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Impact of Additive Manufacturing on Supply Chain Network Structure

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Preface

This research study is made in requirement of a master's degree in international business and marketing at Norwegian University of Science and Technology (NTNU) in Ålesund.

This concludes our two-year master program at NTNU in Ålesund through which we have gained vast amounts of knowledge that we will use to its full potential. This study has proven to be a great way to learn about new subjects and gain a comprehensive understanding of the mechanisms involved in production, supply chain network structure, impact of additive manufacturing on network structure and the degree to which additive manufacturing can be considered as a disruptive innovation.

We would like to extend our gratitude to the companies and individuals that have helped us gain deep insight into matters of high complexity, your help has been truly invaluable.

We would like to thank our supervisor, Per Engelseth, for his countless support and expertise knowledge in supply chain network and additive manufacturing. You have provided us with great input towards looking at methods from another perspective and given us the needed guidance towards structuring this thesis. We are also thankful to our professors at NTNU, who gave us enormous amount of support, knowledge and time throughout our studies at NTNU in Ålesund.

Finally, we would like to dedicate this work to our families and our friends for their encouragement and support in our endeavours, no matter what they might be.

Summary

Purpose of this paper: To empirically ground the networked use of additive manufacturing. Research directs attention to the impact of additive manufacturing on network structure and the degree to which additive manufacturing can be considered as a disruptive innovation.

Design/methodology/approach: This is a research study of different Norwegian firms and their use of additive manufacturing, either advanced or at a trail stage. The study encompasses interviews of 15 companies including observations of some of these companies. The research seeks through a series of qualitative interviews to detect company history of using 3D printing tools, its current use and future prospects as perceived by various informants. The research is founded in supply chain management literature providing focus on how companies integrate to collaborate and coordinate production processes in an industrial network. Proximity to customers is a key analytical factor in the studied networks to facilitate co-creation. This implies considering new business models focusing on proximity in business relationships as a key factor associated with organizing supply.

Findings: Fifteen detailed companies case study is provided. This shows that additive manufacturing is still in its infancy technologically and use is limited. It can at this point in time not be considered as a disruptive innovation due to its current limited use in the supply chain of the studied firms.

Value: The study develops a research approach considering use of additive manufacturing in the supply chain thus laying empirically founded grounds for further research on this is type of technological innovation in industry.

Keywords: Additive manufacturing, Disruptive innovation, 3D printing, Integration, Supply chain structure.

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IMPACT OF ADDITIVE MANUFACTURING ON SUPPLY CHAIN NETWORK STRUCTURE

1. INTRODUCTION

The purpose of this thesis is to analyse the impact of additive manufacturing on supply chains and how they alter the network structures among the supply chains once implemented. Additive manufacturing, also known as 3D printing or desktop fabrication, has somewhat revolutionized the manufacturing industry and is being considered as a disruptive innovation. Unlike traditional manufacturing where one start with a block of raw material and moulds it in the desired form, additive manufacturing uses computer-aided-design (CAD) software or 3D (three dimensional) scanning of the desired object and develop it using the layer-on-layer approach. The American Society for Testing and Materials (ASTM) International, defines additive manufacturing as:

"A process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies."

It was first developed in 1980 and since then it has been gaining huge attention in all areas of product manufacturing including food industry, clothing industry, fashion industry, aircraft and car manufacturing industry, medical industry and culture and heritage industry. This technology has been used to process vast range of materials like polymers, metals, and ceramics with the potential to use a combination of materials. It also promises immense design freedom and the capability to create incredible geometrics, surpassing the effectiveness of CAD. Some of the main advantages of AM are;

1) It can provide flexibility to the product designer. Using a computer problem, a designer can make different complex designs.
2) Reduce the manufacturing time significantly. Since the design process is done digitally, it is possible to make the alterations digitally.
3) Reduce manufacturing cost and material waste.
4) With the use of additive manufacturing, the weight of the parts is significantly reduced, which makes the handling process much easier. In addition to that the strength of the

material is also increased with the use of organic material. Due to these advantages, most of the manufacturing industries have opted for additive manufacturing.

Although there are numerous benefits of this technology, there is still some resistance in accepting the possibilities that this technology can bring into the industrial segment. The process of design increases the amount of virtual prototyping and products subjected to rigorous testing for optimization, which can be time consuming. There is also a need to consider the legal ramifications for patenting of designs, changes in certificate standards (CE) and product proving.

With the rapid advancement in technology, companies must rethink their business models with the ever so changing demands from the customers. Additive manufacturing being one of these technologies is affecting the organizations specially their supply chain network structure. Supply chain network is basically composed of the company, its suppliers, and its customers. An example of such network is shown below in the Figure 1. The supply chain network structure enables the distribution of both raw materials and finished goods, which can finally be distributed to the end customer through various channels. The main objective of the supply chain is to meet the demands of the customers as soon as they are placed.

The increase in demand of customized products and faster delivery of goods and services has not only affected the cost of logistics but also modified the relationships with the suppliers. Therefore, to fulfil the needs of the customers as quickly as possible, there might be a need for customer-proximate production which will also help in reducing the costs related to storage, handling and transportation of finished products to the end user. The global supply chain has become volatile with the advent of sophisticated technology, the phenomenon of glocalization, market competition and lean processes. Additive manufacturing may prove helpful in delivering on demand customized products and in close proximity of the customers, lower inventory, less waiting time for specialized parts thus, rendering some stability and flexibility to the existing supply chains.

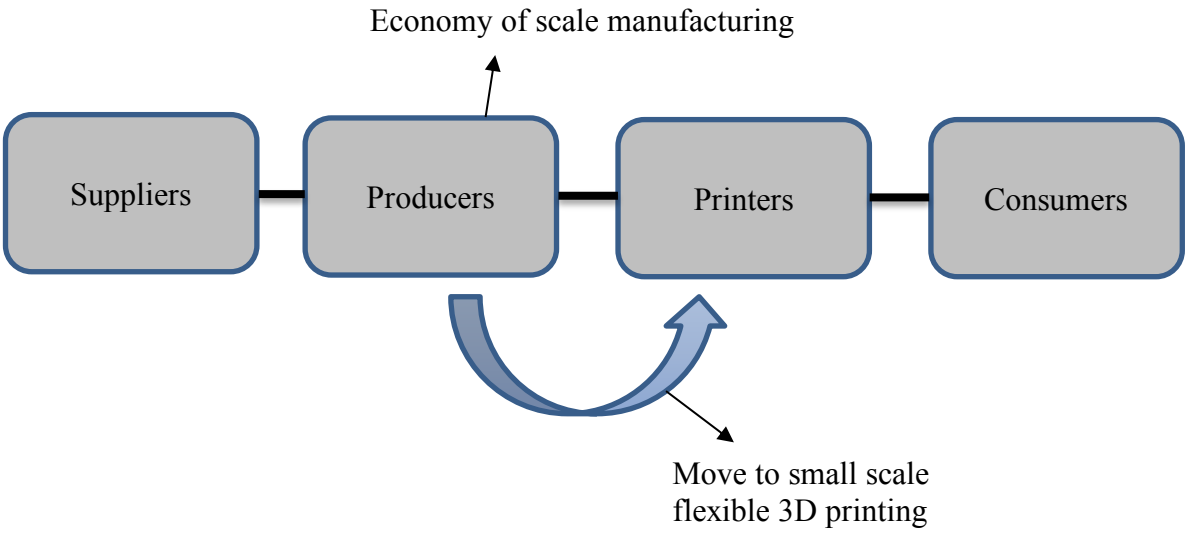


Figure 1: *Hypothetical Supply chain network structure*

Therefore, the scope of this study encompasses three main areas: additive manufacturing, its effects on the supply chain structure and the value addition using this technology. To follow a structured approach in line with the scope of the study, the main objective of this thesis comprises of following research questions (RQs):

- RQ:1 What characterizes additive manufacturing as a technology used by a firm?
- RQ:2 What are the uses of additive manufacturing in the supply chain structure and its impact thereafter?
- RQ:3 What value does additive manufacturing provide to the firm?

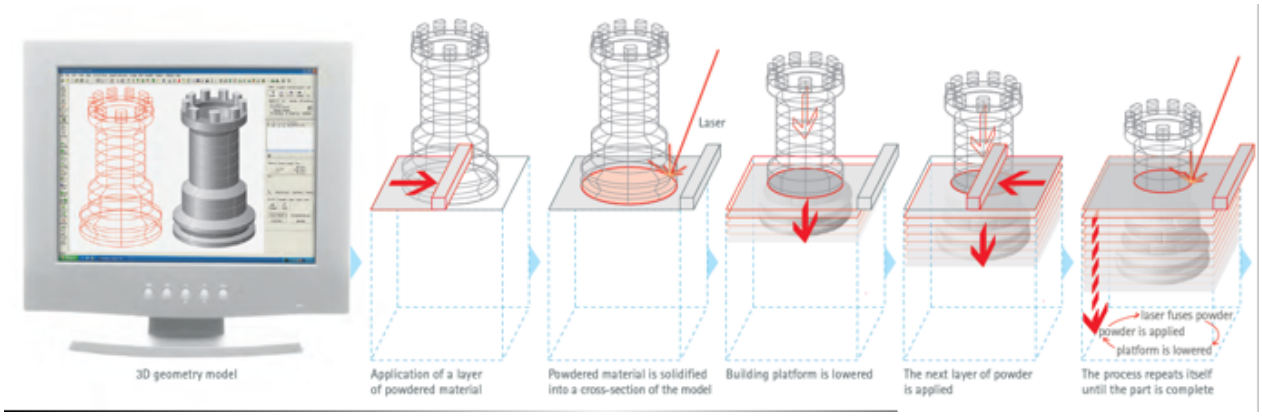
This is a qualitative analysis and the data collection is based on interviews with different companies using additive manufacturing and its impact on their supply chain, whether in prototyping or in production, by asking them few open-ended questions. Further analysis will be done based on the responses from these companies. At least 15 informants will be interviewed, irrespective of any specific industry. Since this study is exploratory and inductive in nature, the analysis will be based on judgement and previous literature available in the fields of supply chain and additive manufacturing.

2. LITERATURE REVIEW

This section will provide an overview of the literature on supply chain and additive manufacturing. It is divided in to three parts, additive manufacturing, its use in supply chain and value addition. Each part reviews different research papers and articles on all three topics in detail. In case of additive manufacturing, the focus will be on the technology, what it is and how it works subsequently followed by its use and impact on supply chain structure and changes in the relationships with suppliers and customers in B2B and B2C networks. While the final section of value addition will focus on the value provision using this technology. The section will now proceed with the literature review on additive manufacturing.

2.1 Additive Manufacturing

Since its invention, additive manufacturing has transformed into several stages from rapid prototyping to rapid tooling and now to rapid manufacturing. Unlike traditional manufacturing, additive manufacturing uses powdered, filamentous, and fluid materials, which are then accumulated layer upon layer to make the final product as illustrated in figure 2 below. It not only provides the opportunity to reduce the number of steps in traditional supply chains, but it also reduces waste of materials and saves the cost of production and tool development. It is best suited for products that are low in volume with complex geometries and have uncertain demand. The products can be manufactured on demand and in close proximity of the customers, resulting in reduction of cost of warehousing, transportation, and packaging (Y Li et al., 2017).



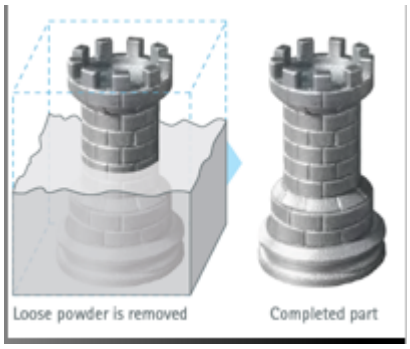


Figure 2: *Steps in 3D printing* (Courtesy of Tronrud Engineering)

The next stage for AM will be to integrate customers into the design and manufacturing process. One of the key reasons to develop products from additive manufacturing is the freedom of design. There are numerous possibilities in design as products of any complexity of geometry can be manufactured without the use of tooling. In injection moulding, products are extracted with the help of expensive tools that not only increase the cost but also limits the design of the product. This is not the case in AM, as the freedom of design reduces lead-time and manufacturing cost immensely. The producers can manufacture products at low cost and the consumers can obtain highly intricated, customized, and cost-effective products. Hopkinson et al (2006) has identified four key areas of this technology. These are; Design, materials and processes, management and organizational issues, and applications. Additive manufacturing also enables the use of any material and any combination of materials which facilitates the production of customized goods. The potential customers can have a say in

the design process of existing or new products offering a unique configuration in the market. The development of prototype through this technology allows the customers to use the product in real time and the final operating product can be improved further with the help of customers' feedback. It can also fill the demand gap until the technology becomes more widespread, easy to use and cheap enough for companies and customers to implement it on a large scale.

Although the technology has the potential to make supply chains leaner, more agile, responsive, cost-effective, more sustainable, and less wasteful (Hopkinson et al., 2006; Holmström et al., 2010) but it is still not able to replace traditional manufacturing processes specially in industries with high production volume, little to no customization and where cost is considered a key performance measure (PwC, 2016). There are several factors that impede the use of this technology like higher cost of the machine or printer, expensive materials, lack of experience with the technology and technical limitations (Hopkinson et al., 2006; Gibson et al., 2015; PwC, 2016). Commercially, the use of this technology is currently limited to basic prototyping rather than large-scale rapid manufacturing (PwC, 2016).

As the technology is still evolving, the conclusions about AM should be revised periodically and through a step by step process to understand and determine the implications of AM on supply chains (Liu et al., 2014). Although AM has some promising benefits over traditional manufacturing, but managers still need to consider their supply chain circumstances when making the decision to implement AM or not.

2.2 Use in Supply Chain

3D printing technology may complement, replace, or even create new supply chain configurations, can offer remarkable results in terms of production volume and location, product customization and complexity, but, it has not yet achieved its full potential. Majority of the service providers have operated on a small scale; enterprise 3D printing service providers have shown steady growth owing to the ability to manufacture in low-cost locations while shipping the products worldwide, on the other hand consume 3D printing firms have resorted to high degree of specialization offering either niche manufacturing via online portals or striving to become a local all-round expert. Thus, the market structures and actors are not stabilized and may change over time (Rogers et al., 2016).

A key task in supply chain management is to reduce operating costs while keeping the customers satisfied. To achieve this, suppliers must overcome the unpredictable demand and make a trade-off between operating cost, inventory level and delivery time. Thus, it becomes difficult for supply chain managers to deliver high level of service at low cost. Some empirical results show that AM based supply chains are superior to the traditional ones in terms of variable costs. These studies also indicated that if the fixed cost such as purchasing cost of the AM machinery are considered, the AM supply chain might be more expensive than the traditional one in AM's current developmental stage. It is believed that the fixed costs will be reduced as the technology will develop further in the future (Y. Li et al., 2017). Some of the studies also indicate that AM technology is more suitable for environment than traditional manufacturing in terms of waste reduction, energy consumption, and carbon emission (Campbell et al., 2011) but other studies show that it can be more energy intensive under certain conditions (Baumers et al., 2011). A study by Y. Li et al. (2017) indicated that, as per their simulation results, the carbon emissions of the AM based supply chains are indeed lower. Thus, AM can be used as mechanism to control carbon emission and waste of supply chains by shortening the channel length.

The use of additive manufacturing in supply chain causes reduction in the number of steps of conventional manufacturing which makes supply chains more cost-effective, responsive, and sustainable. It is used for production of those products that are required in low volume, have complex design and uncertain demand. It renders freedom of design as it can create products with intricate geometrical patterns and complex designs which is not possible with other methods of production. It is a way of producing goods on demand and in close proximity of the customers.

In supply chain studies, the 'network' is used as a metaphor to capture the complexities of interlocked exchange relationships, and to relate to the connection between social change and stability (Knorr-Cetina, 1988). H. Anderson et al. (1998) regard firms as actors that own different resources, perform exchange activities, and have relationships. Therefore, networks can be described as structures composed of exchange relationships between actors who own and use different resources. But these networks are not stable, in fact they are continuously changing due to changes in the existing relationships. It has been argued that

the dynamics in networks can be understood based on the interplay between the positions and roles of the actors i.e., the firms (Anderson and Havila, 1993).

Positions depict the situation of the actors in a given network structure, embrace the expected activities known as 'taken-on-activities'. While role describes what the actors intend to do, how they construct meaning in a situation and how they bring changes to it. The existence of these two dimensions, stated as position and role, can be found in any business network. The dynamics in any network are unique to that of the other networks. Changes in business networks can be explained by the activities an actor performs, given its position within a network structure. The primary determinant of the actors' activities and thereby of the network dynamics is attributed to the ability of the actors to interpret changes and create meaning of their own and other actors' network positions and roles (H. Anderson et al., 1998).

The role and position of actors and their interaction in a network structure may lead to innovations through creation and transfer of shared knowledge. This aspect has been studied by Guercini and Runfola (2015) who has interpreted that the innovational role of actors can be defined in terms of their learning and teaching processes as well as the internal and external relationship that they maintain. The basic assumption in this study is that the actors carry out and leverage a complex set of roles which define their unique profiles. The innovation push of the actor is determined by the set of roles which in turn depend on the nature of interactions with other actors both external and internal to the system.

Håkansson et al. (1999) have elucidated that the characteristics of the two actors (the firm and its supplier) as well as the type of business relationship itself strongly influence the learning process within the network structure. Similarly, this learning is transferred in the form of knowledge (technologies, resources, and skills) to others in the system through interaction with the external actors. Such interactions can be understood as the process of interplay between the firms, that transforms the activities and resources of the firms involved (Ford et al., 2008). So, the networks can be thought of as a conceptual perspective by which other aspects such as innovation can be studied.

The literature has equally emphasized both local and global networks specially with respect to geographical proximity which is considered vital in understanding the development of

firms and their respective industries. Along with geographical proximity, cognitive proximity is also an important factor in facilitating the acquisition and spread of new knowledge and innovation through the network (Camuffo and Grandinetti, 2011; as cited in Guercini and Runfola, 2015). For the creation and spread of the knowledge, the industrial networks are significant as there are many firms in a network producing knowledge and the mechanisms inside the networks facilitate the spread of knowledge.

2.3 Customer Value

A study by A. Barz et al. (2016) has shown that increasing the resource efficiency through additive manufacturing can have a significant impact on the structure of supply networks. They highlighted the main advantages of additive manufacturing as functional integration of parts and a higher resource efficiency for production. The production sited are located closer to the customer and therefore the total transportation cost of material and final product decreases.

The success of 3D printing depends on two supply chains; supply chain of the machine and materials and supply chain of the company intending to do 3D printing. Thus, the company has two choices i.e., either buy the expensive machinery or printer from a specialized vendor or seek the services of 3D printing service provider, with the latter being less capital intensive (Rogers et al., 2016). The decision to implement this technology either by in-housing facility or by out-sourcing must be made while considering strategic, technological, operational and supply chain factors of the organization (Mellor et al., 2014; as cited in Rogers et al., 2016).

Additive manufacturing creates value addition for the firm. The decreased cost of warehousing and inventory handling helps in saving money in the total cost of production. It produces less waste and hence saves cost and the reduced lead time also adds value to the supply chain and ultimately the firm.

Value creation should be treated as being emerged from an interactive process between a buyer and a seller (Tokman and Beitelspacher, 2011). Increased buyer involvement in the production process is associated with more relational orientation and more value creation (Lusch and Vargo, 2006), co-innovation or customization (Lusch and Vargo, 2004a). This can lead to increased satisfaction, increased relational and long-term orientation, and ultimately become a source of competitive advantage (Hammervoll, 2009, 2012).

According to Dyer and Hatch (2006) there has been a shift from competitive to collaborative purchasing strategies. A key tenet of collaborative purchasing is that long-term cooperation between buyers and suppliers in terms of supplier involvement produces more benefits than that of traditional competition-based strategies (Heide and John, 1990; as cited in Hammervoll, 2014). A supply chain relationship integrated the technology of the buyer firm with that of the supplier leading to innovations. Thus, there is a need to consider buyers' and sellers' contribution for co-creation of value i.e., the services provided in the supply chain relationship (Vargo and Lusch, 2008). From buyer's point of view, co-creation of value is commonly understood either in terms of the value created by the object of exchange i.e., goods or services or the value created in the exchange process (Lindgreen and Wynstra, 2005; as cited in Hammervoll, 2014). But seller's concerns should also be considered regarding inter-organizational viewpoint. In this point of view, value co-creation must be considered for the exchange process from the perspective of both buyer and seller.

The two different views on inter-organizational relationships are exchange economy and production economy that provide useful insights for co-creation of value in supply chain relationships. The exchange economy perspective recognizes service provision in terms of information sharing, adaptation, and commitment while the production economy perspective recognizes service provision in terms of production efficiency, quality, and entrepreneurship (Hammervoll, 2014). Both buyers and sellers in a supply chain relationship co-create value by developing their own capabilities and these relationships subsequently act as a means for developing transactions using resource-based view. Under exchange economy perspectives, the co-creation of value in supply chain relationships implies the successful completion of the transactions between buyers and sellers. The focus has shifted to motivating exchange partners to undertake transaction-specific investments, as these increase the potential for co-creating value (Ghosh and John, 1999; as cited in Hammervoll, 2014).

2.4 Demand Chain as Value Chain

Since the beginning, supply chain management has focused on production "push" rather than demand "pull" (Vehlhaber, 2000). Consequently, the focus of supply chain managers has been on "make versus buy", low-cost manufacturing and production efficiency rather than on delivering superior customer value. Christopher and Ryals (2014) have argued that

with the emergence of new manufacturing technology (such as additive manufacturing) and enhanced information flow (big data) the supply chains of today should be demand-driven rather than production-driven. This will not only help in lowering inventory but also enable the firms to respond quickly to customers' demand. This shift will also entail a different role for the supply chain managers, requiring a more integrated approach by responding rapidly to structural changes on both supply and demand side of the business.

The remodeling of supply chains into demand chains is driven by market forces and enabled by new technologies depicting both lean and agile characteristics with the possibility to reduce waste and obsolescence. By reducing waste and being responsive to customer needs, the redesigned supply chains will also help in creating a sustainable environment. New technologies like additive manufacturing and "big data" analytics both shorten time to market and enable greater specificity of the value proposition, shifting the power further towards consumers (Christopher and Ryals, 2014). In the traditional supply chain, managers are under pressure to be both lean and agile; to be customer-responsive and low cost and to offer value-added services with quick order fulfilment while reducing inventory and overhead costs. But the advent of new technologies in manufacturing sector calls for reassessment of supply chain management.

2.5 Research Framework

An overview of our research framework is provided in figure 3 below, the figure shows details of our research approach to guide our research questions and analysis.

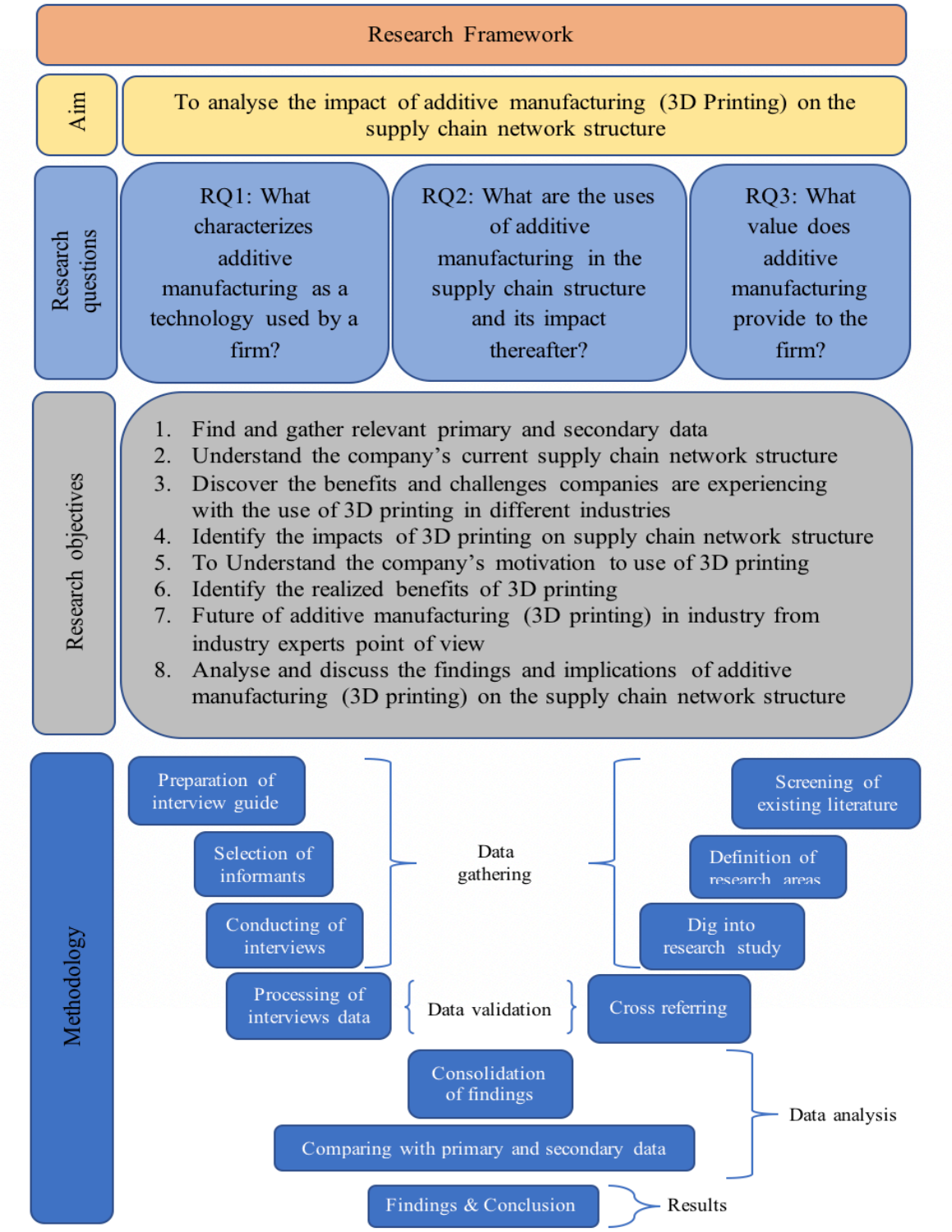


Figure 3: *Flow chart of the research methodology*

3. RESEARCH METHODOLOGY

The aim of this study is to analyse the impact of additive manufacturing (3D Printing) on the supply chain network structure. In order to assess and get rooted information about the use of 3D printing in current manufacturing process, to identify the benefits and challenges that companies are facing from this technology in different industries, how the use of 3D printing impacts on the companies supply chain network structure and what value does it add to the firm. we prepare an interview guide consists of open-ended questions covering basic questions in order to understand a company's current supply chain network structure, current use of 3D printing (benefits and challenges), how 3D printing changes the supply chain network, why company choose to use the 3D printing, the realized benefits from the use of 3D printing and the future use of 3D printing.

This is an exploratory qualitative research, qualitative research is a scientific method of observation to gather non-numerical data (Babbie Earl, 2014). It addresses the knowledge gap in the academic literature regarding the impact of additive manufacturing (3D printing) on supply chain network structure and gives insight into the topics that are valuable to practitioners of supply chain management, companies practice and those looking forward to pursue 3D printing in production, It also give valuable information to the manufacturer of 3D printer's about the challenges faced by companies in different industries and what benefits companies looking forward from the use of this technology, it provide a good feedback to the producer of raw materials used in 3D printing, also it offer a sound awareness about the industrial 3D printers in production and its impact on supply chain network as well as insight for scientists from the same area of expertise.

The two most commonly used qualitative research methods are the interviews, observation and focus group discussions (Len Tiu Wright, 1996). We collected data by interviewing industry experts based on interview guide and observation by conducting site visits in Norway. Based on the information gathered in our interviews and secondary data, we observe, interpret and analyse how 3D Printing will impact on supply chain network structure.

We describe below the steps taken in gathering and analysing the data in order to get entrenched understanding of the current use of 3D printing and its impact on supply chain network structure.

3.1 Data Collection

Data collection is carried out through site visits, face-to-face interviews, skype & telephone interviews and secondary data research. A list of different companies' in Norway is made with the help of our supervisor, respected professor's at NTNU in Ålesund and from internet. Thirty (30) companies were selected from the list and contacted through emails and telephone calls that are relevant to our area of study from different industries in Norway. Out of thirty (30) companies that are contacted only fifteen (15) companies are interviewed (Appendix XVI – List of informants) as some of the companies are currently not using 3D printing technology and few of them didn't respond at all.

3.2 Site Visits

We visited several companies manufacturing facilities in Møre og Romsdal region in Norway (Appendix XVI – List of informants). The site visits provided us better understanding of companies' current supply chain processes, their suppliers and customers (No. of tiers at upstream and downstream levels), their inbound and outbound operations, manufacturing process, how the products are developed and shipped to customers all around the world. We also visited 3D Printing facilities in order to study the additive manufacturing process technology in detail. Multiple steps are required for 3D Printing, it includes producing the 3D model of part/product using Computer Aided Design (CAD) software usually provided by the manufacturer of 3D printers, transfer of file to computer that controls 3D printer, printer setup, layer by layer build-up, removal of part/product from 3D printer and post processing steps including wash with chemical and cleaning. We also discussed the motivation behind the current use of 3D printing, the benefits and challenges of 3D printing usage and how these companies envision the future use of 3D printing.

The purpose of these site visits was to get rooted information about the area of study, to accurately develop the process map of the current supply chain, to become familiar with the different parties involved in the process, how 3D printers works and how the use of 3D printer impact on the supply chain network structure.

3.3 Face-to-Face, Skype and Telephone Interviews

We interviewed industry experts from several different industries either in person (face-to-face) or by Skype or by telephone. A list of informants is provided in the Appendix XVI. The interviews were based on set of questions (Interview guide - Table 1) along with supplementary questions those raised according to the informants replies in order to understand how the additive manufacturing (3D printing) impact on each company supply chain network, how it is change from industry to industry and to what extend it can impact on a company supply chain network structure. We also consider what are the key elements for a company in order to implement the additive manufacturing (3D printing) in production and what are the key elements those restrict a company to implement the additive manufacturing (3D printing) in production and limit them to use 3D printing technology for a prototype only.

Table 1:

S/N	Interview Guide
1	Describe the current supply chain structure (suppliers and customers)?
2	Describe the current use of 3-D printing in your production. Benefits & Challenges?
3	How has the use of 3-D printing changed the structure of the supply chain?
4	Why did the firm choose to implement 3-D printing?
5	What are the realized benefits from the use of 3-D printing?
6	How do you envision the future use of 3-D printing?

Face-to-face, Skype and telephone interviews are extremely beneficial for providing industry insights in the data collection stage. All Interviewees requested anonymity to publish their names, but they allowed to reference their answers and comments. However, all of the Interviewees are of managerial level and having a years of industry experiences in the area of our research study.

In each of these interviews which last for almost an hour, the Interviewee introduces about a company and its activities in his/her particular industry. In addition, the Interviewee described the current supply chain processes, his/her perspective of additive manufacturing

(3D Printing). Followed by the explanations which we questioned the Interviewees to get further insights by using the interview guides mentioned above. These interviews are contributory in developing a complete understanding of the current supply chain system as well as how the additive manufacturing (3D printing) impact on supply chain network structure.

3.4 Secondary Data

Availability of data to study the impact of additive manufacturing (3D Printing) on supply chain network structure from primary sources was limited and thus we required to use secondary sources such as internet. We researched about 3D Printing production process, it's applications, types of 3D Printing materials, current machining manufacturing system, difference between injection moulding and 3D printing production system, quality of 3D printed products, lead and delivery time in each production process from number of journals and web articles. We also searched to find out some companies those are currently using 3D Printing in production to produce products for commercial use as mostly companies using for prototypes only and have intention to extend its usage to production level as well.

Secondary research data sources provided valuable insights and are obliging in filling the gaps where data from primary sources are not available.

4. KONGSBERG (DIVISION: MARITIME)

4.1 Introduction

Kongsberg Gruppen (KONGSBERG) is an international group that supplies high-technology systems and solutions to companies in the industries of the oil and gas, the maritime and the defence and aerospace. The group consists of following business areas; Kongsberg maritime, Kongsberg digital and Kongsberg defence and aerospace.

Kongsberg maritime is a wholly owned subsidiary of Kongsberg Gruppen (KONGSBERG) which is an international technology corporation that delivers advanced and reliable solutions that improve safety, security and performance in complex operations. The headquarter of this division is in Kongsberg, Norway. The manufacturing plants are located both in Norway and abroad including US, Canada, UK, Germany, and China.

The main business activity consists of systems for dynamic positioning and navigation, marine automation, handling systems, safety management, cargo handling, subsea survey and construction, marine training, satellite positioning, and autonomous solutions. The key markets are countries with large offshore, shipyard and energy exploration.

4.2 Synopsis of the interview

The company have a in house production of sonars and they have sub-contractors delivering parts to them which then they mostly finish the product in-house. They have countless suppliers as they are very large company. They have great variation in what suppliers do. So, anything from single part to ready-made industry goes to them. They sell to end customers and end customers are always professional. Not private people. Recently they started 3D printing and the interviewee personally doing 3D printing for 10 years or so. Mostly in prototyping and they have recently about a year ago introduced 3D printing also to do in-house tooling. Usually they don't print products to be sold but recently they have launched a product which they going to sell. However, they are in the introductory stages of 3D printing for sales and for tooling, but they have used it for several years for prototyping. 3D printing has given them new technique, new ways of thinking, new ways of producing and the parts that they 3D print today, have never made before. And partly, because they knew that this part will be 3D printed then the design was made differently. They are

enjoying the advantage of the 3D printing techniques and the tools that they use for in-house that have been designed specially to print from 3D printing. Knowledge of how the product should be designed will save a lot of time and money.

Benefits are cost and time and high turnaround speed where their designer can have an idea for the tools to improve the process and then they are able to create that tooling overnight for example, it can be utilized next day. The challenges are the new materials they must re-learn to design for 3D printing. Its new considerations compared to designing for machining. Time and cost are absolutely a benefit, we have three ultimate gear printers and they are running almost continuously over 3D printing tools and they are cheap to buy and cheap filament and just great benefit. For a designer, the biggest benefit is that they can create parts in 3D printing that simply cannot make using traditional machining or moulding or it would be incredibly expensive. So, there are lots of benefits, but 3D printing is yet a little bit immature so both printers and materials are new. The components that they are printing are usually printed from a supplier and with a SLS-nylon printing. So that's why they can have fantastic complex products. For production, it is accuracy and tolerances. Selection of a printer is also very important to find when it is an appropriate time to use 3D printer and when you should machine the part.

For instance, a Coca cola company, would they like to 3D print the can's and then of course time will be a challenge. As Coca cola makes 1 million cans every hour, they cannot 3D print all of them. But Kongsberg do not make 1 million parts every hour. They make 10 parts a month. They produce relatively low volume, high complexity parts and if they can create a tool overnight or during few days, its much faster than having it ordered it from a machine shop which usually takes three weeks for example. They have standard products but low volume. They have much production of inflated cost and high complexity. Mostly the products are standardized and then maybe will customize the package to the customer. But mostly they build standardized physical.

The supply chain structure hasn't really changed because they have in-house machining, so 3D printing has not change the supply network structure. They do not have such a significant impact because the tools are very low volume compared what they do. They are currently building a production unit with five automaker printers which are controlled by robot which

will make single use moulds 24/7. And they also hope to have access to metal printer not far in future and they will have several different printers both for production and for prototyping.

In printers just like any other tool there is no such thing as this is the world's best printer and they all do their different things in diverse ways with varied materials, however this could be possible in the future where more different printers doing different materials in different ways then perhaps, they will have more 3D printers in-house than other big production machine.

4.3 Empirical analysis

In relation to the research questions, following findings can be extracted from the interview.

Applied technology

The division started 3D printing with the intention to explore new possibilities and new technologies. Currently they have been using the technology for prototyping for several years now, but they have very recently launched a new 3D printed product for the purpose of selling. It is in the introductory stages for tooling and it's not yet matured technology. The parts they are producing from 3D printing are new to them as they have never been made by traditional manufacturing. The products are made in-house with the help of tools specially designed for 3D printing.

Use

The company is using additive manufacturing for prototyping and intends to extend to production in the future. At the moment, the use of additive manufacturing has not changed their supply chain structure because the tools they use are of low volume and they need suppliers for that. So, this has not impacted their suppliers yet. Most of the products are standardized but the packaging is customizable, and the products produced are in low volume but highly complex, so they do in-housing. But they are facing challenges because of new technology and the quality of the materials as they must re-learn the systems, it's basically a learning curve for them.

Customer Value

The value addition includes cost, time, and freedom of design where they can have any tool within a day and improve their processes. This reduces time as the products can be manufactured overnight rather than to wait for the suppliers to deliver them, thus reducing lead time considerably. Due to the realized benefits of manufacturing highly complex parts quickly, the division envisions that the additive manufacturing will have a lot to offer in the future. With the advances in technology, there will be better printers available in the market that can use different materials and produce high quality products.

5. KONGSBERG (DIVISION: DEFENCE & AEROSPACE)

5.1 Introduction

Kongsberg Gruppen (KONGSBERG) is an international group that supplies high-technology systems and solutions to companies in the industries of the oil and gas, the maritime and the defence and aerospace. The group consists of following business areas; Kongsberg maritime, Kongsberg digital and Kongsberg defence and aerospace.

Kongsberg defence and aerospace are a wholly owned subsidiary of KONGSBERG and its headquarters are located at Kongsberg, Norway. The manufacturing plants are located both locally and internationally. The manufacturing plants in Norway are located at Kongsberg, Asker, Tromsø, Horten, and Kjeller while the two international plants are located at Ottawa, Canada and Johnstown, USA. The subsidiary is Norway's premier supplier of defence are aero-related systems. The portfolio of the products includes systems for command and control (land, air and sea-based), weapons guidance and surveillance (maritime and land-based), communications solutions (predominantly for land-based), and missiles (anti-ship missiles and Naval Strike Missile). They also make advanced composites and engineering products for the aircraft and helicopter market. The most important customer of the Business Areas is the Norwegian Armed Forces and they have proven to be quite competitive internationally. The key element of their market strategy is the formation of alliances with major international defence enterprises. The Norwegian authorities approve all defence-related exports.

5.2 Synopsis of the interview

The company suppliers are mostly manufacturers of standard parts, like screws, bearings etc. and machining or casting suppliers for parts made to their design. Final assembly is commonly done in-house before delivery to the customers. Additionally, they also purchase a lot of machined parts for developmental test. Currently, they are using a ProJet 3500 3D-printer to produce plastic parts for simple functional tests during the design process. This gives them the opportunity to try out many different design ideas in a short period of time as they do not have to wait for parts to be delivered from an external supplier. They also use 3D-printer to make a few special tools and jigs. The benefits of this is the ability to make complex, specialized tools fast and at a low cost. The downside of using the current 3D-

printer to make tooling is the limited strength of the plastic material, and that cannot make assembly fixtures where electrical conductivity is required.

The company started 3D-printing as a rapid prototyping tool. But it has not changed their supply-chain at the current time in regard to the products delivery to the customers. Yet it has given them a chance to shorten the design-cycle, and hopefully come out with a better final design. The realized benefits are that it´s much easier to get a good impression of a designs proportions with a scale model compared to just looking at it on a screen; to do test assemblies to uncover design faults before ordering expensive hardware, to make low-cost specialized tools for specific assembly operations, and to replace these tools fast if needed.

Additive manufacturing will widen the design possibilities regarding the structural complexity of parts. Designing additional features into a part, can eliminate assembly steps and reduce time for final assembly. When 3D-printing in metal becomes readily available, it will be possible to make functional components in-house in a shorter time than ordering from an external supplier. Regarding metal 3D-printing, the technology is not quite mature yet. Traditional machining is still in most cases a cheaper and faster solution. For this type of additive manufacturing to be cost-effective, you need parts designed from the bottom up for this process. The future use will involve 3D-printing both in metal and plastic. Metal printing for advanced load bearing parts, where other types of manufacturing becomes very expensive or time consuming. And still plastic printing for prototyping and other components where the physical properties of the plastic is deemed satisfactory.

5.3 Empirical analysis

In relation to research questions, following findings can be extracted from the interview.

Applied technology

From the answers, it can be seen that the intended use of additive manufacturing is to use it as a rapid prototyping tool and is mostly used for the production and design of tools and parts composed of plastic. They are using ProJet 3500 3D printer to produce plastic parts for simple functional tests during the design process. The company has an in-housing facility where they assemble several parts that are purchased from different suppliers.

Use

They are using 3D printer as a rapid prototyping tool to make special tools and jigs. The use of 3D printer has not changed their supply chain structure, but it has given a chance to shorten design cycle and create better designs. In the future, the company is expecting to use the technology with materials other than plastic (for example, metal) as they believe the technology will mature further and 3D metal printers will be widely available. The only challenge for now is the strength of plastic material and fixtures that require electrical conductivity.

Customer Value

The value addition is in the area of design as the company is able to test a number of varied designs in a short span of time which subsequently reduce the lead time. And they are no longer dependent on suppliers to deliver parts to them on time. Another value that it imparts is low cost of production to manufacture specialized and complex tools. This will not only reduce time but also be cost-effective than other types of manufacturing. It also helps in replacing tools and uncover design faults. Additive manufacturing will also widen the scope of design regarding structural complexity and will eliminate steps in the assembly stage, making it possible to manufacture in-house components at low cost and in short period of time.

6. EKORNES ASA

6.1 Introduction

Ekornes ASA was established in 1934 in Sykkylven municipality in Møre og Romsdal county, Norway. Ekornes ASA is the parent company in the Ekornes Group. They are the largest furniture manufacturer in the Nordic region with the well know brand names Ekornes Collection, Stressless, Svane and IMG. Stressless is one of the world's most famous furniture brands whereas Ekornes and Svane are the well-known brands in the Norwegian furniture market. The production facilities are organised according to its product areas: Stressless, Ekornes Collection (furniture) and Svane (mattresses). Their products are manufactured in Norway and advertised across large parts of the world by a network of national and regional wholly owned sales companies.

The headquarter are in Sykkylven and their production facilities in Norway are located in Sykkylven, Fetsund, Hornindal and Morganton in USA.

6.2 Synopsis of the interview

Ekornes ASA is a huge Company with complex and big supply chain network structure. For direct cost materials, they have a several hundred of suppliers and sub-suppliers for each product category such as aluminium, leather, wood, plastic, steel etc from large parts of the world such as Argentina, brazil, china, Italy, India, Norway, Korea, Uruguay and Vietnam. For indirect cost materials they have thousands of suppliers and have millions of end-customers all around the world. Ekornes ASA have factories in Norway as well as in USA. They produce some components like wooden frames and control over the leather colours etc in Norway for a USA factory and shipped to USA to produce final product such as sofas. Majority of the inbound raw materials comes from around the world to the factories in Norway and both the components as well as the final products are shipped to across the world through wholly owned sales companies and Ekornes ASA keeps full control over all the supply chain network structure.

The current use of 3D printing is in the product development and testing of the prototypes. Since they are producing large number of products every day which is currently not possible

to produce from 3D printer and the quality is not good enough in terms of strength. However, for new products, for instance, accessories or sofa parts, 3D printing is very useful to prototype the products, test them, redesign them and test them again before putting the part into actual production. Another benefit is the customization of the product for a customer. There are many challenges in 3D printing. First and foremost is the mass production, quality and finishing of the 3D printed products. As 3D printing is a trending technology, so the printer buy today will be replaced sooner because of the advancement in the technology. The cost of the industrial 3D printer as well as per unit cost because of low volume production could also be a challenge.

Currently, they are not using 3D printing in production, but they believe there will be a change on the supply chain structure because of the use of 3D printing technology. For instance, today to make sofa with fabrics our supplier buy yarn from sub-supplier and make the woven part, make the fabrics, add colours and shipped to a company, then the company must cut it and sew it for the sofas whereas in 3D printing technology a company can perform all these steps by itself. Another example is to make mould from 3D printing which is currently being bought from suppliers. With the help of 3D printing technology this could be done in a couple of days by the company itself. However, the 3D printed product quality as of today is not good enough. The company choose to use 3D printing technology for product development. It is easy to design, test and redesign (if required) all over the night before sending for production. Ekornes ASA is looking forward to the 3D printing technology development so that they can produce all their fast changes products parts in-house.

In recent 5 to 6 years, the change has come to Ekornes ASA by adding all the values in-house for instance, buy raw materials, add values in-house and sell it to the customers. But for the fast-changing products, for instance, today they have a lot of movements in their products such as leg comfort mechanism, they design and prototype the parts from 3D printing, which is then produced by outside suppliers. The realized benefits from the use of 3D printing are: it is easy to design or redesign the product or its parts, it is easy to bring the idea into physical object which can be tested whether it is going to work or not. It saves a lot of time in the product development. The company also run a project called 3D knitting which is a kind of 3D printing technology from computer aided design to automation knitting process.

In future the technology will develop with the possibility of multiple 3D printing i.e. metal, plastic, aluminium, cutting, sewing and knitting all together. With one big 3D printer a company can produce a complete chair and in that case the supply chain network will change completely. However, this may take a very long time as the technology is not there yet. It will also give the possibility to insource all the activities which are currently outsource by a company but only when the volume is high enough. There is continuous improvement in the technology and if it achieves the level to produce large volume with good quality then this can be an easy way to produce much complex products in an effective and profitable way.

6.3 Empirical analysis

Ekornes ASA is a huge company with factories and offices across the world and they are dealing with several different materials in order to produce premium end user products.

In relation to the research questions the following findings we get from the interview:

Applied technology

Ekornes ASA is one of few companies in Norway those heavily invest and use the latest technology in their production. They are looking forward to the Additive manufacturing (3D printing) technology in future but due to the mass production an estimation of thousands of products parts and products every day, 3D printing of any part of the product is not an option for them and therefore currently they are using for the prototype in product development phase. Currently, they have a large number of robotics assembly line and producing thousands of products every day. They use 3D printing is in the product development and testing of the components of the products prototypes.

Use

Ekornes ASA products demands are high and in order to attain economic of scale they are producing very large volume products with premium quality. Currently, it is only possible for them through the traditional manufacturing process and not by 3D printing because of slow production time and low quality.

We identify that at the moment there is no impact of 3D printing on their supply chain network structure as currently they are using for prototype only but in future there is a potential change in supply chain network in terms of addition of new supplier or replace of existing supplier and reducing lead time significantly with a possibility to start print in the warehouses across the world rather than to production in factory and ship to all over the world.

Customer value

Ekornes ASA believe that the lead time will reduce with the advancement in 3D printing technology and the use of 3D printing will impact the supply chain network with a possibility of replacing or completely exit some of the suppliers from the supply chain network but only when the technology is available to print all the production activities in-house and able to produce in large volume.

Moreover, 3D printing adds values to the firm like; ease of design and testing, customization, saves time in product development and opportunity to bring idea into product.

7. PLA-MEK AS

7.1 Introduction

Pla-Mek AS was established as a sole proprietorship in 1991 but in one year by 1992 they received more owners and it was established as a limited company. Pla-Mek AS is a manufacturer and a specialized company in producing technical plastic Injection Mouldings parts, thermoplastic parts for industry and product suppliers. They typically produce for their customers who actually own the products means on contractual order basis. In addition to the actual production they also offer services within the regular manufacture of the product. They have an expertise in tool making trade and good understanding for the production of technical solutions, the company grew rapidly in 90s. They have number of vendors and partner's and therefore their contribution is in the whole process from idea to delivery of the actual products.

The headquarter and production facilities are located in Sykkylven municipality in Møre og Romsdal county, Norway.

7.2 Synopsis of the interview

The current supply chain structure of Pla-Mek AS is simple as they offer production services to the customers and do not own any products. They have a number of suppliers which include suppliers of raw materials for the production of thermoplastic products as well as the suppliers of mould and have a number of customer to whom they produce on order basis. Some of the customers are also their suppliers as they use Pla-Mek AS production services to get their product to be produced on time and with large volume because of the capacity and technology to produce such products in a cost-effective way. Currently the use of 3D printing is as part of product development and not in production for commercial use. They print prototypes in the development process for visualizing product and testing. The development time goes down using 3D printed prototypes. They have also tested out the 3D print of injection moulding tools. 3D printing works suitable with products of simple geometry in small volume. Customization or redesign of a product is very easy and less time consuming in 3D printing and it helps a lot in the development process.

The development of raw material in the 3D printing means that a company can do more tests on the applicable product that brings the development time down. In some cases, the 3D

printed products can be used as a finished product, but only in small volume. Limitations has been the quality of raw material to test the strength and functionality of the product. In addition, with current technology they cannot produce large volume as required by most of the customers and within the specific period. Moreover, the cost of industrial 3D printer is high and number of produced products per day is low in comparison to our current injection moulding system. They have little experience with 3D printing in metal as the printing of the tool in metal is too costly. It is difficult to comment on how the use of 3D printing has changed the structure of our supply chain as currently it is not in use for production commercially. However, if the 3D technology advances and meet the current requirements of the quality and volume then there might be a slight change in the structure of the supply chain for instance in upstream level i.e. change in supplier of the raw materials.

The motivation to use 3D printing was to learn about the technology and to use it for the betterment of the services as it is helping a lot in product development, redesign, customization, and testing. The company is looking forward to the advancement of 3D printing technology to use it in the production in near future for some of the customers with low order volume. The realized benefit of 3D printing is that the redesign of the product is easy and simple through CAD software and product can be produced again overnight for testing. While in traditional manufacturing it is time consuming to get the injection moulding tool which is adapted to the product they are producing. This tool is traditionally produced in stainless steel, where the production time is 3-4 months and investment costs are often high. Cost benefit analysis between investment in the tools and unit price is essential here. Production of tools in stainless steel have traditionally seen the passing of many and time-consuming processes, which affect product development time.

The challenges for the customers and a company, is to reach the market in time as the product and trends are rapidly changing. Whereas, in 3D printing they can redesign and print the product overnight as per customer requirements and test them before the start of the production in large volume. In General, 3D printing brings down the product development time per product. It gives opportunities to produce details of complex geometries and development time on plastic products. Developments in 3D printing are continuous and if it manages to develop a technology to produce faster for a large volume and the development on the raw material side continues for quality of the products then this can certainly be an effective and profitable method to produce in the future.

7.3 Empirical analysis

The Additive manufacturing (3D printing) technology was initially used for plastic products and later with the help of research & development and technology advancement this technology also being used in other materials such a metal. It was interesting to know why Pla-Mek is not using the 3D printing technology in their production and why just for prototyping as they are dealing with plastic products and they are producing for large companies such as Ekornes ASA.

In relation to the research questions the following findings we get from the interview:

Applied technology

Pla-Mek AS core activities is producing large volume products on customer order while keeping the quality standards high and per unit cost low. Currently, it is only possible for them through the traditional manufacturing process i.e. injection moulding system and not by 3D printing because of slow production time and currently the quality is not good enough. Currently they have number of injection moulding machine and one 3D printing machine which they are using for prototyping. They print prototypes in the development process for visualizing product and they also test moulding tools.

Use

The current use of 3D printing is in the product development and it reduce the lead time in product development. Moreover, in terms of lead time their main customer is Ekornes ASA and they are also located in Sykkylven municipality in Møre og Romsdal county, so they are already producing close to customer. They have intentions to use industrial 3D printer in their production so that they can overcome the issue with traditional manufacturing such as redesigning, the cost associate with it and also to get more customers and deliver the customized products. We found out that there is no significant impact of 3D printing on their supply chain network structure as currently they are using for prototype only but in future if they going to use in production then the only possible change in the upstream level i.e. in supplier and this can only be possible if the production volume, cost and quality is comparable with the existing products.

Customer value

For Pla-Mek AS Additive manufacturing (3D printing) add value to their production development and not in their supply chain network at the moment since the use is limited to prototyping only. This value includes such as reduced product development time, customization, ease to redesign, it offers opportunities to produce details of complex geometries and customized products model for testing and to avoid flaws in the product design.

8. STOKKE AS

8.1 Introduction

Stokke AS was established in 1932 in Ålesund, on the west coast of Norway. Stokke AS began with producing bus seats and furniture for adults. In 1972, first product for children was launched called Tripp Trapp chair. Later from 2006 Stokke AS has focused exclusively on premium children´s furniture and equipment within the highchair, baby carrier, stroller, home textiles and nursery market segments. They offer worldwide distribution of premium children´s furniture and equipment. Stokke AS is well known from its premium children's furniture products and the most famous product is the iconic Tripp Trapp.

Today, Stokke AS continues a long tradition of designing smart, sustainable products that promote bonding and healthy development for a whole new generation of children and their families. Stokke AS headquarter is in Ålesund municipality in Møre og Romsdal county, Norway.

8.2 Synopsis of the interview

Stokke AS is a large company and their products are distributed worldwide in over ninety countries under the Stokke trademark through selected specialist stores. The company have several warehouses across the world such as in Netherland, USA, South Korea, China and Japan. Stokke AS have no factories and they do not produce anything by ourselves. All the production is done by their sub-suppliers, but they design the products and have full control over the production line i.e. from placing the order to packing and where to deliver, everything is under Stokke AS instruction and control. Stokke AS design, test, order the production, packing, instruct the production house where to deliver in warehouses across the world, from warehouse to specialist stores and from stores to the end customers.

For fifteen years they are using 3D printing for prototyping and not for production as they do not produce the products. However, if they use it in production then the benefit of using 3D printing in the first place would be to customize part which gives the product added value. For instance, customer name on it or colour, customer can order from a website and it could be done in warehouses. Challenges with the 3D printing is the low speed and technical quality combined with a good surface as Stokke AS have premium products and it

needs the best surface. Producing large volume is also a challenge as currently they are producing and delivering the products in large volume worldwide, an estimation of five hundred thousand Tripp Trapp chairs every year.

On a proximate to customer as a benefit, a company believe that it is difficult and not an option at this time since they are dealing with children furniture and every single product needs to be thoroughly tested and approved before it could be delivered to the customer. So far 3D printing has not change the supply chain structure because the volume is so big, and the products need to be assembled on approved assembly line, so the assembly line must also be distributed because they sell ready to use products and it's not assembled by the end customers. Also, every product is tested by a strict testing team and they run safety test on it therefore it could be difficult to distribute assembly because it is complicated. However, if the products are for decoration then it would be possible that use of 3D printing change the supply chain structure.

At the moment, the use of 3D printing in prototyping which is very helpful for product development. However, if they choose to implement in production then the motivation for the company would be the customization of the product to add more value in the product for the customer. This will also be the realized benefit of using 3D printing in production. There is a lot of work on-going in the improvement of 3D printing technology and it would surprise a company if they do not use 3D printing for their products in future as the production volume will grow and some of the parts which produces in hundreds or thousands per year. So, these parts could be 3D printed as far as the quality becomes good like the products produced by injection moulding system with the same good quality, details, surface and strength.

8.3 Empirical analysis

Stokke AS focused on innovation, modernized and creative design. They have a number of premium products delivering across the world. Although they do not produce any products by themselves, but they have a full control over the production line.

In relation to the research questions the following findings we get from the interview:

Applied technology

The current technology they used in production is injection moulding as they are dealing with large volume of products and in order for them to fulfil the demand worldwide they are not able to use 3D printing in production because of many reasons such as low speed of production in 3D printing where as large volume is required, good quality with premium surface whereas as of today the 3D print products quality and surface is not the same as of injection moulding system.

However, they have been using 3D printing in product development for around fifteen years and this could be a reason for a Stokke AS to produce new innovative products and/or to enhance the current products.

Use

In regard to the impact of 3D printing on supply chain network, so far there is no impact as they heavily used in product development and not in production. We observe that the impact of 3D printing could also be affect by the product itself for instance, as Stokke AS selling children products and it could be risky to use 3D printing specially when the technology is still in developing phase but if the product is a decoration product then 3D printing could be an option and it will impact the supply chain network structure by replacing the production houses with just a 3D printer in their warehouses.

Customer value

3D printing in a first place would be a customize part which gives the product added value for instance customer name on it or add colour, customer can order from a website and it could be done in warehouses and this can reduce lead time significantly.

9. SPERRE INDUSTRI AS

9.1 Introduction

Sperre Industri AS is the family-run business and was started over 60 years ago as a small start-up company. Today Sperre Industri is one of the world leader for starting air compressors. From the very beginning, Air compressors that solve the customers' needs has been the main objective and for more than 75 years, they have developed compressors in close collaboration with the most challenging customers around the world. Today, because of join cooperation between Sperre and their customers they understand how to meet the most stringent requirements and have the ability to supply all the air and ship needs.

Sperre legacy is to deliver state-of-the-art compressor systems with the best life cycle cost which means that Sperre are available for their customers 24/7 and they kept their service promise for more than 50 years now. They deliver any part across the world within 48 hours and it does not matter if the customer compressor is new or 30 years old, they still offer 24/7 services all their customers.

Sperre headquarter and production facility is located at Ellingsøy is the northernmost island in Ålesund Municipality in Møre og Romsdal county, Norway. They have fully owned subsidiaries in Netherland, Belgium, China, Hong Kong, Macau, Singapore, Malaysia, Vietnam, Thailand, Pakistan, Indonesia, Philippines, Australia, Papa New Guinea and New Zealand.

9.2 Synopsis of the interview

The current supply chain at Sperre Industri AS is large and multifaceted. It has over 200 suppliers and customers worldwide. It has a supplier of various product types such as iron castings, valves, electric and control components, sensors for compressors etc. Some of its suppliers are producing their own designs and specified from Sperre. This also leads to the partnership of many other suppliers. Its customers are mainly international. About 97% of all Sperre production is export while 60% of their products goes to China and Korea. Asia is a big market for Sperre Industri AS. Its customers are mainly marine industries and shipbuilders. However, it is growing on land-based solutions which is a power supply in USA & China.

All its production is in Norway. Sperre Industri AS distributes its products worldwide through fully- owned subsidiaries and representative agents. It offers a long-term commitment to the market that it delivers the spare parts worldwide within 48 hours. The spare parts of any of its products will be available in the next 30 years. It keeps a four-month inventory of spare parts. It has 200 standard compressors ready to deliver overnight at any time.

The personnel at Sperre Industri AS have been using 3D printing for the past two years. It is used for modelling, prototyping, marketing, proposals and testing. However, at the moment they are not using it in production. Their current manufacturing is based on robotics CNC machines. Conversely, if they use the 3D printing in production, they believe that the benefits of using 3D printing would be a quick access to casted parts. If the materials and quality are comparable to the existing products. However, as of today, this is a very expensive solution in production. They have some high-volume products and parts but mostly are the standard products while a few are engineering-modified. They are developed according to customer needs. If there are high volume iron casting 3D printers which will be helpful to print spare parts, then they do not need an extremely expensive CNC machine. One challenge in the future would be to protect their own genuine spare parts.

As to customer benefit, they believe that this could be possible to print parts near to the customers and reduce the lead time in the future.

For a time being, there is no particular change to the current supply chain network at Sperre for now. This is so because they are using 3D printing in prototyping and not in production. In the future, they believe that the company can print their parts anywhere in the world for a marine market, harbour etc. They only need to pay a certain fee to the owner for the design and drawings. This could be a global network of intellectual property where a customer pays a fee to print the parts owned by the originator of the product. This is also a challenge to protect the intellectual property in various countries such as in China, Russia etc. There will be a possibility to reduce the number of suppliers when 3D printing is going to be used in production. It will impact the supply chain network significantly in the future once the technology is available and competing with the current production system.

Sperre Industri AS chooses to implement 3D printing machine. The company is learning the technology, to create new ideas and to bring improvements in all value chain with the help of new technology. This helps workers to adopt the new technology in the future. They started with the rapid prototyping and their production engineers continually experimenting with the 3D printing on a routine basis. This helps them familiarize with the technology. It gives them the new opportunities as a big 3D printing machine will be added to the current technological capability.

Sperre Industri AS perceived that 3D printing will make way for a quick access to the parts that can print over the night and test them. For the personnel using 3D printing makes it is easy to redesign. 3D printing is very impressive for modelling and marketing purpose. It helps to create new ideas and to test those ideas. They also believe that as the technology develops they will be able to produce a lot of products in-house with a high quality. For instance, gaskets are a very simple product to produce with a 3D printer. It is just high persistent. Even with the large products they believe it will be possible to print large mechanical parts in their own production with the help of 3D printers in the future. They are excited and looking forward to metal 3D printer for various parts.

9.3 Empirical analysis

Sperre Industri AS is a large company offering its customers with a very high-quality compressors with a very strong commitment to deliver parts within 48 hours across the world for 30 years of their products.

In relation to the research questions the following findings we get from the interview:

Applied technology

Sperre Industri AS dealing with large mechanical parts for which they currently using Computer numerical control (CNC) machines whereas currently with 3D printing it's not possible to produce such quality and large products. However, they are actively participating in 3D printer technology and exhibition across the world in order to learn this technology, to seek new opportunities how this technology can help them in terms of improvements or cost efficient etc. in future and to adopt it to use in the production.

Currently, Sperre Industri has one 3D printer which they heavily use for different type of plastic products prototypes, testing, to innovate the product designs. However, their current production facility is one of the finest high-tech in Norway. All activities are linked to the highly advanced warehousing system. Components come to each work station precisely when they are needed, and the whole factory is virtually forklift free.

Use

Sperre Industri AS using 3D printing for two years now and they are using for modelling, prototyping, marketing, proposals and testing. However, at the moment they are not using in production, but they believe if they use in the future they believe there could be a significant change in supply chain network once the technology is available and the cost of production is low along with large volume. There is a possibility to change of total supply chain from tradition way of supplying products to customers, to just customer pay a royalty fee for using patent design or drawing and they may print the part by themselves or by the supplier anywhere around the world.

Customer value

We identify that 3D printing technology add value in generating new ideas and to bring improvements in all value chain with the help of new technology. The lead time would also be reduced with the availability of 3D printers around the world. Quick access to casted parts, easy to re-design, can print over-night and test them, easier to deliver the product in a short period of time but this all is the future and with the current 3D printing technology is not possible for Sperre Industri AS.

10. TRONRUD ENGINEERING AS

10.1 Introduction

Tronrud Engineering AS was founded in 1977 in a workshop located on the ground floor of the house, in a residential area in Ringerike County in Norway. Tronrud Engineering remained a one-man-business for 7 years, and the customers were Norwegian factories and companies such as Raufoss, Jordan, Stabburet and Grorud Jernvare. In 2011 the company move to a brand-new factory building at Eggemoen Airport. Over the past few years, a growing number of high-tech industries have moved to Eggemoen, becoming part of Eggemoen Aviation and Technology park.

The main customers were in mobile phone production, then photovoltaic production. Then there were projects on oil & gas/geology, medical projects and food packaging projects. Regular customers have been automotive industries and air & space industries. They have completed more than 5000 projects since 1977.

Tronrud Engineering AS have always been at the forefront of "Innovation" in manufacturing. Over the past 40 years, they have developed, produced and delivered customized industrial products and technical solutions for customers both in Norway and abroad, bringing them competitive advantage and profitability. The company currently has two subsidiaries, one in Singapore and one in Moss, south of Oslo Norway.

10.2 Synopsis of the interview

Tronrud Engineering AS supply chain structure starts with buying the machine. It has always had power, gas, and filters on the stock. Customers are ordering parts from Tronrud Engineering AS. Their personnel make an order from their ERP system. The production planner is identities the time schedule of production. They confirm it with their customer. When parts are produced, they deliver them to the customers. Sometimes they have to do the machining before delivery.

For 3D printing, there are two main suppliers of powder. They are the same suppliers who deliver the machine to them. One supplier of gas and couple-off for spare parts, machines, and equipment. In general, for Tronrud Engineering, they have several hundreds of suppliers

with regards their customers, they have at least two or three customers for 3D printing almost every month.

Tronrud Engineering AS needed 3D printer for a project in 2011, Printing different parts were not possible in machining. So, it continues to adopt this technology and continues to grow with the development of 3D printing.

The current use of 3D printing at Tronrud Engineering AS is to produce parts for the customers both in metal and in plastic. For them, it is an expensive way to produce compared to the machining. They cannot use this for parts. They must find products that cannot be done by machine. In order to produce from 3D printing, they need a special design.

The benefit that they got from both 3D printing and machining, is giving good service to their customers. The 3D printing has given them the opportunity to make special parts which are not possible to machining. Delivery is also faster in 3D printing (1-2 weeks) than machining (5-6 weeks). The situation after 6 months is difficult to predict. With regards to quality, they believe that the 3D product is the same as the product produced by machining. There are more benefits when the people know more about this technology. There are still very few people know about this technology. They put a lot of hours to inform the industry players about the technology in which they can produce parts which are not possible with machining.

The challenge is that 3D printing in metal is not well known in the market yet. There are still few companies selling this kind of technology. However, there is not much challenge in the production.

In future the 3D printing will become known in the engineering industry. The price for the printing will drop. There will be faster machines in the future. In the next five to ten years, the company believes that there will be totally different technology that can produce faster products at low cost.

10.3 Empirical analysis

Tronrud Engineering AS is a huge company offering its customers with a very high-quality machines, parts and a several services like design, automation, machining, welding, assembly, waterjet cutting, steel sheet work and additive manufacturing.

In relation to the research questions the following findings we get from the interview:

Applied technology

Tronrud Engineering AS has been using 3D printing in their production since 2011. They confirm that the quality of the product is as good as of machining products. However, it is still an expensive way of producing as compare to traditional method, but it gives a lot of new opportunities for all the players in the supply chain.

They have several different 3D printers for different types of materials and technology.

Use

Tronrud Engineering AS, delivery time is significant lower by use of 3D printing technology than machining process and there is an impact on supply chain network structure with an addition of new suppliers for the 3D printer and their customers are growing almost every week but still they believe that the biggest challenge is the awareness of the technology as most of the companies believe that the current 3D printing technology is not good in term of quality, production time.

Customer value

3D printing adds various value in a firm supply chain such as quick delivery of parts or reduces lead time from weeks to hours which save a lot of customer and company time, ability to made parts those are not possible with machining, save a lot of time and warehousing cost and increasing customers every week because of 3D printing technology. The industrial 3D printing technology not only add value to the producers but to all players in the supply chain.

11. PLASTO AS

11.1 Introduction

Plasto AS was founded in 1942 but official registered as Plasto AS in 1978. They started with an idea to start manufacturing wood gas and continue to invest plastic products and begin the production of plastic ballpoint pens in 1953. However, with the passage of time Plasto AS grow dramatically and they invest heavily in the production and development of plastic shopping carts and this build the foundation for injection moulding in large machinery. They are currently works only with the production technique call injection moulding with a thermoplastic. As of today, they are around twenty (20) injection moulding machines and each of these machines can have different moulds and tools that can produce specific plastic components.

Plasto AS does not own any products. They are a production supplier and all the products they produce are owned by their customers. They deliver a wide range of products to many different industries; whose demands and requirements are quite diverse. Plasto AS is located at Åndalsnes, a town in Rauma Municipality in Møre og Romsdal county, Norway.

11.2 Synopsis of the interview

Plasto AS has 3 to 4 big customers. They also have and several smaller ones. The biggest customer at the moment is Akva Group. It is a supplier of equipment for fish farming. Its main products are parts of fish farms. The circular rings in the sea are the main product of the company. Plasto AS makes the brackets and walkways (excluding the pipes) in different sizes. For injection moulding, this is a very big part. The company purchased thermoplastic materials from a number of big international producer/suppliers to serve their growing of having a number of customers. The company has one big international supplier for one big customer that represents the most.

The thermoplastic is melted and injected into a mould and then they have the finished plastic parts. The other parts of the supply chain are the moulds. Workers need a mould in order to produce the products, so they have also the mould makers companies that supply moulds to them aside from Norway, their supplies are coming from China and Portugal.

Plasto AS has been using 3D printing in prototyping for 10 years. When it has a new product, the personnel always discuss or design new plastic parts with their customers. They are experts in injection moulding. They need to see if the design is good for producing and also for mould the design. If they need to modify something on a part, it is very expensive and time-consuming when they make changes in the existing mould. So, it is very important that they eliminate the need for adjustment of changes before they start making the mould. This is the one big advantage of prototypes. There is lesser risk of mistakes when prototypes are developed.

This big customer for a fish farm equipment requires a lot of other components other than the brackets and walkways. They are working very closely with them. Plasto AS is also a kind of development department for all injection moulding parts. They also do design and product development for their prospective customers. The personnel of Plasto AS do the design and print for their customer's approval. Their designers do a lot of CAD works with simulation to see how's things can be assembled and fitted so physical sample is required for checking.

Scaled models are created for their big customers. The fish farm parts are very big. It is around 60 – 70 diameters so it cannot be possible to print such big models with 3D printing to show to the customers. However, currently, they print small scaled like 1 diameter models for sale purposes. The company presents a lot of small-scale models. Moreover, most of the parts that they have are at least around 10kgs or more. The 3D printing is found to be competitive for small parts and for very low volume when compared to injection moulding. The 3D printing is very useful in specific areas where they have specific problems with traditional methods, they can use 3D printing to overcome those problems.

Plasto AS used to have external suppliers for 3D printed prototypes and models. Now, they can print in-house for showing new products to prospective customers. It is easier for them to choose Plasto AS as a supplier because the company is willing to develop new parts. They print over the night for a sample rather than ordering from a supplier. The 3D printing is an advantage for in-house samples. Possible mistakes are eliminated with this technology which could be very costly if personnel fix them in the finished mould.

The 3D printing is perceived to be beneficial to the company because it is very helpful in prototypes. It has scaled models for its customers for assessment and approval. They also show these for exhibits to prospective customers. They would like to sell fish farm parts, so it is easier for them to show prototypes which are scaled to a smaller size. It is also for potential new types of parts to be checked whether to put in production or not. Personnel try to get the customers approval first before making the mould and contract signing for a real production.

The company vision for 3D printing is that it will be used more and more for small parts. It is possible to print the parts rather than to produce from injection moulding through 3D printing. The company believes that 3D printing may compete with other production technique. Injection moulding is really a high-volume production i.e. several thousand parts a year an injection moulding machine is very automatic. It can operate almost with no human monitoring unless one needs to stop the machine. The robots that take out the finished parts and put them on pallets. So, it is almost no work after they start the machine. Normally, they produce parts in weeks or even months. A number of parts that are produced are huge such number is not possible with 3D printing.

11.3 Empirical analysis

Plasto AS is a company with huge potential and capabilities offering its customers with a very high-quality thermoplastic parts and a several services like design and prototypes.

In relation to the research questions the following findings we get from the interview:

Applied technology

They are experts in injection moulding production technique and they have around 20 machines to fulfil almost every kind of customers' needs from small parts to a really bigger once. Plasto AS has been using 3D printing for prototyping for almost 10 years now, and it is helping them a lot in product development and for marketing purposes. They also used to test the mould for potential parts before they actually put the parts or order a mould into a real production.

Use

We observe from this interview that currently there is no significant change in the supply chain because of the use of 3D printing. However, 3D printing helping them to get more customers. Before they asked their supplier for the 3D prototypes and now they are printing in-house. So, we believe if in the future 3D printing technology develops and the cost of the machine and producing parts are low with high production volume then we believe there could be a change in supply chain same as in scenario of prototyping as of today.

Customer value

Reduced risk and cost of modifying the design, easy to showcase samples, 3D printing gives them an opportunity to work closely with the customers to finalize the design of the product and test before the actual production starts. It also helps in developing a new product or to create productive product for the customers which can be use in certain way that have never been used before. 3D printing is useful for small parts and low volume as compare to injection moulding.

12. AS OM BE PLAST

12.1 Introduction

AS OM BE Plast was established on 1st of January 1962 in the basement premises and registered under the name Fredrikstad Plastic Tools. The company name was changed to AS OM BE Plastics in 1966. In 1969 AS OM BE Plast built own industrial building and by 1997 they build a new industrial building. Manufacturing facilities, warehouses, workshops, assembly and inspection department with the administration all are under the one roof.

They provide innovative and competitive solutions for prototyping and plastic production. They have over 50 years of manufacturing experience in plastic and they help to improve the implementation of customer ideas.

AS OM BE Plast primary delivering the different types of plastic produced parts from injection moulding and they are subcontractor of other companies, mostly Norwegian companies but they also have some exports to the Norwegian companies out of Norway. They are producing technical components for several big customers. AS OM BE Plast is located at Sellebakk, which is a community in the town of Fredrikstad in Norway.

12.2 Synopsis of the interview

AS OM BE Plast has many suppliers for all product categories. They have 30 active customers. The company produces, assembles and delivers the customer-owned products. These products are shipped to the end users.

The company workers guide the customer from the early stage of the product development to the initial product. This is the reason why they are also doing prototyping to help their customers get the right product. They started using a 3D printer in 2005 for the prototype. Few years after they started the patented process called “Duo Combe”. If a product has advanced functions in a part and it is complex, then the mould gets very expensive. To reduce the cost especially for long volume products, they develop this technology called “Duo Combe” where they printed the advanced parts of the product and we put it into the simple mould and moulded the easy parts, so they keep the mould cost low for low volume products. This is to initially test the products in the market. After that, they start with a

project which has been very success called “AddForm” where we simply print different types of moulds with different types of materials. With the help of suppliers, they combined different types of materials and technology in one mould so that it can be useful to produce specific products from injection moulding.

There are 3 main areas where the company is using 3D printing includes “AddForm” which is still in a research and development phase. The stability, material properties are one big are their challenges. However, the development is going very fast with the cooperation with SINTEF in Oslo for testing and development of the product. The second area is the use of 3D printing for prototypes and the third area where they use 3D printing is the fixtures and other parts for atomization in serial production. They print these parts for making logos, text and robot fixtures.

The company has its own 3D printer which was bought in 2005. The personnel are using it a lot for making the parts. But after they started the “AddForm” project, the machine has become obsolete and they have seen that there are many different technologies with superior properties. They purchased printed parts from external suppliers. The parts they earlier produced in-house are bought from the sub-suppliers. The reason for that is they have a good cooperation with some of these companies which are their partners in the “AddForm” project. Since the development in 3D printing is going very fast so it is hard to find which is the right technology to rely on for the future because the best technology now may not the best technology in the next 2 years. To be at par with the latest in technology, the company may purchase its own printer to insure quality and efficiency.

The firm’s motivation to implement 3D printing was to find the weak spots of the product designs early on. So, if one discovers flaws before the buys the mould then he can save a lot of money and time. For high technology products, the time is a very critical factor.

In “AddForm” project, the customers of AS OM BE Plast get a part of the right material. They can do a lot of qualification testing at a very early stage before they start with the production mould. The moulds produced are tested as to physical strength in order to meet the customers’ needs. Those who want to test the transmission of lights through parts for fire testing can do so. Their customers need to test a lot of different types of materials before they start with the high-cost mould.

The AS OM BE Plast believes that eventually a lot of the parts that are produce in injection moulding in their factory now will be produced directly by 3D printing in the future. The use of 3D printing will make products more customized to a much higher degree than today instead of just mass producing and make the same products for everyone. For the management, there will be more customized products for every customer as they want it.

With regards to reducing the lead time because of the use of 3D printing, it is more developing model rather than transporting. Transporting moulds is a very small part of their time. To make traditional moulds it takes about 5 to 8 weeks. If they print a prototype they usually produce it in a week. Moreover, the company produces 10,000 or more units a year. For some products, they are around 1,000 to 2,000 a year. So, if they split the mould cost over the number of products a year or two then the product gets very expensive.

At 3D printing is more of supplement at AS OM BE Plast. There is no specific change in the supply chain yet. After some time, if the "AddForm" project is good enough for all kinds of production. They may stop ordering from Asian mould maker companies. As the 3D printing technology develops and gets better, there will be a significant change in the supply chain as they will start printing the mould by themselves faster. They believe that it will take some years for 3D printing to have an impact on supply chain network.

12.3 Empirical analysis

AS OM BE Plast is an innovative and creative company those putting a lot of efforts in lean manufacturing and offering its customers with a very high-quality plastic product with lowest cost and time.

In relation to the research questions the following findings we get from the interview:

Applied technology

AS OM BE Plast basically produce, assemble and deliver the customer owned products. They launched their own manufacturing techniques such as "Duo Combe" where they printed the advance parts of the product and then put it into the simple mould and moulded the easy parts, so they keep the mould cost low for low volume products in order to initially

test the products in the market and “AddForm” where they simply print different types of moulds with different types of materials with the help of suppliers and combine different types of materials and technology in one mould so that it can be useful to produce specific products from injection moulding. These projects not only helping them to save a lot of money but also a lot of time which is a critical factor specially in producing the high technology products.

Use

There are 3 main areas where the company using 3D printing. First of them is the “AddForm” which is still in a research and development phase. The second area of using 3D printing for prototypes, when the customers have a product they need to produce then the company get the prototypes from a sub supplier and deliver to their customer as a prototype of the product. The third area where they also use 3D printing sometime for fixtures and other parts for atomization in their serial production. For example, they have to print on the parts for making logos, text and also for robot fixtures.

Currently, the 3D printing technology is more of supplement and it is in testing and development stage and therefore, no significant impact on the supply chain however, there are many factors plays an important role before a company can start to use 3D printing technology in their production such as the cost of the machine, the cost of producing the product, producing time, the quality of the products and many other factors those different from company to company according to their needs. However, in the future if the development in 3D printing improve then there will be a significant change in the supply chain network as we get an example from AS OM BE Plast that they may stop ordering mould from their Asian mould maker suppliers.

Customer value

3D printing helps to find the weak spots of the product designs which saves a lot of time for a company as well as for their customers, it also reduces the lead time in development which eventually reduce time for overall cycle of the product.

13. ISIFLO AS

13.1 Introduction

Isiflo AS was founded in 1965. Since 2004, Isiflo AS is a fully owned subsidiary company of the Dutch industry group Aalberts Industries NV. They develop and supply couplings and related products to the Scandinavian and European water and gas distribution industry. The company's main products are composite and brass couplings, ductile Iron, threaded pipe fittings and tapping saddles.

Isiflo AS holds the trademark "ISIFLO" it is one of the leading brands on the European market for water and gas distribution. They have a universal range of brass couplings, which has been developed for use with PE/PVC, steel, copper and lead pipe is manufactured at their own new factory in the Raufoss industrial park.

Isiflo AS is located at Raufoss Industripark, Raufoss is the municipal centre of Vestre Toten, a municipality in the county of Oppland, Norway. They have own subsidiary companies in Sweden, Spain, Germany and France.

13.2 Synopsis of the interview

Isiflo AS has European customers. It has distributors in the different countries in Europe. It is working with water and gas supplies and related products. On the production side, they have several suppliers for different materials like for brass. Isiflo does in-house assembly as well as in France and Germany. In general, Isiflo has multiple suppliers for different types of our products. It has customers across Europe and it has reached through several distribution channels.

For Isiflo AS, the use of 3D printing allows the company to check the assembly. The prototypes are checked according to the standards of material properties and foresee the final products.

As to benefits, 3D is used for showcasing the product. It helps producers and consumers to discuss the features and the strengths and the strengths and weaknesses of the product outcome.

Currently, the company is challenged by the continuous upgrading of the quality of their products in terms of durability and volume of orders. The challenge in the volume of products. Specifically, if the concern is injection moulding then the company has to make injection moulding tools. It is a big investment. To profitable in these projects, there is a need to produce more of these but the available technology, so far, is limited.

The realized benefits include it helps to show to the customers the product. It is an instrument for discussion. The maker of the printer also provides the materials. They become the supplier as well so there is an addition of a new supplier in the supply chain.

It is the vision of the company to use 3D printing in production based on the material and printing technology. The company prints with the EOS material. Polyamide powder is a good material, but it does not give the desired strength and also the quality for 3D printing is currently not available for the company's application.

13.3 Empirical analysis

Isiflo AS is a huge company and expanded all over the Europe. They are not only working with Norwegian market but to whole Europe. They offer very high quality and durable fittings products for water and gas and in large number of volume to fulfil the demand of the product as well as to increase market share of their product all over the Europe.

In relation to the research questions the following findings we get from the interview:

Applied technology

Currently, Isiflo are using injection moulding process and the materials, the quality, strength they required cannot be fulfil from 3D print products as the material properties is not good enough in order to use 3D printing in production. However, they have 3D printer as well which they use only for show case and prototypes.

Use

Mostly they use 3D printing to study the concepts, to check assembly how it works and prototypes. This is more for showing the shape and to discuss the threads, how to assemble

the parts. It is helpful for discussions with the customers those looking for a sample part. It reduces the product development time and help a company to produce different samples with different dimensions over a night to check with the customers before making a contract for actual production of the products.

Customer value

Additive manufacturing (3D printing) technology adds a great value to a firm, even with today 3D print technology it is helping a lot in terms of getting new customers, testing, redesigning of the products, prototyping but since it is using in product development and at very initial stage of implementation to the industry it has not impact on supply chain network at the moment. However, as the technology develops and improved with the material properties, cost of producing and machine, speed of printer in future then there will be a change in company supply chain network for instance no further required the supplier of mould, a company can print their product anywhere across the Europe according to their customer demands which eventually reduce the lead time as well as material used for producing the product and cost.

14. NORSK TITANIUM AS

14.1 Introduction

Norsk Titanium AS was founded in 2007 by Norwegian entrepreneurs, scientists and engineers with an oversized dream to pioneer the next industrial revolution by develop and commercialize very less expensive aerospace-grade titanium components. They collaborate with several organizations those believe and invest in their project and help them to achieved essentially changed manufacturing forever and launched the new industrial age. Norsk Titanium AS is revolutionary a new era of on-demand metal additive manufacturing that will revolutionize industries.

Norsk Titanium AS Rapid Plasma Deposition (RPD) is an FAA-certified, OEM-qualified additive manufacturing process that delivers structural titanium parts with reduced lead time and cost, less titanium, less machining and less inventory. These benefits give their customers better flexibility and major cost savings.

Norsk Titanium AS headquarter is located in Hønefoss at Eggemoen Aviation & Technology Park. Hønefoss is a town and the administrative centre of the municipality of Ringerike in Buskerud county, Norway.

14.2 Synopsis of the interview

Norsk Titanium AS has a high standard supply chain structure. They have at least 2 end-users. On the other supplier side. They have a supplier for raw materials. Others belong to the downstream activities for processing the parts. Raw materials are bought from suppliers. Designs are taken from their customers. Additive manufacturing technology is maximized. Parts are shipped to further downstream customers and other suppliers such as heat treatment, machining of the parts, non-destructive and destructive testing. Production of the parts and shipment always require customer approval. Third-party logistics is employed so Nork Titanium AS has an ultimate supply chain.

The 3D printing is the cornerstone of Nork Titanium AS. They are the only company in the world that is FAA-certified for use of additive manufacturing to produce titanium parts for

aircraft. 3D printing is perceived to reduce the significant lead time and cheaper raw materials since they do not have to machine out the parts from massive blocks out of titanium. The process saves materials and time and money.

To maintain the production cost to a low level and maintain a low lead time at the minimal level continues to be a challenge for the company. The cost of the 3D printer machine is also identified as their challenge. However, in regard to volume, the machine can produce 10 to 20 metric tonnes of aerospace-grade titanium parts per year that the company meets the demands of their clients

Norsk Titanium AS was founded on the basis of additive manufacturing technology it is the whole idea and whole concept of this company. There is not much major change in the structure of the supply chain by using additive manufacturing. There are a few changes in the changed of the manufacturing process but not in the structure of the supply chain has changed. The benefits of using 3D Printing is perceived to be more efficient and cost-effective.

They opened a factory in the USA with more machines for their potential clients in order to have a faster delivery system and this takes the advantage of proximity to customers with the use of 3D printing

They see potentials of 3D printing. The management is certain the additive manufacturing will be the world's leading manufacturing process for titanium parts. For Norsk Titanium, additive manufacturing is the future of this industry.

Reduction of cost and lead time can only be achieved in additive manufacturing. Waste cannot be used in any other parts because they have to change the capabilities of the material then need to melt it down again to create a new block of titanium. So, the additive manufacturing (3D printing) is definitely the sufficient way of manufacturing with low cost and reduced lead time and without any waste.

14.3 Empirical analysis

Norsk titanium AS is a name of revolutionized manufacturing concept to process. They are purely additive manufacturing (3D printing) company offering aerospace-grade titanium components at a low cost and with a short lead time to their potential customers.

In relation to the research questions the following findings we get from the interview:

Applied technology

Norsk titanium is purely establish on additive manufacturing (3D printing) technology for aerospace-grade titanium components. The 3D printing or additive manufacturing is the cornerstone of the company, that is the whole idea of this company and currently they are the only company in the world that is FAA-certified (Federal Aviation Administration) for the use of additive manufacturing to produce titanium parts for aircrafts. This is the process that they have developed and solely company to use it.

Use

Norsk titanium AS was founded on the basis of additive manufacturing technology and additive manufacturing (3D printing) is the core activity of the company but if we compare to traditional supply chain network we observe that there is no major change in the structure of the supply chain by using additive manufacturing because its either a company have to machine the parts or 3D print the parts, so a company just change the manufacturing process, so it would be prejudicial to say that the structure of the supply chain has changed as mentioned by the expert from Norsk titanium AS.

However, we observe that those companies who going to implement the additive manufacturing (3D printing) in their production they will have a significant change in their supply chain such as reduce lead time because of producing close to customers as an example of Norsk titanium a 3D printing machine in USA for USA customers, change/replace or addition/elimination of suppliers because of different inputs for different manufacturing process i.e. machining to 3D printing, from stocking to on demand manufacturing, standard to customization of products. This 3D printing technology will have the significant impact on the supply chain network in future as it will change the whole structure of the supply chain in years to come.

Customer value

Additive manufacturing (3D printing) delivers various value to a company which ultimately offers to the customers. Everyone is looking to reduce cost and lead time in traditional way of manufacturing with a lot of waste and this waste cannot be used in any other parts because then a company have to change the capabilities of the material, melt it down again to create a new block of titanium but Norsk titanium technology of additive manufacturing (3D printing) is definitely the sufficient way of manufacturing fast, low cost and without any waste and this is the future in this industry. It gives reduction of lead time and cost of raw materials, low waste of materials, saves time and money.

15. NORDIC ADDITIVE MANUFACTURING (NAM) AS

15.1 Introduction

Nordic Additive Manufacturing AS is a young company and in market for 3 years now. They are co-operated with SINTEF a research facility in Raufoss. Nordic Additive manufacturing has 10 owners mostly are SME's, few of them are big players and few foreign investors. NAM is the first Norwegian company to implement Laser Metal Deposition technology for additive manufacturing. This technology is complementing other techniques available in their network and completes the capability at today's technological level.

They have a machine for about 1 year and they deliver the first produced part before Christmas in 2017 for a space company and it is for a satellite component. They are working only with metal parts and more or less their owners are also their customers.

Nordic Additive manufacturing is located in Raufoss Industrial Park, Raufoss is the municipal centre of Vestre Toten, a municipality in the county of Oppland, Norway.

15.2 Synopsis of the interview

Nordic Additive Manufacturing (NAM) AS is working with different parts. The company testing different business models that are slightly different from other companies in different sectors. It is working a lot with Kongsberg Automotive one of the important customers especially on tool repair. So, basically, the customer sends them the tools then they fix it and rebuilt the surface, do the finishing before their customer has a complete refurbished part. Their end customers are also their suppliers, but they also have suppliers of metal powder which they use for refurbishing the products.

Nordic Additive Manufacturing finds it cheaper to refurbish the product through additive manufacturing. Their main focus is to refurbish the parts rather than to make a new part. For the management, 3D print is good enough to use for commercial purpose. They use the only superalloy for additive manufacturing.

The machine may be costly, but 3D printing machine is part of the company's production facility which reduces the lead time. They observed that the traditional way of refurbishment

for some components take several weeks. Their focus is to make it within a week. 3D printing technology speeds up refurbishment. The amount of metal that they use with additive manufacturing is not wasted. They find the quality to be superior and the price of refurbishment is much cheaper compared.

The production volume and size, the company has no mechanism to produce high volume. They only deal with specialized products. The company believes that additive manufacturing is not necessarily a fast production process.

One of the major projects that the company is involved in is the repairing of the injection moulding tools. Normally, the cycle of the refurbishment of tools takes 4 to 5 weeks or longer. The same thing they do in their own facility within 2 days with much higher quality. Even at the moment their prices are higher because of the process is so expensive but it saves a lot of time. For other customers, like Oil & Gas, they have a huge lead time on the refurbishment of the components. For a new product, lead time is longer around 5 to 12 months. They can, however, do with 3D printing technology much faster, efficient and effective way. Their technology is not limited to certain components. They can work with tiny parts to huge parts all can deliver in a very short time.

They have been working with additive manufacturing from few years before the start of this company as a researcher at NTNU. They saw and experienced in the industry that some people did not really have the necessary knowledge or skills to operate and to utilize this technology. So, the opportunity where they can make an impact. They can deliver parts with shorter lead time. So, basically, that is how to be motivated. They are the early adaptor of technology worldwide. Not a lot of companies is doing this. So, it is good time to introduce this technology in production. They try to focus on products that can utilize where the alternative cost of components is very high. For instance, with the maintenance components, they try to find where they can add more value with their technology.

In terms of benefits, the realized benefits are reduction of lead time from weeks to hours; very high quality of products, easy and affordable maintenance or refurbishment of special components; no waste of metal; and saves a lot of time and this has a huge impact on the way how parts are produces especially in Norway where the cost to produce parts is very high. So, in order to compete they develop this digital manufacturing. The company believe

that a lot of the companies are afraid that 3D printing will take away their markets and change the way they manufacture parts. For a Nordic Addictive manufacturing, it is just another tool in a toolbox with new limitations and opportunities.

The 3D printing could not replace the traditional manufacturing such as injection moulding, it will perhaps replace in some aspect but not in general terms. 3D printing will stand next to injection moulding machine, but both will produce different components. It also depends on the number of the products.

15.3 Empirical analysis

Nordic Additive Manufacturing (NAM) AS was formed after several years of research & development at NTNU and with collaboration of SINTIF but they have many owners those invest in this company in order to develop this technology and which eventually helps them in a long run.

In relation to the research questions the following findings we get from the interview:

Applied technology

NAM is the first Norwegian company to implement Laser Metal Deposition technology for additive manufacturing. This technology is complementing other techniques available in their network and completes the capability at today's technological level. They develop and early adaptor of the metal additive manufacturing technology worldwide and the mainly focus on a market where they can add value for the customers more specifically in maintenance / refurbishment of the components with significantly reduce lead time and cost.

Use

Nordic Additive Manufacturing (NAM) AS established with additive manufacturing for metal products and they are not implementing it or using along with traditional manufacturing methods. They actually start with it therefore there is no change in their supply chain. However, we observe from this interview that the companies those going to implement the additive manufacturing (3D printing) in their production they will have a substantial change in their supply chain such as reduce lead time (from weeks to hours) as

the 3D printing technology is capable to produce the parts in much quicker way than traditional method and with no waste.

There may also be a change/replace or addition/elimination of suppliers depends if a company using both technology together or replacing with another as according to the industry expert from Nordic Additive Manufacturing AS 3D printing can replace certain components but cannot all of them. Moreover, Additive manufacturing is the trending topic in manufacturing environment and there is a lot of research and development going on across the word as this technology will not only help to reduce the lead time but also the cost which could be a main reason for a need to invest in this technology specifically for those countries where production cost is higher for instance in Norway in order to compete the world.
This revolutionised technology can save a lot of cost and time which can give a huge flexibility to any business. However, this 3D printing technology will have the substantial impact on the supply chain network, but it depends on a company business models whether they are going to use it along with the traditional manufacturing methods or in a replacement, but this will take some years before many companies can utilize this technology in their production.

Customer value

Additive manufacturing (3D printing) adds huge value for a company as well for the customers an example we see that Nordic Additive Manufacturing AS focus on refurbishment of the products and their customers send them a product for refurbishment as their metal 3D printing technology is cost effective and effective way to refurbish of the products and they send the product back to the customer. They not only save a customer time but also a lot of money in comparison to refurbish through traditional way or even to buy a new product.

16. PANALPINA LTD

16.1 Introduction

The Panalpina Group is one of the world's leading providers of supply chain solutions. The company combines its core products – Air Freight, Ocean Freight, and Logistics and Manufacturing – to deliver globally integrated, tailor-made end-to-end solutions for twelve core industries. Drawing on in-depth industry knowledge and customized IT systems, Panalpina manages the needs of its customers' supply chains, no matter how demanding they might be. The Panalpina Group operates a global network with some 500 offices in around 70 countries, and it works with partner companies in another 100 countries.

Panalpina's business activities are primarily regionally oriented. The operating structure is divided into the following regional units: Americas, Asia Pacific, Europe, Middle East, Africa and CIS. The business activities are subdivided into the following business segments: Air freight, ocean freight, logistics and manufacturing, energy and project solutions. Panalpina World Transport (Holding) Ltd. (PWT), is the ultimate holding company of the Panalpina Group and has its registered office in Basel, Switzerland.

16.2 Synopsis of the interview

Panalpina is a logistics company. They move freight around the world and realized few years ago that just moving things around the world is no longer the thing which satisfy the customers. So, a company started something which is logistics manufacturing services. Panalpina realized that lot of the customers' goods are lying in the warehouse especially spare parts for years and years and at the end of the day the customer might not even need them at all, so we just have to scrap these warehouses for spare parts. At this point additive manufacturing was explored as a potential solution for this. Rather than storing these spare parts for years and not needing them can a company print when the need arises? That's the angle they were looking at it from. Also, from another angle of rather than shipping these goods or using air freights can they just manufacture where the demand is?

The kind of products they store in the warehouses vary. It could just be from any sector; automotive, perishables, chemicals, fashion. So, there is no fix set of customers. To start in this industry, they partnered with 'Shapeways' which is an online platform for 3D printing

and they have been using different additive manufacturing technologies for years. The company started with buying a 3D printer which is a Projet 3500 HD max printer by 3D systems. They started exploring by doing it themselves and that's when they realized that it is not as straight forward as it looks. It is not just one printer which prints everything, there's a range of technologies, range of materials. What would be best for Panalpina to start with is to develop a solution. Panalpina is a supply chain company so they will never be going to be as good as manufacturing company who is been doing this for years. The solution they developed looks at Panalpina's customers' supply chains and identifies those products from hundreds and thousands of products which will be suitable for 3D printing. These would be slow moving, low in volume, high in value, which are very complicated, hard to source.

Panalpina provides the services of supply chain so they are a service company. Basically, they move products around the world for the customers, they link their suppliers and manufacturers and where the demand is. The challenges would be, as additive manufacturing is a new industry which a company ventured into, are the skills required, it's the skill set which logistics company do not have. The company need engineers, but they have supply chain specialists. So that's when a company change its model and developed the supply chain solution rather than an engineering solution. Although it considers engineering principles, it focuses on supply chain which is where their core strengths are. It is also beneficial in terms of what value-added service a company are willing to bring to the market. If customization is required, then they can bring that to the market exclusively on demand. An example would be if a customer wants a phone tomorrow in a specific color, a company can get it assembled at their warehouses, they will have all the spare parts in the warehouses, so they can assemble it in the way a customer wants and get it delivered to them. The customer could be anywhere in the world and that could be done in the nearest warehouse to the customers. So, in additive manufacturing it becomes a step closer to getting that done, customization is achievable.

Panalpina have warehouses in about 150 countries around the world. They are presence in some form or another, it could be offices or warehouses. In terms of their customers' supply chain, they have established a 3D printing hub where the customers are, rather than the manufacture and ship they manufacture and ship directly in the same country. It reduces the supply chain complexity or the delay which it had initially. The company supply chain has not changed**.** They have only one printer and doing for one customer now in terms of

manufacturing. So, it doesn't really affect the production now whereas it allows them to flexibility to take on more production.

They no longer need the things which are mass produced, they need things which are specific, customized, and personalized. They are also not willing to wait for weeks but want to quickly deliver the products the next day or two days. The company will go to someone else who is willing to provide them faster, anticipating the consumer needs and demands and understanding their challenges. This is what that has led us to additive manufacturing. Most of the companies are focus on the benefits regarding manufacturing, of course it provides the design complexity without additional cost, personalization, and customization. But the benefits of supply chain overlooked on a large scale. The benefits in the supply chain are more than the customer can think of and in the future more customers will understand. As the technology improves, it will be applicable to a wide range of products. So, more products will be printable and at a large scale. That is where Panalpina see the future today.

16.3 Empirical analysis

In relation to the research questions, following findings can be extracted from the interview:

Applied technology

To manage the problem of spare goods lying their warehouses for prolonged period, the company ventured into additive manufacturing with the objective to use this technology to manufacture the products on demand when and where they are needed without causing any wastage. They intended to explore this technology because of the changing needs and demands of the customer as they needed quick delivery of customized and personalised products. Their system identifies the products suitable for 3D printing which are manufactured in partnership with other manufacturers and delivered by the company itself.

Use

The technology is used to print products that are low in volume, hard to source, have complicated design and are high in cost. The use of additive manufacturing has changed the supply chain structure by reducing the supply chain complexity and the delay that they were facing initially, as they are able to manufacture and ship the products directly to their customers. The company is of the view that, in the future, people will also realize the benefits

of additive manufacturing on the supply side. Nowadays, they only focus on the benefits related to manufacturing such as freedom of design, ability to produce complex products at low cost, customisation, reduced lead time and minimum wastage. The main challenge for the company is the skills and knowledge required to manufacture products by 3D printing. As they are a service company, they have supply chain specialist but lack engineers and human resource for R&D.

Customer value

The use of 3D printing has been beneficial for the company in terms of value-added service that they provide to their customers. Customization is one of the key benefits that the company is able to bring in the supply chain service industry. They can produce goods on demand and within brief period, which can then be delivered anywhere in the world.

It has helped in reducing time and the cost associated with the supply chain. With the increasing development of the technology, it will become more affordable and applicable to a wide range of products. So, more products will be printable on a large scale.

17. GLAMOX AS

17.1 Introduction

Glamox AS was founded in 1947 in Molde and currently they are a leading supplier to the world's marine and offshore markets, and a significant supplier to the professional building market in Europe. Glamox group develops, manufactures, and distributes professional lighting solutions worldwide. They have different division for different market segments such as Professional Building Solutions division offers lighting solutions to the office and commercial buildings, industrial buildings, educational establishments, health institutions, retail and shopping centres, hotels and restaurants. Its Global Marine & Offshore division supplies lighting solutions for the marine and offshore markets. The company's Sourcing, Production, and Logistics division engages in order handling, procurement, manufacturing of goods, warehousing, and distribution activities. They have sales and production in several European countries, as well as in Asia, the USA and Canada. The Group owns a range of quality lighting brands including Glamox, Luxo, Aqua Signal, Norselight, Høvik Lys, and LINKSrechts. Glamox AS is committed to meeting customer needs and expectations by providing quality products and solutions, service and support.

Glamox AS headquartered is in Oslo, while we conducted our interview with Glamox biggest manufacturing facility in Molde. Molde is a town and municipality in Romsdal in Møre og Romsdal county, Norway.

17.2 Synopsis of the Interview

Glamox AS has many different suppliers. Some special producers whom their personnel are working with are for injection moulding parts. They have started a project in which product development department preselects the suppliers they choose potential suppliers. They test their projects, transfer them to their factories for production. Then, the factory does the individual purchase from supplier group for taking over.

They have a number of suppliers for different product categories which produce products in their own factories. This is to supply the demands of their huge number of customers worldwide. They have a redundant system. They do not depend on only one supplier because

they cannot afford to delay and sacrifice their product quality. There are a lot of changes in the suppliers from time to time. That is why they are always looking for the best supplier for their products.

Most of their shield metals are in-house. In Molde, Glamox AS has a huge facility. Many pieces of equipment such as stamping, bending and bending all are in-house. They are producing some parts in China. Injection moulded parts are generally outsourced. Their producers are situated in Norway and Estonia to name a few. For bending operations or bending parts, the company uses steel or aluminium for fittings in-house. They have also cast aluminium produce from sub-suppliers. So, in general, they have multiple suppliers for both steel and aluminium.

They use 3D printing for prototyping. They have a prototyping facility workshop in Molde which also include the 3D printing facility which is used to produce prototypes. However, for one project they use 3D printing for serial production. Currently, they have a project where they have a little plastic part which they only need 200 pieces per year. For this part, it is not effective to build a moulding tool. So, they decided to order it from a sub-supplier in Norway for prototype 3D printed product. They also use 3D printing to build production equipment's in the factory.

Glamox AS is very price-focused and has no product for the commercial purpose. They only have the small plastic. Normally, the luminaire they are selling has a minimum of about 5 to 10 thousand products per year. So, for the company**,** it is not cost-effective to have them in 3D printed.

Based on the experience of Glamox AS, one of the challenges in the use of 3D printing is the price per part. Production time is also another challenge. As for high volume products, it is more effective to inject moulded products. Cost of the machine is considered as a challenge. Mostly, it depends on the product material being used. For SLS material, the machine is affordable but for metal parts, the machine is much more expensive.

The advantage, for them, is the flexibility. This is the reason why they use it for mounting. In redesigning they are not limited to mould tools only.

Glamox AS places a high value on speed as essential to the development process. For the management, it is also important to get better products because for product developers. They have more flexibility to test things. For example, if they have an idea, they can build it up using CAD system. With 3D printing, they have the possibility to build it as a physical model and test it which is easier compared to the practice 20 years ago. They can test several solutions to get better products. That is a big benefit of a 3D printer.

The company has been using the machine in-house for 3 years now though this technology has been here for more than 10 years already. They had the opportunity to make vacuum moulded silicon parts, but it is time-consuming. Ordering the prototypes from sub-suppliers is another option for the company. However, after using the 3D printer, everything is done in-house by Glamox AS. They used to order prototypes from another supplier. For example, if they have parts which they cannot print, such as FDM technology or they have very small and thin parts, they usually order these parts from the sub-suppliers.

Glamox AS chose to implement 3D printing because it helps them in the development process. They use 3D printing to test the ideas, concepts and to speed up the development process. With 3D printing, the personnel can do more experiments. They can test them in real time. This is the firms' avenue to promote innovation and development of the products and services. More than anything else 3D printing resulted in speedy process. It speeds up the development time. It is flexible. It is good for their testing and innovation. They have a lot of experience with 3D printing technology. They have enjoyed the many benefits of 3D printing which they did not enjoy the traditional machine and process of product development and showcasing.

The suitably of 3D printing is dependent upon the kind of industry using it. For example, the medical industry has expensive supplies and machines. Then it could be a solution to use a 3D printing because it could be a customized product for that particular patient. In metal printing, it is also interesting for aerospace. There are other issues, however, like certification. But in this industry, there are many possibilities as moulded parts especially in combination with moulding manufacturing in China is so cost-effective compared to 3D printing. The 3D printing reduces the cost of the product development and manufacturing.

At Glamox AS, technology development is part of their innovator. 3D printer promotes high speed and high quality. With the use of 3D printing in production, there is so much comfort, flexibility and efficiency in the firm.

17.3 Empirical analysis

Glamox AS is a huge company founded in Molde and spread not only in Norway or Europe but all across the world.

In relation to the research questions the following findings we get from the interview:

Applied technology

Glamox use mainly injection moulding process for the he numbers of products because of large volume products. However, they have prototyping facility work shop in Molde which also include the 3D printing facility which they use to produce prototypes. However, for one small project they are using 3D printing for serial production since to produce low volume and small products moulding tool will be expensive.

Use

They have been using 3D printing in-house from almost 3 years now, but they have the technology for around 10 to 15 years which clearly shows that they have invested a lot of time in research and development of upcoming technologies and to adopt them in order to be more cost-effective producer in their industry.

They currently use 3D printing in product development and only for one small project in production. However, as Glamox AS is a huge company so the use in small project does not affect their supply chain network structure and hence currently there is no impact of 3D printing on their supply chain network structure.

However, we observe that the way 3D printing make slightly change on supply chain while using in product development for instance, Glamox producing in-house models and prototypes whereas before some time they used to order from sub-supplier then, we believe that in future when the 3D printing will be at maturity stage and able to produce in high speed, high volume and good quality products there will be a significant change in the supply

chain probably the same as of today in prototyping i.e. change/replace or addition/elimination of suppliers, reducing the lead time, more smarter and innovative products and solutions, possibilities for companies to bring back the outsourced activities back to in-house. Though, this might take some more years in future in order for companies to use 3D printing in production and to actual see how it can impact the supply chain network structure.

Customer value

Additive manufacturing offering many benefits with its current technology to almost in every industry and it do have some challenges different from industry to industry for instance, as an expert from Glamox said the cost of the machine variable is a challenge or not depends on the industry is it is use for SLS materials then the machine is cheaper and the cost of the machine is not a challenge but if it is a metal industry then yes, the cost could be a challenge. But those added value by use of 3D printing in prototyping such as Flexibility, redesign, innovation and customization according to customer requirements without costing time & money will surely impact significantly in the future.

18. FOSSTECH AS

18.1 Introduction

Fosstech AS was established in 2004. Fosstech AS is a technology company making cables, connectors and moulding a lot of electronic equipment's into plastics. They offer a full range of products within the field of mechatronics. The company has departments for mechanical and electromechanical development and production. Their customers are from a wide range of fields including oil and gas, ocean space, naval defence, fisheries, fish farming, and mining.

Fosstech AS is a specialist company, continually investing in skilled employees and modern technology. In addition to be a "one stop shop" Fosstech have recently developed new products and technologies for the subsea and fishery industries They are the preferred development partner for many of the major technology companies in Norway as they provide added value and are known for their flexibility. They are ISO, Ex and HSE certified. Fosstech AS is located in Stokke. Stokke was a municipality in Vestfold county, Norway. On 1st January 2017, the municipality, along with Andebu, became a part of the new Sandefjord municipality.

18.2 Synopsis of the Interview

Fosstech AS has around 100 suppliers and customers. It is a company working on new products all the time. It is always looking for new suppliers for the new product required by their existing and new customers. So, there the number of suppliers and customers are changed rapidly. They have some regular suppliers and customers, but no fixed supplier in all their products. Kongsberg Maritime is one of their regular customers.

The company is producing some finished products for Kongsberg maritime and other products that have bigger assemblies such as cables. Fosstech AS got a 3D model from some of their customers and their personnel print them in different materials from plastic to metal (Appendix XVII). They do some engineering works, identify which printer is the best for this particular job before deliver back to the customer.

Fosstech AS has two 3D printers. The company partnered with other firms working with their employees and collaborate in their printing needs. The firm uses 4 different types of industrial 3D printers. The biggest printer they have at the moment has a volume of 250x250x300mm and it covers most of the jobs related to their products.

The current use of 3D printing is in production as most of the products they produce are made from industrial 3D printing. They deliver finished products, but they also use for prototyping. For example, from idea to finished parts with good quality.

Fosstech AS also prints metal and titanium so there are many opportunities. It is just that the customers are not aware of these products and services. This is what they try to change so people will start thinking that the 3D printing can be used to produce finished products and not only prototypes. It is a challenge to find a product which can print from 3D printing to sell.

Printing large quantity depends on the size of the product of course. If it is the small part they can fill up a whole chamber of the 3D printer with the products. It will print overnight. It takes a shorter time to market.

Another challenge with the 3D printer is when they are designing the product they have to design it in a different way. In 3D printing, they are adding a material instead of subtracting it. In the traditional manufacturing process, as some customers demand, products are designed for machining. These are not cheap to produce with the 3D printer so the knowledge about designing the product in a way can be printed from a 3D printer.

The cost of the printer is also a challenge. That is why they have worked with other firms especially those which have different 3D printers because they cannot have all of the 3D printers. Printers cost a lot of money. For this reason, they do not have the opportunity to buy all types of printers and they have to work together with other companies.

Fosstech AS believe that the printer can be anywhere in the world as they do not have traditional assembly chain. Also, it is easy to move the printer from one place to another compared to the traditional manufacturing setup.

Fosstech AS has a shorter time to market. From idea to the finished product, they can print overnight. In the traditional way, they have to add 2 to 3 weeks in production before they finish a product. So, they have significantly shortened the time to market. They have produced products that they use here for moulding business. So instead of going out to other suppliers, they can produce their own parts. For the management, there is a change in the supply chair particularly on the side of the supplier. The suppliers are changed not because they add the industrial 3D printer in the production. They now have different suppliers for a 3D printer for some products. Some suppliers finished in their supply chain network and some new added because of the use of 3D printing technology. It is like they still use traditional way. So, they use the same suppliers as before. For the 3D printer, they have different supplies.

On the customer side, reducing the lead time is a big change. Before, they required a longer time to deliver the product to the customers. Now, they can deliver in hours. It also gives the opportunity to produce such products which were not produced before using the traditional machining. They can experiment and innovate more with 3D printing technology. They can print, test and redesign if needed. It also helps them to find new customers in a new sector. They have many new customers because of 3D printing.

Fosstech AS want to make a change as it not a good time with the Oil business. So, the company has to make a change and they want to invest in the future. They thought about the 3D printing as it reduces a lead time. It helps the company to innovate. They are also using 3D printing in order to be competitive in the market with the digitalization manufacturing technology.

The company believes that the 3D printing will be more advanced. More people will know about it. There will be more use of it. The current major challenge is that peoples are not aware of the industrial 3D printers. However, the company believes that it will not take over traditional machining, but 3D printing will get a bigger share in the production and product.

Peoples are starting to learn in schools now particularly the 3D printing technology. So, it has already entered into the school system. In the future, the new generation will start thinking to design the products using 3D printers. Though 3D printing is not new, it has been

in the research and development stage for a long time. It is now in the application stage. It will take some more time to be used more for mass production and manufacturing.

18.3 Empirical analysis

Fosstech AS is a technology company offering their customers variety of products within the field of mechatronics. They offer products in different types of materials i.e. plastics, metal, titanium, aluminium etc to customers in oil and gas, ocean space, naval defence, fisheries, fish farming, and mining.

In relation to the research questions the following findings we get from the interview:

Applied technology

We find out that additive manufacturing (3D printing) technology is available with good quality for a finished product as Fosstech is "one stop shop" for many customers in different industries. They are mainly focus on 3D printing technology and they have two different type of industrial 3D printer. The current use of 3D printing is in production as most of the products they are producing as of today are made from industrial 3D printing. They also use 3D printing use for prototyping for example, to convert an idea to finished part. They are working with plastic, metal and titanium which give them huge opportunities with in different industries.

Use

Fosstech AS implement the additive manufacturing (Industrial 3D printing) and it has impact their supply chain network structure i.e. changes of suppliers, flexibility to produce anywhere in the world (close to customer), it changes the business model from make-to-stock to make-to-order, in-house production rather than outsource from supplier.

Customer value

Additive manufacturing (industrial 3D printing) could be a disrupted innovation in the manufacturing industries and it offers many benefits i.e. add value to the product, customization of the product is endless, reduce lead time significantly from months to weeks and from weeks to hours, no waste, easy to produce/refurbish and many others. They are

also a preferred development partner for many of the major technology companies in Norway as they provide added value and are known for their flexibility.

We believe that currently very few companies use additive manufacturing in their production and they all have some impact on supply chain network structure because of 3D printing technology however, currently the technology is new in production and not many firms using for production purposes except a few so it will take some time in future for most of the companies to adopt this technology and it will be interesting to see how the 3D printing has an impact on the supply chain network structure from industry to industry and product to product.

19. SUMMARY OF THE FINDINGS

This section summarizes the findings from the interviews conducted with the companies. Based on the interview guide, the following table briefly shows the findings to provide a quick overview.

COMPANIES	Needs to use 3DP	Current Use	Benefits	Challenges	Effect on SCN	Future Use
Kongsberg Maritime	New possibilities and techniques. Time and complexity of the parts.	Prototyping only, in-house tooling. Low volume, highly complex products.	Reduced cost and lead time, high turnaround speed, creation of complex parts.	Re-learn to design, quality vs accuracy and tolerance.	No impact because of in-housing.	Access to metal printer, start production.
Kongsberg Defence & Aerospace	As a rapid prototyping tool.	Production of plastic parts for simple functional tests in design process.	Production of complex, specialized tools fast at low cost.	Limited strength of plastic material, limited use due to electrical conductivity.	No impact but it has shortened design cycle.	Widen the design possibilities regarding structural complexity. Will start metal printing.
Ekornes ASA	Product development, production of fast changing parts in-house.	Product development and testing of prototypes.	Ease of design and testing, customization, saves time in product development.	Mass production, quality and finishing of the product, high cost.	No impact since it is not used in production.	Use of multiple materials in 3D printer, production of large volume in good quality.
Pla-Mek AS	To improve the services offered.	Prototyping	Reduced time, customization, ease of redesign.	Quality of raw materials, strength and functionality of the product.	No impact till now as it is not used in production.	The improving technology, will produce faster, good quality products in large volume.
Stokke AS	Product development and	Prototyping	Customization, reduced lead time.	Low speed, technical quality,	No changes yet.	Will improve quality and surface strength.

	customiza-tion.			large volume.		Increase in volume.
Sperre Industri AS	Learn the technology and bring new ideas and imp-rovement in the value chain.	Modelling, prototyping , marketing, testing and proposals. Not in pro-duction.	Quick access to casted parts, easy to re-design, can print over-night and test them.	Expensive, will create copyright issues in future.	No par-ticular change in supply chain network.	More in-house pro-duction with high quality, will reduce the number of suppliers.
Tronrud Engineering AS	For a project whose parts could not be made by machining.	Production of parts in metal and plastic.	Quick delivery of parts, ability to made parts not possi-ble with machining .	Not well known in the market yet, few people have knowledge of it.	Increase in the number of suppliers and cus-tomers.	Will be more well known, faster pro-duction at low cost.
Plasto AS	For testing samples, fix possible mistakes.	Prototyp-ing and designing.	Reduced risk of modifying the design, easy to showcase samples.	Can only print small scale models, low volume pro-duction.	No need of suppliers for 3D printing, can be done in-housed.	Will be used for producing large parts and in high volume.
AS OM BE Plast	To find weak spots in product design.	Research and deve-lopment, prototype-ing, atom-ization in serial pro-duction.	Testing at early stage saves time and cost later in production , reduced lead time.	Stability, material properties, accuracy, high cost of production.	No specific change in the supply chain yet.	More pro-duction of customized parts, may have an impact on supply chain in future.
Isiflo AS	For assembly study with prototypes.	Prototypin g for study -ing the concepts.	Displaying to customers, testing samples, flexibility, short developme nt time.	Better properties with higher strength.	No impact yet but will add suppliers when used for produc-tion.	Technology will improve to produce high quality metal and plastic parts.
Norsk Titanium AS	To deliver parts with less lead time.	Produce titanium parts for aircrafts.	Reduction of lead time and cost of	Maintain low cost, maintain lead time at	No change in supply chain,	Huge potential, will be world leading

			raw materials, low waste of materials, saves time and money.	minimal level, quantity and quality of raw material at right price.	only changed the manufa-cturing process.	manufact-uring process for titanium parts.
Nordic Additive Manufactur ing AS	Opportuni-ty to deliver parts with reduced lead time.	Production of specialized products.	Reduced lead time, zero waste, cheap refurbish-ment, high quality, saves time.	High cost of the machine.	No change in supply chain as the firm is based on 3D printing.	Huge impact in future, way to compete with the rest of the world.
Panalpina	Customers need and demands, reduce wastage.	Production of parts on customers' demands.	Value-added services, customiza-tion, reduced lead time.	Technical skills and knowledge.	Reduce the supply chain complex-ity and delay.	Will become affordable and hence applicable to more products.
Glamox AS	For testing different ideas to speed up the devel-opment process.	Prototyp-ing,	Flexibility , redesign, and innovation .	Price per part and the production time for high volume products.	No change in supply chain network.	More pro-duction at high speed and good quality.
Fosstech AS	To invest in the future and be com -petitive in the market.	Production and prototyping in plastic, metal and titanium.	Reduces lead time, helps to innovate, offer huge flexibility, ability to print anywhere.	High cost, lack of knowledge on customer side.	Shorten-ed time to market.	More knowledge of the technology will cause more production in the industry.

20. CONCLUSION

To conclude, the following table summarizes the answers to the research questions that were raised in the introduction section.

COMPANIES	Technology	Use	Value*
Kongsberg Maritime	Prototyping	in-house tooling	Low
Kongsberg Defence & Aerospace	Rapid prototyping tool	Testing in design process	Low
Ekornes ASA	Product development	Testing of prototypes.	Low
Pla-Mek AS	Prototyping	Design and testing for production	Low
Stokke AS	Product development	Prototyping	Low
Sperre Industri AS	Prototyping	Modelling and testing	Low
Tronrud Engineering AS	Commercial production	Metal and plastic parts	High
Plasto AS	Prototyping	Designing and samples testing	Low
AS OM BE Plast	Prototyping	Research and development, atomization in serial production.	Low
Isiflo AS	Prototyping	Sample testing and assembly	Low
Norsk Titanium AS	Commercial production	Titanium parts for aircrafts.	High
Nordic Additive Manufacturing AS	Commercial production	Specialized products, refurbishment	High
Panalpina	Commercial production	Customized products, value-added services	High
Glamox AS	Prototyping	Testing and redesigning	Low
Fosstech AS	Production and prototyping	Plastic, metal, and titanium parts	High

***Value Scale**

Low: No impact on supply chain. (Companies using 3D printing only for prototyping, so it does not affect the supply chain yet. The impact can only be seen once the companies use 3D printing for production).

High: Imparts value to the firm and supply chain. (Companies are using 3D printing for production and thus it impacts their supply chain and provides value addition).

Most of the firms started to explore this technology because of the vast opportunities and new possibilities that it has to offer. So, that they can stay ahead with the technology and compete in the market. Many of the firms that we interviewed began with product development and prototyping and used it as a rapid prototyping tool, with only few using it in commercial production. By implementing this technology in manufacturing, these firms have experienced a lot of benefits such as customization, reduced lead time, freedom of design, zero wastage, flexibility, short development time and cheap refurbishment. At the same time there are also some challenges associated with the use of additive manufacturing. These include low quality and strength, lack of accuracy and tolerance, inability of mass production, lack of requisite skills and knowledge, expensive printers, copyright issues and lack of awareness on the customer side. Another challenge is that the technology, for the time being, is mostly used for producing small plastic parts and in low volume.

But the overall impact of additive manufacturing on the supply chain structure has been minimal. Out of 15 companies, 12 stated that they did not experience any significant change on the structure of their supply chain networks. Only 3 companies mentioned the change in their supply chain which include an increase in the number of suppliers and customers, reduced supply chain complexity and delay, and shortened time to market. On the other hand, every company seems to be optimistic about the future use of this technology and envisions enormous potential in manufacturing and supply chain. They believe that with the passage of time the technology will improve, and it will help in overcoming the challenges. More customers will realize the benefits and its use will be widespread. The advancement in the technology can lead to printing of multiple materials, possibility to produce high volume parts with excellent quality and strength, less expensive printers, reduction in the number of suppliers and production of high quality metal parts at low cost.

Although the future seems promising, but the technology is still in its infancy and it will take some time when we can evidence more success stories and reap the benefits specially in the supply chain networks. There is still a long way to go before supply chain benefits can be attained as more customers will get to know the technology and the advantages associated with it, though there have been some developments over the last couple of decades. The key challenges ahead are the building of resilient, flexible supply chains to manage increased demand, copyrights and legal ambiguities associated with the products. However, the

acceptance of this technology is gaining momentum with many opportunities lying ahead and the ability to manage supply chains in turbulent times (Rogers et al., 2016).

21. LIMITATIONS & FUTURE IMPLICATIONS

Being a qualitative research, this thesis has some limitations as well. For example, it is not possible to verify the results and the findings objectively as it is based on the judgements and opinion of the researchers. Secondly there were limited number of informants with limited amount of time to analyse and further expand the research. An in-depth analysis is required in the future to validate the results.

The impact of new technologies, particularly additive manufacturing, on production will alter the supply chain landscape and will transform the traditional paradigm of the 'economies of scale' to 'economies of scope.' This will enable mass-customization to become the norm by achieving the possibility of 'economic batch quantity of one' (Christopher and Ryals, 2014). There will also be greater emphasis on "local for local" manufacturing and distribution with the transition from make-to-stock toward make-to-order (Waller and Fawcett, 2013a, b). This 3rd Industrial revolution, as some refer it, will provide a strong incentive for integrated marketing and supply chain management as the activities of demand creation (marketing) and demand fulfilment (supply chain management) are inextricably linked (Christopher and Ryals, 2014).

The possibilities are enormous, with freedom of design, use of any material in any desired shape and form without the need of moulding and tool making process. The technology is not far away from giving customers the possibility to alter the design themselves with no need to incur extra cost. But the involvement of customer at the initial stage runs the risk of confidentiality being compromised. Another limitation in the use of additive manufacturing is the properties of the materials used and hence the quality of the products manufactured so that these are accepted by the most in the manufacturing sector (Hopkinson et al., 2006).

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APPENDICES

APPENDIX I

KONGSBERG

DIVISION: MARITIME

Describe the current supply chain structure (suppliers and customers).

Interviewee 1: We have a in house production of sonars and we have sub-contractors delivering parts to us and then we mostly finish the product here in-house.

Q: How many suppliers do you have?

Interviewee 2: Countless, very many.

Interviewee 1: We have countless suppliers (very many). We are very large company.

Interviewee 2: I think we cannot answer this question well. We have supplier that do anything from sell-up industries till suppliers that just do machining of one part or machining of 500 parts for us and we have suppliers that actually do complete assemblies that are ready to go when they arrive to us so it's a big and complex. So, anything from single part to ready-made industry come to us.

Q: How many customers, how many tiers, types?

Interviewee 2: We sell to end customers and end customers are always professional. Not private people.

Describe the current use of 3-D printing in your production. Benefits & challenges.

Interviewee 2: We have recently started 3D printing and I am personally doing 3D printing for 10 years or so. Only in prototyping and we have recently about a year ago introduced 3D printing also to do tooling, in-house tooling. We do as of today. I was about to say that we don't print products to be sold but its incorrect because we have just launched a product where we actually 3D-print parts that we sell. So, it's a little bit not mature yet that we have introduced 3D printing, we are in the introductory stages of 3D printing for sales and for tooling. But we have used it for several years for prototyping.

Q: Those products which you are going to 3D print in house are these products previously you purchase from any of your suppliers and now you are producing it yourself through 3D printing?

Interviewee 2: No, it's more that 3D printing has given us new technique, new ways of thinking, new ways of producing and the parts that we 3D print today, we have never made before. And partly, because we knew that this part will be 3D printed then the design was made differently. Taking advantage of the 3D printing techniques and the tools that we use

for in-house use they have also been specially designed will 3D printing in mind. Knowing that if we 3D print them in this way then we will save a lot of time and money rather than making them in a different way.

Interviewee 1: The tools and projects where we are changing existing parts with 3D printing parts but that's in-house tooling.

Benefits & Challenges: -

Interviewee 1: Benefits is cost and time and high turnaround speed where our designer are able to have an idea for the tools to improve the process and then they are able to create that tooling overnight for example, it can be utilized next day. The challenges are the new materials we have to re-learn to design for 3D printing. Its new considerations compared to designing for machining. Time and cost are absolutely a benefit, we have three ultimate gear printers and they are running almost continuously over 3D printing tools and they are cheap to buy and cheap filament and just great benefit.

Interviewee 2: As a designer, my biggest benefit is that we can create parts in 3D printing that we simply cannot make using traditional machining or moulding or it would be incredibly expensive. So, there are lots of benefits, but 3D printing is yet a little bit immature so both printers and materials are little bit new and not matured yet.

Interviewee 1: The components that we print they are usually printed from a supplier and with a SLS-nylon printing. So that's why we can have fantastic complex products.

For production, it is accuracy and tolerances. We have chosen a cheap printer and you can't rely on it always delivering high quality that we need sometimes. It's not really a challenge but it's a learning curve to find when it is a good time to use 3D printer and when you should machine the part.

Q: One of the benefit you mentioned is the challenge for other companies. It is the time and the cost, but I am trying to understand that maybe because of the products used or produced in 3D printing, because of that. What about the volume of the product produced by 3D printing?

Interviewee 2: No, if you are not Coca cola. Would you like to 3D print the can and then of course time will be a horrible thing? You can't 3D print a Coca Cola Can because it takes about one and a half second to stamp a Coca cola can but then again Coca cola makes 1 million cans every hour. We don't make 1 million things every hour. We make ten parts a month.

Interviewee 1: We produce relatively low volume, high complexity parts. And if we can create a tool overnight or during few days, its much faster than having it ordered it from a machine shop which usually takes three weeks for example.

Q: But do you say that your products are more customized?

Interviewee 1: No, they are stereo-products but low volume.

Interviewee 2: We have much production of high cost and high complexity. Mostly the products are standardized and then maybe will customize the package to the customer. But when we build physical items they are mostly standardized yet.

How has the use of 3-D printing changed the structure of the supply chain?

Interviewee 1: It hasn't really changed because we have in-house machining machine, so 3D printing hasn't change the supply network structure. We don't have such a large impact because the tools are very low volume compared what we do. We still need the other suppliers, so I don't think our suppliers have noticed any difference.

Q: So, it means that it does not have any major impact or any major effect on your whole supply chain structure?

Interviewee 1: No, No impact at all.

Why did the firm choose to implement 3-D printing?

Interviewee 2: New possibilities, new technique and time and complexity.

What are the realized benefits from the use of 3-D printing?

Interviewee 2: We are selling the 3D printed product. We manage to make a very complex part, lots of details and functionality and its cheap to 3D print the parts.

Interviewee 1: With the tooling we are able to create a single use item which can be thrown away instead of being cleaned and this saves us lot of time in production. So, we make the moulds and instead of cleaning the moulds we just throw it away and we make that in PLA which is supposed to be less polluting than other plastics.

Q: The 3D printer you have is to produce only plastic products?

Yes, do you know automaker printers? We have three of those and one large printer which creates plastic which is UV-cured polymer. It's for high detail, high precision, and high cost parts but they can be for prototyping.

How do you envision the future use of 3-D printing?

Interviewee 1: We are currently building a production unit with five automaker printers which are controlled by robot which will make single use moulds 24/7. And we also hope to have access to metal printer not far in future and R2 (Interviewee 2) with his experience I think he can talk what your plans are.

Interviewee 2: I guess we will have several and different printers both for production and also for prototyping. And in printers just like any other tool there is no such thing as this is the world's best printer and they all do their different things in different ways with different materials, so we'll just see in future where we have more different printers doing different materials in different ways. Maybe we will have more 3D printers in-house than we will have other big production machine.

Interviewee 1: We see that possibility for example for weight saving. It's in products and metal printed parts the great opportunity to make better and more expensive products.

APPENDIX II

KONGSBERG

DIVISION: DEFENCE & AEROSPACE

Describe the current supply chain structure (suppliers and customers).

Interviewee: Our suppliers are mostly manufacturers of standard parts, like screws, bearings etc. And machining or casting suppliers for parts made to our design. Final assembly is commonly done in-house before delivery to our customers. Additionally, we also purchase a lot of machined parts for developmental test.

Describe the current use of 3-D printing in your production. Benefits & challenges.

Interviewee: At the moment we use a ProJet 3500 3D-printer to produce plastic parts for simple functional tests during the design process. This gives us opportunity the try out a large number of different design ideas in a short period of time, since we don´t have to wait for parts to be delivered from an external supplier. We also use our 3D-printer to make a few special tools and jigs.

The benefits of this is the ability to make complex, specialized tools fast and at a low cost. The downside of using our current 3D-printer to make tooling is the limited strength of the plastic material, and that we can't make assembly fixtures where electrical conductivity is required.

How has the use of 3-D printing changed the structure of the supply chain?

Interviewee: 3D-printing has not changed our supply-chain at the current time, in regard to our products delivered to customers. But it has given us a chance to shorten our design-cycle, and hopefully come out with a better final design.

Why did the firm choose to implement 3-D printing?

Interviewee: We chose to buy a 3D-printer as a rapid prototyping tool.

What are the realized benefits from the use of 3-D printing?

Interviewee: The ability to test many design options fast and at a low cost. It´s much easier to get a good impression of a designs proportions with a scale model compared to just looking at it on a screen. To do test assemblies to uncover design faults before ordering

expensive hardware. To make low-cost specialized tools for specific assembly operations. And to replace these tools fast if needed.

How do you envision the future use of 3-D printing?

Interviewee: Additive manufacturing will widen the design possibilities with regard to the structural complexity of parts. Designing additional features into a part, can eliminate assembly steps and reduce time for final assembly. When 3D-printing in metal becomes readily available, it will be possible to make functional components in-house in a shorter time than ordering from an external supplier. I have looked into metal 3D-printing, but at this point the technology is in my opinion not quite mature yet. Traditional machining is still in most cases a cheaper and faster solution. For this type of additive manufacturing to be cost-effective, you need parts designed from the bottom up for this process.

Our future use will, as I see it, involve 3D-printing both in metal and plastic. Metal printing for advanced load bearing parts, where other types of manufacturing becomes very expensive or time consuming. And still plastic printing for prototyping and other components where the physical properties of the plastic is deemed satisfactory.

APPENDIX III

EKORNES ASA

Describe the current supply chain structure (suppliers and customers)?

Interviewee: Ekornes ASA is a huge Company and has a very complex and big supply chain network structure. For direct cost materials, they have a several hundred of suppliers and sub-suppliers for each product category such as aluminium, leather, wood, plastic, steel etc from large part of world such as Argentina, brazil, china, Italy, India, Norway, Korea, Uruguay and Vietnam. For indirect cost materials they have in thousands of suppliers. Ekornes ASA sell their products to a large part of the world and they have millions of end-customers all around the world. They have factories in Norway as well as in USA. They produce some components like wooden frames and control over the leather colours etc in Norway for a USA factory and shipped to USA for the production of final product such as sofas. Majority of their inbound raw materials comes from around the world to their factories in Norway and both the components as well as the final products are shipped to across the world through wholly owned sales companies and Ekornes ASA keeps full control over all the supply chain network structure.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: The current use of 3D printing is in the product development and testing of the components of the products prototypes. Since they are producing large number of products every day which is currently not possible to produce from 3D printer and also the quality is not good enough in terms of strength and surface of the 3D printed parts as most of the product have a construction part and they demand forces and surface means the finishing of the product. However, for new products for instance accessories or sofa part 3D printing is very useful to prototype the product, test them, redesign them and test them again before putting the part into actual production. Also, the customization of the product for a customer is a benefit for instance, if a customer wants their picture on the sofa. Challenges are many with the current technology in 3D printing, first and the most important is of mass production, quality and finishing of the 3D printed products, as the 3D printing is the current trending technology, so the printer buy today will be replace sooner because of the advancement in the technology. The cost of the industrial 3D printer as well as per unit cost because of low volume production could also be a challenge.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: Currently, they are not using the 3D printer in a production, but they believe there will be a change on the supply chain structure because of the use of 3D printing technology. For instance, today in order to make sofa with fabrics our supplier buy yarn from sub-supplier and make the woven part, make the fabrics, add colours and shipped to them, then they have to cut it and sewing it for the sofas whereas in 3D printing technology a company can perform all these steps by themselves. Another example to make mould from 3D printing which currently being bought from suppliers, with the help of 3D printing technology this could be done in couple of days by company itself for producing the new design products. However, the 3D printed product quality as of today is not good enough.

Why did the firm choose to implement 3D printing?

Interviewee: In recent 5 to 6 years, this change has come to Ekornes ASA by adding all the values in-house for instance, buy raw materials, add values in-house and sell it to the customers such as they buy tubes and bend it according to their requirements, they buy leather, cut it and sewed it etc but for the fast changes products for instance today they have a lot of movements in their products such as leg comfort mechanism, Ekornes ASA design and prototype the parts from 3D printing but it actual produce the product part from outside supplier due to the fast changes in the product design and to market new product in time. The company choose to use 3D printing technology for a product development. It is easy with the help of 3D printing to design, test and redesign (if required) all over the night before send for production. They are looking forward to the 3D printing technology development so that they can produce all their fast changes products parts in-house.

What are the realized benefits from the use of 3D printing?

Interviewee: Some realized benefits from the use of 3D printing are: it is easy to design or redesign the product or its parts, it is easy to bring the idea into physical object which can be test whether it is going to work or not. It saves a lot of time in the product development. They also run a project called 3D knitting which is a kind of 3D printing technology from computer aided design to automation knitting process.

How do you envision the future use of 3D printing?

Interviewee: In future, as the technology developing there is possibility with the help of multiple 3D printing i.e. metal, plastic, aluminium, cutting, sewing and knitting all together

with one big 3D printer they can produce a complete chair and in that case the supply chain network will change completely. However, this may take a very long time as the technology is not there yet. 3D printing technology will also give us the possibility to insource all the activities which we are currently outsourcing but only when the output numbers are high enough.

Developments in 3D printing are continuously improving and if it achieves the technology to produce large volume with good quality then this can be an easy way to produce much complex products in an effective and profitable way.

APPENDIX IV

PLA-MEK AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: The current supply chain structure of Pla-Mek AS is simple as they are the producers only and do not own any products. They offer production services to their customers. They have a number of supplier which included supplier of raw materials for the production of thermoplastic products as well as the supplier of mould and they have number of customer to whom they produce on order basis. Some of their customers are also their supplier as they use Pla-Mek AS production services to get their product to be produced on time and with large volume because of their capacity and technology to produce such products in a cost-effective way.

Describe the current use of 3D printing in your production. Benefits & challenges.

Interviewee: Currently they are using 3D printing as part of product development and not in production for commercial use products. They print prototypes in the development process for visualizing product and do simple tests. The development time goes down using 3D printed prototypes. They have also tested out the 3D print of injection moulding tools. 3D printing works suitable to products with a simple geometry in small volume. Customization or redesign of a product is very easy and less time consuming in 3D printing and it helps a lot in the development process. The development of raw material in the 3D printing, means that we can do more tests on the applicable product that brings the development time down. In some cases, the 3D print products can be used as a finished product, but only in small volume. Limitations has been the quality of raw material to test the strength and functionality of the product. In addition, with current 3D printing technology they cannot produce large volume as required by their most of the customers and within the specific time frame. Moreover, the cost of industrial 3D printer is high and number of produced products per day is low in comparison to their current injection moulding system. They have little experience with 3D printing in metal as well but as the printing of the tool in metal is too costly.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: Currently, they are not using the 3D printer in a production for commercially use products. Therefore, it is difficult to comment on how the use of 3D printing changed

the structure of their supply chain. However, if the 3D technology advances and meet the current requirement of the quality of product and producing large volume then there might be a slightly changed in the structure of the supply chain for instance in upstream level i.e. change in supplier of the raw materials.

Why did the firm choose to implement 3D printing?

Interviewee: The motivation to use 3D printing was to learn about the technology and to use it for the betterment of our services as it is helping a lot in product development, redesign, customization and for testing purposes. They are looking forward to the advancement of 3D printing technology to use it in their production in near future for some of their customers with low order volume.

What are the realized benefits from the use of 3D printing?

Interviewee: The realized benefits of 3D printing is redesign of the product is easy and simple through CAD software and produce again the product over a night for testing while in traditional manufacturing it is time consuming to get the injection moulding tool which is adapted to the product we are producing. This tool is traditionally produced in stainless steel, where the production time is 3-4 months and investment cost are often high. Cost benefit analysis between investment in the tools and unit price is here essential. Production of tools in stainless steel have traditionally seen the passing of many and time-consuming processes, which affect product development time and the challenges for our customers and us, is to reach the market in time as the product and trends are rapidly changes. Whereas, in 3D printing they can redesign and print the product over the night as per customer requirements and test them before they actual start the large volume of production.

In General, 3D printing brings down the product development time per product. 3D printing gives good opportunities to produce details of complex geometries and development time on plastic products.

How do you envision the future use of 3D printing?

Interviewee: Developments in 3D printing are continuously improving and if it manages and develop a 3D print technology to produce faster for a large volume and the development on the raw material side continues for quality of the products then this can certainly be an effective and profitable method to produce in the future.

APPENDIX V

STOKKE AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: Stokke AS is a large company and their products are distributed worldwide in over ninety countries under the Stokke trademark through selected specialist stores represented in over ninety countries. They have several warehouses across the world such as in Netherland, USA, South Korea, China and Japan. Stokke AS have no factories and they do not produce anything by themselves all the production are made by their sub-suppliers, but they design the products and have full control over the production line i.e. from placing the order to packing and where to deliver everything is under Stokke AS instruction and control. They design, test, order the production, packing, instruct the production house where to deliver in warehouses across the world, from warehouse to specialist stores and from stores to the end customers.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: For fifteen years they are using 3D printing for prototyping and not using for production as they do not produce their products. However, if they use it in production then a benefit of using 3D printing in a first place would be a customize part which gives the product added value for instance customer name on it or add colour, customer can order from a website and it could be done in warehouses. Challenges with the 3D printing is the low speed and technical quality combined with a good surface as Stokke AS have premium products and its need a best surface. Producing large volume is also a challenge as currently they are producing and delivery the products in large volume worldwide an estimation of five hundred thousand Tripp Trapp chairs every year.

On a proximate to customer as a benefit, they believe that it is difficult and not an option at this time since they are dealing with children furniture and every single product need to be thoroughly tested and approved before it could be deliver to the customer.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: So far it hasn't change anything because the volume is so big, and the products need to be assembled on approved assemble line, so the assembly line must also be distributed because they sell ready to use product and it's not assemble by the end customers. Also, every product is tested by a strict testing team and they run safety test on it therefore

it could difficult to see that to distribute assembly because it is complicated. However, if the products are for decoration then it would be possible that use of 3D printing change the supply chain structure.

Why did the firm choose to implement 3D printing?

Interviewee: At the moment, they are using 3D printing in prototyping which is very helpful for product development. However, if they use to implement in production then the motivation for a company would be the customization of the product in order to add more value in the product for the customer.

What are the realized benefits from the use of 3D printing?

Interviewee: For Stokke AS the realized benefits is the customizing the product to add feeling added value in the product.

How do you envision the future use of 3D printing?

Interviewee: There is a lot of work on-going in the improvement of 3D printing technology and it would surprise me if we do not use 3D printing for our products in future as the production volume will grow and some of the parts which produces in hundreds or thousands per year so these parts could be 3D print as far as the quality becomes good similar to the products produce by injection moulding system with the same good quality details, surface and strength.

APPENDIX VI

SPERRE INDUSTRI AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: The current supply chain is large and multifaceted as they have over 200 suppliers and many customers worldwide. The have a supplier of various product types such as for iron castings, valves, electric and control components, sensors for compressors etc some of their suppliers are producing own design or specified from Sperre and that also leads to the partnership of many other suppliers. Their mainly customers are international customers about 97% of all Sperre production is export while 60% of their products goes to China and Korea. Asia is the big market for Sperre Industri AS and their mainly customers are marine industries and ship builders. However, they are also growing on land-based solutions which is power supply in USA & China.

All their production is in Norway and the distribute their product worldwide through fully owned subsidiaries and representative agents. They offer a long-term commitment to the market that they deliver the spare part worldwide within 48 hours and the spare parts of any of their products will be available for 30 years. They keep a four-month inventory of spare parts and have 200 standard compressors ready to deliver overnight at any time.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: Sperre Industri AS using 3D printing for two years now and they are using for modelling, prototyping, marketing, proposals and testing. However, at the moment they are not using in production. Their current manufacturing is based on robotics CNC machines. Conversely, if they use the 3D printing in production, they believe that the benefits of using 3D printing would be a quick access to casted parts if the materials and quality is comparable to the existing products. However, as of today this is a very expensive solution for a production. They have some high-volume products and parts but mostly are the standard products while a few are engineering modified according to customer needs and if there are high volume iron casting 3D printers which will be helpful to print spare parts, then we do not need an extremely expensive CNC machine. One challenge will be in future to protect own genuine spare parts when to print high quality parts in 3D printer will not be expensive and people start printing easily. On a proximate to customer as a benefit, they believe that this could be possible to print parts near to the customers and reduce the lead time but in the future not at the moment.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: At the moment, there is no particular change to the current supply chain network as they are using 3D printing in prototyping and not in production. In future few decades, they believe a company can print their parts anywhere in the world for a marine market, harbour etc and you only have to pay a certain fee to the owner for the design & drawings. This could be a global network of intellectual property where a customer pays a fee to print the parts owned by the originator of the product. This is also a challenge to protect the intellectual property in various countries such as in China, Russia etc. There will be possibility to reduce the number of suppliers when 3D printing is going to be use in production and it will impact the supply chain network significantly in future once the technology is available and competing with the current production system.

Why did the firm choose to implement 3D printing?

Interviewee: Sperre Industri AS choose to implement 3D printing machine to learn the technology, to create new ideas and to bring improvements in all value chain with the help of new technology. This will help us to adopt the new technology in the future. They started with the rapid prototyping and their production engineers continually experimenting with the 3D printing on routine basis. This will help to familiar with the technology and it gives the new opportunities. They are expecting a big 3D printing machine in house very soon.

What are the realized benefits from the use of 3D printing?

Interviewee: The realized benefits are the same as explained above i.e. quick access to the parts can print over the night and test them, easy to redesign, very impressive for modelling and marketing purpose and helps to create new ideas and to test those idea.

How do you envision the future use of 3D printing?

Interviewee: The future use of 3D printing would be exciting, and they believe as the technology develops they will be able to produce a lot of products in-house with a high quality. For instance, gaskets are very simple product to produce with 3D printer, it is just high persistent. Even with the large products they believe it will be possible to print large mechanical parts in their own production with the help of 3D printers in future. They are also looking forward for metal 3D printer for various parts.

APPENDIX VII

TRONRUD ENGINEERING AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: It is difficult to answer for such a gigantic question. However, as a big picture, it starts with buying the machine, we must always have powder, gas and filters on stock. Customer is ordering parts from us. We make an order in our ERP system. The production planer is planning time schedule of production, we confirm customer. Parts get produced and we deliver them to customer. (Sometimes we have to machining them before delivery). For 3D printing the two main suppliers for powder and they are the same who deliver the machine to us, one supplier of gas and couple-off for spare parts, machines and equipment machines. However, in general for Tronrud Engineering we have several hundreds of suppliers. In regard to the customers, there are a number of customers, we get at least two or three customers for 3D printing almost every month.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: The current use of 3D printing is to produce parts for the customers both in metal as well as in plastic. It is an expensive way to produce, as compare to the machining. You cannot use this for parts you have the possibility to machine. You must find products that cannot machine. In order to produce from 3D printing, one need a special design and not the design used for machining.

Benefits is that we have both 3D printing and machining, so we can serve the customer with both services. The 3D printing has given us the opportunity to make special parts that not is possible to machining. Delivery is also faster in 3D printing (1-2 weeks) than machining (5-6 weeks) at the moment but what will be the situation after 6 months is difficult to say. In regard to quality, it is the same as product produce by machining.

Challenges is that 3D printing in metal is not well known in the market yet, because there are so few companies that working with sales of this technology. However, there are no special challenges in the production.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: We are a machine builder and we use both machining and 3D printing technology. We have four new suppliers because of the use of 3D printing and several customers are added in our supply chain.

Why did the firm choose to implement 3D printing?

Interviewee: We needed it for a project in 2011, printing different parts that was not possible in machining. Afterwards, as we are a machine builder so, we just continue to adopt this technology and continue to grow with the development in 3D printing.

What are the realized benefits from the use of 3D printing?

Interviewee: The benefits is up till now that we can produce parts that not is possible to machine. The more benefits we can see people know more about this technology as still very few people know about this technology and we put a lot of hours to inform industry players about the technology in which we can produce parts which cannot be possible with machining.

How do you envision the future use of 3D printing?

Interviewee: 3D printing will be more and more known. The price for the printing will drop. There will come faster and faster machines. From five to ten years by now, I think there will be totally different technology that can produce faster product and with a very low cost.

APPENDIX VIII

PLASTO AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: We have 3 to 4 big customers and several smaller. The biggest customer at the moment is called Akva Group they are suppler of equipment's for fish farming. Our main product which covers the most of Plasto AS sales is parts of fish farms. If you have seen the circular rings in the sea, that is our main product. We make the brackets and walkways (excluding the pipes) in different sizes and for injection moulding this is a very big parts. An example: we purchase thermoplastic materials from a number of big international producer / suppliers and we have a number of customers. However, we have a one big international supplier for a one big customer that represent the most.

For the on-going production we purchase the thermoplastic, we melt it and inject into a mould and then we have the finished plastic parts, but the other parts of the supply chain are the moulds. We need a mould in order to produce the products, so we have also the mould makers companies that supply moulds to us. Mainly from china, some are from Portugal and still exist some Norwegian mould makers.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: For around 10 years we are using 3D printing in prototyping. when we have a new product, we always discuss or a design of the new plastic part with our customer and we as an expert in injection moulding we need to see if the design is good for producing and also for mould the design. If we need to modify something on a part its very expensive and time consuming when we make changes in existing mould, so it is very important that we eliminate the need for adjustment of changes before we start making the mould. This is the one big advantage when we can make prototypes from 3D printing and test them and then we can reduce a risk of a need of modification after we have a sample from the mould.

Our big customer for a fish farms equipment's we also make a lot of other components other than the brackets and walkways and we are working very closely with them. Plasto AS is also a kind of development department for all injection moulding parts that they have, and we also do a lot of design and product development for them. We print a lot of prototypes to get new products design which is suitable for the customers. We also design for the customers according to their requirements. We do a lot of CAD works with simulation to see how's things can be assemble and fits so we need to have a physical sample to check.

In addition, we also do a lot of scaled models for our big customer and as you know the fish farm parts are very big it's around 60 – 70 diameters so its cannot possible to print such big models with 3D printing to show to the customers. However currently we can print small scaled i.e. 1 diameter models for sale purposes and we make a lot of small scaled models.
3D printing technology as of today, you can use it for serial production of very small parts as 3D printing can only print a small volume every hour as normally most of the parts that we have are at least around 10kgs or more so if you make from 3D printing it will take a really long time. However, 3D printing can be competitive if it is really small parts and in very low volume compare to injection moulding but for bigger parts it is not.
3D printing is very useful in specific area where we have a problem with traditional methods we can use 3D printing to overcome such problems.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: Before we have external suppliers for this 3D printed prototypes and models and now we can print in-house which we can show potential new products to prospective customers and its easier for them to choose Plasto AS as a supplier rather than one of our competitor that do not have the possibility for the development of new parts. It also easier for us to print over the night for a sample rather than ordering to a supplier and to get it in a week or two.

Why did the firm choose to implement 3D printing?

Interviewee: As discussed earlier, this could give us advantage to have it in-house and it is very easy to make some samples and also, we can eliminate possible mistakes which could be very costly if we fix them in the finished mould.

What are the realized benefits from the use of 3D printing?

Interviewee: The realized benefits are the same as stated earlier that it is very helpful in prototypes and also, we have scaled models which our customers use to their customers and they go exhibitions and they would like to sell like fish farm parts so, it is easier for them to show prototypes which is scaled to a smaller size. It is also for potential new types of parts to check whether to put in production or not and try to get the customers first before making the mould and have a contract for a real production.

How do you envision the future use of 3D printing?

Interviewee: I believe it will be use more and more and for small parts it could be possible to print the parts rather than to produce from injection moulding but for bigger parts I do not know if the 3D printing technology has the combination of detailed, how small details you can make and at the same to make really big parts and with a quick processing time. Perhaps, 3D printing may compete with other production technique, but injection moulding is really a high-volume production i.e. several thousand parts a year and injection moulding machine is very automatic, and it can operate almost with no human monitoring unless one need to stop the machine. The robots that take out the finished parts and put them on pallets, so it is almost no work after we start the machine. Normally we can produce for several days or weeks or even months, so it is a huge number of thousands of parts can be produce and such number could not be possible with 3D printing at the moment.

APPENDIX IX

AS OM BE PLAST

Describe the current supply chain structure (suppliers and customers)?

Interviewee: Currently, we have multiple suppliers for all product categories and we have around 30 active customers. We do not own the products, we basically produce, assemble and deliver the customer owned products and they shipped to the end users.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: First it is important to guide the customer from the early stage of the product development to the initial product so that is why we are also doing prototyping to help the customer to get the right product. So, we started a 3D printer in 2005 for prototype and few years after we started the patented process called "Duo Combe" because if a product has advance functions in a part and it is complex then the mould gets very expensive. To reduce the cost specially for long volume products we develop this technology called "Duo Combe" where we printed the advance parts of the product and we put it into the simple mould and moulded the easy parts, so we keep the mould cost low for low volume products in order to initially test the products in the market. After that we start with a project which has been very success called "AddForm" where we simply print different types of moulds with different types of materials with the help of suppliers and we combine different types of materials and technology in one mould so that it can be useful to produce specific products from injection moulding.

There are 3 main areas where we are using 3D printing now. First of them is the "AddForm" which is still in a research and development phase and of course the stability and material properties is one big challenge also the accuracy is another challenge. However, the development is going very fast with the cooperation with SINTEF in Oslo for testing and development of the product. The second areas are using 3D printing for prototypes, when our customers have a product they need to produce then we get the prototypes from a sub supplier and deliver to our customer as a prototype of the product. The third area where we also use 3D printing sometime for fixtures and other parts for atomization in our serial production. For example, we have to print on the parts for making logos, text and also for robot fixtures.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: As I mentioned we have our own 3D printer which we bought in 2005 and then we use it a lot for making our parts but after we started the "AddForm" project this machine we have is obsolete and we have seen that there are many different technologies with different properties so now we only purchase our printed parts from external suppliers. So, parts earlier we produce in-house now we are buying from sub suppliers. The reason for that we have a good cooperation with some of these companies since some of this companies are also our partners in our "AddForm" project. Since the development in 3D printing is going very fast so it is hard to find which is the right technology to rely on for the future because the best technology now maybe is not the best technology in 2 years. We may buy our own printer in 1 to 3 years but not sure what will be the technology then.

Why did the firm choose to implement 3D printing?

Interviewee: The motivation was to find the weak spots of the product designs very early because if you make a mould for a product for around NOK150,000 and you find out that the parts has some flaws and need to fix then you may have NOK30,000 to NOK50,000 extra cost in the same mould. So, if you can find these flaws before you buy the mould then you can save a lot of money and time. For high technology products the time is a very critical factor.

What are the realized benefits from the use of 3D printing?

Interviewee: For instance, in "AddForm" project our customer and get a part with the right material and they can do a lot of qualification testing at a very early stage before they have even started with the production mould and it is a lot of different testing, it is not only the physical strength, but we also meet the customers those want to test the transmission of lights through parts for fire testing. The customer wants to test a lot of different types of materials before they start with the high cost mould.

How do you envision the future use of 3D printing?

Interviewee: I think that eventually a lot of the parts that we produce in injection moulding in our factory now will produce directly by 3D printing in the future and also the use of 3D printing will make products more customize in a much higher degree than today instead of just mass producing and make the same products for everyone there will be more customize products for every customers as they want it.

What about the reduction in lead time because of using 3D printing?

Interviewee: In regard to reducing the lead time because of the use of 3D printing, I think for moulds the transportation is a very small part of the time because to make traditional moulds may takes about 5 – 8 weeks and if we print instead then we have it in 1 week so there is a lot of time saving.

What about the production volume?

Interviewee: Mostly, from 10,000 or more units a year and for some products is around 1,000 to 2,000 a year so if we split the mould cost over the number of products a year or two then the product gets very expensive.

How do you think the impact of 3D printing on supply chain network?

Interviewee: At the moment it is more of supplement and no specific change in the supply chain but after some time if the "AddForm" project is good enough for all kind of production then I think we may stop ordering from Asian mould makers companies. As the 3D printing technology develops and gets better then there will be a significant change in the supply chain as we will start printing the mould by ourselves and in quick time, but I think it will take some years in the future.

APPENDIX X

ISIFLO AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: We have basically European customers and we have distributors in different countries in Europe, they work with water and gas supplies and related products. In production side we have several suppliers for different materials like for brass we have some suppliers. We also have supplier which make an Isiflo fitted forged products which we machine during the final dimensions with the right thread etc. We do in-house assembly as well as some in France and Germany. In general, we have multiple suppliers for different types of our products and huge number of customers across the Europe to whom we reach through several distribution channels.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: Mostly we use 3D printing to study the concepts, to check assembly how it works and prototypes because we do not get the strength from the material properties with this 3D print parts as we get in the final products. This is more for showing the shape and to discuss the threads, how to assemble the parts etc.

What are the benefits to use the 3D printing?

Interviewee: It is showing and help the parts for discussions and sometimes we take this 3D print parts to potential customers and it is always very interesting for test with the customers along with the sample parts.

What about the challenges you face to use 3D printing in production?

Interviewee: The challenge would be to get better properties and for the future we could imagine that we could print with much higher strength for small volume parts this could be feasible, but the technology is not there yet.

So, the volume could also be the challenge in order to produce from 3D printing?

Interviewee: Yes, let's say you have some products in a range that will run for a few thousands a year, but this customer also need some other dimensions which they need a hundred a year. So, if you look at injection moulding then you have to make injection moulding tools and it is a big investment so in order to get more profitability on these

projects it could be feasible to print low volume parts in future but then we need good properties.

What about the time 3D printer use to produce the product do you think it could be a challenge?

Interviewee: At the moment it is only for show case and prototypes and the time is such samples or prototypes is not a problem but if we going to make a future production with 3D printing then the cycle time also an important factor to consider.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: we get this technology to meet the requirements it give much flexibility to us; shorter development time and less investment as compare to injection moulding tools etc. and this will make us even more competitive. The maker of the printer also provides the materials and they become the supplier as well so there is an addition of a new supplier in supply chain.

Why did the firm choose to implement 3D printing?

Interviewee: As mentioned earlier it was for assembly study with the prototypes and to see how to assemble the parts, to see how the product will be in physical object, its shape, design etc.

What are the realized benefits from the use of 3D printing?

Interviewee: The realized benefits are the same as mentioned earlier that it helps us to show to the customers about the product, to discuss and study about the assembly and to propose the idea into a physical product.

How do you envision the future use of 3D printing?

Interviewee: To use 3D printing in production is depend on the material and printing technology. For now, we have seen the improvement in metal printing, but we do not have come that far in plastics although the plastic material was the first to print from 3D printer but that products are not structural products. We print with the EOS material and with some polyamide powder it is pretty good, but it is not gives the strength we need. The quality for 3D printing is currently not available for our application so may be in next some years it might be available then it will be interesting to see how we could use 3D printer in production.

APPENDIX XI

NORSK TITANIUM AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: We have a quite standard supply chain structure. At customers side we have at least 2 end-users an ultimate customer. On the other supplier side, it is hard to come up with an exact number of suppliers, but we have supplier for raw materials and we also use others for downstream activities for processing the parts that we produce. We buy raw materials from suppliers and we receive a design from our customer then we produce the parts by using our additive manufacturing technology, shipped the parts to further downstream to customers or other suppliers of downstream activities such as heat treatment, machining of the parts, non-destructive and destructive testing to gets the parts verified and then we start the production of the part and then shipped them to the customers. We also use third party logistics. So, in general I would say we have an ultimate supply chain.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: The 3D printing or additive manufacturing is the cornerstone of our company, that is the whole idea of this company and currently we are the only company in the world that is FAA-certified for use of additive manufacturing to produce titanium parts for aircrafts. This is the process that we have developed and solely company to use it. This is our main core business activities.

The benefits are reduction of lead time and cost of raw materials since we do not have to machine out the parts from massive blocks out of titanium in that way we will cut down on waste of materials and save a lot of time and money. This is the main benefit and purpose to reduce the cost.

Some challenges are to maintain the production cost to a low level and maintain a low lead time at the minimal level as this is our cornerstone to produce parts at lower cost and less lead time that's also include the procurement of raw materials both in quantity and quality for a right price.

What about the cost of the 3D printer is it also a challenge?

Interviewee: Yes, it is as the cost of the machine is quite high but for now it is not a challenge it is more challenge to produce the parts.

What about the volume of the produce parts? Is it possible to produce large volume with 3D printing?

Interviewee: Yes, each machine can produce 10 to 20 metric tonne of aerospace-grade titanium parts per year, so it is a huge volume and as for now we are meeting the demand of the products with current printer.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: Norsk titanium AS was founded on the basis of additive manufacturing technology but if we compare to traditional supply chain network I do not think there is any major change in the structure of the supply chain by using additive manufacturing because its either you have to machine the parts or 3D print the parts, so we just changed the manufacturing process, so I would not say that the structure of the supply chain has changed.

Why did the firm choose to implement 3D printing?

Interviewee: This is because we see an opportunity in the market to deliver the titanium parts for the commercial aircrafts with less lead time, so we develop the additive manufacturing process to save the time as well as the cost. We have not implemented the 3D printing at some stage, we start with it! That is the whole idea and whole concept of this company.

What are the realized benefits from the use of 3D printing?

Interviewee: The realized benefits are the same as we expected during the development of this process technology i.e. there is a reduction in lead time and cost. We use much less material and time than traditional manufacturing and this is the quicker way to produce the parts.

Do you think the 3D printing also help to produce proximate to customers?

Interviewee: This is the end goal to have quick delivery of the parts and we also have open a factory in USA with more machine for our potential customer in USA.

How do you envision the future use of 3D printing?

Interviewee: The future is potentially huge. We are not in doubt that the additive manufacturing will be the world leading manufacturing process for titanium parts. We envision that the in future the additive manufacturing (3D printing) has a great potential.

Everyone is looking to reduce cost and lead time in traditional way of manufacturing with a lot of waste and that waste cannot be used in any other parts because then you have change the capabilities of the material then you have to melt it down again to create a new block of titanium. So, the additive manufacturing (3D printing) that we use is definitely the sufficient way of manufacturing with low cost and reduce lead time and without any waste and this is the future in this industry.

APPENDIX XII

NORDIC ADDITIVE MANUFACTURING (NAM) AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: We are working with different parts and testing different business models and that is slightly different from companies in different sectors for instance, one of our customer we work a lot with this is Kongsberg Automotive where we do a tool repair for them. So, basically customer send us the tools we fix it, rebuilt the surface, we will provide the tool making and they will do the finishing before our customer have a complete refurbishing tooling return.

Our end customers are also our supplier for instance for refurbishing they provide the product which need to refurbish, and he will also get the return once we done with the refurbishing. We also have suppliers of metal powder which we used for refurbing the products. The same example is with the Oil & Gas industry, if they want to refurbish the components, they shipped to us the product, we refurbish them and return the product.

Do you think that the refurbish of the product through additive manufacturing (3D printing) is much cheaper than to buy the new product?

Interviewee: Yes, it is definitely cheaper and that is how we adapt our business model, the alternative is to make a brand-new part, but our main focus is to refurbish the parts rather than to make a new part.

Is the quality of the 3D print part being good enough to use for commercial purpose?

Interviewee: Yes, absolutely. We use only superalloy for additive manufacturing.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: We only have 3D printing machine in our production facility and that is the only thing we do. The benefits are it reduce lead time. Traditional way of refurbishment for some components take several weeks whereas our focus is to make it within a week and 3D printing technology make it possible for us to really boost up the speed of refurbishment. Another benefit is the material quality we get and the amount of metal that we use with additive manufacturing as we do not waste any materials and also the price of refurbishment is much cheaper as compare to other ways i.e. traditional of refurbishment or to buy new product.

The challenges are cost of the machine as it is a very expensive equipment to run and to buy. The cheapest machine we have is over a million Euros and the knowledge required to run the machine is also a challenge as it is difficult to operate.

What about the production volume and size, is that a challenge?

Interviewee: We do not have a machine to produce high volume as we only deal with specialized products, but the size is not the issue as we put robotics arm and can deal with as big as you want. Additive manufacturing is not necessary a fast production process it totally depend on the components itself, it is very difficult to generalize in order to say that is more effective than others as the additive manufacturing is very components specific, so each component has to be one beneficial technology that has to be made with.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: One of the major project we are involve in is the repairing of the injection moulding tools. Normally the cycle of refurbishment of tools take 4 to 5 weeks or longer but the same thing we can do in our facility within 2 days with much higher quality and even if our prices are higher as our process is so expensive but its saves a lot of weeks i.e. time. For other customers in Oil & Gas, they have a huge lead time on the refurbishment of the components and for new product also lead time is longer around 5 to 12 months, but we can do with 3D printing technology much faster, efficient and effective way. Our technology is not limited to certain components we can work with tiny parts to huge parts and can deliver the parts in a very short time.

Why did the firm choose to implement 3D printing?

Interviewee: We work with additive manufacturing from quite a few years before the start of this company as a researcher at NTNU. What we saw and experience that the industry did not really have the necessary knowledge or skills to operate and utilizing this technology, so we see the opportunity where we can make an impact and we can deliver part in less reduce lead time. So, basically that how to get motivated and we are the early adaptor of technology worldwide not a lot of companies is doing this, so we think it is good timing to introduce this technology in production. We try to focus on production on companies that can utilize where the alternative cost of components is very high for instance, with maintenance components. We try to find where we can add more value with our technology.

What are the realized benefits from the use of 3D printing?

Interviewee: The realized benefits are the same as mentioned earlier i.e. reducing the lead time from weeks to hours, very high quality, easy and cheapest way for maintenance or refurbishment of special components, no waste of metal, save a lot of time.

How do you envision the future use of 3D printing?

Interviewee: Definitely it is a huge impact on the way you produce parts specially in Norway where cost to produce parts is very high, so we need to be clever in way to compete the rest of world. This is the digital manufacturing and I believe a lot of companies are afraid of that 3D printing will take away their markets and change the way we manufacture parts but for me it is just another tool in a toolbox with a big limitation what you can do and cannot do.

So, do you think that in future 3D printing could replace the traditional manufacturing such as injection moulding?

Interviewee: No, I do not think so, for certain components it will perhaps but not in general terms. 3D printing will stand next to injection moulding machine, but both will produce different components depends on the number of the products.

APPENDIX XIII

PANALPINA LTD

Panalpina is a logistics company. We move freight around the world and what Panalpina realized few years ago is just moving things around the world is no longer the thing which satisfy our customers we need more so we started something which is logistics manufacturing services. We realized that lot of our customers goods are lying in the warehouse especially spare parts, they are in the warehouses for years and years and at the end of the day we might not even… well the customer might not even need them at all, so we just have to scrap these warehouses for spare parts and that's the point. Additive manufacturing was explored where looking at it if additive manufacturing could be a potential solution for this rather than storing these spare parts for years and not needing them. Can we print when the need arises? That's the angle we were looking at it from. Also, from another angle of rather than shipping these goods or using air freights can we just manufacture where the demand is? So that was one of the aspect we were looking at it from.

Can you explain what kind of products do you have in your warehouse?

Interviewee: It could vary for instance like…. it could just be from any sector, could be from automotive, it could be perishables, it could be chemicals, it could be fashion. It ranges so there is no fix set of customers. We have customers that are from every industry you can think of. But what…. To begin with… to start in this industry we partnered with 'Shapeways' which is an online platform for 3D printing and they have been using different additive manufacturing technologies for years. We partnered with them, we started with buying a 3D printer which is a Projet 3500 HD max printer by 3D systems. We started exploring by doing it ourselves and that's when we realized it's not as straight forward as it looks. It's not just one printer which prints everything, there's a range of technologies, range of materials. What would be best for Panalpina to start with, so we started with that and developing that and also then I started working for Panalpina and my colleagues do, and we developed a solution wherein we realized that manufacturing is not a strong point of Panalpina, we…. Panalpina is a supply chain company so they will never be going to be as good as manufacturing company who's been doing this for years. We developed the solution and what it does is it looks at Panalpina's customers supply chains and identifies those products from hundreds and thousands of products which will be suitable for 3D printing. These would be slow moving, and these would be very low volume, and these would be

products which are high in value, which are very complicated, which are hard to source, and we look at those products and we identify their supply chains and we are able to provide manufacturing, so we have partnered with different manufacturers around the world and we can manufacture these for them and deliver them where they are needed to be delivered.

So how would you describe your current supply chain structure (suppliers and customers)? Without using 3D printing or before using 3D printing?

Interviewee: You mean our customers I assume, because Panalpina provides the services of supply chain so…. we move the products of our customers where they are having. We are service company so, you know, example would be tomorrow we are going to buy… I don't know…chocolate or something like that and that's basically for our customers so we move it around the world for them, so we link their suppliers and their manufacturers and where the demand is for and we move things around the world for them.

Describe the current use of 3-D printing in your production. You already described that you basically manufacture the products for your customers in partnership with other companies, right?

Interviewee: Yes, that's right. So, at the moment we are doing production with 'Shapeways.' So, we contract manufacturers for 'Shapeways.'

What are the benefits & challenges that you have encountered during the use of additive manufacturing?

Interviewee: I think challenges would be, being a service company and be supply chain focused company, that's what we have been doing for years, that's what we are good at. Additive manufacturing would certainly a new industry or new field which we ventured into and quickly after learning from 3D printing, first printer we had, and learning more into it Panalpina realized that we are never going to be as good at it as manufacturers are. Because of the skills required, it's the skill set which logistics company don't have. We need engineers, but we have got supply chain specialists. It's a great challenge to have that and to be able to provide that. So that's when we change our model into what we are able to provide, where we want to focus in the future. That's the reason we developed the supply chain solution rather than an engineering solution. Although it takes into account engineering principles, it focuses on supply chain which is where our core strengths are.

And what would you say about benefits?

Interviewee: It certainly is beneficial in terms of what service or what value-added service we as a service company or as a logistics service provider is willing to bring to the market because we not only move things around the world but with additive manufacturing we are able to provide some more value to our customers. So, example would be if customization is required we are able to bring this to the market exclusively on demand so there's something known as the product postponement, so we have got telecom industry service providers as our paid customers. An example would be if you want a phone tomorrow and you want it in a specific colour, we can get it assembled at our warehouses so rather than manufacturing it in the way you want, we will have all the spare parts in our warehouses, so we can assemble it in the way you want, these features that you want in your phone and that we get it delivered to you. You could be anywhere in the world and that could be done in the nearest warehouse to you. So, in additive manufacturing it becomes a step closer to getting that done. Customization is achievable, so this is something that Panalpina is able to provide. This is one of the unique offerings of Panalpina in the logistics market.

So, your warehouses are located near to the customers or are they scattered at different places?

Interviewee: Yes. We have got warehouses in about 150 countries around the world. We have got presence in some form or another, it could be offices or warehouses in 150 countries around the world.

How has the use of 3-D printing changed the structure of the supply chain?

Interviewee: I'd say in terms of our customers' supply chain. So, example would be a few customers we are dealing with rather than been having to ship the manufactured product in a country then ship it to another country, we have established a 3D printing hub where the customers are, rather than they manufacture and ship we manufacture and ship directly in the same country. It reduces the supply chain complexity or the delay which it had initially.

To reduce the time and the cost?

Interviewee: Yes.

But does the use of 3D printing in proximity to the customer has changed the old supplier. Has it changed?

Interviewee: In this case not a surge, I think in this case where we are looking at this particular customer, we actually have only one printer and we are doing for one customer at the moment in terms of manufacturing. With this particular customer, it's actually a good and positive thing because the existing SD's are neutralized for taking more orders in the current market and where our capacity comes in is when we have got additional orders for the market we serve. So, it doesn't really affect the production at the moment whereas it allows them to flexibility to take on more production.

Why did the firm choose to implement 3-D printing? I think you have mentioned it earlier in the introductory part where you mentioned that products were lying around in the warehouses, so you thought to manufacture rather than store?

Interviewee: That's right, yes. And also, what we found is, our customers, they need the changing and its down to the end customer, the consumer need the changes. We no longer need the things which are mass produced, we need some things which are specific, we need something specific to our need and taste. We need things customized, we need things personalized. We are also not willing to wait for weeks, we want to go online, and we want to quickly deliver the products the next day or two days like we are no longer willing to wait weeks. We'll just go to someone else who is willing to provide us faster and all of this, anticipating the consumer needs and demands and also understanding our customers' challenges. This is what that has led us to additive manufacturing.

What are the realized benefits from the use of 3-D printing? I think we have already discussed the benefits as our next question is about benefits. So, we can skip to the last question.

How do you envision the future use of 3-D printing? With respect to your firm and overall.

Interviewee: I think within our firm it would be a lot more customers as they understand. So, what happens is, we have been talking with a lot of customers and in conversations we realized, a lot of these companies, engineering companies or manufacturing companies, focus only on the benefits of additive manufacturing as it would go for manufacturing. So, yes of course it provides the design complexity for free, so you can manufacture as complex products as you want at no additional cost and things like that. And it provides

personalization, customization. But what we will look is for the supply chain side that, the benefits of supply chain our overlooked on a large scale. You don't need to manufacture and store in high volume, whereas with 3D printing you can print it as the demand drives as far as the volumes are low and we don't need to ship it around the world. You can produce it where the demand is. The product obsolescence just sitting in the warehouse till the end because it's never been used. So, things like these. The benefits in the supply chain are more than our customer can think of. This is what we think more and more customers will understand and will take benefits of additive manufacturing even more. And I think it's also as the technology improves, at the moment it's still quite expensive, it's not applicable to every product you can think of. As the technology improves, it will be applicable to more and more products. So, more and more products will be printable and the scale, at the moment its very low volume as we can produce only hundreds, as the technology improves it will be more. It will be thousands or hundreds of thousands. That is where we see the future today.

Appendix XIV

GLAMOX AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: In general, we have many different suppliers and some special producers with whom we are working together for injection moulding parts which is important for our production. Now we have start project in which we in product development department we preselect the suppliers means we choose potential suppliers, test them and then transfer the project to one of our factories for production. Then the factory individual purchase from supplier group to taking over.

Multiple number of suppliers for different product categories, produce at different own factories and huge number of customers worldwide.

We also focus on that we have redundant system that we do not depend on only one supplier for one product in order to secure ourselves and therefore there is a lot of changes in the suppliers from time to time as we always looking for the best supplier for our products.

Do you have in-house facility, or do you outsource from suppliers?

Interviewee: You can say most of the shield metal we work with is in-house. In Molde for example we have huge facility and many equipment's such as stamping, bending and bending all are in-house. Some parts we are producing in China. Injection moulded parts are generally outsourced, and producers are in Norway or Estonia or other places we work together with.

What about the materials, what sort of materials do you use for in-house?

Interviewee: For bending operations or bending parts its steel or aluminium for fittings in-house but we have also casted aluminium produce from sub-suppliers. So, in general we have multiple supplier for both steel and aluminium.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: Mainly, it is for prototyping. We have prototyping facility work shop in Molde which also include the 3D printing facility which we use to produce prototypes. However, for one project we use 3D printing for serial production. Currently, we have a project where I have a little plastic part which we only need 200 pieces per year and for this part it is not effective to build a moulding tool, so we decided to order from a sub-supplier in Norway for

prototype 3D printed. We also use 3D printing to build mounting checks or production equipment's in the factory.

Do you produce any product for commercial purposes?

Interviewee: No, only the small plastic piece which I mentioned earlier because our business is very priced focused and normally luminaire we are selling is minimum about 5 to 10 thousand products per year and it is not cost effective to 3D printed them.

What are the benefits and challenges?

Interviewee: One of the challenge or disadvantage of the use of 3D printing is the price per part and the production time. As for high volume products it is more effective to inject moulded.

Benefits or advantage is the flexibility that is the reason we use it for mounting checks etc for example for redesign and we cannot limited to mould tool only.

What about the cost of the machine?

Interviewee: It may consider as a challenge but mostly it depends for which product material we going to use it in product for example for SLS material the machine is not expensive but for metal parts the machine is much more expensive.

How has the use of 3D printing changed the structure of the supply chain?

Interviewee: For this question, I can answer for the development process as it is very essential to speed up the development process and it is also important to get better products because for product developers, they have more flexibility to test things for example, if we have an idea, then we build it up in CAD system and with 3D printing we have the possibility to build it as a physical model and test it this is much more easier as of 20 years ago. So, now we test more, and we can test several solutions to get better products and that is a big benefit of 3D printer.

Does this impact any on your supply chain even in prototyping like you doing now by yourself and before it supposed to get done by your supplier? i.e. before the use of 3D printing, you used to do test and prototyping in-house or outsource from supplier?

Interviewee: If you go back about 10 or 20 years, we have done it in-house as we had the possibilities to make vacuum moulded silicon parts, but it takes much more time and the other possibility was to order from a sub supplier.

But now after using the 3D printer everything you are doing by your own self and in-house?

Interviewee: Yes, mostly as some time we order from other supplier for example, if we have parts which we cannot print such as FDM technology. If we have very small and thin parts, then we order to a supplier who have this machine.

How long you have been using 3D printing?

Interviewee: We have a machine in-house for 3 years now, but the technology is about 10 to 15 years.

Why did the firm choose to implement 3D printing?

Interviewee: because it helps us in development process and as I said earlier to test for example, ideas, concepts to speed up the development process.

Does 3D printing also help to innovate the product as well?

Interviewee: Yes, absolutely we can do more experiments and test them in quick time and this was also one of the main reason to promote more innovation.

What are the realized benefits from the use of 3D printing?

Interviewee: The realized benefits are the same as mentioned earlier i.e. speed up the development time, flexibility, testing, innovation etc we have a lot of experience with 3D printing technology before we buy the machine so what benefits we were expecting from the machine we actually have all those benefits.

Do you think that a 3D printing is suitable for companies those producing large volumes or with the current technology it is limited only with the certain number of volume?

Interviewee: That actually depends on which industry we are looking for example, if you are looking at medical industry you normally have one expensive product and then it could be a solution to use a 3D printing because it could be a customize product for that particular

patient. If you are looking at metal printing it is also interesting for aerospace but then you have other issues like certification and all but in our industry much possibilities as moulded parts specially in combination in moulding manufacturing in China is so cost effective as compare to 3D printing. The 3D printing is not competitive at the moment.

How do you envision the future use of 3D printing?

Interviewee: I think if the technology development improves and the printer start producing at high speed with good quality then we can see the use of 3D printing in production will be more as it is easy way to produce products.

Appendix XV

FOSSTECH AS

Describe the current supply chain structure (suppliers and customers)?

Interviewee: We have many suppliers and customers around 100 to 200 and we are working on new products all the time so some time we have to find new supplier for new product required by existing or new customers, so the number of supplier and customers are change rapidly.

So, you do not have fixed supplier for all your products?

Interviewee: No, we have some regular suppliers and customers for example Kongsberg Maritime is one of our regular customers.

Are you producing end user products or intermediary products for your customers?

Interviewee: We are producing some finished products for Kongsberg maritime but also some products that are part of bigger assemblies such as cables. It is a combination of both and it is the same with most of our customers.

Describe the current use of 3D printing in your production. Benefits & Challenges.

Interviewee: From some of our customers we received a 3D model and we print them in different materials from plastic to metal (Appendix XVII) and deliver back to the customer again. However, in this process we need to do some engineering works, identify which printer is the best for this particular job.

How many 3D printers do you have at the moment?

Interviewee: We have two 3D printers here, but we have cooperated firms to whom we work with they have different printers than ours, so we use their printers as well so mostly we use 4 different types of 3D printers and these are the industrial 3D printers and not the cheap 3D printers.

Are you able to print large products as well?

Interviewee: Yes, we have some bigger printers as well. I think the biggest we have at the moment which we use a lot has a volume of 250x250x300mm that is pretty small, but it covers most of the jobs related to our products.

The current use of 3D printing is in production as most of the products we produce are made from industrial 3D printing and we deliver finished products, but we use also use for prototyping for example, we have an idea, we do the design and print it with 3D printing. The technology now is good to print finished parts.
We also print metal and titanium so there are many opportunities it is just the customer does not know about this and this is what we try to change so people start think that the 3D printing can be used to produce finished products not only prototypes and that is a challenge to find a product which can print from 3D printing to sell.

Is it possible to print large quantity with industrial 3D printing?
Interviewee: Yes, it depends on the size of the product of course, if it is small parts you can fill up a whole chamber of 3D printer with the products, it will print overnight, and it is really short time to market.
Another challenge with 3D printer is when you are designing the product you have to design it in a different way as in 3D printing you adding material instead of subtracting it as in traditional manufacturing process as some customer demand a product that are design for machining and they would not be cheap to produce with 3D printer so the knowledge about the design the product in a way, so it can print from 3D printer.

What about the cost of the machine is it a challenge?
Interviewee: Yes, that is a challenge and that is why we have cooperated with other firms those have different 3D printer than us because we cannot have all of the 3D printer as it cost a lot of money and for this reason we do not have the opportunity to buy all types of the printers and we have to work together with other companies.

The possibility to print proximate to customer, is this a benefit for the company?
Interviewee: Yes, the printer can be anywhere in the world as we do not have traditional assembly chain and also it is easy to move the printer from one place to another as compare to the traditional manufacturing setup.

How has the use of 3D printing changed the structure of the supply chain?
Interviewee: Now we have shortened the time to market from idea to the finished product and can print overnight whereas in traditional way we have to add 2 to 3 weeks in production before have a finished product. So, we have shortened the time to market significantly. We

have been able to produce products that we use here for moulding business so instead of going out to other suppliers we can produce the parts here by ourselves.

So, does this mean that you used to buy from the supplier before and now you producing by yourself and no more from the supplier?
Interviewee: Yes, that is a change in supplier side.

Does the supplier also change from supply of parts to the supply of raw materials of 3D printer?
Interviewee: Yes, the suppliers are changed not as we add industrial 3D printer in our production, so we have different supplier for 3D printer for some products and it is the same who deliver the printers actually.

Is it correct to say that some suppliers finished in your supply chain network and some new added because of the use of 3D printing technology?
Interviewee: Yes, it is like we still use traditional way, so we use same supplier as before but for 3D printer we use different.
From customer side, reducing the lead time is a big change as before we required long time to deliver to the customers but now we can deliver in hours. It also gives the opportunity to produce such products which never able to produce before in traditional machining. We can make new products which we were not able to produce before. We can experiment and innovate more with 3D printing technology, we can print, test and redesign if needed. It also helps us to find new customers in new sector actually we have many new customers because of 3D printing.

Why did the firm choose to implement 3D printing?
Interviewee: For us we have to make a change because it not a good time with the Oil business, so our company have to make a change and we want to invest in future and we thought about the 3D printing and also in order to be competitive in the market with the digitalization manufacturing technology.

What are the realized benefits from the use of 3D printing?
Interviewee: The benefits are the same as mentioned earlier that it reduces a lead time, helps to innovate, print anywhere in the world and offer a huge flexibility.

How do you envision the future use of 3D printing?

Interviewee: Imagine it will be more advance and more people know about it then there will be more use of it as the current challenge is not many people knows how well the industrial 3D printers are even today. However, I do not think it will take over traditional machining, but it will make up of a bigger part of the product.

But as you said for 3D printing that design of the product is very important, so currently most of the products are designed which suites the traditional production, do you think in the future this concept is going to change and people will start designing the products that are suitable for 3D printer?

Yes, I think so because people are learning in schools now particularly about the 3D printing technology, so it has already entered into the school system so in the future the new generation will start thinking to design the products in such way which will be suitable for 3D printers. Though 3D printing is not new it has been in research and development from a long time and it is today in application as well, but it will take some more time to be used more for production.

Appendix XVI

LIST OF INFORMANTS

Overview of the participating companies, their location, industries, and interview dates & times. Most respondents requested anonymity to publish their names.

ID	Companies	Date & Time *(dd.mm.yyyy)*	Interview via	Companies located	Industry
1	Kongsberg Maritime AS	24.04.2018 14:30 CEST	Skype	Kongsberg, Norway	Maritime
2	Kongsberg Defence & Aerospace AS	02.05.2018 17:36 CEST	Email	Kongsberg, Norway	Aerospace & Defence
3	Ekornes ASA	13.04.2018 12:00 CEST, 19.04.2018 13:00 CEST	Site visit, Face-to-face	Sykkylven, Norway	Furniture
4	Pla-Mek AS	19.04.2018 14:00 CEST	Site visit, Face-to-face	Sykkylven, Norway	Industrial plastic products
5	Stokke AS	17.04.2018 12:00 CEST	Site visit, Face-to-face	Ålesund, Norway	Children´s furniture and Equipment
6	Sperre Industri AS	23.04.2018 15:00 CEST	Site visit, Face-to-face	Ellingsøy, Norway	Air compressors
7	Tronrud Engineering AS	02.05.2018 12:00 CEST	Skype, Telephone, Email	Eggemoen, Norway	Industrial products, oil & gas/geology, medical, packaging
8	Plasto AS	27.04.2018 12:00 CEST	Skype	Åndalsnes, Norway	Industrial plastic products
9	AS OM BE Plast	30.04.2018 10:00 CEST	Skype	Sellebakk, Norway	Industrial plastic products

10	ISIFLO AS	30.04.2018 15:00 CEST	Skype	Raufoss, Norway	Water and Gas fittings
11	Norsk Titanium AS	03.05.2018 10:00 CEST	Skype	Hønefoss, Norway	Aerospace-grade titanium components
12	Nordic Additive Manufacturing AS	30.04.3018 13:00 CEST	Skype	Raufoss, Norway	Metal parts
13	Panalpina Ltd	18.04.2018 13:00 CEST	Telephone	United Kingdom	Supply chain, Logistics
14	Glamox AS	03.05.2018 13:00 CEST	Skype	Molde, Norway	Professional lighting solutions
15	Fosstech AS	02.05.2018 10:00 CEST	Skype	Stokke, Norway	Mechatronics

Appendix XVII

FOSSTECH AS 3D PRINT PRODUCTS