to give access to everyone for full transparency. A lot of companies get data from us.
    - HOW the data is used is up to the individual companies. This can help improve all processes.

5. **What have been important factors that have played a role in creating partnerships?**

- It is about control
- What is important to us is that the companies extract both the oil that is difficult to get and not just the "easy oil" as that is an inefficient way to do it. As he said you don't want the companies to just "ta skummen av fløten"
- Their role is to give advice to make sure that they are extracting and producing oil in a "smart way".
- They also approve sites

6. **Academics describe two types of innovation: sustaining which makes current products and services better and disruptive which brings about a paradigm shift. Which of these do you consider ML to be?**

- BOTH
- New ways to improve ways to use seismic data
- A lot of research is being done.
- Digging wells should get better
- Improvement and renewing

- There is a lot of changes coming especially in regard to environment and high wind
- There is going to be certain environmental requirements that are going to have to be upheld.

Other things said:
In the future they are going to have to focus on a balance of profit and environment. They are going to have to close down fields and open new ones how will this be done well? What does that entail? What has to change? Ultimately new technology can lead to finding new resources without digging (borring).

Interview 2

Roy Rusås- Chief Digital Officer at Petoro

"I have seen many problems between the companies because there is such a focus on competitive advantage and having the new "edge". It is about finding a balance between competing and working together to have the best technology and using the research available to it's full potential. The operations model has to improve drastically, overall new technology is going to change the principle of leadership. And the culture as the mindset and the structure is changed. Development is going to have to focus on the agile side of it all. The new technology being introduced changes the overall structure and AI is either way, if we want it or not, going to result in a paradigm shift.

When it comes to digitalization our main challenge is this. It is easy if a task previously done by a person is now done by a machine- that is one in and one out. But because there is a lack of trust in the system, people whose job tasks change due to the machines- who now have to change the way they work and learn new things. It is just more difficult to have to get people to change.

Now there is a lot of waiting- for the right licenses, approval etc- but the companies have to know what they actually want. But overall, 25% of employees are willing to change right off the bat. 50% thinks it all sounds complicated and like a lot of effort but do it with a little push and are ultimately willing to learn and to do the work. The reaction from the employees however is 70% about the culture. The biggest mistake companies make in these changing times is that they put data ahead of business- business and knowing what you want to do with it and how people will react – strategy – will ultimately play a larger role in how the changes will be received. Unclear problem statements are at the core. BI before AI – knowing what problem needs to be solved.

Reservoirmodels- parameters
Software to generate data
More information processed faster

ML and AI can help with reservoir models, the parameters and create innovative solutions on use and execution of generating large amounts of data. There is so much room for development- in this industry it is incredibly important to innovate or to "think new". In finding new opportunities and moving technology "forward". However, ML and AI has its limits; It cannot think like a business- and regard full circumstance and effects. Full transparency is key"

1. **What advanced technological innovations do you use?**

- We work with (Schlumberger) to organize the data we have available, in order to use it to it′s fullest potential. Ultimately, we are working with technology that helps the oilfields, the well planning and processing construction site to communicate with each other. We are working on ML to help for seismic data and search. Everything is going to be low carbon soon.
- Models for extraction

2. **Why do you believe ML is important? Where do you think there are ML opportunities in your company?**
    - There is so much room for development- in this industry it is incredibly important to inn ovate or to ″think new″. Finding new opportunities and moving technology ″forward″.
3. **What can ML improve in the supply chain? What can it not do?**
    - It cannot think like a business- and regard full circumstance and effects.
4. **How do you utilize technology to gain competitive advantage over other established companies in the industry? Is this the use of ML? If so how?**
    - Full transparency
5. **What were the important factors that have played a role in creating partnerships?**
    - Transparency and honesty and willingness to collaborate.
6. **How do your competitors use ML? Is this different from you?**
7. **Academics describe two types of innovation: sustaining which makes current products and services better and disruptive which brings about a paradigm shift. Which of these do you consider ML to be?**
    - ML and AI are going to be disruptive players in our industry. The second technology can help give accurate readings of the surface rather than having to dig to then find out it is a huge game changer for both costs, environment and what is left behind.

Interview 3

Jeroen Scheer- Business Lead Architect Projects & Technology at Shell

1. **What advanced technological innovations do you use?**
    - 5 categories
    - **AI and ML**: where we are investing heavily
    - **Robotics**: Visual Inspection use drones and robots on the platforms
    - **IOT**: sensors- using data
    - **Blockchain**: Block chain integrated supply chain for example if we create new refinery parts for manufacturing material storage material codes half-filled storage focus on the right data because that your administration where everyone is in their domain share data from vendor and then there is traceability oil and gas origination from which oil rigs did it where did it come from what borders as a crossing where is extracted where is that refined where does it go for full control so that they can always share data with the customs and for government and official purposes innovation is mainly used to learn and that is very important to show.
    - **Cameras:** which is a mix of AI robotics, where we use the cloud

2. **Why do you believe ML is important? Where do you think there are ML opportunities in your company?**
    - Innovation is mainly used to learn and that is very important to show.

3. **What can ML improve in the supply chain? What can it not do?**
    - We are not so brilliant at tapping into the right data to optimize processing, so it′s important to bring data into the right hands. The most important thing is IOT and sensors where there′s about 9 million data points per second collected from Shell. Placing and utilizing this data and optimizing it and building an optimization model is going to be incredibly important. There is ultimately right now too much data. If we have models to train we can fully automate the oil rigs. If we want to know where the data is and how we can analyze it specific places interesting or not we have a model based on all time data we can train then cut down drilling time from nine months to a week. This just means that you can not only make processes more efficient but you can find potential places to drill a lot easier and without doing as big of a ″deal″ of it. because you can use the data you already have to shorten the process from nine months to one week question 90% of what is done can be done through an iron machine learning but there′s also new energy and there′s always going to have to be made personal decisions where people have to be involved to consider all circumstances number four we are a tech company we use data to up to meet my aunt to and value chain. Final decisions will always have to be made by humans.

4. **What gives your company competitive advantages related to tech? Does ML do this? How?**
    - The effort that is made

5. **Are your company's ML efforts internal or external? What were the important factors that played a role in creating partnerships? Or why did you make the decision to make an effort internally?**

- The overall turnover for shell is around €300 billion a year and ask they are a oil and gas technology company they are not Microsoft and Google specific knowledge and experience is incredibly important and collaboration is the focus right now they have a 25 year strategic partnership with Microsoft azure but they also have job logical data that they work with Amazon on when it comes to internal versus external Shell does not fully rely on a partner to get competitive advantage. Core capabilities need to be in house and that is a specific strategy that we have put down to focus on getting core values in house. However, there are also things that we know that we need help with like data crunching. Here we need experts to do this well. There is also a clear integration- there is a data science focus and overall our data science efforts are around 70% internal.

6. **How do your competitors use ML? Is this different from you?**

- In comparison Exxon mobile is always out to protect their core so they use technology only for efficient reasons and it′s more similar to a military operation.

8. **Academics describe two types of innovation: sustaining which makes current products and services better and disruptive which brings about a paradigm shift. Which of these do you consider ML to be?**

    - There is a clear answer that it is both. It is very clear that his competitors mainly do it for sustaining the kind of just protect the cord that they have and make the processes that they already do as efficient as possible however as shells overall goal is to be the number one green electricity and Hydro company in the world it′s important to use innovation folks that innovation and having it be a disruptive sing in the industry.

Interview 4

Kari Nielsen Director of Production at Lundin Petroleum

1. **What advanced technological innovations do you use?**
    - ML – different forms – see Cognite breakdown
    - Digitalizing all processes, all reports are now digital, and they are aiming to be ″paperless″.
    - Attempting to eliminate all manual tasks
2. **Why do you believe ML is important? Where do you think there are ML opportunities in your company?**

    - Licence to Operate
    - HMS – helse miljø sikkerhet (Health, environment and safety)

    – The main aim is to automate as much as possible in order to have less people offshore as this can be a huge liability in regards to HMS.
    - Conditions based- anamoly detection-
    - Cost efficiency
    - Production efficiency

3. **What can ML improve in the supply chain? What can it not do?**
    - Security- has to come first- trial and error is not an option - Don′t dare to fail

4. **What gives your company competitive advantages related to tech? Does ML do this? How? How do your competitors use ML? Is this different from you?**
    - Everyone is doing the same but it′s just about doing it fast, When it comes to ML, everyone is doing similar things, but it′s just about doing it fast. At Lundin, due to smaller size we can make things happen faster. We can produce fast, make decisions fast and the fact that we can run the system fast gives us a competitive advantage

    What is important when investing in innovation within the company?
    - Encourage innovation in house

5. **What were the important factors that have played a role in creating partnerships?**
    - Modernisering- big data – had to innovate and get in a company that could

6. **What do you believe are the innovation effects of developing ML within your company? Academics describe two types of innovation: sustaining which makes current products and services better and disruptive which brings about a paradigm shift. Which of these do you consider ML to be?**

- ML and the maximum utilization of BIG DATA will disrupt the industry and change the industry and the processes and supply chain drastically.

Interview 5

Sindre Hammerlund- Software Engineer at Cognite

Cognite works with both Lundin and Aker BP in Norway and deliver digital solutions made for the oil platforms. The core of what they do is to collect and organize all active data in one place. Important things mentioned in the interview:

- Asset data insight
- Live data mixed with set systems
- Accurate 3D models of the oil platforms can help optimize efficiency by keeping all partners in the loop at all times.

1. What advanced technological innovations do you use?

But the following relatively new technologies are used

Photogrammetry

- Software that makes it possible to build 3D models automatically using images

Machine Learning

- Computer vision
    - OCR (Optical Character Recognition), to read flow charts and retrieve information automatically. In addition, this is used to read physical ID tags that identify equipment.
    - Object recognition, for example use live video stream to keep track of different objects.
    - Look for security issues, for example electrical equipment that is damaged (cables etc.)
- Regression,
    - to be able to use live sensor data to optimize production.
- Classification,
    - to be able to classify point clouds from laser scans. So that we can decide what is vegetation, streamlines and masts.

Physics Simulators

- Depending on which Yield optimization case we are working with, it may be appropriate to run physics simulators with live data. In this way we can better understand how time series values real.

AR

- To be able to utilize data in CDF and make it available for different applications.

Game Engines / Unreal Engine

- To create real-world 3d models of equipment and areas.

Lidar Scans

- To generate real-world 3D models in the form of equipment and areas.

2. Why do you believe ML is important? Where do you think there are ML opportunities in your company?

ML can be used for several different things. We mainly see two uses that ate and will be especially important to us in the future.

Computer vision
- With photogrammetry for automatic construction of 3D models.
- Object detection to be able to detect rust, leaks, cable breakage and the like.

Yield Optimization
- Our estimates indicate that yield optimization is the category of solutions, the majority of which is 60% of possible value creation for our customers. Ability to use live sensor data to optimize production.

3. What can ML improve in the supply chain? What can it not do?
- When we started Cognite, we had big plans for how we could use ML to produce oil smarter and move from calendar-based maintenance to state-based maintenance. Eventually it turned out that it was not so easy, this was mainly due to poor data quality, and that seeing relationships between symptoms and cause required a larger data base than we were able to obtain.

4. How do you utilize technology to gain competitive advantage over other established companies in the industry? Is this the use of ML? If so how?
- What is important to us is that we constantly develop products that deliver value to customers. That's why we spend a good amount of time identifying that greatest needs of customers. In the next phase, we map how long it would take to develop a solution to those problems. Finally, we select number of "use cases" to focus on based on a cost/ benefit assessment.

5. What were the important factors that played a role in creating partnerships between Aker BP, Cognite and Google Cloud?
- Aker BP, like many other industrial companies, experienced great challenges when it came to digitalization. The data to be used in different projects was originally stored in different source systems was in several different formats and was not optimized for use in applications or understanding. Over a period of about a year, the management of Aker Bp in collaboration with John Markus Lervik mapped the needs and concluded that a cloud-based data platform could solve several of the challenged that were constantly encountered. In the startup phase of Cognite John Markus brought Geir Engdhal, a former Google employee as CTO. The various Cloud players were mapped.

6. How do your competitors use ML? Is this different from you?
- our biggest competitors seem to use ML in similar ways to us. Ultimately, it is about using ML in a smart way (and on the right projects). In addition, it is largely about utilizing the data ML generates in the best possible way. Which player is currently the best at this date will only show in the future.

8. Academics describe two types of innovation: sustaining which makes current products and services better and disruptive which brings about a paradigm shift. Which of these do you consider ML to be?
- In order to place ML in one of the two segments, I think it is important to look at the scope of ML. A good portion of the various uses of ML will serve as small improvements in overall performance, but also a good portion can radically change the way a product performs and functions. I am therefore somewhat uncertain as to whether ML as a whole falls into one or the other category.

Disruptive Innovation

- Ex. In computer vision where the intention was to classify images and extract information from images or video, ML has helped to radically change the performance and basis for building models. This also applies to
    - OCR, read text and symbols in images.
    - Other models that require large data bases for training.

Sustaining Innovation

- If ML is used to build statistical models to predict something that has previously been done using mathematical methods then the category of incremental innovation falls to me. This can for example apply to the development of simple classification or regression models.