Barriers for Adopting Additive Manufacturing in the Norwegian Oil and Gas Industry

- a qualitative case study of Equinor`s suppliers

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Sammendrag:

Additive Manufacturing er en teknologi som bygger deler i lag fra bunnen og oppover. I denne studien har vi undersøkt barrierer for å implementere AM som produksjonsmetode i den norske olje- og gassindustrien. Vi har brukt følgende forskningsspørsmål:

Er AM en disruptiv teknologi for den norske olje- og gass industrien, og hvordan kan den forandre industrien?

Hvilke barrierer må norsk olje- og gassindustri overkomme for å implementere AM i stor skala? Er AM, som teknologi, moden nok for industrien?

Vår forskning avdekker flere likheter med definisjonene fra kjente innovasjonsteoretikere og konkluderer med at AM kan betraktes som en disruptiv teknologi for denne bransjen. Videre viser denne oppgaven at implementering av AM i stor skala vil føre til flere endringer. Disse endringene krever at industrien bruker en ny forretningsmodell. Leverandørene spiller alle en rolle i et stort og komplekst nettverk av leverandører og underleverandører i bransjen. Dette resulterer i at de har forskjellige perspektiver på hvordan implementeringen av AM vil påvirke dem. Denne oppgaven viser at det er flere barrierer industrien må overkomme for å implementere AM i stor skala. På grunn av alle de barrierene vårt studie har avdekket, konkluderer vi med at AM ikke er moden nok for industrien, ettersom teknologien nå befinner seg i en utviklingsfase. For at AM skal være et kommersielt levedyktig alternativ, må Equinor dele noe av risikoen med sine leverandører. Dette krever at Equinor offisielt godkjenner AM som produksjonsmetode og utvikler en samlet strategi mot sine leverandører. At Equinor spesifiserer i kontraktene at AM er en foretrukket metode er nødvendig for å redusere risikoen til leverandørene. Dette vil gjøre leverandørene i stand til å gå videre med AM.

Stikkord for bibliotek: Additive Manufacturing, 3D print, disruptiv innovasjon, disruptiv teknologi, verdikjede, forretningsmodell, olje og gass, adopsjon av ny teknologi

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Summary:
Additive Manufacturing is a technology that builds parts in layers from the bottom and up. In this exploratory study we have investigated barriers for adopting AM as a production method in the Norwegian oil and gas industry. We have used the following research questions:
Is AM a disruptive technology for the Norwegian oil and gas industry and how may it change the industry?
What are barriers the Norwegian oil and gas industry must overcome for implementing AM on a large scale? And is the AM technology mature enough for the industry?

Our research unveils several similarities to the definitions of well-known innovation theorists and concludes that AM can be considered a disruptive technology for this industry. Further, this thesis shows that the implementation of AM on a large scale will lead to several changes. These changes require the industry to use a different business model. The suppliers all play a part in a big and complex network of suppliers and sub suppliers in the industry. This results in them having different perspectives on how the implementation of AM will affect them. This thesis shows that there are several barriers the industry must overcome for the implementation on a large scale. Due to all the barriers our study unveiled, we conclude that AM is not mature enough for the industry as the technology finds itself in a development phase. For AM to be a commercially viable option, Equinor must share some of the risks with their suppliers. This requires Equinor to officially approve AM as a production method and unite in a strategy towards their suppliers. Equinor specifying in the contracts that AM is a preferred method is necessary to mitigate the risk for their suppliers. This enables the suppliers to move forward with AM.

Keywords for library: Additive Manufacturing, 3D print, disruptive innovation, disruptive technology, value chain, business model, oil and gas, adopt new technology

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“If you look at history, innovation doesn’t come from just giving people incentives; it comes from creating environments where their ideas can connect.”

– Steven Johnson

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Finally, we would also like to thank all the respondents who were positive and provided us with good information during interviews. In what we assume was a hectic workday, we cannot be more thankful for them using their valuable time on us.

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Abbreviations

AM	Additive Manufacturing
CAD	Computer Aided Design
CEO	Chief Executive Officer
CNC	Computer Numerical Control
IP	Intellectual Property
LWDC	Laser Wire Direct Closeout
MMO	Maintenance, Modifications and Operations
NASA	National Aeronautics and Space Administration
NOK	Norwegian Kroner
OEM	Original Equipment Manufacturer
O&G	Oil and Gas
SBIR	Small Business Innovation Research Program

1 INTRODUCTION

The first additive manufacturing machine was invented in 1983 by Chuck Hull. It was primarily invented to make prototypes and product models. The technology has since evolved to become faster, more precise and capable of handling several materials including metals. The technology is today used as a production method in many industries for components that cannot be made with other technologies. As the technology advances it will also be applicable for serial production of complex components. This makes it very interesting for the oil and gas industry because of the benefits we will cover in chapter 2.2.

In our third and second last semester, both authors of this master thesis had a student internship at Equinor's department of digitalization. One of the steps for digitalizing the organization is to implement additive manufacturing into their value chain. Equinor plays a major role in the industry as they are the biggest operator in the Norwegian continental shelf with the Norwegian state as majority shareholder owning 67%. This creates the debate if Equinor has a certain responsibility to help implement technologies that can benefit our countries most profitable industry (Larsen, 2019).

Through our internship, we were made aware of what the technology potentially can do for Equinor, but there are still a lot of barriers to overcome for a large scale adoption of AM in the industry. We have in this study explored what suppliers consider barriers and supplemented with what we learned during our internship in light of well-known and respected innovation theory.

Gartner, a research and consultant company publishes a yearly report about emerging technologies and how long it will take before they become mainstream. After twenty years of existence, they year after year manage to be quite accurate with their predictions. In their report for AM in 2018, they conclude that AM still has another 5-10 years before the technology has reached a plateau of productivity in oil and gas (Appendices I).

1.1 Research questions

Based on our internship experience at Equinor and our chosen theme "Barriers for adopting Additive Manufacturing in the Norwegian oil and gas industry", we have made the following research questions:

RQ1: Is AM a disruptive technology for the Norwegian oil and gas industry and how may it change the industry?

The term disruptive in this context, implicates something that shakes up an industry. Considering innovation theory, we want to discuss in which ways we can look at AM as a disruptive technology and investigate how it may change the industry.

RQ2: What are barriers the Norwegian oil and gas industry must overcome for implementing AM on a large scale? And is the AM technology mature enough for the industry?

To this day, Norwegian oil and gas industry seems to be unwilling to invest in AM as a technology. Is AM mature enough for the Norwegian oil and gas industry? We want to discuss the main barriers related to the technology based on the data we have gathered. Further, we will discuss which barriers the technology has to overcome to be a commercially viable production method for the Norwegian industry.

1.2 Thesis structure

Chapter 2 is a background chapter about the technology. We will in this chapter go through what additive manufacturing is and what it can do for the industry.

In Chapter 3 we will provide the theoretical framework for this master thesis. Firstly, we will present relevant theory about disruption and innovations. Here we will also present relevant theory regarding business model innovations and diffusion theory. Diffusion theory describes how new and emerging technologies are spread in an industry. As we wish to investigate barriers for how the industry can adopt a new way of manufacturing this theory is crucial for our analysis. Further, we will present organizational theory. We will explain the concept of a value chain, transaction costs and how an organization can gain value from coordination.

In Chapter 4 we will present our chosen research design and discuss our methods for collecting data. We will also present our case and suppliers we have gathered data from.

Chapter 5 is where we will analyze and discuss our findings to answer our research questions. First, we will discuss in which way AM can disrupt the Norwegian oil and gas industry and how AM may change it. Secondly, we will discuss the main barriers for implementing AM and evaluate whether the technology is mature enough for the industry.

In Chapter 6 we will conclude with what we have analyzed in Chapter 5. We have also included a Chapter 7 to discuss weaknesses, position in literature and possible areas for further research.

2 ADDITIVE MANUFACTURING – The “new” method

To be able to understand the barriers for an industry to adopt a new manufacturing method, we will in this chapter explain the concept of conventional methods and the technology of Additive Manufacturing. To be clear, AM can also be used in a combination with conventional methods.

The process of classifying a manufacturing process starts with a material stock. The type of material being used determines the primary shaping process of the product. Of conventional methods we have casting, molding or forming the material (Ashby, 2017). The secondary process involves machining or heat treatment. Machining can be done by cutting, turning, drilling or grinding away material to achieve the desired form from the piece of material. This applies to what a [1]CNC machine does. These machines are considered as one of the traditional methods. As opposed to AM that adds material, a CNC machine transforms a stock piece of material by a removal process. Heat treatment is done afterwards to decrease material stress that has occurred inside the part from the primary shaping process. Last comes the third and final step: Joining and finishing. Joining can be done by fastening, welding, snap fits or adhesives. Finishing can be done for gaining further properties. The finishing process may include coating, polishing or anodizing the part (Ashby, 2017).

Before we present what AM is, we want to make something clear. Mainstream media and a lot of people in the industry use the terms 3D-print and Additive Manufacturing interchangeably. This can cause some confusion in our thesis since our sources talk about both, when meaning the same thing. Until now AM is the all-inclusive term and is commonly associated with industrial applications of the method including mass production of components. Both the terms are referring to a process where a component is being built layer by layer. (GE, 2019)

[1] CNC machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to control a range of complex machinery, from grinders and lathes to mills and routers. With CNC machining, three-dimensional cutting tasks can be accomplished in a single set of prompts. (Astro, 2017)

2.1 Additive manufacturing

AM is today one of the fastest growing automated manufacturing techniques. The technology makes it possible to go from CAD models to finished components with little to no aftertreatment before the parts are ready for use. In conventional processes for manufacturing specific parts 2D drawings have been used, but with AM comes complex 3D models (Prakash, K. Nancharaih, T. Subba Rao, V. 2017).

This process of converting the geometric data before printing may also be referred to as "layering". With the help of a computer and the right software, the model is then divided into horizontal layers perpendicular to the vertical "z-axis". The printer then knows where to lay out the material in each layer, and builds the part starting from the bottom. This process generates each layer over the previous one until the part is complete. The process can be described in five basic steps (Prakash et al, 2017):

1. A 3D model of the part as solid.
2. Next step is converting the file into "layers" like previously mentioned. This will be done by computer aided help resulting in a standard AM format, or the most updated AM file format.
3. The file will then be sent to an AM machine that manipulates the file. The manipulation could be changing the position, the orientation or scaling the part.
4. The part is then built in layers by the machine.
5. Cleaning and aftertreatment.

2.1.1 Construction competence: Adding vs subtracting

Construction competence today is based around casting, molding or forming the chosen material, before removing material in the *secondary process* to create the wanted geometry. With AM the competence is tied to adding material and in the long run can completely change the way products are designed and built (Bromberger & Kelly, 2017). In contrast to previous methods AM has almost no restrictions to shape. Because of this, parts can be made smaller, lighter and more stable, but this new way of constructing parts must be learned (Mann-Hummel, 2018).

2.1.2 Limitations of metal AM

Both the cost of machine and material feedstock for metal AM is still very high. Because of this it may still be more cost-effective for most applications to choose a conventional method. Printing a part is also very time-consuming. To remain cost-effective, it is therefore desired to have the machine printing as often as possible with minimum idle time. The largest AM machines for metal have a small build volume of around $250mm \times 250mm \times 300mm \ (x \times y \times z)$. This volume is small compared to other options. (Redwood, 2018)

2.2 Benefits of AM in Oil & Gas

Benefits	Explanation
Visualization	The aesthetics of a part may only be evident when viewed as a prototype.
Repair	In many cases the cost of repairing a part with AM will be lower than manufacturing a completely new one.
Component cost	Parts can be redesigned to require less material while still meeting the required mechanical properties. This will result in a lower component cost when less material is needed.
Optimized function	Components consisting of several parts can be merged into one with improved or additional functions. This will also save assembly time.
Environmental footprint	Producing a part with AM creates almost no wasted material. When a part is redesigned and weighs less, it will also help cut emissions during transport. Transport will also be mitigated if a part is printed on, or close to worksite from a **virtual warehouse**.
Obsolete parts	Outdated parts can be remade with AM, resulting in minimal rebuilding of the surrounding system when being replaced.
Alternative materials	Expensive materials can be replaced by cheaper alternatives that still meet the required mechanical properties.
Lead time[2]	Printing parts on demand can reduce the lead time from weeks to days.
Virtual warehouse	Having a cloud-based storage of CAD models for parts to print helps cut physical storage. This will require a new **business model**.

Table 1: Overview of benefits for AM in oil and gas

[2] Lead time: A good example on timesaving is from Joe Gibbs Racing who started manufacturing a duct outlet with AM. This has reduced the overall process of designing and machining the part from 33 to just 3 days. (Giffi & Gangula, 2014)

Table 1 explains which areas the Norwegian oil and gas industry can benefit from using AM. This also applies to the global industry. Today, Equinor have completed one pilot project and are currently in the process of successfully executing another. The first one was some plastic covers that did not require much testing before installing. The second, and still ongoing project is a collaboration between Equinor, Tronrud Engineering and FPE Sontum. FPE Sontum have placed the order of Twenty-nine identical fire hose inlets from Tronrud Engineering. The parts printed in titanium, are supposed to be installed on a production vessel in the Johan Castberg-field for Equinor. During the project they have redesigned the original part to weigh less, in addition to optimizing its flow function. (E24, 2019)

2.3 AM in other industries

The field of oil and gas is one of many that can use this method of manufacturing to make their supply chain more effective. For us to better understand what is happening in the Norwegian oil and gas industry, we have also researched other fields using AM, in hope of finding correlations between the industries in our analysis. We will start with the aero plane industry, before we continue with NASA and Automotive industry.

The aerospace industry is very concerned about weight. They are always trying to improve methods for making parts more efficiently, with the same or better mechanical properties. Until now there has been a focus on the parts for engines. These components often weigh a lot and have a complex geometry. As an example, with aircraft operations, it has been estimated that a weight reduction on parts that are manufactured by AM technology could reduce as much as 28001015Joule/y (Watson, J.K. Taminger, K.M.B. 2018). In 2016, the company GE started using AM for manufacturing a fuel nozzle. This is done by a method called *Direct Metal Laser Melting.* The result of using this method, has brought the weight of the nozzle down by 25 percent and upped the fuel efficiency by 15 percent (Winick, 2017). This led to over 10.000 orders being placed after the *Federal Aviation Administration* and *European Aviation Safety Association* approved the nozzle in December 2016.

Regarding NASA, the International Space Station that orbits the earth heavily depends on cargo supplies for the astronauts onboard. The shipments mainly consist of tools, supplies and parts. When a shipment can take weeks for critical components to get there, NASA has had to consider alternative options and have now installed a 3D-printer on the ISS. This is now reducing the time it takes to get ahold of parts from weeks to hours or minutes. NASA also states that the first astronauts on Mars will be using the technology to produce necessary tools and equipment for the mission. (National Aeronautics and Space Administration, 2014)

Nasa has also invented their own AM technology that they began testing in 2017. This method is called *Laser Wire Direct Closeout* and is for printing metal with the specific purpose of manufacturing a nozzle. Nozzles might look like a simple thing to make due to the simple surface design, but they are in fact very complex (Stanfield, 2018). With the new LWDC method of production, NASA hopes to greatly reduce development, time and cost. This technology is now being licensed for commercial applications in the industry (Stanfield, 2018). The technology was developed through NASA's *Small Business Innovation Research Program.* The SBIR program is for smaller corporations with the purpose of improving advanced manufacturing methods. (Torrez, 2019)

According to Forbes, the Automotive industry has also been a major adopter of AM technology (Goehrke, 2018). BMW has since the 90's used AM for prototyping. For one of their new models: BMW i8 Roadster, they have started printing a window guide rail. Using one of HP's Jet fusion printers they can manufacture a hundred of these parts within twenty-four hours (BMW Press Release, 2018).

Volkswagen have also announced their integration of a Hewlett Packard metal jet printer in operations. They will start using these printers for mass production of parts with complex geometries and advanced tooling (Goehrke, 2018). In 2014 Deloitte, an international auditing and consulting company did a study where they pointed out the benefits for the automotive industry adopting AM. In their study they try to understand valuable drivers and alternative pathways the industry might choose to take. They conclude with that the industry is driven by volume. As the speed of an AM system is getting faster it will be more profitable for manufacturers to implement this method in more areas of production.

Some of Deloitte’s key discoveries for using AM in the Automotive industry (Goehrke, 2018):

- Ability to design more complex parts
- Possibility of redesign, leading to less use of material.
- Less material used for a given part will result in weight reduction
- Ability to print parts on demand may have a major impact on decreasing physical storage
- To reduce assembly time, components with different functions may be designed and merged into one

These are examples of what is happened in other industries. Based on the benefits we covered in Table 1 we can argue that many of the drivers for adopting AM also apply to other industries.

3 THEORY

3.1 Innovation Theory

In this chapter we will present the innovation theory and literature we have used to understand the situation. The theory we have chosen will be our tools when analyzing our collected data to answer our research questions.

The word Innovation comes from the Latin word Innovare. Joseph Schumpeter (1934) defines innovation as new combinations, of new or existing knowledge, resources and machines. This also includes new products that get introduced to a market, new production methods, new ways of organizing and new ways of marketing a product or a service (Fagerberg, 2005). As AM is a new production method in oil and gas, we will further discuss applicable innovation theory for our case.

3.1.1 Disruptive Innovations

To be able to explain if using AM in the Norwegian O&G industry is a disruptive innovation, we will in this chapter need to explain what a disruptive innovation is. First off, we want to present the history of evolutions tied to the term, before we move on to explaining the link between our thesis and disruptive innovation.

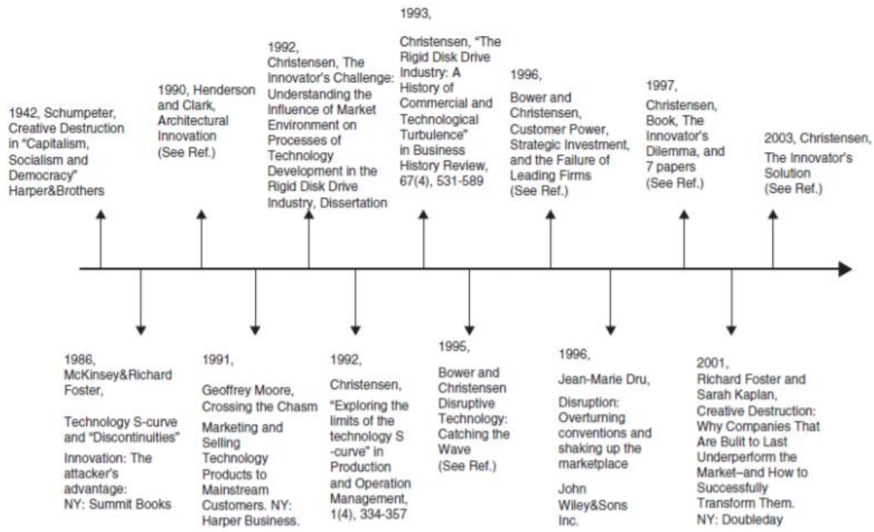

Figure 1: Timeline of the evolution of Disruptive Innovation Theory (Yu & Hang, 2010)

By the timeline above, we can see that this is not a new phenomenon. The theory regarding disruptive innovations was first introduced by Schumpeter in 1942 under the term “Discontinuous innovation” (Yu et al, 2010). It has since been evolved through time before Clayton Christensen (1995) introduced the new term: “Disruptive innovation”, in his article “Disruptive technologies: Catching the wave” (Bower & Christensen, 1995).

When someone is using the term disruptive technology correctly, they are talking about a new technology that makes the old one less desirable to use. Christensen concludes that it is not the technologies themselves that cause the disruption, but rather the business models the technology lays grounds for (Garnes, 2018).

In the article “What is Disruptive innovations?” (Christensen, Raynor & McDonald, 2015), they define a disruptive innovation by introducing the terms; low-end or new-market footholds. In the case of new-market footholds, disrupters create a market where none existed, as they put non-consumers into consumers. Low-end footholds exist because incumbents typically try to provide their most profitable customers with ever-improving products and services. (Christensen, Raynor & McDonald, 2015)

They further tell us that the criteria for a disruptive innovation is that it originates from one of these two “market scenarios”, and that the disruptive innovation is made possible because they get started in these two types of markets that incumbents overlook. Bower & Christensen (1995) say that a criterion for their definition is that a disruptive technology brings a new value proposition to the market. Further they say at the initiation of a disruptive technology can be inferior compared to other products in the market, but also bring new customer values, such as being smaller/larger, more practical, cheaper etc. (Bower and Christensen, 1995)

Christensen, Raynor & McDonald (2015) claims it is not enough that something shakes up an industry to call it disruptive. They explain this to us by using Uber as an example, in which they claim that this is not defined as disruptive. The reasoning being that Uber did not originate from either low-end or new-market footholds. Instead, Uber built a position in the mainstream taxi market first. (Christensen et al. 2015)

Over the years other researchers have come up with a widening perspective on disruptive innovation have offered other definitions for a disruptive technology. In 2006, Govindarajan and Kopalle introduced the term “high-end disruption”, in which the technology provides a service or product which has better attributes, but a higher price. (Govindarajan & Kopalle, 2006)

In the article: “Catching the wave”, Bower & Christensen explain the difference between sustaining technologies and disruptive technologies. Sustaining technologies are described as the technologies which the incumbents are currently offering to their customers in the mainstream market. This is developed in incremental steps to improve the service or product. In other words, they give customers something more or better in the attributes they already value. On the other hand, disruptive technologies offer customers a different set of attributes compared to what is valued from the customers in the mainstream market. These types of technologies also tend to perform far worse in one or two dimensions that are important to these customers.

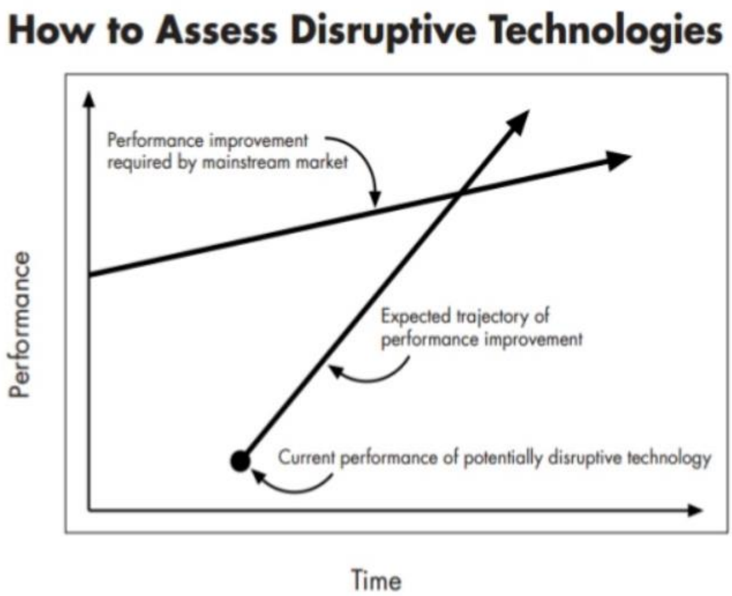

Figure 2: How to assess disruptive technologies (Bower & Christensen, 1995)

Bower and Christensen (1995) states that; as a rule, mainstream customers are unwilling to use a disruptive product as a replacement for a known product. As we can see from figure 2, the curve of performance by the potentially disruptive technology will intersect with the curve of performance required by the mainstream market. In the article “What is disruptive innovation” (Christensen et al, 2015), they emphasize that disruption is a process and tells us that when mainstream customers start adopting the entrant’s offerings in volume, disruption has occurred. Again, we can see from figure 2 that disruptive technologies don't catch up with mainstream customers until the quality catches up to their standards.

In the article "Catching the wave", the authors ask an interesting question regarding leading companies within an industry; *"Why is it that companies like these invest aggressively-and successfully-in the technologies necessary to retain their current customers but then fail to make certain other technological investments that customers of the future will demand?".* They follow this up with a very interesting statement; *"these same companies are rarely in the forefront of commercializing new technologies that don't initially meet the needs of mainstream customers and appeal only to small or emerging markets"* (Bower & Christensen, 1995).

The authors further conclude that customers wield extraordinary power in directing a company's investments. Because of this most leading companies within their industry focus on their sustaining technology and continuously improve their product according to customer demands in the current mainstream market they are serving. To answer the question in the article, the authors say that the fundamental reason for this is that leading companies succumb to one of the most popular and valuable management dogmas; "They stay close to their customers". In other words, the managers keep allocating company resources to improve their "sustaining technologies". They do this to please the performance demanded and required by their mainstream customer. Based on this, any rational resource-allocation process in companies serving established markets will choose going upmarket rather than going down. This seems only logical and is based on the rationale that the resource-allocation processes that are critical to a company`s profitability and competitiveness will not - and should not - direct resources to markets in which sales will be relatively small.

The authors explain further that a company`s revenue and cost structures is a decisive factor when it evaluates proposed technological innovations and highlights that disruptive technologies generally look financially unattractive to established companies. In well-managed companies, where managers are evaluated on their ability to place the right bets, often with short term investments horizons, it makes sense that mid- and top-level mangers back projects in where the market seems assured. Companies are aiming to use their resources well and set relatively high thresholds for the size of the markets they should consider entering. As a result of this, established companies often have installed higher cost structures to serve sustaining technologies than those required by disruptive technologies. They further answer their question by saying the problem is that managers keep doing what has worked in the past, and states that the processes in well-managed companies are bad at funneling resources into projects consisting of disruptive technologies. The reason for this is that the companies will not be serving their most profitable customers and the profit margins seems unattractive. (Bower & Christensen, 1995)

Due to the reasoning above, Bower and Christensen tells us that companies have big challenges when it comes to coping with sustaining and disruptive technologies within the same organization. From this topic we are introduced to another perspective. The term ambidextrous organizations, which essentially is an organization that is structured and designed in a way that manages both sustaining and disruptive technologies within the same organization. Ambidextrous organizations we will cover further in the chapter about organizational theory.

3.1.2 Business models and business model innovation

In this chapter we will introduce the concept of a business model, before we present theory on how companies are able to innovate through their business model and what the challenges are concerning this. As research regarding disruptive innovations have mentioned new business models, we will in this chapter go through what a business model is before we continue with business model innovations.

Over the recent year's researchers have come up with many different approaches and definitions when it comes to business models. Alex Osterwalder is widely known for his work and especially "the business model canvas". Osterwalder and many others have chosen to distinguish between business model and business strategy. In 2010, Osterwalder portrays the following definition of a business model; *"A business model describes the rationale of how an organization creates, delivers and captures value"* (Osterwalder et al., 2010, p. 14). From his earlier work he says that a business model is a conceptual tool that offers a composition of elements, so that the company can express its logic of earning money. Understanding these elements and their relationship is vital for doing so. It describes the company's value proposition and how it is offered to its customers, as well as the infrastructure required by the company to be able to deliver this value.

In the article "Business Model Innovation: Opportunities and Barriers", Henry Chesbrough explores the barriers to business model innovation, in which he states the following;

> *"The economic value of a technology remains latent until it is commercialized in some way via a business model. The same technology commercialized in two different ways will yield two different returns." (Chesbrough, 2010, p. 354)*

In this, Chesbrough implies that a great business model to fit the technology is vital for successfully taking advantage of a new technology when commercializing it. In the article he stresses the importance of companies being able to experiment with business models so that when a new and promising technology presents itself, the companies can implement it successfully.

Chesbrough highlights earlier research done by Christensen et al. and Amit & Zott, in which they identify that the root of the tension caused by disruptive innovation is that the established business model used for their existing technology, might not be enough when trying to exploit the emerging, disruptive technology. In other words, the disruptive technology often requires a different business model than the one they currently use for their existing technology. The managers recognize the right business model, but development is resisted due to conflicts with the prevailing business model or with the underlying configuration of assets that support that prevailing model. (Chesbrough, 2010)

In further research done by Chesbrough, he disagrees with Christensen et al. and Amit & Zott. He says that the problem often occurs because it is far from clear for the managers what the right business model ought to be. Chesbrough suggests that one way managers can overcome these barriers, is to experiment with alternative business models through a "mapping approach", where he mentions the business model canvas provided by Alex Osterwalder.

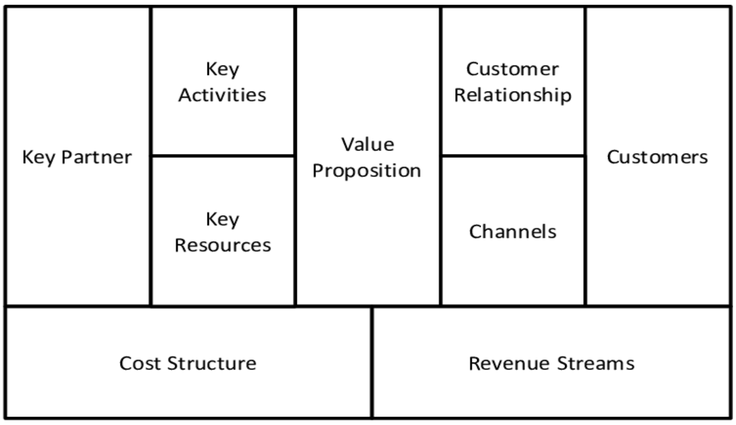

Figure 3: Business model canvas (based on Osterwalder and Pigneur 2010)

In the figure 3 we can see the categories that Osterwalder's business model consist of. The nine different categories he refers to as "building blocks", namely; Key Partners, Key activities, Key resources, Value proposition, Customer relationships, Channels, Customers, Cost structure and Revenue streams. Osterwalder puts these nine blocks into four different dimensions; Product, Customer interphase, Infrastructure management and Financial aspects.

Chesbrough states that it does not only makes sense for businesses to develop and innovate their business models, but they are in fact in need of developing their capability to innovate the models. Businesses can do this with business model experimentation. He further says that while business model innovation is vitally important, it can be hard to achieve as the barriers for changing the business model can be tough (Chesbrough, 2010). Mapping tools such as the business model canvas provided by Osterwalder are helpful, but not always enough.

Chesbrough (2010) stresses that they must be able to find a model before the disruptive innovations render their traditional models redundant. One of the barriers for business model experimentation he explains to by looking at the people in charge of these activities. Managers are likely to resist experiments as they may often conflict with the more traditional configurations of the firm assets. This might threaten their ongoing value to the company. Further he explains that typically the gross margins for the emerging technology are initially far below those of the established technology, and as the firm allocates its capital to the most profitable technology, the established technology will be favored. The disruptive technology can then end up being starved for resources. This is based on the same logic as we provided earlier by Christensen and Bower when talking about the management dogmas most companies succumb to; “they stay close to their customers”.

The CEO`s of small businesses will often tend to resist working on a new model as they feel attached to the existing model and the new one might seem threatening. In big companies the problem could occur as the managers in charge of experimenting often change positions within the company and is therefore unable to fully complete such experiments. (Chesbrough, 2010)

All of this represent challenges as organizations are in need to continue to perform well with their current business model, while at the same time undertaking the experiments necessary to nurture a new model. As the search for a new business model often requires an extended period of co-existence between the current and new models. It becomes a delicate balancing act knowing when to shift resources from the former technology to the new one, with the possible career consequences for the managers involved. (Chesbrough, 2010)

3.1.2.1 Pay-per-use

This is a business model that works well when the service is effectively metered. For the customer it eliminates the risk of buying expensive equipment and having the necessary competence. Instead the customer pays a subscription or every time they use the service (Reason Street, 2019). For AM this business model can be applicable for large print centers. Suppliers who don’t yet have the construction competence or economic capacity to buy an industrial 3D printer, can then purchase the service in cases when it is beneficial.

In summary, we have explained different views from previous research regarding disruptive innovations. We have also covered what a business model is, using Osterwalder’s model. Further we covered the importance of business model experimentation, when trying to implement a disruptive technology. We will now continue with research of how a new technology spreads in a market. Since AM arguably has just started to spread in the Norwegian oil and gas industry, we will be referring to their models in our analysis.

3.1.3 The theory of diffusion

The theory of diffusion tells us the spread rate and scope of the technology. The term was first introduced in 1903 by the French social psychologist Jean-Gabriel De Tarde. He is considered the originator of the S-curve according to Garnes (2018).

Figure 4 illustrates how the emerging technology shown in orange, has a slow spread rate in the beginning. This is partly because users are skeptical, and partly because of the time it takes to optimize production to the point where the price is right for the consumer. If the innovation breaks through the demand and production of the product will increase. (Garnes, 2018)

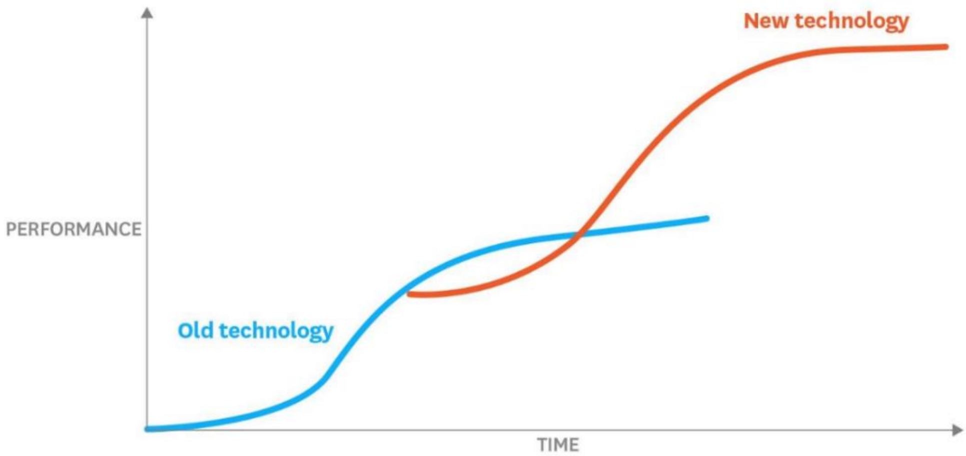

Figure 4: The S-curve inspired by Tarde's (Adner & Kapoor, 2016)

According to Tarde, many innovations never get past the start phase before they are replaced by newer innovations. He says there are five different stages when realizing an innovation and putting it to use:

1. Initial knowledge and competence about the innovation
2. Forming an attitude towards the technology
3. Deciding to use or not use
4. Implementing the innovation
5. Confirmation of the decision

3.1.3.1 Different consumers

After Tarde's discoveries, the American sociology professor Everett M. Rogers did further research on the theory of diffusion. In 1962 he published a book called: *"Diffusion of Innovations".* The research he did was based on 508 different technological innovations. The innovations were spread out from various fields ranging from agriculture to medicine. At the end of his research he classified the consumers of the new technologies in to five different groups. (Garnes, 2018)

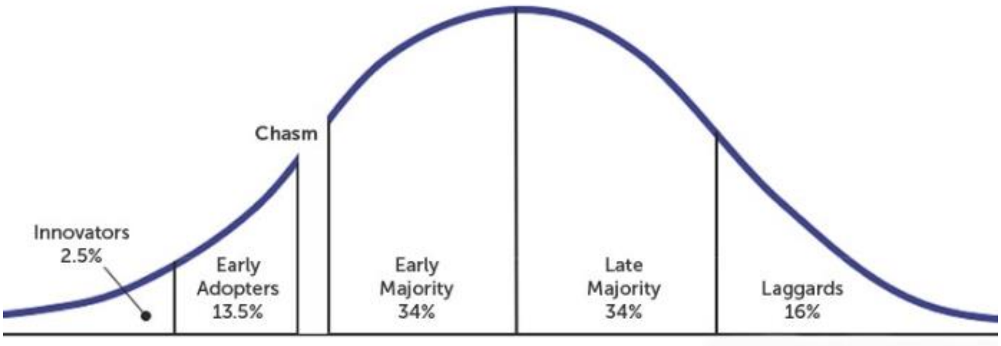

Figure 5: The different types of consumers in the spread of new technology inspired by Rogers (Torres, 2017)

Figure 5 shows when the five different groups start using the technology, starting from left to right with the x-axis in the figure representing an ungiven time. The first group Rogers refers to as the innovators. These are not afraid to take the risk of buying an early accessible product. These people can be very focused on giving others the impression of having a higher social status. The next group Rogers calls the early adopters. Compared to the innovators, this group uses a little longer time before buying the product and are also focused on having a higher social status. According to Rogers these people also have the highest status as [3]opinion leaders. Third comes the early majority. Rogers says this group is also focused on social status, but not as much as the two previous ones. The fourth group is the late majority. These individuals are more sceptic than the three previous groups and may have a lower income. They are not opinion leaders and usually don't interact with one either. (Garnes, 2018)

If we wish to find out how AM can spread in the Norwegian industry, we must also understand a crucial point for this to happen. This can be explained by Moore's further research of Rogers's diffusion theory.

3.1.3.2 The "Chasm"

The "chasm" is a term developed by the American author and adviser, Geoffrey Moore. The term was first introduced in his book: "*Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers"*. The "chasm" can be seen in figure 5 between the early adopters and early majority. The results of his work indicate that when new and advanced technology emerge, there could arise problems tied to the consumers understanding and acceptance of the technology. Further, this can result in problems when trying to get a hold of the necessary resources in the form of funding for technological development, so that the technology can be fully industrialized. In large scale, the path from idea development towards commercialization, the costs of further development significantly increase. Garnes (2018) says that there are several factors that can be tied to overcoming the "chasm";

- Lack of competence by customer
- Cultural/linguistic barrier with the new technology
- Lack of required infrastructure
- Lack of competence by investor
- Lack of trust in technology by investor
- Investor classifies the risk as too high
- Price to high and sale too low
- Funding is absent

[3] Opinion leader: Minority group that passes information on new products to less adventuresome or not as well-informed segments of the population. (Business Dictionary)

This “gap” between the early adopters and early majority is also referred to as the “commercialization gap”. This is not just an issue with consumers but also with investors who help with the financing. Overcoming this “gap” is therefore considered a crucial step for the spread of new technology (Garnes, 2018). Moore describes typical problems in the evaluation process inside companies. These problems are caused when companies already have a foundation around the new technologies, before trying to overcome the chasm (Garnes, 2018).

Issues regarding internal evaluations in an organization for implementing a new technology, can be based on the following arguments (Garnes, 2018);

- The new technology can result in “cannibalization” of what they already provide
- They have invested in, and have long term plans for the new technology
- The new technology requires change in both competence and how to work
- They have a strong belief in the current technology they already master

An important perspective when looking at diffusion of new technologies is the concept of the “valley of death”. This is important when trying to overcome the “commercialization gap”. This concept Garnes (2018) describes as the process when a new technology needs investment for technological research and development so it can be commercially profitable in the future. During this phase the technology will accumulate costs while under development, hence through the “valley of death”, before it becomes commercially attractive. When the accumulated revenue stream from sales equal the amount used in the research and development phase, we now have a break-even point and the “Valley of death” is passed. After reaching this break-even point, the companies will now be able to show a profit from the new technology. (Garnes, 2018)

3.1.4 Gartner's hype cycle

Gartner is an International research and advisory company within technologies. They are members of the [4]S&P 500 and have more than 15.000 clients in over a hundred different countries. The institute mainly operates within the three segments of research, consulting and events. Every year they publish reports made by their industry analysts. The reports highlight trends to consider and predictions for a broad list of tech. These reports are then bought by investors, technology end-users and organizations to make decisions and stay abreast with the latest technology. (Gartner, 2019)

When new technologies make promises or hype their product. How do we know it is commercially viable? Humans tend to sometimes overestimate the ability of a new technology or in other cases underestimate what it can do long term. (Gartner, 2019) This brings us to the curve of expectations, also known as Gartner's hype cycle.

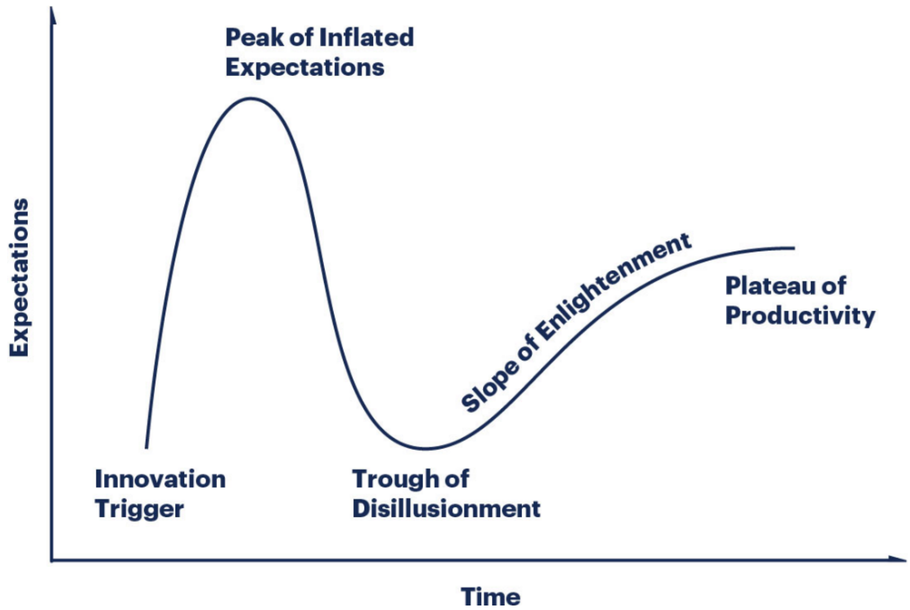

Figure 6: Gartner's general hype cycle (Gartner, 2019)

[4] S&P 500 is a stock market index that ranks the 500 largest American publicly traded companies based on market capitalization. (Kenton & Murphy, 2019)

Figure 6 is a graphic illustration of the five different stages in the cycle and how mature the technology is. We further want to explain what every phase means:

1. The innovation trigger is the first phase. When a new technology is created by entrepreneurs or scientists, we as humans can get excited. We tend to see the future potential more than we like to see the downsides. This is shown on the curve by a rapid increase of the expectations of the newly developed or discovered technology.
2. The second phase starts when the curve almost hits the peak of our expectations. After the peak is where the entrepreneur, scientist and media start to lose hope in the technology (Gartner, 2019). The expectations of the new technology then drop until the third phase starts.
3. The third phase is described as the trough of disillusionment. The company is then dependent on gaining revenue from early adopters or investors to survive. If experiments and implementations fail to deliver this could be a hard time for the company.
4. The fourth stage of the cycle is referred to as the slope of enlightenment. As the product becomes more developed Now the product enters the slope where new expectations arise (Diamandis, 2017). The product becomes more advanced and
5. The fifth and final stage of the cycle is called the plateau of productivity. This phase is when the product is fully mature and we start to take the product for granted (Diamandis, 2017).

Gartner have made the prediction that Additive Manufacturing in oil and gas has another 5-10 years before the global industry has reached the plateau of productivity (Appendices I). Although this is interesting to our study, we cannot base our conclusion on predictions. We will therefore use the hype cycle to compare our conclusion.

3.2 Organizational theory

Organizational theory is the study of how organizations function and how they are affected by the environment they operate in. In this chapter we will be looking at the theory of an organization's environment, how they are designed and how they can adapt to changes. Gareth Jones says in his book "Organizational theory and design", that understanding how an organization works is the first step in learning how to maintain control and make changes in organizations. (Jones, 2013)

3.2.1 The Organizational environment

To understand an organization and how it operates, it is important to understand the forces in the environment surrounding the organization. Jones (2013) says that the environment has a set of pressures and forces surrounding it. He further explains how these factors potentially may affect how an organization operates and its ability to acquire scarce resources. This theory can be applied to both Equinor and all of Equinor's suppliers. Further, Jones divides the organizational environment into two parts; the general environment and the specific environment. (Jones, 2013)

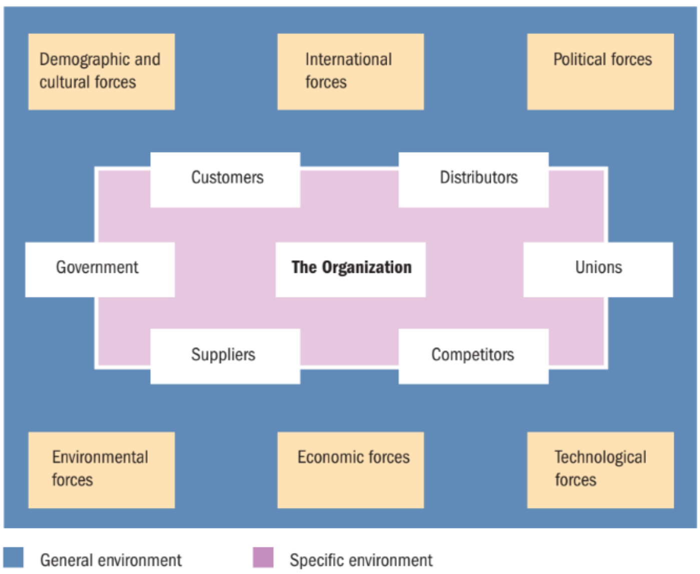

Figure 7: The Organizational Environment (Jones, 2013, p. 82)

The general environment (Figure 7) consists of technological, economic, environmental, demographic, cultural, political and international forces. These forces are shaping the organization's specific environment and affect how an organization obtains resources. Economical forces, such as interest rates and unemployment rates will have an impact on the demand for products and services. New technological development will have an influence on how they operate. In a global market, different countries have different laws and legislation. In these cases, it will have a big impact on how organizations navigate in their environment. The specific environment consists of customers, distributors, unions, competitors, suppliers and government forces. These forces represent the outside stakeholders, which directly can affect the ability of obtaining these resources. Out of all the forces surrounding an organization, it is the specific environment an organization can affect the most itself. (Jones, 2013)

3.2.1.1 Uncertainty

All the forces surrounding an organization represents a potential source of uncertainty for the organization. It is therefore important for an organization to mitigate the risks that the uncertainty represent. This affects how the organization navigates in its environment and plan out their strategy to reach their goals. (Jones, 2013)

3.2.2 Value Chain

In this chapter we will introduce the concept of a value chain. As an organization`s value chain is tied closely together with how an organization chooses its design and structure, we will present organizational design and structure in the following chapter. In this chapter we will use the concept of value chain to help us understand the value of transaction costs, and how organizations can gain value through coordination.

Garnes (2018) describes a value chain as a visualization that represent revenue streams and costs in form of a diagram of arrows. For companies that produce goods, the value chain starts with the raw materials used to make their products. Further the arrows follow the chain through every activity that adds value before the product is sold to the consumer or end user. Together, all these activities form a chain where every activity is adding value. Within this chain is different types of costs related to each activity. At the end of the chain is the profit. For a company to survive, it is necessary that the revenue is greater than the sum of costs from each activity (Garnes, 2018), as this gives the margin.

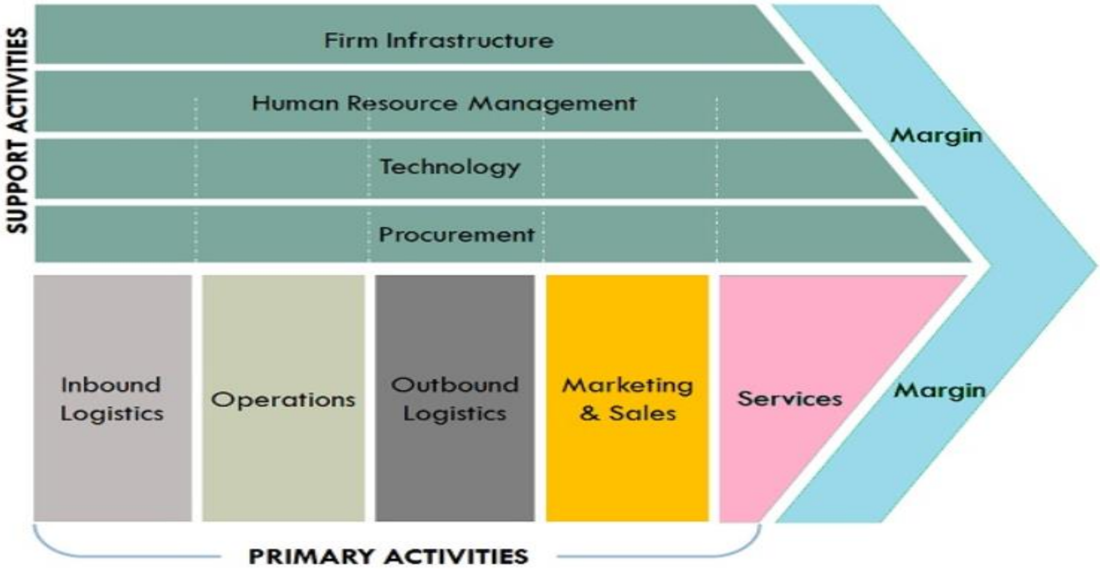

Figure 8: Porter's value chain (Porter, 2004)

Michael E. Porter is widely known for his work on value chain and value chain analysis. In fig 8 we can see his version of the value chain and how he divides the activities into different categories. He divides the activities into what he calls Primary activities and Support activities. The primary activities include everything that involves around creating a product and getting it to the consumer, as well as product assistance after the purchase. The support activities are meant to support the primary ones. These include: human resources, technology and various firmwide functions (Koc & Bozdag, 2016).

In this thesis we have interviewed companies in Equinor's value chain and have therefore included this theory to better understand what is happening. Although all the suppliers are a part of Equinor's value chain, each supplier also have their own chain that Equinor is a part of.

Primary Activities		***Support Activities***	
Inbound logistics	Receiving Storing Product & Material handling	**Procurement**	Purchase: Materials Supplies Machines Office equipment
Operations	Machining Packing Assembly, Maintenance	**Technological**	Product improvement
Outbound logistics	Warehouse Orders Distribution	**Human Resources**	Recruiting Hiring Training Development
Marketing and sales	Advertising Sales Pricing Channel relations	**Firm Infrastructure**	Management Planning Finance Legal Quality assurance
Service	Installation Repair Maintenance Product adjustment		

Table 2: Primary and Support activities (Koc & Bozdag, 2016), based on Porter's value chain.

3.2.2.1 Transaction-cost theory

According to Garnes (2018), the value chain analysis was supplemented and explained by the theory of transaction costs, provided by Oscar Williamson in 1981. He describes the total cost picture by grouping the activities into two parts; production and transactions costs. Production costs are directly tied to the value creation, while transaction costs are the costs activities necessary to keep the production going. Examples of transaction costs are planning, negotiation, costs caused by friction, slack in logistics, costs caused by coordination between departments, groups and businesses. By introducing the concept of transaction cost and dividing the costs into two parts, it becomes easier to analyze the total value chain cost picture. (Garnes, 2018)

3.2.2.2 Gaining value through coordination

From an economic point of view, it is the coordination of activities and costs that create the rationale for why organizations can exist and survive (Garnes, 2018). This theory is based on the work from Oliver Williamson in 1986, which Ronald Coase further researched in 2007. Garnes argues that coordination is not only valuable for minimizing costs, but also that one can gain value through coordination of the activities (Garnes, 2018).

Further, Garnes (2018) explains that by coordinating production activities, one will achieve a better result compared to if everyone was working independent of each other. He also points out that the probability of developing new competence and new products is increased when taking advantage of combining different competences. By working together and coordinating the work it will result in coordination effects. These effects enable us to work more efficiently, build larger and more complex structures or increase the probability of developing new ideas. Garnes differentiates between three kinds of coordination effects; Additive effects, synergies and transcendental effects. Additive effects are the effects of optimizing the sum of each individual contribution to better utilize the available resources. Synergies are effects from combining effort and resources in certain ways that result in qualitative improvements; different, bigger and more complex. Transcendental effects are achieved through cooperation and dialog and increasing the probability of innovating or creating something new (Garnes, 2018).

3.2.3 Structures, design and strategies to adapt

This chapter is meant to give insight in different organizational structures and how a company can adapt to changes. We believe this is important when an industry is starting to use a new technology, as some companies may see AM as a threat and need to make changes within the organization to adapt. Other companies might already have a structure that makes them ready to implement a new technology.

3.2.3.1 Structures

The structure of an organization is designed to establish control over the necessary activities that result in accomplishing collective goals. To ensure the highest level of effectiveness, the type of structure should at any time be evaluated by executives (Jones, 2013). For the purpose of being able to adapt to changes that may erupt from the environments surrounding the organization. Further, organizations create value through a system in which inputs are added value and transformed, before they are sent out to the environments as outputs. Sales form outputs enables the organization to obtain new supplies and resources for inputs. In this way the organization can repeat this cycle to generate value, given that the input side is greater than the output side (Jones, 2013).

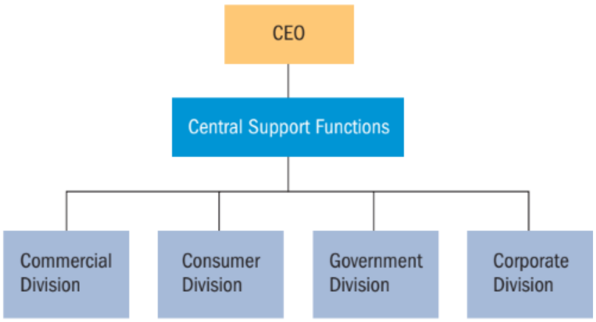

Figure 9: Market structure (Jones, 2013)

In Figure 9 we can see an example of how each division focuses on the needs of a distinct customer group. When designing the structure of the organization, it will result in a situation where the company finds themselves placed somewhere between a mechanistic and an organic structure, with elements from both. We will therefore go through both expressions and define them.

If an organization wants their employees to behave in a predictable and reliable way, they might choose to have a mechanistic structure. In this type of structure tasks are given from the top-down and is referred to as a centralized setup. The authority to make important decisions is retained to top managers in the hierarchy. Every person is specialized in what they do and knows precisely what their responsibilities are. There is therefore no need for a complex mechanism for integrating new tasks. (Jones, 2013)

In a mechanistic organization the specific tasks are handed down the hierarchy. This structure combined with standardization makes this structure suitable for a stable environment. However, it does not always adapt easily to market changes. In situations where the top management get overloaded with decisions, there becomes little time for long-term strategic planning of future activities for the organization. (Jones, 2013)

Organic structure is the opposite of mechanical. Instead of tasks being given from the top-down, these structures are rather decentralized. The roles of employees are loosely defined which helps contribute to independent thinking where people continually learn new skills, while performing challenging tasks. This also means that the authority of making decisions initiating new projects are distributed throughout the hierarchy at all levels and actions are taken when needed. (Jones, 2013)

This joint specialization, which we have in an organic organization, brings people with different functions together and they get engaged in each other's activities. To successfully achieve a high level of productivity in this design, there must be a high level of integration. When integrating new tasks there is a need for a complex mechanism that effectively allows information to be shared. This is often resolved by teamwork. Coordination is handled by mutual adjusting people's roles, functions and responsibilities. Compared to the mechanistic design, this design promotes a flexible environment and makes this type of structure capable of adapting to changes quickly (Jones, 2013).

Large corporations nowadays have an element of both mechanistic and organic in their organization. Jones refers to this as: "Balancing centralization and decentralization". Both the designs have positive and negative aspects to them based on what they are wanting to accomplish. Balancing these structures within the organization allows them to be effective while keeping up with their competitors in the current market. This is achieved by being able to adapt to changes (Jones, 2013). This brings us to another term for this "balance", Ambidextrous Organizations.

The balance between organic and mechanistic is also referred to as Ambidextrous organizations. This term was first presented by O'Reilly and Tushman to better explain the hybrid between the two structures (O'Reilly & Tushman, 2004). They further go on to explain that the term covers the organizations ability to meet the market needs, while being prepared to adapt to changes from the environment. Four years later the two of them published a new article. This time they concluded that Ambidextrous organizations will easier manage to tackle disruptive innovations. This can be done through exploitation and exploration innovation (O'Reilly & Tushman, 2008). Exploitation is about using the resources available. This includes improving production or current products to be more efficient and give more value to the customer. Exploration is about exploring new areas. This includes experimenting with new ideas to discover innovations. Maintaining a balance between exploitation and exploration is important for an organization to survive and improve (March ,1991). As it is important to have a plan for surviving and improving, we will further cover strategies for organizations to adapt.

3.2.3.5 Strategies to adapt

Competition is something that organizations do not like. This can create an uncertain environment for the company. Sometimes the competition becomes so intense that organizations choose to drive their prices down to attract customers. The higher the competition becomes, the higher the chances are they lose their current place in the market, or go bankrupt (Jones, 2013). It is therefore important for any organization to be aware of their surrounding environment and be prepared to adapt.

There are several techniques that can be used to manipulate the environment directly: Third-party linkage mechanism, strategic alliances and merger and takeover (Jones, 2013).

In a Third-party Linkage Mechanism*,* the parts involved agree on sharing information that helps regulate the way they compete. This is a formal, but an indirectly method where they share information through a third-party. The third-party provides the linkage system for flow of information and the set of rules and standards that each part must agree on.

Strategic Alliances can be found between companies that share common technology. Competitors form an alliance where they for example develop technology together. This form of cooperation can sometimes be formed by smaller organizations to bring down or harm a larger player in the market.

Jones describes the Merger and Takeover strategy as the ultimate weapon. This method involves merging with, or completely taking over a competitor. If the organizations merging are two of the biggest market players, this might result in them becoming a monopoly. They then become too strong to compete with for smaller competitors. (Jones, 2013)

In summary, we have in this chapter portrayed applicable theory for both understanding the case, and for analyzing our gathered data in Chapter No 5. Of innovation theory, we have portrayed different perspectives of what a disrupted technology is before we also discussed business models and the term "business model innovations". Further, we covered theory about how new technologies spread in a market and the crucial point, "the chasm". To understand Gartner's predictions of AM, we have also described the different phases in Gartner's hype cycle. Our research includes different types of organizations. We have therefore covered organizational theory to understand the different perspectives of our interviewees.

4 RESEARCH DESIGN AND METHODOLOGY

In this chapter we will present the research design and methodology used for this master thesis. We will describe the different methods available to us and explain why we have made the choices we have made. Further, we will describe different methods of data collection before presenting our chosen methods. Lastly, we will discuss the reliability and validity of the data we have collected and how this might have affected our master thesis.

4.1 Research design

A research design is guide or a model for how to organize and carry out the research activity. It represents a plan for collecting, analyzing and interpreting data. Essentially, a research design is a framework which provides a plan for how you will go forward to be able to answer your research question. According to Saunders et al (2016) there are three different approaches when creating your research design: explanatory, exploratory or a descriptive design.

An explanatory design enables you to do research when the primary objective is to investigate different variables and find correlations among them. A descriptive design is an approach where the researcher aims to describe the characteristics of the subject or phenomenon that is being studied. The primary objective when choosing an exploratory design is to gain insight and understand the topic that is being investigated. Saunders states the following about an exploratory study;

> *"An exploratory study is a valuable means to ask questions to discover what is happening and gain insight about a topic of interest."* (Saunders et al., 2016).

As our goal with this study is to gain insight in how an industry can adopt a new technology, we found it appropriate to choose an exploratory research design. This approach is also beneficial as it allows us to modify and change our research questions as our study develops and we gain a deeper understanding of what is important.

4.2 The case

The plan for our explorative single case study was to choose suppliers that Equinor use today and that either use AM as a method of manufacturing or have the option of using it to provide their service. Two of the suppliers are also taking part in Equinor's current pilot project. The projects end goal is to install 3D-printed metal parts on an offshore vessel located at the Johan Castberg-oilfield. While we are writing this thesis, the parts have already been printed and are awaiting installation. The four other suppliers are a part of Equinor's value chain.

4.2.1 Limitations

In this sub chapter we want to clarify some of the limitations we have set as a premise for our master thesis.

In this master thesis we wish to investigate the barriers tied to different aspects of implementing the technology in the Norwegian oil and gas industry. We do not have the intention of going into the technical aspects of the technology by explaining how 3D printing works, as there is a lot of research available previously done on this subject. We will neither discuss the different AM production methods available in the market today but rather portray what the technology can do for the industry. We will also encounter issues regarding IP and Copyrights when talking about new business models. We are aware of and acknowledge the issues these factors represent, but we do not have an intention of finding a solution for this.

4.3 Data collection

Usually one distinguishes between qualitative and quantitative methods regarding data collecting methods. Yin (2014) focuses on six different data collecting methods when carrying out a qualitative research design; Documentation, archive, interview, direct observation, participant-observation, and physical artefacts. With a qualitative approach, the more sources of data you have available when conducting a study will strengthen the reliability of the conclusion.

In our master thesis we have used three different data collecting methods; interview, participant-observation and documentation. These data sources are classified as both primary and secondary data and are presented in table Q.

Data source	Primary data	Secondary data
Interviews	Interviews with key personnel from Equinor's different suppliers.	
Participant-observation	Student internship at Equinor working closely with AM pilot project manager.	
Documents		Scientific articles, emails, company power points, AM blog posts, reports.

Table 3: Data collection sources

4.3.1 Primary data

Primary data is all the data we have collected from first-hand experience. For this Master thesis we have collected two different types of primary data. We have conducted interviews as our main source of data and as a part of our internship at Equinor we have data in the form of participant-observation.

4.3.1.1 Interviews

Interviews were our main method for gathering data. Through meetings with Equinor we got access to a list of suppliers that they use or have established connections with. In total we got a list of fifteen different companies within maintenance, production and repair. We split the companies into three different categories; 1) Maintenance, Modifications and Operations (MMO). 2) Original Equipment Manufacturer (OEM) and 3) New Suppliers. We chose to limit our interviews to six: two from every category. We believe that conducting interviews with companies from all these categories would give us a broad perspective of barriers due to different organizational sizes and services. This will also contribute to a higher level of validity. The chosen companies are listed in table 2 below.

When	Company	Tag	Purpose	Communication	Length
07.02.19	Equinor	n/a	Introduce supervisors to Equinor and discuss aspects of case	In person	90m
13.03.19			Get access to interviewees and secondary data		90m
25.03.19	Tronrud Engineering	R5	Barriers	Video Call	63m:37s
26.03.19	Aibel	R2	Barriers	In person	76m:48s
26.03.19	FPE	R4	Barriers	Phone	47m:51s
28.03.19	Aker	R1	Barriers	Phone	65m:12s
29.03.19	Karsten Moholt	R3	Barriers	In person	63m:13s
08.04.19	Trio OilTec	R6	Barriers	Phone	42m:51s

Table 4: Interviews and meetings

We arranged interviews with one representative from each company, all of whom had insight with the companies stand on AM. We wanted to conduct as many of the interviews as possible in person, but some of the chosen companies were far away from our location and had to be done by video calls or phone. The length of the interviews was in the range of forty to ninety minutes and everyone agreed to being recorded. After every interview we analyzed and discussed key discoveries before we transcribed them.

Before we started the interview process, we called all the informants to discuss the study. Before the interviews we also sent an email with more precise topics we wanted to cover. This helped our informants be more prepared. In the email we also pointed out that it was important for us that the informant did not feel limited to only talk about the topics. We emphasized how we wanted feedback on every aspect our informant felt was important for the study. By doing this, we made sure the informants were well prepared before interviews.

Our interviews were performed as a semi structured, in which we made an interview guide to help us have an overview of the topics. Since this is an exploratory study, we added new questions and discussed how we could improve our questions for the next interview, based on previous answers. Under the interviews we sometimes deviated from this guide to pursue new issues that came up during the interviews that we had not thought about. The purpose of the interviews was to gather enough data to answer our research questions tied to implementing AM. We started every interview with presenting ourselves, the thesis topic and purpose of the interview before we continued to ask the questions. The guide can be found in 9 Appendices, at the end of this paper.

4.3.1.2 Participant-observation study

During our internship at Equinor we worked together with Brede Lærum who is the project manager for AM in the department of Digitalization. Our main task during our stay was to research companies providing AM services in the Nordic region. Most of the days we spent working together with Brede at Equinor`s office building in Bergen and other days we worked remotely from school. In total we spent approximately 7 weeks as interns for Equinor. During this period, we also got to attend meetings Brede had arranged with suppliers regarding prototyping projects for 3D-printing. This was our first encounter with barriers for the implementation of AM in the Norwegian oil and gas industry.

The advantages with this arrangement were that it allowed us to observe how Equinor was working towards implementing AM. Through discussions with the project manager and other employees in the department we gained a lot of insight. Being allowed to participate in meetings with Equinor`s suppliers was a great and exciting way to get a better understanding of the barriers and challenges from the supplier’s point of view.

4.3.3 Secondary data

The secondary data is all the data we have used that others have gathered on the topic before us. This data has been collected for other purposes but is still applicable to our thesis. The secondary data we have used consist of document analysis. We have performed searches for scientific articles, read company emails, company PowerPoints, reports and trusted AM community blogposts.

4.3.4 Data weaknesses

Here we will go through what may be weaknesses tied to our collection of data. We have divided the weaknesses into primary and secondary.

4.3.4.1 Primary data weaknesses

One of the aspects we took into consideration was that all the companies we interviewed sell products or services to Equinor and therefore might answer their questions in favor of future business. In other words, sugar coat certain facts. We did not really get this impression during or after the interviews when discussing the answers, but we cannot be sure.

We also conducted all the interviews in Norwegian but are writing the paper in English. The two languages have different ways of building sentences and may therefore be a weakness when translating quotations, we have used. But we are still confident that we have not lost important elements or altered the data when translating.

During interviews we covered expressions regarding; business models, mechanistic and organic, organizational structures and so on. Although both writers of this thesis know the meaning of these expressions, our interviewees might not. We therefore tried to build our questions so that they knew what we were talking about. This may be a weakness, but we are fairly sure everyone understood what we meant.

4.3.4.2 Secondary data weaknesses

Referring to Gartner's hype cycle for AM 2018 (Appendices I), we can see that this is a new method of manufacturing in a lot of fields. There is therefore an exponential growth of academic articles being written about the topic. A weakness tied to this is that information is constantly updated and sources we have used may or may not be outdated by the time this thesis is finished.

We did not manage to get access to all the PowerPoints and internal documents regarding the AM project as we wanted to from Equinor. This is due to company privacy reasons and might have affected aspects and our conclusion.

4.4 Presentation of case study

The case we will be presenting are companies from Equinor's current value chain or are participating in pilot projects using AM. They all deliver different products or services to some degree and are structured in different ways. We therefore assume we will get different answers to similar questions during interviews, but also hope to find correlations between suppliers. The companies are displayed in table 5.

End User
equinor
Tier II - MMO
AkerSolutions, aibel
Tier III - OEM
FPE SONTUM AS, KARSTEN MOHOLT
New Suppliers - AM
TRONRUD ENGINEERING AS, TrioOilTec services

Table 5: Overview of case

In our case, Equinor is the customer and end user but still hosts storage for parts made, assembled and to be installed by some of these companies. Lowering the storage may cause a dramatic decrease in expenses tied warehousing. Equinor have been very clear with us about not wanting to provide the service of AM internally, but rather buy this service from someone else who has machines, competence and enough capacity to cover their demand.

4.5 Presentation of Equinor and Suppliers

<table>
<tr><td>End User</td><td>equinor</td></tr>
<tr><td colspan="2">Company information</td></tr>
<tr><td colspan="2">Equinor is an international energy company and is the leading operator on the Norwegian continental shelf with their headquarters located in Stavanger, Norway. The Norwegian state has an ownership of 67% in Equinor, which is managed by the Ministry of Petroleum and Energy. The company has substantial international activities and is present in more than thirty countries, including several of the world’s most important oil and gas provinces. Equinor is engaged in exploration, development and production of oil and gas, as well as wind and solar power. They sell crude oil and are a major supplier of natural gas with activities including refining, processing and trading. (Equinor, 2019)</td></tr>
<tr><td>Additive Manufacturing</td><td>Pilot project</td></tr>
<tr><td>Equinor wish that their suppliers start using AM as a production method because of the drivers discussed in chapter: 2.2 Benefits of AM in Oil & Gas.

They <u>do not wish</u> to provide this service themselves.</td><td>Installing a 3D-printed part offshore:

Tronrud Engineering have printed twenty-nine inlet parts in titanium for fire hose reels. The parts are currently awaiting installation on a production vessel at Equinor’s Johan Castberg-oilfield. The fire extinguishing system is planned, installed and maintained by FPE Sontum. (E24, 2019)</td></tr>
</table>

Table 6: End user - Equinor

Supplier # 1	
Company information	
Aker Solutions ASA is a global engineering company with its headquarters located in Fornebu, Norway. They are an oilfield and subsea service company design products, systems and services required to unlock energy, with Equinor as one of their biggest and most important customers. Aker Solutions deliver and provide a wide variety of services to energy companies, ranging from subsea to surface and concept to decommissioning. The company is active worldwide and is present in more than 20 countries. (Aker Solutions, 2019)	
Additive Manufacturing	
Have until now not been using AM but are actively working towards finding cases where AM is beneficial.	

Table 7: Supplier 1 - Aker Solutions

Supplier # 2	
Company Information	
Aibel is one of Norway's leading suppliers of services related to oil and gas and renewable energy. They provide a wide range of services with their business split into 3 parts; Modifications and yards services, Field development and Renewables. The company has six offices in different cities in Norway with its headquarters located in Stavanger. They also have international offices in Thailand and Singapore. Aibel has yards that supply modules and topsides to customers worldwide, in both Haugesund and Thailand. (Aibel, 2019)	
Additive Manufacturing	
The company has two plastic printers at their yard in Haugesund. They currently use the printers to make brackets for securing cargo and material.	

Table 8: Supplier 2 - Aibel

Supplier # 3	KARSTEN MOHOLT
Company Information	
Karsten Moholt is Norway's leading supplier of monitoring, analysis, and services and maintenance of rotating machinery and equipment. The company has its headquarters and facilities located at Askøy, Norway. They operate around the world to do service, repair and inspections of equipment for their customers in the field. They offer lifetime extension of rotating equipment through smart maintenance to their customers. Karsten Moholt divides their services into three parts; Service, repairs and lifetime extensions, Monitoring, analysis and consulting. Equinor is their largest customer and of February 6th they were awarded a new contract with Equinor that includes condition monitoring, service and repair of rotating electrical equipment pertaining to equipment on all of Equinor's installations. (Karsten Moholt, 2019)	
Additive Manufacturing	
In addition to having a plastic 3D printer, they have advanced 3D scan equipment to generate CAD models of machines and equipment.	

Table 9: Supplier 3 - Karsten Moholt

Supplier # 4	FPE SONTUM AS
Company information	
FPE Sontum AS is a Norwegian company with its headquarters located in Stavanger. The company is a global supplier of firefighting equipment and systems for the oil and gas industry, with Equinor as their biggest customer. They supply the full range of firefighting systems for use on fixed and floating offshore installations, refineries and land-based installations. They provide a wide range of services covering engineering, procurement, assembly, installation, commissioning and documentation. (FPE Sontum, 2019)	
Additive Manufacturing	Pilot project
Have before the pilot project not been using AM to provide their services.	FPE's role in the project consist of engineering and installing the system for the fire hose inlets.

Table 10: Supplier 4 - FPE Sontum

<table>
<tr><td>Supplier # 5</td><td>TRONRUD ENGINEERING AS</td></tr>
<tr><td colspan="2">Company information</td></tr>
<tr><td colspan="2">Tronrud Engineering is a Norwegian company with its headquarters located in Hønefoss. The company develop, produce and deliver automated solutions for their customers in a wide range of industries. The company has divided their business into four parts; Prototyping and serial production, Packaging machines, Special machines and aftermarket. (Tronrud, 2019)</td></tr>
<tr><td>Additive Manufacturing</td><td>Equinor’s Pilot project</td></tr>
<tr><td>Tronrud have since 2011 used AM in addition to their conventional manufacturing methods.</td><td>Manufactured the 3D printed inlets for the fire hose reels in Equinor’s ongoing pilot project.</td></tr>
</table>

Table 11: Supplier 5 - Tronrud Engineering

<table>
<tr><td>Supplier # 6</td><td>Trio OilTec services</td></tr>
<tr><td colspan="2">Company information</td></tr>
<tr><td colspan="2">Trio OilTec is a Norwegian company located in Stavanger, Norway. They provide refurbishment services and parts for the oil and gas industry. After many years of industry experience, Trio OilTec uses advanced welding and coating technologies to provide a wide variety of services within repair, rebuilding, wearfacing and production technologies. The company`s core competence includes stabilizer refurbishment, hardbanding of drill pipes, wearfacing of down hole assembly equipment and production of OEM parts subjected to high wear. (Trio OilTec, 2019)</td></tr>
<tr><td colspan="2">Additive Manufacturing</td></tr>
<tr><td colspan="2">Trio have since 2014 owned two AM machines and is now one of the leading companies worldwide when it comes to competence in their specific niche of wear protection.</td></tr>
</table>

Table 12: Supplier 6 - Trio OilTec

4.4 Validity and Reliability

In this section we will discuss the validity and reliability of this master thesis. According to Easterby-Smith et al. (2015) validity is whether the research findings provide an accurate representation of what they were supposed to represent. In this master thesis we wanted to conduct a study in which we investigated barriers for implementing AM for the oil and gas industry by interviewing Equinor`s suppliers. As the interviews are our most important data source used to answer our research questions, the validity in this thesis will be strongly tied to these interviews.

4.4.1 The four tests

To judge the quality of a research design there are four commonly used methods. Yin (2014) describes these as logical tests with relevant tactics for each test. We have listed the tests and tactics in Table 13 and will go through the ones that are applicable for our design to determine the validity and reliability.

Tests	Explanation	Tactics
Construct validity	Identifies the correct measures for the concept being studied	➢ Use several sources of evidence ➢ Get feedback from key informants
Internal validity	Refers to how well an experiment is done and whether it avoids confusion. Low confusion means high internal validity	➢ Find matching patterns ➢ Build explanations ➢ Address rival explanations ➢ Use logical models
External validity	Shows how and if the findings can be generalized	➢ Apply theory in single-case studies ➢ Use replication logic in multi-case studies
Reliability	Demonstrates how the study can be repeated getting the same results	➢ Use case study protocol ➢ Develop a case study database ➢ Maintain chain of evidence

Table 13: The four common design tests to determine the quality of a research design (Yin, 2014)

4.4.1.1 Construct validity

In our study we have used multiple sources of data getting feedback from key informants, both in Equinor and from our chosen suppliers. As we have several sources of data and evidence when conducting our study and analysis, we argue that the construct validity his high. Out of the six suppliers we interviewed, Trio OilTec is a company that uses AM in a special niche, primarily for repair. Our interviewee from this company was very clear about how certain things we asked did not apply to them. Regardless, we still wanted to interview them because of their experience and knowledge about AM and the Norwegian O&G industry.

4.4.1.2 Internal validity

We believe that the research findings we have provide during our study represent an accurate representation of what we were supposed to investigate. As presented in Table 13, the internal validity refers to if it causes confusion. In our analysis we have tried to find patterns in the form of correlations from the data we have gathered from suppliers, but also address different explanations and perspectives provided by our informants. We have tried to build explanations when discussing theory and our findings and have also used well known and logical models to avoid confusing the reader.

4.4.1.3 External validity

Even though we could have conducted more interviews, we believe that our findings from our study can be generalized to some degree. This is a study aimed towards the Norwegian oil and gas industry, a lot of what we discuss and conclude with can also be applicable for AM in other industries. For achieving this we have used well known theory provided by well-respected authors. However, our case is unique in that Equinor are so big with many sub suppliers in a complex network. This makes the external validity somewhat challenging to argument for, as this is not an ordinary situation.

4.4.1.4 Reliability

Yin (2014) describes reliability as how well other scientists can repeat the study and achieve the same results. As mentioned earlier we added questions to improve our guide after every interview. We also recorded and transcribed all interviews after discussing key discoveries from different aspects with ourselves and supervisors. If the same guide had been used by someone else shortly after us, we believe it would give the same results. If the research is done after some time, we believe the answers will change due to the barriers that already have been overcome.

4.5 Privacy

This project has been reported to the Norwegian Centre for Research Data (NSD) and received the following reference code: 456002. Based on anonymous participation from our chosen interviewees, NSD has classified the risk of privacy recognition as low.

5 ANALYSIS AND DISCUSSION

This study aims to answer the following questions: 1) Is AM a disruptive technology for the Norwegian oil and gas industry and how may it change the industry? 2) What are barriers the Norwegian oil and gas industry must overcome for implementing AM on a large scale? And is the AM technology mature enough for the industry? In the first part of the analysis we wish to find out if Additive Manufacturing can be called a disruptive technology for the Norwegian industry. If so, we wish to find out what might be disrupted, and tie this to our theory to identify what the industry should be aware of. This will provide enough basis for a conclusion to our first research question.

Further, when discussing our second research question, we will move on to the main barriers we have found for adopting the technology on a large scale. This question will be answered based on what suppliers view as barriers.

Lastly, we will discuss whether the technology is mature enough for the industry. This conclusion will also be based on what suppliers have told us and compare this to what theory says about how emerging technologies spread in a market. This will give us enough basis for a conclusion to answer research question No 2.

5.1 Research Question 1

Is AM a disruptive technology for the Norwegian oil and gas industry and how may it change the industry?

First, we will discuss if AM is a disruptive technology for the Norwegian oil and gas industry in light of the theory presented in the theory chapter about disruption and innovation. After this, we will discuss how the technology may change the industry by looking at Equinor`s drivers for implementing AM in the Norwegian oil and gas industry. Further, we will look at these changes from a value chain perspective, which brings us to discussions about new business models and organizational structural changes required. Theory tells us that the implementation of new business models can be challenging for businesses and therefore represents barriers for the implementation of AM on a large scale.

5.1.1 *AM as a disruptive technology*

When talking with people what they think a disruptive innovation is, they often describe it by saying that the current innovation is a "game changer" for the given industry. Is this applicable, when looking at AM as a new technology for the Norwegian oil and gas industry? Of course, that depends on how one wishes to define "game changer". In our case, studying AM in the oil and gas industry also requires us to look at the different perspectives from both the supplier and the customer, as they will perceive this differently. From the supplier's perspective it can certainly change things drastically. This we will discuss later in the research question. When looking at the customer, which in our case is Equinor, we realize that they probably perceive this differently. For example, when buying a valve produced by AM compared to traditional production methods, the customer receives a product that does the same job as before. While saying this, the implementation of AM certainly will change for the customer, as these changes represent the drivers for why Equinor wishes the industry to adopt this technology. We will elaborate on this later when discussing what AM might change.

To help us understand what a disruptive technology is they describe the difference by the terms sustaining and disruptive technologies. Sustaining technologies are described by being the technologies that companies are currently providing their customers in the mainstream market. These are developed in incremental steps to improve the service or product, and in this way the company offers their customer something more or better in the attributes they already value. Disruptive technologies, on the other hand, offer customers a different set of attributes compared to what is valued from the customers in the mainstream market. These types of technologies often tend to perform far worse in one or two dimensions which is important to these customers.

As presented in the theory chapter about disruptive innovations, theorists have come up with different definitions and criteria for what a disruptive technology is. According to their definitions it is not enough that something "shakes up" an industry, to call it disruptive.

According to Christensen et al. (1995), a disruptive technology originates from either low-market or new-market footholds. The first AM machine was invented in 1983 primarily to make prototypes and product models for the purpose of visualization. Considering this, one could argue that this satisfies the criterion.

Further, Bower and Christensen (1995) state that, as a rule, in the start mainstream customers are unwilling to use a disruptive product as a replacement for a known product. Currently AM as a technology finds itself in a development phase, in which the industry tries to validate the method through executing successful pilot projects. The reason for doing this, is that AM as production method has yet to gain the necessary trust in the industry needed for the implementation on a large scale. Taking this into consideration, we would say that this satisfies the statement above.

Bower and Christensen (1985) state that disruptive technologies bring new value propositions to the market. Further, that disruptive technologies can be inferior compared to other products in the market while bringing new value such as being smaller/larger, more practical, cheaper etc. These values are all applicable to the benefits this technology can fulfill. AM also enables the industry to reduce the lead time of parts to a minimum, which includes drastically reducing the logistics required. This will also result in Equinor being able to reduce their physical warehouse for parts as parts can now be printed on demand when using AM. For the customer this represents a new value proposition, but also offers the customer new values, such as being more practical. Since AM as a production method has not been looked upon as a viable production method by the oil and gas industry until recently, one could argue that the industry perceived it as inferior compared to traditional production methods. Based on the discussion above we can conclude that AM is a disruptive technology for the Norwegian oil and gas industry, according to the definitions provided by Bower and Christensen (1995).

When searching the internet, we found several articles which criticize Christensen et al. (2015) in how they applied their definitions to an innovation such as the Über concept in the taxi industry. Christensen et al. argued that this does not qualify for being a disruptive innovation, but people on the internet argue that they are wrong. As there are several different definitions.

In summary, AM as a technology will be perceived differently by the suppliers and customers in the Norwegian industry when looking at it in terms of the technology being a "game changer". We believe that it is more important to understand how and why the technology disrupts the given industry, as opposed to labeling it by its following implications.

5.1.2 What may AM change?

In this subchapter we will discuss in which ways AM can change the industry. Further we will investigate how some of these changes can require the suppliers to implement a new business model if they want to take reap the benefits that can be provided by using AM as a production method.

Before we discuss how the industry might change, we first need to look at Equinor`s different drivers and incentives for implementing this technology. By doing so, we can discuss the changes that will occur as a consequence by the industry realizing these drivers. We will start by describing the drivers for Equinor which we provided in chapter 2.2 Benefits of AM in oil and gas;

- Visualization
- Repair
- Component cost
- Optimized function
- Environmental footprint
- Obsolete parts

- Alternative materials
- Lead time
- Virtual warehouse

The implementation of AM in the industry is necessary for Equinor to be able to reap the rewards from these drivers. Some of the drivers are already under implementation, such as visualization and repair. The rest of the drivers are in the idea development phase, in which further research and cooperation within the industry is necessary for Equinor to be able to realize the full potential of these drivers. One of the key factors in realizing the full potential is that the management in Equinor must officially approve of the technology. By doing this they unite in a strategy for how they will move forward with AM. This represents a barrier we will discuss further in research question 2, together with all the other barriers from our findings.

As we in this chapter want to discuss how AM might change the industry, it makes sense to look at the drivers that may cause the biggest changes because of implementing them. The drivers that first come to mind are; Environmental footprint, Lead time and Virtual warehouse. During our internship at Equinor we were introduced to their vision and hypothetical future. Equinor want to cut their warehouse requirements significantly by implementing AM. They want to achieve this by creating a virtual warehouse for parts. This enables a solution where if you have the component design as a CAD file, it is possible to print the component on a desired location when needed. This will cut the physical storage, consisting of components provided by traditional production methods, as many of the parts can now be stored in this “virtual warehouse”. This hypothetical future enables Equinor to leave a much smaller environmental footprint, as they no longer would have to transport the physical parts from a production site to a storage, and from this storage to desired work site. If Equinor can print a part at the time of demand, this will also cut the lead time significantly.

This future represents big changes in how business may be done and a change in how the industry is currently working. If Equinor wants to realize this future it requires the industry to come up with a business model which enables them to do so. In the theory chapter we provided a business model concept described as “pay-per-use”. “Pay-per-use” could be a fitting business model for the future we have just portrayed. When discussing this future with our interviewees they provided us with a lot of feedback. They all seemed to agree on that sooner or later we will see AM implemented in the industry, as the incentives and drivers for Equinor are so big.

From a value chain perspective, we may see some changes in the different activities in the value chain model made by Porter in our theory chapter. The most obvious change can be found within logistics and how the product is delivered to its customers, as in this hypothetical future one is able to almost cut the transport of products completely. Porter`s value chain model consists of Primary and Support activities. To get a better understanding of what could change we want to look at the different activities that may be affected by Equinor's drivers. Looking back at table 2 in the theory chapter, it looks like every Primary and Support activity can potentially be affected, both for Equinor and their suppliers.

For the primary activities, we have *Inbound logistics* and *Outbound logistics* that consist of; receiving, storing and product & material handling, warehouse, orders and distribution. All these will be affected to some degree. Further, we will see changes in the primary activities *Operations*, *Marketing & sales* and *Service,* consisting of; machining, packing, assembly, maintenance, advertising, sales, pricing, channel relations, installation, repair, service maintenance and product adjustments.

In the Support activities we have *Procurement*, *Technological, Human Resources* and *Firm Infrastructure.* We will also here see changes in the activities regarding; Purchase (materials, supplies, machines and office equipment), product improvement, recruiting, hiring, training, development, management, planning, finance, legal and quality assurance, if and when the industry adopts the technology.

The changes required by implementing the drivers for Equinor will inflict a lot of changes in the different activities in the different value chains in the industry. Some will be affected more than others. When all these activities require change to some degree, the industry must look at new business models for AM, especially for realizing the virtual warehouse.

In the theory chapter we presented business models. We chose to use Osterwalder`s definition of a business model; *"A business model describes the rationale of how an organization creates, delivers and captures value".* All the changes required by analyzing the value chain activities also represent changes within a new business model. This seems logical, as business model is a tool for explaining how businesses make money and what product or service the business offers. Further, it explains the value of the product or service for the customer and what infrastructure is needed to be able to deliver this value to the customers.

When talking about new business models our interviewees all acknowledged that the scenario above regarding the hypothetical future will require a new business model. At the same time, none of them had a clear vision on how this should be done and what exactly this new business model would look like.

In our theory about innovation, Chesbrough et al. argues that the introduction of a new technology can cause challenges to companies, as the new technology often requires new business models. Further, in the theory chapter we presented research on business model innovation done by Chesbrough, Christensen et al., which is very relevant when discussing new models, in which he stated the following;

> *"The economic value of a technology remains latent until it is commercialized in some way via a business model. The same technology commercialized in two different ways will yield two different returns." (Chesbrough, 2010, p. 354)*

In this research Chesbrough stresses the importance of businesses innovating their business models through business model experimentation. His reasoning being that finding a great business model that fits the technology is vital for successfully taking advantage of a new technology when commercializing it. This becomes clear if one takes the meaning of the quotation above into consideration.

In our theory chapter we also introduced research that explains different barriers and challenges that arise when trying to implement a new and disruptive technology. In Christensen et al. and Amit & Zott`s research, they tell us that the managers recognize what the right business model is for the new technology but resist development due to conflicts with the prevailing one. They explain this by pointing towards one of the most popular and valuable management dogmas that leading companies succumb to; "They stay close to their customers". This is based on logical and rational thinking in resource-allocation in companies in which resource-allocation processes are critical to a company`s profitability and competitiveness. These resource-allocation processes will not – and should not – direct resources to markets where sales will be relatively small. The reason for this is that disruptive technologies generally look financially unattractive to established companies.

While Chesbrough acknowledge the research above, his research also shows that often the problem occurs because it is far from clear for the managers what the right business model ought to be for the new technology.

When talking with our interviewees about the business model concept "pay-per-use" mentioned above, our interviewee from Aibel told us the following;

> *"(…) We need new business models that take care of and protects both the customer and the supplier. One can imagine a scenario where one has a digital warehouse using pay-per-print or pay-per-use." (R2)*

Later in the interview process, our interviewee from FPE Sontum followed up on this subject, saying the following;

> *"I can easily understand why Equinor wants to push this technology on the industry. (..) But I have yet to see any suggestions for how the suppliers will be compensated for the parts" (R4)*

In the two quotations above, they both emphasize the importance of the future business model protecting both the customer and the supplier. The interviewee from FPE Sontum also had a hard time seeing how suppliers would be compensated for the parts using a business model like pay-per-use. If, or when a virtual warehouse becomes a reality, Equinor will no longer have the same demand for spare parts in their physical warehouse as these parts can now be printed. Because of this, our interviewee from FPE Sontum is worried that suppliers will not be compensated for their loss in revenue from sales of spare parts. The FPE Sontum interviewee continued with the following;

> *"Equinor envision a future where they can buy the part as a CAD file once and then they are finished doing business. I am not sure if they manage to get their suppliers onboard with this (…)" (R4)*

In the quote above he is clear that suppliers will be affected by the loss in revenue from sales. This gives the suppliers little incentives to come onboard with this future business model. This topic requires us to talk about barriers related to a future market situation, in which the suppliers need to be able to make money using AM. This we will be discussed further in research question 2.

The usage of business models like “pay-per-use” represents barriers in the form of IP and copyright regulations regarding obsolete parts designed by someone else. Our interviewees acknowledged this as a challenge, but at the same time some of them pointed out that if other industries have overcome this challenge, why would not the oil and gas industry manage to do the same. When discussing this with our interviewee from Aker Solutions, he told us;

> *“Regarding IP and copyrights… I don’t quite see why this should be a big problem. They have managed to find a solution in other businesses, like Spotify. I believe we will be able to find a solution here as well. But this is for the lawyers… When it comes to scanning products and printing them, this will maybe be little trickier” (R1)*

In the last sentence of the quote above, our interviewee is talking about “obsolete parts”. Before we move on, we wish to clarify what we have stated earlier in the research and design chapter about limitations for our master thesis. We do not have any ambitions of analyzing how IP and copyrights should be handled by the industry when adopting AM. We will however highlight our findings from what our interviewees told us, as these factors certainly represents barriers. Further on this topic, our interviewee from Aibel said;

> *“As an MMO supplier, we are doing maintenance on many different installations on the Norwegian continental shelf. Here we encounter a lot of old parts which you cannot find on the market today, but still have rights in terms of ownership tied to them.” (R2)*

During our conversation with R2 from Aibel, he was aware of the challenges that come with IP and copyrights. IP and copyrights may be tied to parts that you cannot longer find today and will therefore be an issue when wanting to 3D print them. At the same time, “obsolete parts” are one of the drivers listed by Equinor. This is a driver for Equinor because if no one is providing these parts anymore, one should be able to make a similar design or scan the component to reproduce with an AM system. During our internship at Equinor we were made aware of that lawyers at Equinor were currently working on this subject and trying to find a solution.

We have now discussed the changes from a value chain perspective and discussed what our informants told us regarding new business models that will be required for implementing AM. These are barriers that need solutions for Equinor to get Norwegian suppliers on board.

Further, we will discuss how this will inflict organizational structural changes in the industry. When talking to our interviewees about this topic, we expected a lot of feedback on visions they had set for the future. On the contrary, most of them told us that they did not see any big challenges regarding the necessity to change their organizational structure. We believe that this can be explained by the fact that every supplier in the industry have their own perspective of how adopting AM on a large scale will affect them. The different perspectives we will cover further in research question No 2. Even though our interviewees apparently did not see this as a big challenge, they all acknowledged that this will require many suppliers to structure themselves differently. Our interviewee from Aker Solutions told us the following on this topic;

> *"The area where it might affect us might be our supply chain function. This department follows up products from our sub suppliers all the way through logistics, delivery and all of that. All it really comes down to is that this function will be disrupted. They must be ready to follow up 3D printing instead. Instead of metal components, in the future they will have follow up these 3D-drawing or CAD files. (…) I think it comes down to adding an element in our structure, rather than removing one (…) So, for us I believe this will not be very organizational challenging." (R1)*

What our interviewee from Aker Solutions told us here, confirms what we earlier said would affect value chains compared to Porter's model. R1 believes this will affect their inbound logistics and outbound logistics, regarding all aspects concerning receiving products from sub suppliers, handling these products and further distributing them. When comparing our findings to Porter's value chain model, these findings point towards most noticeable changes in the supplier's supply chains. If these components are in the form of a CAD model, he further thinks this will cause changes in their support activities.

Further, our interviewee from FPE Sontum told us;

> *"No, we are not. We are way too traditionally organized. We have a strategy for how we want to develop and adapt for the future. In this there lies a dynamic overview for how we are adapting internally to handle the different tasks given to us by our customers. If the customer is changing their demand and how they want to do business, we are forced to follow and adapt to that. Today we receive a request for a service, somebody receives it etc., same old procedure. But today… this is the reason why I say no to your question… Today we are organized in the exact same way we were during the 90`s." (R4)*

Here our informant thinks they are not organizational structured to meet the demands of the future. Business has been going well since the 90's and they have not needed to focus on a plan for reorganizing their structure but rather adapt to what the customers want. These two quotations sum up our impressions from talking to our informants about the organizational structural transitions required by the suppliers to adapt in the future. They all recognized that there will be a structural change, but they do not see this as a big challenge now.

In summary, for Equinor to reap the benefits of their drivers, they need to find a solution together with suppliers. A new business model for AM needs to be in place to give suppliers incentives. Everyone we interviewed, agrees on that organizational change will happen, but none of them currently have a plan for this yet.

5.2 Summary Research Questions 1

Is AM a disruptive technology for the Norwegian oil and gas industry, and how may it change the industry?

Firstly, we have in this chapter discussed if we can call AM in the Norwegian oil and gas industry disruptive. As we have said before, the technology was invented already in the early 80's but has until recently not been used as a common production method in the Norwegian industry. In the theory chapter we have portrayed different criteria that have to be fulfilled for a technology to be defined as disruptive, according to Bower and Christensen. During our discussions we have found several similarities between AM and these criteria. Amongst the several similarities, the drastic reduction in lead time is very important for the customer, and therefore brings a new and different value proposition to the market. We therefore conclude from the criteria, that AM is a disruptive technology for the Norwegian oil and gas industry.

Secondly, we have discussed how AM might change the industry. To investigate what might change, we started with looking at the drivers and benefits for Equinor. If they want to reap the benefits of these drivers, it will require changes according to our discussions, especially when realizing the drivers; lead time, virtual warehouse and obsolete parts. Further, we looked at how these will affect the activities from a value chain perspective. Taking these changes into consideration, it also becomes clear that the implementation on a large scale will require a new business model. All of whom we interviewed agreed on that things will change, both in terms of a new business model and organizational transitions. Currently none of them has a clear vision of what this might look like. This matches the theory from Chesbrough, where he says that it is often far from clear for the managers what the right business model ought to be for a new technology. According to innovation and business model theory, this situation represents a barrier when implementing an emerging technology in an industry. Knowing what the right business model ought to be is therefore essential for a successful implementation. This requires businesses to develop the capability to experiment with business model innovation. Theory tells us that this often causes problems, as resource-allocation processes in companies that are critical to their profitability and competitiveness will not – and should not – direct resources to markets where sales will be relatively low.

5.3 Research Question 2

What are barriers the Norwegian oil and gas industry must overcome for implementing AM on a large scale? And is the AM technology mature enough for the industry?

We will analyze research question 2 in two sections, as there are two different questions to be discussed. In the first section we will discuss what the main barriers are for implementing AM in the industry. We will discuss technological barriers and further talk about the market situation with Equinor being in a powerful position as they are one of the largest players in the Norwegian oil and gas industry. In section two, we will discuss if AM as a technology is mature enough for the Norwegian oil and gas industry. To draw a conclusion, we will compare our findings to research of how emerging technologies spread in a market.

5.3.1. *Barriers for large scale adoption*

In this chapter we will discuss what the main barriers are for implementing AM in the industry. But first, we start by discussing the supplier industry of the Norwegian oil and gas industry. We want to shed some light over the situation the suppliers find themselves in, as they all have different perspectives, which in turn, implementation of AM on a large scale could affect them in very different ways.

5.3.1.1 Different perspectives

In the supplier industry we have a wide range of different companies consisting of different organizational sizes and structures. In addition, they deliver a wide range of different services and/or products and they each play a small role in a big complex network of suppliers and sub suppliers. Some of them deliver a broad spectrum of services, while some focus on a niche market and product.

Aker Solutions and Aibel on the one hand are among Equinor`s biggest suppliers as they are listed in the Tier 2 group of suppliers by Equinor. Tier 2 is as mentioned in the case description, suppliers of maintenance, modifications and operations (MMO) services and typical for these suppliers is that they have big and long-term contracts with Equinor. In their perspective, implementing AM on a large scale is not a big threat to their business now at first, as they mostly deliver bigger projects to their customers. For both companies Equinor is their most important customer as described in the supplier profiles. They provide larger projects and services, like for example bigger piping systems or big modules for platforms. The parts considered to be affected by AM is mostly delivered to them by their sub suppliers.

On the opposite side of the spectrum, we have Tronrud Engineering which is listed as a "new supplier". During our interview we were told that only 3-4% of their services are directed towards the Norwegian oil and gas industry. As described in their supplier profile, they focus on providing automated special machines to big industrial companies. In 2011 Tronrud Engineering started with 3D-printing and have later invested in a metal 3D-printer, which lately was used for providing the parts for the pilot project initiated by Equinor. To this day, 3D-printing in both plastic and metal equals a total of 1-2% of the company`s annual turnover. When talking with the interviewee from Tronrud Engineering, he could tell us the following regarding their perspective on AM as a production method;

> *"We are, as previously said, mainly a producer of industrial automated machines, with a CNC-center with 23 CNC machines. 3D-printing is a perfect fit in our company, as we now have the opportunity to 3D-print the parts which are difficult to make with our CNC machines. The parts for 3D-prinitng that are not profitable, we can use the CNC machines. (…) This has worked out really well in our organization" (R5)*

Our interviewee from Tronrud Engineering told us that they look at AM as an opportunity and not a threat, as they now are able to provide an additional production method. When asking him if they look upon AM as a threat, he told us;

> *"No, AM is most definitely a good opportunity for us. Well, that is easy for me to say… We have both AM and CNC as a production method here. The ones that only have a CNC workshop would look at this in a completely different way." (R5)*

In the statement above he describes that AM is a good market opportunity for Tronrud Engineering. However, he also acknowledges that other suppliers that have not invested in AM yet, will look at AM as a threat to their business.

In our case description we have listed FPE Sontum and Karsten Moholt as OEM suppliers. While FPE mainly delivers tailormade firefighting systems, Karsten Moholt is a supplier providing monitoring, analysis, services and maintenance of rotating machinery and equipment. Our interviewee from Karsten Moholt told us that from their point of view, AM is an opportunity, focusing on that they are working on finding suitable components that will be beneficial for the company to produce with a 3D-printer. During our interview with FPE Sontum, we got the impression that they did not see AM as an immediate threat either, but agreed with what our interviewee from Tronrud Engineering told us when talking about other suppliers, saying the following;

> *"I believe that many companies will look at AM as a threat. I'm not in doubt that if I were managing a company providing products in a machinery workshop, I would have said the following; In 5 or 10 years, our machines using the conventional production methods is cut in half and replaced by 3D-printing machines" (R4)*

In summary, we can say that the supplier industry for the Norwegian oil and gas industry is very large and complex. This industry consists of everything from big suppliers such as Aker Solutions and Aibel, which have big maintenance contracts with Equinor, compared to sub suppliers that often provides the smaller components for these contracts. This is a big network of companies and for most of them Equinor is the end user, either indirectly or directly, which means they are a part of Equinor`s value chain. As they all provide different products and services, the implementation of AM as a technology will affect them in different ways. Especially in the cases where suppliers are providing parts that are too big to produce in a 3D-printer.

5.3.1.2 Technological barriers

We will now further discuss the barriers tied to the technology, starting with issues tied to the price of a printed part. The price of a printed part comes down to the cost of machine, cost acquiring competence and the time it takes to print a part. It also comes down to having a demand for the printer throughout the machine's lifetime. Industrial AM machines for manufacturing metal can be a heavy investment for most companies. When asked questions regarding how they viewed risk tied to implementing AM, most of them were very focused on having enough jobs lined up for the printer. We wish to start with what our interviewee from Tronrud Engineering told us. In our case, Tronrud Engineering is one of the companies with most experience regarding AM and is as previously mentioned one of the participants in Equinor's ongoing pilot project. This experience has been obtained through projects dating back to 2011, when they bought their first machine for printing metal. The printer was bought for a special project without having any jobs planned for it afterwards. Even though they have successfully created a small market for AM now, it has not been easy. R5 tells us it was tough the first years to break even with the investment, because of the small market they first had to create.

> "*I don't think this will become a success for Equinor before 3D printing has come a lot further with bigger and faster machines. This is to get the price down. I think the price will be too high the next ten years." (R5)*

Here R5 is referring to AM in oil and gas. He thinks the technology has some more improving to do, in the form of print speed. This will help drive down the overall cost-per-print. When talking to our interviewee from Aibel, we got the same impression. As previously mentioned Aibel is one of the MMO-category companies. They are different from Tronrud in that they deliver services to the industry, compared to Tronrud that sell components and custom systems.

> *"The technology is moving forward rapidly. What I think it comes down to is two things: One is that the cost of each individual component needs to go down compared to produced. The other is to break down conservative knowledge. We don't yet trust this in our industry. They have managed to do it in the aerospace industry so we should manage to do it offshore as well". (R2)*

Here our representative from Aibel confirms what R5 from Tronrud Engineering told us, but also thinks it comes down to trust in the technology. When saying "compared to produced", our interviewee means compared to a conventional manufacturing method. He further mentions how AM is used in the Aerospace industry, which includes both aviation and space flight. Like oil and gas, these industries also have strict procedures for testing parts before installation and he thinks that similar ways of quality assurance should be possible to implement into oil and gas as well. To even more confirm that suppliers view it as a big investment compared to cost-per-print, we want to include a quotation from Trio OilTec. This is one of the smaller companies we spoke to and have since 2014 obtained special competence within their niche. It is important to point out that Trio provides specialized wear protection services to the oil and gas industry and therefore differ from our other suppliers in that they use AM to operate within a niche market. They started with AM after the oil price dropped in 2014 and are now one of the leading companies globally, when it comes to special competence within wear protection.

> *"The cost per print is still fairly high in my world as long as we are talking about metal parts. In the future this cost will drop, but for now this is a barrier. Size is also a limitation. There is a maximum build size there and that is not big". (R6)*

When the price drops and the technology improves, it will lower the overall cost for a printed part. We have now covered how suppliers view the investment and will now cover the build size of an AM system for metal. R6 from Trio OilTec also talked about the limitations tied to dimension. All of whom we interviewed agreed on that this is still fairly small for the oil and gas industry, even with the newest machines. A lot of components used in oil and gas are way bigger than this volume. When we covered the subject of build size, our interviewee from Tronrud Engineering stated the following:

> *"It is here the limitations lies. The build dimensions of the machines. The machines we have today can build components of (250x250x280) mm and it only has one laser. There are machines today with four lasers and that can print components up to (400x400x400) mm." (R5)*

Here, R5 confirms how Tronrud Engineering also view the build size as too small and further goes on to explain how this limits AM for smaller components within the volume size of the system. Our interviewee from Tronrud Engineering also talks about how machines with more than one laser have started to come to market. This will contribute to faster production and help push the cost-per-print further down, like we discussed earlier in the chapter when covering print-time.

Especially for the suppliers within MMO, we discovered a correlation. For them the build size is crucial because they more frequently than the other suppliers, deal with large components.

We will now present a quotation from our interview with Aker Solutions when covering the small build size. Together with Aibel, Aker Solutions is also in the MMO category.

> *"I do realize that if we were a compressor manufacturer, or someone who makes a lot of advanced, small components, to be used in something bigger, this had been gold for us. Right now, we deliver a lot of big pipes and large structures. This makes it challenging to find the good cases." (R1)*

What R1 from Aker Solutions told us here, is tied to the lack of incentives. Compared to the other suppliers there are a lot fewer cases for suppliers in the MMO category to use AM, due to AM`s size limitations. There are still a lot of situations where these suppliers can use it, but first these cases must be found. Finding the specific cases where it is beneficial to use AM is seen as a challenge. We must emphasize that until the technology of AM improves, a conventional manufacturing method will in most cases still be the cheapest.

We have now covered barriers tied to price, time and dimension. We will now go through how suppliers view material testing. All platforms are in harsh environments and must handle tough weather conditions. Because of this, the oil and gas industry have a high standard when it comes to quality assurance of products before installation. During our internship and several of the interviews we conducted, we were made aware of that AM is not yet included in [5]NORSOK but will be before the end of 2019. Tronrud Engineering printed the fire hose inlets for Equinor's ongoing pilot project. When discussing the quality assurance, they had to go through for testing the parts, R5 from Tronrud Engineering told us:

> *"…. the enormous amount of paperwork we have had to provide, to get them approved. What this testing has costed Equinor, I don't know, but it will be more expensive than a conventional method if the testing continues to be as comprehensive as now." (R5)*

The paperwork for testing was a lot according to our interviewee. The Twenty-nine identical fire hose inlets were made in a serial production but were tested individually. This process caused a lot of time and money and should be standardized for oil and gas. Without a

[5] The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. (Standard)

standard procedure for testing it will continue to be more expensive than a conventional method that already has a trusted test process. Since Tronrud Engineering is one of the companies with most experience with AM, we also covered how they view construction competence.

> *"It's really not that easy. You need to work with people that know how a 3D printed part shall be designed. Today we have twenty designers and have 3D printed since 2011. I dare to claim that only a few of these people are able to make drawings we can send directly to the printer without any adjustments." (R5)*

Today Tronrud Engineering has around twenty CAD designers with a few of them focusing on AM when needed. R5 further goes on to explain the design process for AM compared to other methods. A design is limited to what a machine can do. When designing for a process where material will be added layer by layer, it gives the designer much more freedom. With more freedom comes more complex geometries. This allows the designer to create shapes within structures that cannot be made in any other way than with AM. When there is little of this competence among designers it becomes a barrier. When interviewing Tronrud Engineering and others we discussed the subject of why AM is not already in educational plans for engineers. Universities do not yet offer courses that involve the design process of AM to cast light on the technology and make the industry aware of what AM can do.

In summary, we have now discussed technological barriers, starting with how suppliers view the current cost-per-print. They all consider the cost-per-print as to high compared traditional production methods. As the technology develops, the print speed will increase and lower the cost-per-print. Further, we have covered the problem with the required amount of paperwork regarding quality assurance of printed parts needed to be used offshore and how the new competence required also represents a barrier.

5.3.1.3 Market situation

Above we have discussed the barriers tied to the technology itself and discussed barriers regarding construction competence. In research question No 1, we discussed in which ways AM can change the industry. We looked at different scenarios that in some instances, will require the implementation of new business models. Implementing new business models represent a new set of challenges and barriers for the supplier industry. To this day it seems like none of our informants had a clear plan or vision for how this could be done. This is understandable, as 3D-printing is yet to be a commonly accepted technology within the Norwegian oil and gas industry. Although we understand why they do not have a clear plan, previous research tells us this can be a barrier.

The next barrier we want to discuss is tied towards a fundamental barrier that must be solved before the supplier industry will even consider starting to implement AM as a part of their business. This requires us to discuss Equinor`s role and how the company’s strategy and decisions affects the market situation for the supplier industry. Before we move on to that, we want to sum up the barriers we have discussed;

- ✓ Technological barriers
- ✓ Barriers related to new competence
- ✓ Barriers by implementing new business models

As described in the case description, Equinor is the largest operator on Norwegian continental shelf, in which the Norwegian state is their largest shareholder with 67% of the shares, managed by the Ministry of Petroleum and Energy. For most suppliers in the Norwegian oil and gas industry, Equinor is their largest customer, directly or indirectly. Equinor`s dominant role in the Norwegian oil and gas industry leads to a market situation where the demand of products and services is given by what Equinor decides for and want. In other words, Equinor`s demand is the decisive factor for how the market is for the suppliers.

This leads us to the fundamental barrier for implementing AM in large scale as mentioned above, which is that Equinor needs to decide if they want AM as technology. Without Equinor having decided internally and in turn creating a demand for the supplier industry for products and services provided by AM, there is not an AM market for the supplier industry. One could argue that this is not only a fundamental barrier, but a premise and prerequisite that needs to be sorted out. If the Norwegian oil and gas industry is to adopt AM as a technology, this fundamental barrier leads us further on to an important discussion regarding the market situation in the industry. On this topic, our interviewee from Aker Solutions focused on the contracts and offering documents. He pointed out that if a supplier wants to generate income by using AM as a production method, it needs to be stated in these documents from Equinor;

"I think it's important to start with the offer documents and contracts from the operator… I think this is the most important driver… (…) If they want us to do this, we need to get it specified in the job offer and contracts. What often happens is that we say we will try and do something, but then the contract gives no incentives to do it but rather the opposite." (R1)

In this statement the interviewee points out that it is difficult to invest in AM before it is stated that AM is to be used as a production method in the offering documents and contracts from Equinor. Our Aker Solutions interviewee followed up on his statement above, saying the following;

"Equinor has a lot of strong competent employees who are experts within their discipline, but from our perspective it feels like we are talking to different experts within the Equinor organization all the time. Every time there is a new project, we deal with different people with different demands representing Equinor. There is no homogeneity in the demands for how we are to perform our service from Equinor. This is why the most important thing is to get it specified in the offering documents and contracts." (R1)

This statement emphasizes how important it is that Equinor decides internally and officially approve of AM as a technology, in which the whole organization unites and agrees on a strategy on how to move forward using AM. This is necessary so that Equinor can specify in their contracts that AM is a preferred production method. Due to this reasoning, the authors of this master thesis argue that Equinor deciding to approve AM as a technology, is a fundamental barrier that needs to be sorted out if AM is to be adopted by the industry.

In 2014, the global oil and gas industry was hit by a substantial fall in oil price, which had a huge impact on the global industry. The price of crude oil fell more than 50% from its peak in June 2014 to January 2015, resulting in Equinor cutting vastly in their demand for products and services from their suppliers. The fall in oil price made projects that were profitable prior to the fall, no longer profitable, resulting in big projects and contracts getting canceled. As a part of this price development, Equinor started to focus on cutting costs and find every possible way in which they could become a more efficient organization. This has had an impact on more or less every supplier and sub suppliers, which was a part of Equinor`s value chain, and as result the Norwegian oil and gas supplier industry got an immense pressure of cost reduction, which in turn meant that the suppliers had to provide products and services at a lower price for Equinor. All of this has resulted in higher competition for work among the suppliers in the industry, where the suppliers find themselves in a market situation, in which the profit margins are very small.

When conducting our interviews, almost every interviewee highlighted the market situation that their company found themselves in, competing for small profit margins. Our interviewee from Aker Solutions told us the following;

> *"Equinor has challenged us saying they want us to buy 3D printers and start. But we, in which I mean the suppliers in the industry under the operators, are really pressured for lowering our costs. We have been through a really tough time in that sense, call it a famine if you want… So, it is easier said than done… Unless we are to build up a heavy amount of work in terms of overhead again. It is difficult to find the resources and say; Let's go ahead and buy this" (R1)*

This statement represents what we discussed with most of our interviewees when talking about the industry and how the landscape in the oil and gas industry has changed since the dramatic fall in oil price in 2014. Following up on this subject, our interviewee from FPE Sontum also spoke to us about how heavily pressured they are for lowering costs and prices, saying the following;

> *"It is not a secret that the market today is characterized by an overwhelming high competition among suppliers to win jobs, with low and bad profit margins for the suppliers." (R4)*

The market situation that has developed since the oil price dropped in 2014, has resulted in the industry`s suppliers now working with small profit margins. This is not ideal now, when Equinor wants the supplier industry to adopt a new technology. Implementing a new technology requires investments, and the suppliers are obligated to look at the associated risk that comes with these investments. In an industry that is already under pressure to lower costs, it is important to have a future market situation where the suppliers are able to earn money and have some predictability doing so. In our interview with Tronrud Engineering, he told us the following on this subject;

> *"We need to have contracts secured in advance to be able to invest in a metal 3D-printer, which will cost us 15 million NOK at a minimum… (…) Without any predictability for our income, we cannot start to invest." (R5)*

When speaking to our informant at Aibel he also emphasized the importance of the predictability of having enough jobs lined up, as industrial AM machines for manufacturing metal can be a heavy investment for most companies.

> *"When talking about printing of metal we are talking about huge investments. If we are going to obtain new competence and buy our own printers, we wish to have the machines producing 24/7." (R2)*

In the chapter about AM as a technology we listed the benefits of implementing AM as technology on a large scale, from Equinor`s point of view. All these benefits could represent massive cuts in costs in different ways for Equinor, and therefore they all represent drivers and incentives for why Equinor has initiated their 3D-printing project. But as we stated above, there must be incentives for the suppliers to come along as well.

During our interviews, everyone could see the incentives of implementing AM from Equinor`s point of view, but they all questioned what the incentives would be for the suppliers. They all seemed to agree that if the industry managed to successfully implement AM as a technology, it would be very beneficial for Equinor in many ways. When asking them which incentives they had, they could only name a few. Every interviewee seemed to end the topic about incentives with pointing out that it was difficult to see how the suppliers could earn money using 3D-printing. Our interviewee from Aker Solutions told us the following;

> *"If one takes a risk, there has to be a profit. If we buy a printer worth 10 million NOK it is a risk without any guarantee for income in the nearest future. It may sound stupid, because we so badly want to. You may see the upside with a 10 million NOK risk, but we need incentives" (R1)*

During our interviews we got some feedback when talking about incentives that the suppliers have. Many of them talked about keeping up with the technology trends and that satisfying their customers was important incentives, so that they maintain their competitive advantage. Both Aker Solutions and FPE also focused on the incentives given to them by AM as a production method, in which this technology enables them to mitigate their environmental footprint when providing service and products. Our interviewee from FPE told us the following on this subject;

> *"We, who are in the oil and gas industry, have a bad reputation when it comes to the environmental footprint which we leave behind… when using traditional production methods we only use, let`s say 10% of the material… in other words you have a material waste of 90%. With 3D-print there will be almost no material waste, which will give a much better result when looking at the environmental footprint." (R4)*

Our Aker Solutions interviewee followed up on this statement with the following;

> *"This is one of the most important incentives maybe. We believe that, how our environmental footprint looks, will be one of the decisive factors when we are bidding to win contracts in the future." (R1)*

In summary, our interviewees all agreed that Equinor has big incentives and drivers for implementing AM, but they all seemed to question what the big incentives were for themselves. In both quotes above, the interviewees told us that mitigating the environmental footprint were an important incentive for them, in which our interviewee from Aker Solutions also said that this could be decisive when trying to win job contracts.

5.3.2 Is AM mature enough for the industry?

Here, we will discuss if AM as a technology is ready to be adopted by the industry and explain our thoughts by using presented theory concepts of how new technologies spreads through industries. As a part of this we will also discuss findings related to how the industry`s suppliers perceive theirs, and Equinor`s role in developing the technology, in terms of how the risk should be shared between them.

So, where do we start? To evaluate if the technology is mature enough, we must look at the findings from our study presented so far in this chapter. In research question No 1, we discussed how implementing AM could change how they organize and run their businesses.

In some instances, this will require the suppliers to use a different business model. The usage of a new business model, in which one incorporates the concept of “pay-per-use”, represents challenges and barriers in terms of IP and copyright regulations. It is important that the industry cooperates and finds a solution that is accepted by everyone, if one wishes to implement AM as a technology on a large scale.

Furthermore, in research question No 2 we have presented our findings from our conducted interviews in terms of barriers by implementing AM in the Norwegian oil and gas industry. Everyone we interviewed was convinced that AM was coming to stay in the industry, but for now there are several obstacles the technology must overcome before the industry can fully take advantage of its potential. Firstly, we presented barriers related to AM being too costly, as the cost of each component printed is currently too high compared to conventional methods. Some of our interviewees also focused on the limitations regarding the slow print time of the metal 3D-print machines available in the market today, as a factor when looking at the total cost of each component printed. The next technological barrier discussed, was the limitations in form of the small build size that the 3D-printing machines provides today. We also presented findings, in which our interviewees told us that the high amount of paperwork and testing required to get a component approved for usage would be a barrier if one wishes to make AM as a production method profitable for the suppliers. Lastly, regarding technological barriers, we discussed the barrier in terms of the new competence required to implement AM. Designing and 3D printing of components required a new way of thinking and in turn require a new skillset regarding constructing competence. Our interviewee from Tronrud Engineering we believe had the best insight on this topic due to their experience using AM. He told us that this represents a big challenge, as gaining and developing this competence for the employees took time and was easier said than done.

We then talked about the market situation in which Equinor plays an important role. We discussed the market situation, after the fall in oil price in 2014, where most of the suppliers in the industry find themselves in an environment with very tough competition when trying to win job contracts. This has resulted in suppliers focusing on cutting costs and being more cost efficient, so that they are able to provide the lowest possible price of services and products to their customers. This is not an ideal situation, having suppliers fight for survival when the goal is to implement a new technology that requires a lot of resources and investment. Secondly, we described the situation that represents what we call a fundamental barrier. The industry depends on Equinor to approve of the technology and in turn create an AM market for the industry. The market situation described, results in an industry which has a low willingness to invest, which is necessary if Equinor wants the industry to implement the technology, so that Equinor can take advantage of AM`s fully potential and all of the benefits.

All these factors represent different barriers that Equinor and the supplier industry has to overcome for the technology to get adopted and implemented in the Norwegian oil and gas industry. Some of these barriers are more important than others to overcome and some barriers will be solved when other barriers have been overcome. In summary we have the following barriers;

- Technological barriers
- New competence required
- New business models
- High competition for contracts amongst suppliers – low profit margins
- One customer setting the premise for the demand for product and services
- Equinor not united in their strategy for requesting AM I contracts
- Currently there is not an AM market for the suppliers
- Uncertainty in demand for products provided by AM
- Unwillingness to invest (partly due to barriers mentioned above)

So, is AM as a technology mature enough for the industry? If we take all these barriers into consideration, we can say that AM as a technology is not mature enough for the industry at the moment. As we will discuss further, this is only natural as AM as a new technology is currently in the middle of a process, in which the industry is putting their effort into research and development so that the technology can become a commercially viable option. This process requires the industry to overcome the different barriers step by step. In the theory chapter we presented the concept of diffusion of new technologies, which describes different phases a new technology goes through when spreading in an industry.

The process of implementing AM as a new technology in the Norwegian oil and gas industry, is highly relevant to the concepts we provided in the theory chapter about diffusion of new technologies. The S-curve (Figure 4) illustrates how the new technology has a slow spread rate in the beginning, as the users are skeptical and because it takes time to optimize production to the point where the price is right. Further, if the innovation breaks though this phase, the demand and production of the product will increase.

When looking at the process of breaking down barriers, so that the industry can adopt AM as a technology, the explanation from the S-curve makes sense. Further, we saw from Figure 4, the different stages when the different groups start using the technology, starting with the innovators and all the way to end of the curve where we find the laggards. As stated earlier, in our case study, the suppliers can be seen as consumers adopting a new technology. In this context Tronrud Engineering can be viewed as a company in the innovator group, as they were among the first companies in the oil and gas industry to invest in industrial AM machines.

Later in the theory chapter we presented a concept, which is characterized by issues occurring when trying to make the new technology commercially viable for the users, also known as "the chasm". As described here, overcoming "the chasm" or "the commercialization gap", is considered to be a crucial step for the spread of a new technology. This phase is characterized by people who are not convinced of the capabilities of the new technology, as the new technology is seen as disruptive compared to the current technology the company has built its foundation around. This is very applicable for describing the current situation when the industry, with Equinor in the driver seat, is working towards the implementation of AM. Our findings show that for many of the suppliers, AM as a production method can start to cannibalize their current products provided by the current technology. As people in companies often feel attached to the current technology they have invested in and made plans for, it may take some time to convince the people in a company to go forward with a new technology. Especially since the new technology may require change in both competence and how to perform the work.

5.3.2.1 Overcoming "the chasm" and "the valley of death"

So where do we begin when discussing how AM can become mature enough? It only seems logical to us to start with the fact that there must be an AM market for the suppliers for this to be even possible. Equinor plays a key role as they are the ones capable of creating this market, by deciding internally and officially to approve the technology so the suppliers have a demand for products provided by this new production method.

We believe, as stated earlier that this is a fundamental barrier and solving this is a prerequisite if the industry is to implement AM. For this to happen, the management in Equinor and the rest of the industry needs be convinced and trust AM as production method. A crucial step towards this is representatives from Equinor working on the 3D-project, cooperating with Equinor`s suppliers and executing successful pilot projects together, so that the management of Equinor is convinced to keep going forward with AM, and eventually officially approve of the technology.

We believe that overcoming this barrier will end up resulting in many of the other barriers we have mentioned being broken. As soon as there is an AM market with a demand for products provided by this production method, the suppliers will be more willing to invest in AM, compared to what we see today. Investments will lead to further technological research and development. Step by step the different barriers will start to be eliminated.

Right now, the AM technology finds itself in a development phase described as “the valley of death” by Garnes, in the theory chapter. This phase is characterized by the accumulation of different development costs, necessary to make the technology commercially profitable. Not before accumulated revenue streams from sales from AM is equal to the accumulated development costs, will the industry be able to be profitable using AM. This phase has its challenges tied to it, presented in the theory chapter that fits our case. The different factors like lack of competence by both customer and investor leads to lack of trust in the technology from both customer and investor certainly fits our AM case. Even though the people in the industry working with AM actively possess the required competence and also trust the technology, it is important that the rest of the people in the industry follows and also gains this trust. Further, the lack of required infrastructure and lack of willingness to invest is also described earlier as challenges for the industry when implementing AM. Finally, the factors where investors and people in charge of the companies evaluates the price as too high and sales too low, which in turn leads them to evaluate the risk tied to the investment as being too high.

This requires us to discuss how the supplier industry perceives their role and Equinor`s role about sharing the risk associated to the developing phase of the technology. In our interviews we got a lot of feedback on this topic, in which our interviewees claimed that the suppliers were dependent on Equinor`s contribution in taking some of the risk, especially since Equinor as the end user are the ones pushing the technology on the suppliers, and as they are the ones with the clear incentives and drivers to implement AM. During our interview with Aker Solutions we were told that it is essential that Equinor states that AM should be a required production method in the offer contracts. This step would enable Aker Solution to prioritize AM. In other words, this action by Equinor results in mitigating the risk for Aker Solution so that they can move forward using AM. Our interviewees from both FPE Sontum and Karsten Moholt also emphasized the importance of Equinor helping the supplier industry to mitigate the risk in this developing phase. Our interviewee from FPE Sontum told us the following on this subject;

> *«I expect Equinor to support and subsidize the new technology as long as they are the only ones reaping a benefit from it. In the case with the fire hose inlets Equinor paid for the material testing and approved the technology. The suppliers have offered a lower price to enter the market and we have bought them for more than usual to do this together with Equinor. But, compared to how they are pushing the supplier industry regarding price and cost, they must be in the driver seat pushing the technology forward. The industry can`t make this happen on their own, as it is not profitable at the moment (…) This is why I believe Equinor have to push the technology, make demands and lead the way by taking some of the risk, until a certain point in which the technology is sustainable for the industry. If you take into consideration the role they have in Norwegian continental shelf, they have to take this responsibility" (R4)*

Our interviewee from Karsten Moholt told to us the following on the same subject on risk sharing;

"Equinor must contribute in developing solutions, processes and procedures. They should be contributing in paying for some of the development costs and share some of the risk… (…) If not, we are the ones taking all the risk… all the risk shouldn`t be placed at the suppliers as this is something we are developing together." (R3)

Both quotes above represents the viewpoint on risk sharing from most of our interviewees, in which they all seem to agree that it is necessary that Equinor share some of the risk, as they are the ones pushing the technology on its suppliers.

Finally, we will conclude this research question by looking at an extra incentive the industry could benefit from in the process of implementing AM, which is the concept of gaining value through coordination within a value chain. In the beginning, when working with a new technology, the transactions costs are at its peak. But as time goes by, these transactions costs caused by planning, friction, slack in logistics and cost for coordination between departments, groups and businesses, will be lowered and as a result one can achieve better production results. As the level of coordination increases, one can gain value in the form of different coordination effects described by Garnes in the theory chapter. These effects were split into three categories; Additive coordination effects, synergies and transcendental effects. In summary this will hopefully result in optimizing each individual contribution so that one can better utilize the available resources. Further one will have synergy effects which results in qualitative improvements. Also, trough cooperation and dialog one is increasing the probability of innovating and creating something new. These are the different perks one can be gaining value from when the level of coordination is increasing within a value chain as time goes on. This is applicable to every organization, which also has its own value chain in the Norwegian oil and gas industry. Equinor represents the biggest value chain, with every supplier and sub supplier as a part of it, but these coordination effects everyone will benefit from at some degree.

As our final words in our analysis, comparing conventional production methods to AM, many will argue that AM is more expensive. If one takes into consideration the effects of coordinating the whole industry as a part of Equinor`s value chain using AM, these coordination effects outweigh the fact that traditional production methods are currently cheaper.

5.4 Summary Research Question 2

What are the barriers the Norwegian oil and gas industry must overcome, for implementing AM as a technology on a large scale? And is the AM technology mature enough for the oil and gas industry?

The suppliers in the Norwegian oil and gas industry consist of a wide range of different companies with different sizes and structures that all provide different types of services and products. They all play a role in a big complex network of suppliers and sub suppliers. This gives them different perspectives on the organizational environment surrounding them. This means they can have very different perspectives on how they view AM as a technology. Some suppliers view it as threat, others as an opportunity.

There are several different barriers tied to technology itself, but also barriers related to obtaining new competence. Today the cost-per-print is to high when using AM as a production method, partly due to its slow print time. The high amount of paperwork needed, and the small build size also represent technological barriers. New business models are required when implementing AM in large scale. This also represents barriers for implementing AM.

After the oil crisis in 2014, in which the oil price fell more than 50%, the supplier industry has been through a tough time. An industry pressured for lowering costs and prices, operating with low profit margins due to the high competition is not ideal when trying to implement a new technology. Because of the investments and resources required. Equinor`s dominant role in the Norwegian oil and gas industry leads to a market situation where the demand of products and services are given by what Equinor decides. As Equinor is the one who creates an AM market, this results in a situation where there is currently not an AM market for the suppliers providing AM as a production method. This situation represents a big barrier for the industry. Based on all the presented barriers, we can conclude that AM is currently not mature enough for the oil and gas industry. This is only natural as the technology finds itself in the development phase aiming to eventually overcome "the Chasm", also known as the "commercialization gap".

While the drivers for implementing AM represents big incentives for Equinor, the industry has a hard time seeing how it can earn money. This results in the suppliers having small incentives and being unwilling to invest, especially considering the market situation. As implementation of AM requires huge investments and resources for the suppliers, they are obligated to look at the associated risks. With the high amount of uncertainty and low incentives, the suppliers are dependent on Equinor to share these risks. As the suppliers are dependent on Equinor to mitigate their risks in the development phase, Equinor first needs to decide internally, and officially approve of AM as technology. This will require the whole organization of Equinor uniting in a strategy on how to move forward using AM. Our study shows that it is essential that Equinor states that AM is a required production method in the contracts. This will enable the suppliers to mitigate their risks and prioritize AM as a method and then go forward using AM.

If Equinor wants the industry to implement the technology, so that they can take advantage of AM`s full potential and all of its benefits, they need to take some of the risks away from the suppliers within their value chain. This depends on Equinor having a united strategy, coordinating all of its suppliers within Equinor`s value chain. As this is only possible after Equinor officially decides for a united strategy, the authors of this master thesis argue that this is a fundamental barrier and a prerequisite that needs to be sorted out if AM is to be adopted by the industry.

6 CONCLUSION

The first research question in this thesis was: Is AM a disruptive technology for the Norwegian oil and gas industry and how may it change the industry? We have found several similarities between AM and the different criteria that must be fulfilled for a technology to be defined as disruptive. We have concluded that AM is a disruptive technology according to the definition of Bower and Christensen. If Equinor want to reap the benefits of their drivers for implementing AM on a large scale, it will require changes. Especially when realizing the drivers; lead time, virtual warehouse and obsolete parts. Further, these changes will affect all the activities to some degree from a value chain perspective. Taking these changes into consideration, the implementation on a large scale will require a new business model. Currently none of the suppliers have a clear vision of what this might look like and this situation represents barriers for implementing AM on a large scale.

The second research question in this thesis was: What are barriers the Norwegian oil and gas industry must overcome for implementing AM on a large scale? And is the AM technology mature enough for the oil and gas industry? The suppliers in the Norwegian oil and gas industry all play a role in a big complex network of suppliers and sub suppliers. This results in them having different perspectives of how the implementation of AM on a large scale will affect them. Our study shows that there are several technological barriers, such as cost-per-print being too high, but also the new competence required by this technology. Further, the market situation in which the suppliers find themselves in is not ideal when Equinor is trying to push AM on the industry. An industry, that is pressured for lowering costs and prices, operation with low profit margins due to the high competition. This is not ideal when trying to implement a new technology. As Equinor are the ones who create a market, this results in a situation where there currently is not a market for the suppliers providing AM as a production method yet. Based on these barriers we conclude that AM as a technology is not mature enough for the industry. This is natural as the technology finds itself in the development phase, aiming to eventually overcome "the Chasm". As implementation of the technology requires huge investments and resources for the suppliers, they are obligated to look at the associated risks. With the high amount of uncertainty and low incentives for taking this risk, the suppliers are dependent on Equinor to share the risk during this development phase. Equinor first needs to decide internally, and officially approve of the production method. This will require the whole organization uniting in a strategy on how to move forward using AM. Our study shows that it is essential that Equinor states that AM is a required production method in the contracts they want to reap these benefits from. This will in turn, lower the risk for suppliers and give them the incentives they need to start using AM.

If Equinor wants the industry to adopt this technology, so they can exploit AM's full potential and benefits, they first need to take some of the risk away for the suppliers within their value chain. This depends on Equinor having a united strategy and coordinating all suppliers within their value chain. However, this is only made possible after Equinor officially decides on this strategy. The authors of this master thesis argue that this is a fundamental barrier and a prerequisite that needs to be sorted out for AM to be adopted by the industry.

In final, AM is generally more expensive and currently more time consuming when compared to traditional production methods. Only when viewing the overall picture, one can see and understand why AM is so attractive for the industry to adopt.

7 WEAKNESSES, FURTHER RESEARCH AND POSITION IN LITERATURE

In any research project there can arguably be found weaknesses to some degree. For us as scientists it has therefore been important to be open and continuously question ourselves and the data we have gathered during the whole process. As previously mentioned in our research design chapter when discussing weaknesses, we argue that all the suppliers we interviewed might base their answers on future business with Equinor. We did not get this impression during or after the interviews, but we cannot be sure. Also, we could have included more suppliers to interview to get a broader aspect of the situation to gain higher validity. Especially suppliers that only provide smaller components with the conventional production method, since these are in most danger of being cannibalized by AM as a production method. Further, the technology of Additive Manufacturing is in a rapid stage of growth. This means that some barriers tied to the technology will resolve themselves as the companies producing these systems continuously strive to advance the speed and size limitations.

In this study we have studied what we found to be important barriers to overcome for large scale adoption of AM in the Norwegian oil and gas industry. This is a broad industry with a complex network of different suppliers. We therefore chose to narrow it down to Equinor, the largest operator and six of their different suppliers to represent the Norwegian sector.

This thesis can help contribute to further research regarding business models among suppliers, Equinor`s value chain and how to further optimize transactions between suppliers and Equinor. When the ongoing pilot project for the Johan Castberg Vessel is finished, this may also be a good case to study.

Concerning contribution and position in literature. During our study we had conversations with different people, at school, in our internship at Equinor and with friends and family in our spare time regarding our master thesis. They often argued, saying that “this” is something that will force itself on the industry as the drivers and incentives are so big for Equinor. While not necessarily disagreeing with them, the authors of this master thesis argue that for successfully implementing AM in the industry, it is essential to know about the different barriers and the underlying reason why these barriers exist. We hope that we have managed to shed some light on this, and by doing so, helping Equinor and the industry to be able to achieve this.

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9 APPENDICES

9.1 Appendices I Gartner's hype cycle for 3D print 2018

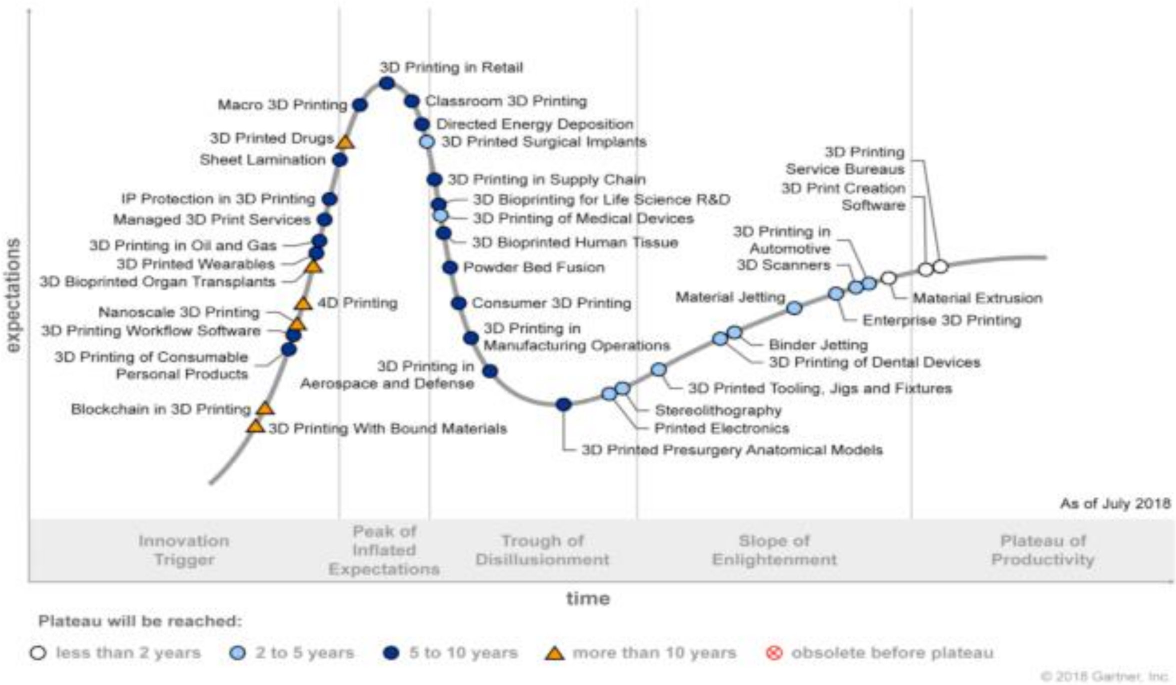

Figure 10 - Gartner's Hype Cycle 2018 for 3D Printing (Carlota, 2019)

"Metal 3D printing is on the rise in 2019. By 2020, 3D printed metals and alloys will become a critical element in supply chains for replacement parts in commercial, military and even some consumer markets according to the report." (Carlota, 2019).

Gartner have also made the prediction that by 2023, 25% of medical devices in developed markets will be manufactured by additive manufacturing (Basiliere, 2019). This prediction is based on using the technology for pre-surgical planning, replacing joints, surgical implants and prosthetics (Carlota, 2019).

We can see from the figure above that Gartner has predicted another 5-10 years before 3D printing in oil and gas has reached the "plateau of productivity".

9.2 Appendices II Previous research on the field and gaps in the literature

Before we started this research, we already knew a lot about the AM technology from the market research we did for Equinor in our participant observation study. We were therefore aware of the overwhelming amount of research tied to the technology itself. As this is an exploratory study concerning barriers to implement the technology on a large scale, we performed searches regarding adoption of the technology in oil and gas.

We did find some articles that were written for both the oil and gas industry and general. The most applicable ones are a few years old and portray potential drivers and benefits for the industry but do not discuss any barriers and how to overcome these for a large-scale adoption. As Equinor already have told us benefits for implementing AM, we therefore conclude that none of these articles intervene with our original research questions.

Via the keywords: *Business model pay per use 3d print oil and gas*; we came across these two articles via Google Scholar.

In the article "*Additive Manufacturing and 3D Printing for Oil and Gas - Transformative Potential and Technology Constraints",* the authors describe additive manufacturing as a potentially disruptive technology for the oil and gas industries. They further mention how the technology is now capable of printing metal alloys and its future potential for oil and gas applications. (Camisa, Verma, Marler & Madlinger, 2014)

We further found an article called: "*3D Printing Disrupts Manufacturing: How Economies of One Create New Rules of Competition"*. This article also focuses on how the innovation of 3D-printing can be viewed as disruptive but also focuses mainly on the future potential for industries. (Petrick & Simpson, 2015)

When searching the same keywords in different combinations on Science Direct, we did not find any relevant articles. We tried further refining the results by year, publication title and article type, but nothing seemed applicable for our case of implementing 3D-print in oil and gas. After a significant amount of browsing, both in the beginning of our research and from tips from our interviewees, we conclude that there is not much research done concerning barriers or implementation of AM on a large scale. As our case represents the Norwegian industry, we are confident there has not been done similar research.

9.3 Appendices III Interview guide

As this is an exploratory study, we added questions to our interview guide throughout the process after new aspects were discovered during interviews.

Interview Guide

Part I: Introduction and general information

- Short presentation of us and our background
- Presentation of our thesis
- Explain what our goal for the thesis is and what we wish to obtain from the interview
- Ask for concent to record
- Inform the interviewee that he/she can choose to not answer questions they find personal or sensitive
- Short presentation of interviewee
  - Role in company
  - Education
  - Time in company
  - Experience

Part II: General - Challenges & Barriers regarding AM

- What services/products does your company provide today?
- What role does your company have in the Norwegian oil and gas industry?
- Relationship to Equinor
- What are the biggest challenges for a large scale implementation of AM
- Current business model
  - Prototyping or mass production
- How can AM affect this business model
- Is there a plan for how such a business model will look like?
- Thoughts regarding IP
  - Digital business model
  - Pay-per-use
- Views on certification process for printed materials
- Risk tied to implementing AM
  - Cost
  - Timeframe for implementation
  - Level of investment
  - Competence
  - Sharing risk with Equinor
- Cooperation with Equinor
  - What is expected from Equinor?

    - What role should Equinor have when implementing AM in the oil and gas industry
- Is there any cooperation projects or competence environments your company can benefit from?
- Thoughts regarding maturity for the industry
    - Trust in technology

Part III: Organizational change
- Organizational
    - Structure
    - Knowledge
    - Culture
    - Willingness to change
- Is you company organized to tackle a change?
- To which degree do you mean a restructuring of the company will be necessary to meet this technological development?
- Is there a short process from idea to decision?
- Do you foresee an organizational change?
    - Mechanistic/Organic
    - Centralized/Decentralized
- In what areas is AM considered a threat compared to conventional methods?
    - Competence
    - Technology
    - Production
    - Culture
- Willingness to change among employees
- Thoughts regarding cultural circumstances that can impact a change in the organization

5Part IV: Various - Summary
- Are there any other aspects the informant can think of?
    - Summary
    - Upsides/downsides of AM
- Are there any other incentives for implementing AM other than Equinor request it?
- Do you foresee any other customers than Equinor, possibly in other industries?

Part V:
May we contact you later for further questions if necessary, or to clarify answers?

9.4 Appendices IV Description of master thesis and agreement of consent

Description of master thesis and agreement of consent

Description of master thesis
We are both students at the University of Oslo's master's program in Innovation and Entrepreneurship taken through Western Norway University of Applied Sciences. Our supervisors in this project are Åge Garnes (Age.Garnes@hvl.no) and Ole Andreas Brekke (ole.andreas.brekke@hvl.no).

The questions we will be asking in the interview will be related to the topic: *Implementing Additive Manufacturing in the Norwegian Oil & Gas industry*. The purpose of the study is to identify barriers tied to spreading the technology.

Our choice of methodology for gathering data for this master thesis will be by conducting interviews with key companies. These companies are either directly tied to implementing AM as a method for manufacturing parts, or may be affected by it in some way. The data collected in this study will help us answer our research questions and contribute to further research.

The interview will consist of questions about your companies role in the Norwegian oil & gas industry, current organizational structure and how/if your company is planning to adjust to the changes AM might cause.

Anonymous participation
Your participation in our master thesis is completely voluntary. As a participant, you have the right to draw your answers at any given time both during and after the interview. For this thesis to meet the rules of publication, both us as interviewers and you as the interviewee must sign this document. Notes, audio and personal information gathered during interviews will be destructed when the paper is handed in. All quotations will be presented to interviewees for approval before published. If desired, your identity or information that might lead you to be identified will be made anonymous.

By signing my name below, I certify that I have read all the information above and I agree to consent. I also understand what is required of me. A photocopy of this document is just as valid the original.

Date (DD.MM.YY)/Place: ____________/____________________

Printed name of interviewee: ________________________________

Signature of interviewee: ________________________________

Printed name of interviewer #1: ________________________________

Signature of interviewer #1: ________________________________

Printed name of interviewer #2: ________________________________

Signature of interviewer #2: ________________________________