JÖNKÖPING UNIVERSITY
International Business School

Impact of 3D Printing on Supply Chain Relationships

A Study within the German Automotive and Logistics Sector

MASTER THESIS WITHIN BUSINESS ADMINISTRATION

Number of Credits: 30 ECTS
Program of Study: International Logistics and Supply Chain Management
Author: Felix Eckes
Tutor: Imoh Antai

JÖNKÖPING May 2016

Acknowledgement

Writing a master thesis is a hard and long but also an enjoyable endeavor. During the last 4.5 months a lot of people were involved and here I would like to thank all of them. Without their support and guidance this master thesis would not have had the same outcome.

First, I would like to state my infinite gratefulness to all interview respondents as I could not undertake this research without their help and valuable answers as well as insights into the future of 3D printing.

Secondly, I express my gratitude to my supervisor Imoh Antai. He helped and supported me during the entire process in a beneficial way. By challenging all my work he pushed me even further to improve this master thesis.

Finally, I would like to thank my family, friends, and fellow students for all the support I received during my entire time at Jönköping International Business School and especially during the sometimes stressful process of writing this master thesis.

Jönköping, May 2016

Felix Eckes

Master Thesis in Business Administration

Title: Impact of 3D Printing on Supply Chain Relationships – A Study within the German Automotive and Logistics Sector

Author: Felix Eckes

Tutor: Imoh Antai

Date: 2016-05-23

Keywords: 3D printing, outsourcing, supply chain relationships, automotive, logistics, Germany, additive manufacturing, TPL

Abstract

Background By introducing new technologies in the production processes, manufacturing is going digital. 3D printing is a technology that will change the way goods are produced. Entire supply networks have to adapt to changes that will arise by the implementation of additive manufacturing. Hence, the existing relationships between supply chain actors will alter.

Purpose The purpose of this study is to explore the relationship changes between automotive original equipment manufacturers and logistics service providers in Germany by investigating the possibility of outsourcing the production via 3D printing.

Method A multimethod qualitative research strategy is used to explore the topic. Through two cases – original equipment manufacturers and third party logistics providers – data were gathered by semi-structured interviews. Additionally, archival research as well as observations took place to strengthen the findings by triangulation.

Findings Original equipment manufacturers and third party logistics providers see a bright future for 3D printing and anticipate that their supply chain relationships will be affected. Considerations to outsource the production via 3D printing play a major role in both types of companies. But to whom it should be outsourced cannot be assessed today as the technology has to be developed further. Third party logistics providers are suitable candidates as they already have a global distribution network at strategic locations. Furthermore, they could add 3D printing to their value added services portfolio and combine several tasks.

Conclusion 3D printing will change entire supply chains. Even today, all companies need to be aware of these changes and take all possibilities into consideration. These changes will not occur in the short run as 3D printing needs further development. Outsourcing 3D printing and offering it as value added service are topics that will alter the connections between original equipment manufacturers and third party logistics providers.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
3DP	Three-dimensional printing
CAD	Computer-aided design
OEM	Original Equipment Manufacturer
PDI	Pre-delivery inspection
RBV	Resource based view
TPL	Third Party Logistics Provider
TTM	Time to market
USD	US Dollar
VAS	Value added service

1 Introduction

This study deals with the topic of three-dimensional (3D) printing. As 3D printing (3DP) is a fairly new technology this chapter gives a short overview of the evolution of new technologies since the 18th century. Afterwards, the identified problem, the purpose as well as the research questions of this thesis are presented. This chapter closes with some delimitations of the study.

1.1 Background

Since the first industrial revolution in the second half of the 18th century, new technologies disrupt entire supply chains and affect especially the manufacturing of products as well as the logistics activities. However, there is no unique solution for coping with new arising technologies as every innovation is different. New disruptive technologies that will have a huge impact on the global economy in the near future are the automation of knowledge work, advanced robotics, autonomous and near-autonomous vehicles as well as 3DP to mention just a few (DHL, 2014; McKinsey Global Institute, 2013).

In the late 18th century the first industrial revolution started in Great Britain and was spread out all over Europe in the 19th century. The mechanization of production - especially by the use of the steam-engine and trains as means of transportation – took place – *'from an agrarian, handicraft economy to one dominated by industry and machine manufacture'* (Beckett, 2013, p. 181). What was done before manually in a lot of different places was brought together into one building – the factory.

In the beginning of the 20th century the second industrial revolution took place. It was mainly initiated by Henry Ford and his new organizational structure. Ford introduced the standardized mass production and assembly lines to increase productivity by producing a large amount of cars at the lowest costs (Ford Motor Company, 2016). Both revolutions increased the production speed and the efficiency of production dramatically but the social and working life of the people was also negatively affected, e.g. loss of jobs.

The third industrial revolution takes place right now (Rifkin, 2014; Rifkin, 2012). By introducing technologies like 3DP or advanced robotics '*manufacturing is going digital'* (The Economist, 2012a). As in the two revolutions before, the way of producing goods will change but also the place of production will be affected by these technologies. Production will be closer to the end-consumer in decentralized production and distribution structures (Petschow, Ferdinand, Diekel & Flämig, 2014) Workers are no longer required as the machines can run unattended for a long period of time. A shift in the types of work will be one important consequence of the third industrial revolution. But one of the most revolutionary aspects of the new technology is that everyone can be a developer and a producer at once (Fastermann, 2014). 3DP can enhance individual mass production.

This study deals with the new technology 3DP which is '*a fabrication method in which an object is formed in three dimensions often through a series of consecutive layers*'

(Sculpteo, 2016). 3DP and additive manufacturing are used interchangeably throughout this master thesis. 3DP is not a brand new technology. Charles Hull invented the first type of additive manufacturing – stereolithography – in 1984 and protected the technology by patent, namely United States Patent 4,575,330 (USPTO, 2016). Since then additive manufacturing got more and more attention by practitioners, especially in the field of mechanical engineering. As only 10% of executives in the manufacturing industry see the technology as highly relevant for them today, one can state that 3DP is still in its infancy. But 33% anticipate that the technology will become highly relevant within the next three years (Cohen, George & Shaw, 2015). In combination with high governmental investments in 3DP this shows that additive manufacturing has the potential to change the manufacturing industry dramatically (White House, 2012; PWC, 2013). Adopting 3DP in an early stage can bring tremendous advantages. Hence, it should be considered by all affected parties as early as possible.

Prototyping, product development, and innovation are the most common uses of 3DP today (Columbus, 2015). Especially in the medicine sector 3DP is indispensable as here individualization of components is important. Customized bone implants and hearing aid devices are only few of several applications within medical sciences (Seitz, 2008; Bak, 2003). Those devices have to be highly individualized and hence they are produced in small batch sizes or even lot size one. As 3DP makes '*small production runs economically feasible*' (Sachs, Cima & Cornie, 1990) costs for the production can be reduced dramatically. In 2014 the last of the original additive manufacturing patents expired. Since then the development is faster than before and costs for 3D printers decreased dramatically (McKinsey Global Institute, 2013; Columbus, 2014). Further opportunities where 3DP is or will be applied are given in chapter 2.4.

Academics of other disciplines than mechanical engineering have just recently started to investigate additive manufacturing and its associated technologies for their area of interest.

Most of the work that is done in the field of 3DP is concerned with the advantages this new technology will bring along compared to other manufacturing technologies (Berman, 2012; Kieviet & Alexander, 2015) as well as in terms of cost efficiency (Gebler, Uiterkamp & Visser, 2014). The implications 3DP will have on sustainability and ecological aspects of companies are also investigated in several papers (McKinsey Global Institute, 2013; BSR, 2015; Gebler et al., 2014). Other researchers concentrate on the process of implementing additive manufacturing within existing processes (Mellor, Hao & Zhang, 2013; Holmström, Partanen, Tuomi & Walter, 2010). The conclusion of those articles is that additive manufacturing has advantages when producing in small batch sizes as well as when producing individualized products. Another positive aspect of 3DP lies in the reduction of CO2 emissions due to a lower need of transportation and a massive reduction in waste compared to established manufacturing technologies. Although there are several articles focusing on the use of 3D printers in the spare parts supply chain (Khajavi, Partanen & Holmström, 2013; Holmström et al., 2010), no research is done at the interface between the original equipment manufacturer (OEM) and the logistics firms that transport the parts to their final destination. How will the relationship between manufacturers and logistics companies change when implementing additive manufacturing processes? Will 3DP increase the trend of re-shoring or will it be an outsourced activity? Who should perform 3DP to achieve the most value for all participants – manufacturer, logistics services or a different actor?

1.2 Problem

Introducing new technologies always has an impact on the performance of an entire supply chain and the relationships between supply chain members. When a company does not carefully evaluate benefits and downsides of such a new technology long lasting relationships can easily be destroyed. Information exchange about new trends and potential changes in the processes is extremely important for a well-performing and reliable supply chain. This will lead to a good collaboration between all supply chain members and the highest value for all (Lee, Kwon & Severance, 2007). Especially logistics activities are highly important for manufacturing firms. Introducing a new technology like 3DP and simultaneous re-shoring from low-wage countries back to the countries where the consumers are located can disrupt a company's entire network which consists of several actors - suppliers, manufacturers, logistics companies and consumers. Suppliers provide the raw materials the manufacturers need to build their products. The logistics companies are responsible for shipping materials as well as products around the globe to satisfy the consumers' demands.

Big companies like Airbus or DHL consider potential changes in the manufacturing networks already today and try to anticipate future challenges as well as benefits (Airbus, 2015; DHL, 2014). Manufacturing companies have been using additive manufacturing techniques for years and are doing a lot research in the area of 3DP (BMW, 2015). They try to be leaders in the innovation to receive as much benefits out of the implementation as possible (Volkswagen, 2015). New emerging firms which are specialized in the new technology are publishing white papers about the opportunities 3DP will have (AEB, 2014). Potential shifts in the relationship between manufacturers and third party logistics providers (TPL) are not investigated. Therefore, a gap concerning potentials and disadvantages regarding this relationship is identified.

The automotive sector and especially its spare parts supply chain is seen as one area where 3DP can change established patterns (DHL, 2014; Fastermann, 2014). 3DP can bring high economic savings for the companies. The McKinsey Global Institute (2013) estimates the impact of additive manufacturing up to 550 billion US dollar (USD) per year by 2025. Changes in the production network will occur. Automotive spare parts will be produced near to the end-consumer and therefore a decentralized distribution structure compared to a centralized production structure will be preferred (Sharma, 2014; DB Schenker, 2015; Petschow et al., 2014). Distributed production combined with well-developed additive manufacturing processes has lower total costs than centralized production (Khajavi et al., 2013; BSR, 2015). In centralized production, transportation is highly important to serve the customers at high service levels. This means that the collaboration with TPLs is crucial to stay in the market and to get a competitive advantage by maintaining existing customers as well as gaining new customers. By introducing additive manufacturing and distributed production the last mile logistics gets more crucial for the business. TPLs become unnecessary to serve the customers by shipping spare parts around the entire globe. This will impact the relationship between those two types of companies. New companies will be founded and other firms will expand their portfolio of offered services (DHL, 2013). Other types of collaboration can take place; for example the outsourcing of the manufacturing process 3DP to TPLs (DHL, 2014) or even the opposite, meaning the insourcing of the manufacturing via 3DP (Mourdoukoutas, 2015). Outsourcing is '*purchasing your product, components, or services from an outside party*' (Reiss, 2015). Especially when the technology will be outsourced, the question of intellectual property rights and other legal regulations have to be considered.

Nowadays, TPLs and car makers have strong relationships. The automotive industry accounts for a huge share of the entire transportation volume of the TPLs and the logistics companies ensure availability of materials for an uninterrupted production flow (Bennett & Klug, 2012; DHL Freight, 2016). By implementing 3DP or outsourcing this technology relationship shifts between manufacturers and TPLs may take place. Therefore, this thesis investigates potential relationship changes as well as the potentials of outsourcing 3DP.

1.3 Purpose

The purpose of this study is

to explore the relationship changes between automotive OEMs and logistics service providers in Germany by investigating the possibility of outsourcing the production via 3DP.

1.4 Research Questions

The research questions that should be answered by this study are:

- RQ 1: How will the implementation of 3DP change the OEM-TPL relationship?
- RQ 2: Why could it be interesting for OEMs to outsource the production via 3DP?
- RQ 3: Why should logistics firms offer additive manufacturing?

1.5 Delimitations

This study focuses solely on the relationship between the actors in a simplified four-tier supply chain. The actors were prior named and are shortly defined in chapter 2.3 to eliminate any confusion regarding the meaning of such a company. The influence of all other involved parties (e.g. carriers) in the supply chain will not be taken into consideration for this thesis.

Due to my origin all companies are located in Germany and firms in other countries are not explored. However, all companies are global players and the conclusions that will be drawn are not limited to the German market only.

On the manufacturing side, all considered companies are in the automotive sector and other sectors may see the technology 3DP in a completely different way.

As this study is written in business administration and not in law, regulations regarding protection of intellectual property rights are excluded but should be investigated by specialists in the field of legislation.

Due to time constraints the sample is limited to three TPLs which are providing a wide range of value added services to other companies as well as three manufacturers which are highly involved in collaborations that investigate new manufacturing technologies.

2 Frame of References

This chapter introduces the concepts of 3DP and outsourcing as well as the implications that arise from those strategies. Afterwards, the actors of a simplified supply chain are introduced and their respective relationships to each other. Thereafter, the future of 3DP is shown and finally a conceptual framework is developed.

2.1 3D Printing

3DP is one of the newly arising manufacturing technologies and has according to US President Barack Obama '*the potential to revolutionize the way we make almost everything*' (White House, 2013). It is also called additive manufacturing which means that objects are not build by molding or subtractive techniques but by building the object layer by layer (Cohen, Sargeant & Somers, 2014). As stated earlier, the terms 3DP and additive manufacturing are used interchangeably. The development of new 3DP materials and 3DP are seen as one of the Top 10 Technology Trends according to the world's leading information technology research and advisory firm Gartner, Inc. (Forbes 2016; Gartner, 2014). Wohlers Associates which is a consulting agency within the field of additive manufacturing shows that this technology is used in several industry sectors (figure 1).

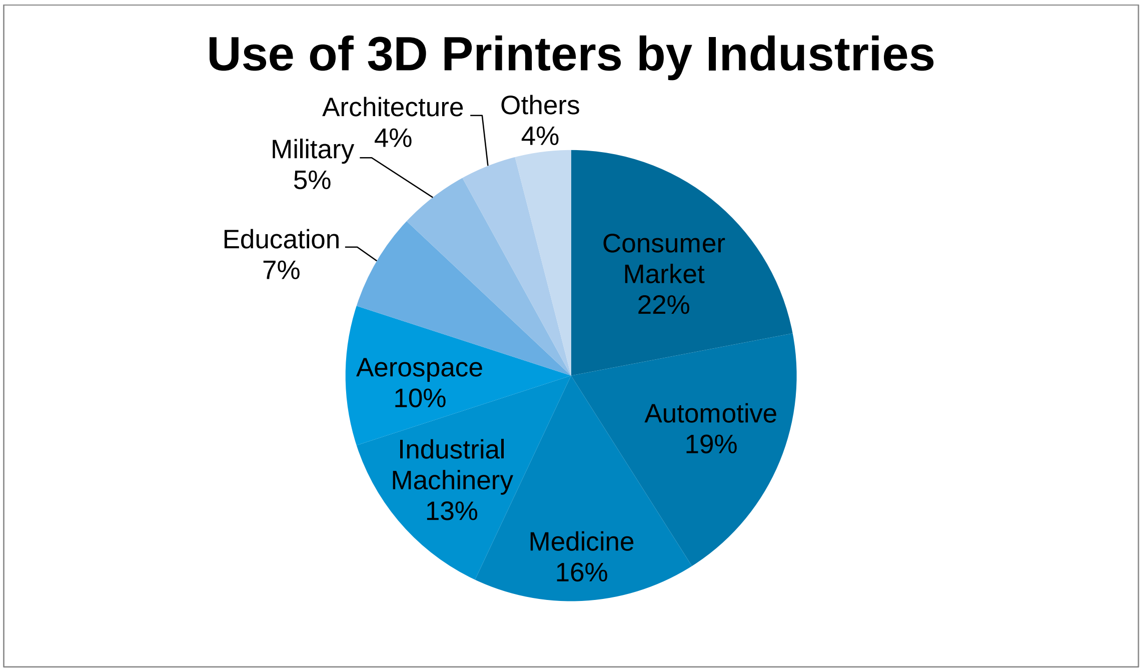

Figure 1: Use of 3D Printers by Industries (own illustration; Source: Wohlers Associates, 2013)

As this is a master thesis within business administration, the engineering procedure of additive manufacturing will only be presented in a very short way. Thereafter, advantages and disadvantages of additive manufacturing are presented. An outlook how academia as well as the industry see the future of 3DP is given in chapter 2.4.

2.1.1 The 3D Printing Process

The procedure starts with the development of a three-dimensional model by using Computer-Aided Design (CAD) software on a computer. This model consists of all details and specifications the end-product will have. Another program, which is programmed for 3DP, slices the model in very thin two-dimensional (2D) layers. The quality of the product is very much dependent on the thickness of these 2D layers. The information about the layers is sent to the 3D printer which uses material powder instead of ink like a normal printer to print the object. The final product is now produced layer by layer which means that after each printed layer a new film of powder has to be spread to build the next layer. The process can last from few minutes up to several days (Berman, 2012; Khajavi et al., 2013).

The range of materials that can be used for 3DP has recently increased dramatically. In the beginning only plastics and specific metals were suitable for the process but nowadays even food and stem cells are substances to print with (Cohen et al, 2014; DHL, 2014).

Another dimension which expanded rapidly is the type of end products produced by additive manufacturing. Designs and prototypes produced by 3D printers are common practice for years (McKinsey Global Institute, 2013; The Economist, 2012b). Direct manufacturing is a new field in which 3DP will play a major role and could be an alternative to traditional manufacturing technologies (Cohen et al., 2014). The reason behind this is mainly driven by cost and time reductions in the production process. By using additive manufacturing technologies it is possible to produce respectively print an idea directly from the design file without having costs for molds for example (McKinsey Global Institute, 2013).

With the expression ‘three-dimensional printing’ several production techniques are meant. The most common procedures are selective laser sintering, powder bed printing, direct metal laser sintering, fused deposition modeling, stereolithography, laminated object manufacturing, and inkjet-bioprinting (Fastermann & Ciric, 2014; McKinsey Global Institute, 2013). Explanations of some of the mentioned techniques can be found in appendix A1.

2.1.2 Advantages and Disadvantages of 3D Printing

To get a deeper understanding which implications the implementation of 3DP can have, the main advantages as well as the main disadvantages or barriers that have to be overcome will be presented in the following section.

Additive manufacturing has the big advantage of producing parts on demand which means that they are built just when a customer order is set. This can lead to a reduction of warehousing costs and therefore the production is more efficient (C. Brons, personal communication, DHL, 2016-02-11). As 3DP is also called additive manufacturing, material is added instead of subtracted. This makes the entire supply chain more sustainable because less material is wasted (McAlister & Wood, 2014; Fastermann, 2014). Another environmental issue that is positively influenced by the implementation of 3DP is transportation. Parts and especially spare parts can be produced next to the customer instead of shipping them from factory to factory around the entire globe (Campbell, Williams, Ivanova, & Garrett, 2011). Nevertheless, last mile transportation is still needed (Deutsche Post, 2010; Panalpina, 2013). Besides making the supply chain more environmental friendly it is also speed up by a potential shift of production from low-wage countries back to the countries in which the products are consumed (McAlister & Wood, 2014). Another advantage of additive manufacturing will change the current warehousing practices. Nowadays, it is necessary to store massive amounts of spare parts in warehouses. Especially for older versions of products this is very costly and at some point in time not feasible anymore. By having all parts as a three-dimensional CAD file, storage will be superfluous, costs can be cut down, and products are produced on demand (Campbell et al., 2011). The cost aspect is also significant in 3DP. By using conventional manufacturing technologies costs rise dramatically when the parts get more complex. Additive manufacturing costs are not dependent on the complexity of the products and therefore complex parts can be produced in an efficient way and almost all geometrical shapes can be built (Fraunhofer-Institut, 2015; Forbes/Wolfe Emerging Tech, 2011; Fastermann & Ciric, 2014). Amongst the mentioned benefits there exist several others which are summarized in table 1.

To fully utilize 3DP, several barriers have to be overcome by companies and also governments. Today's technology is relatively slow when the end products should achieve a certain quality standard. Therefore, it is not suitable for mass production (McAlister & Wood, 2014). Another limitation of 3DP is the small object size which can be built right now (Sculpteo, 2015a). The materials that are applicable for 3DP are expensive and research and development for more diverse substances is costly (Wang, Wang, Yang, Liu, Tong, Tong, Deng, Chen & Liu, 2013). This hinders smaller companies to utilize the new technology. Terry Wohlers, who is the president of a consulting agency within the field of additive manufacturing, states that the printers need to be developed further to produce the same part with the same quality level at different places in the world. This is not possible yet (Forbes/Wolfe Emerging Tech, 2011).

By now just a few regulations regarding additive manufacturing exist. Therefore, governments have to establish clear rules for additive manufacturing. The technology makes it less difficult to infringe copyright and patents (Desai & Magliocca, 2014). Having all product designs stored as files is risky for companies and their IT systems. Especially due to the emergence of more and more internet platforms where users can upload own and download other CAD files the concerns regarding copyrights are huge (Fastermann & Ciric, 2014). Rules regarding property rights as well as safety of products when not produced by the product designer have to be developed to protect the companies against any threats (Lewis, 2014).

Table 1 summarizes and expands the mentioned advantages and disadvantages respectively barriers.

Table 1: Advantages & Disadvantages/Barriers of 3D Printing

Advantages	Disadvantages/Barriers
Shortening of production and supply chain by printing a product directly from the design file	Building up speed is relatively slow if a certain quality should be achieved
Reduction of waste material → material is added instead of subtracted	Object sizes very limited right now
Complex internal structures are possible	Costs for material search and material very high
Weight savings → cost reduction for transportation	No uniform guideline for designing and manufacturing with 3D printers → quality issues
No or less shipments of parts around the globe needed	Pre- and post-production steps are needed to reach the same quality as with convenient technologies
Only limited final assembly of products needed	Intellectual property rights
Produce on demand	Safety of products when not build by the company which designed the part
Spare parts for older versions of product do not have to be stored in warehouse → design file in a computer is enough	More reliable and repeatable machines need to be developed

2.2 Outsourcing

The origin of the term 'outsourcing' is the expression 'outside resourcing' which is '*the practice of buying goods and services from outside suppliers, rather than producing them within a firm*' (Black, Hashimzade & Myles, 2012). This business practice can be seen as a shift from activities which were previously done in-house to an external third party (Ellram & Billington, 2001). Outsourcing is seen as a strategic tool which can be used by several organizations to achieve competitive advantages (Power, DeSouza & Bonifazi, 2006). The concept of competitive advantage is introduced in the next chapter.

Outsourcing has developed over the recent years. All started with the outsourcing of manufacturing functions, the next step was the divestment of the IT department, and nowadays also other functions like human resources and accounting are outsourced (Ryan & Delgado-Sanchez, 2010). Today, outsourcing is a common business practice for small and big companies in every business sector (Weele, 2010).

Companies can have several reasons to outsource a task or service. In most of the literature the cutting of operational and labor costs is the main driver for outsourcing followed by shifting non-core businesses to specialists to improve the own performance and the discharge of internal labor (Bardi & Tracey, 1991; Ruffo, Tuck & Hague, 2007; Sitel, 2014). Risk sharing is also an outcome of outsourcing which is highly appreciated by many firms (Kedia & Lahiri, 2007). For companies one motive to outsource a service or a task which is getting more and more important is flexibility (Dr. Wlcek, personal communication, KIT, 2016-04-14). Even if demand fluctuations become stronger big companies are not able to shift work forces within a certain time period. By outsourcing several services, the flexibility regarding resources can be increased and hence the performance level is raised (Müller-Dauppert, 2009).

Behind most of the outsourcing decisions stands the popular trend of globalization. Companies must stay competitive in this global environment and therefore try to save as much costs as possible (Weele, 2010). Saving costs can be achieved through focusing on the core-business functions and the skills a company already has and use external specialized parties for the rest (Porter, 1980; Bruch 1998). Quinn and Hilmer (1994, p. 43) summarize this advantage: '*By strategically outsourcing and emphasizing a company's core competencies, managers can leverage their firm's skills and resources for increased competitiveness*'.

Two theories which are directly connected to outsourcing are the transaction cost theory and the resource based view (RBV). The boundaries between firms are the main component within these theories (Fredriksson, 2011). Outsourcing a task will change the borders between firms as they get closer together and collaboration has to take place in a certain way. The RBV will be explained in chapter 2.3.

By the emergence of 3DP, new specialized firms like APWorks by Airbus Group or Stratasys arose and developed advanced skills in the field of additive manufacturing. But also already established firms which offer value added services (VAS) to other companies do research in the field of additive manufacturing, for example DHL and DB Schenker. Also the OEMs like BMW and Volkswagen which are using additive manufacturing for many years started to do more research in the area of 3DP. As the latter ones own and design the CAD files for printing parts, they have the opportunity to utilize other external firms for the production via 3DP and just leave the design in-house which can be seen as a very important production step.

Outsourcing a business function, even if it is not a core function, also brings several downsides for a company. The costs for establishing a good relationship and implementing the new process in the new company can be very high and often are underestimated (Wißkirchen, 1994). In the long run of outsourcing a task, a major disadvantage is that the original company loses control over the outsourced function and thus is highly dependent on the other firm (Ketler & Walstrom, 1993). Another downside of outsourcing a business function is the lack of knowledge about the outsourced area (Tayauova, 2012; Ketler & Walstrom, 1993). This also leads to more dependence on the task performing company.

When undertaking make-or-buy decisions firms have to evaluate all those factors before they make the ultimate decision. Figure 2 shows the outsourcing matrix by Savelkoul (2008 cited in Weele, 2010). This matrix can help to understand the two main components of make-or-buy decisions and when to outsource or not. The first dimension is the importance of the function for the business. A function can be either non-core or core which means it is of low or high importance for the company. The second dimension deals with the ‘level of competitiveness relative to suppliers’. Business functions can either be of high importance for having a competitive advantage over competitors or not. It is obvious that functions which are of high strategic importance and which bring a high advantage compared to the competition should never be outsourced (in-house functions). Only business areas on the other side of the scale, meaning they are not core for the business and they are not providing any advantage relative to the competition, should be outsourced (Weele, 2010).

Regarding 3DP no one can estimate which of the streams will be gone. Some companies see 3DP as a technology which will bring the production back to their home country and therefore in-house production is preferred, whereas others see a clear trend towards outsourcing to keep the focus on the product development instead of the production (Stratasys, 2015; Ruffo et al., 2007; Ghausi, 2002; McNulty, Arnas & Campbell, 2012; DHL, 2014). The first stream is known as the procedure of insourcing and means that a prior outsourced task is done by the original company again (Chorafas, 2002).

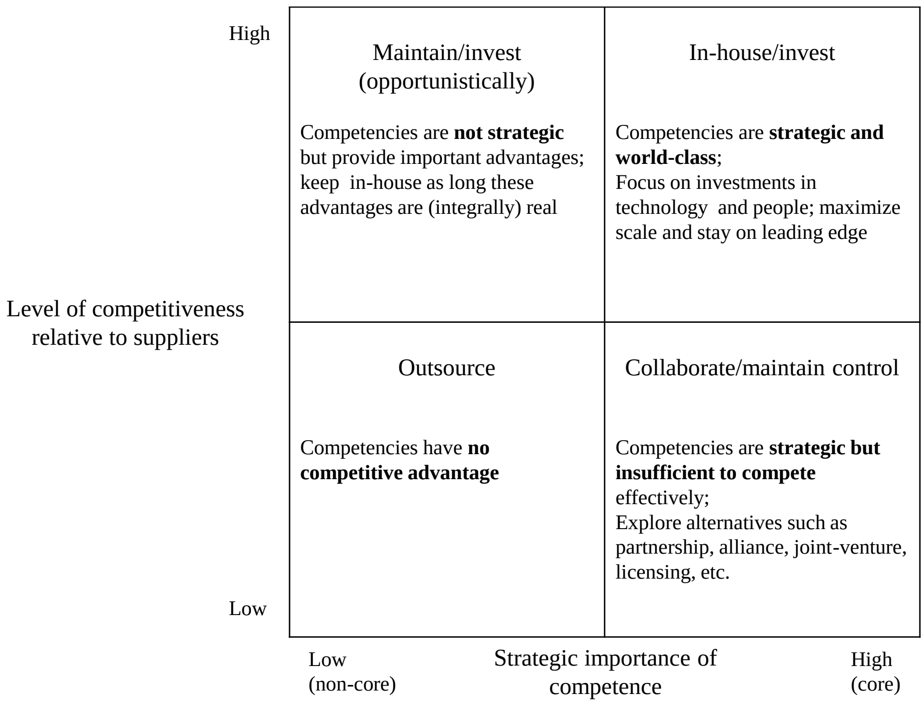

Figure 2: The Outsourcing Matrix (own illustration; Source: Savelkoul, 2008 cited in Weele, 2010)

3DP is not one of the core competencies of OEMs because it is just an emerging technology with a huge future impact. Therefore, 3DP is, according to the outsourcing matrix, a task which gives the opportunity of outsourcing to a knowledgeable company. This decision can have big implications for the independence of OEMs when the power of additive manufacturing is at its highest state as the level of competitiveness relative to others can be nowadays only estimated. Additionally, making the wrong decision regarding outsourcing ‘*can result in cost overruns, project delays, or a solution that does not fit business needs very well*’ (Murthi, 2002).

When a company establishes good knowledge about 3DP and offers this as a service to others it can strengthen the own position and become more competitive (Friedrich von den Eichen, 2002). TPLs are studying new emerging technologies and trends that will influence their business to a high extent (DHL, 2014; DB Schenker, 2014). For example, the world’s leading logistics company DHL publishes on a regular basis a report which is called ‘Logistics Trend Radar’ and is investing a lot in the field of additive manufacturing (DHL, 2016). TPLs are already providing a lot more services than pure transportation to their customers. Hence an expansion of the existing portfolio is possible. Additionally, the already existing worldwide facility and distribution networks of TPLs are perfectly suitable for the setup of a global 3DP network (Dr. Wlcek, personal communication, KIT, 2016-04-14).

By combining those two aspects, collaborations between OEMs and TPLs can take place for mutual benefit. This leads to the decision to focus within this study on the OEM-TPL relationship.

2.3 Supply Chain Actors and their Relationships

In a supply chain many companies are linked together in one network. Relationships within such a network are of high importance when companies want to stay competitive and therefore, they have to be managed carefully (Hagberg-Andersson & Grønhaug, 2010). Staying competitive is a prerequisite for the long-term success of a company. Therefore, firms have to adapt to changes often and quickly. One academic theory regarding competitiveness is the RBV which is deep-seated within the literature about companies’ strategies (Wernerfelt, 1984; Barney, 1991; McGrath, MacMillian & Venkataraman, 1995; Amit & Schoemaker, 1993; Prahalad & Hamel, 1990). Within the RBV of a firm each company is seen as a bundle of resources which are connected and intertwined in different ways for each company. Those resources are ‘*anything which could be thought of as a strength or weakness of a given firm*’ (Wernerfelt, 1984, p. 172) and can be either tangible or intangible. Therefore, each firm is unique. The RBV of a firm was first developed by Edith Penrose in 1959 in her book ‘The Theory of the Growth of the Firm’. Penrose (1959) stated that a firm’s bundle of resources has to be heterogeneous in order to convert a short term advantage into a sustained advantage. According to Barney (1991), to achieve a long-standing competitive advantage resources have to have four characteristics, which are called the VRIN attributes:

1) Resources have to be **valuable**.
2) Resources have to be **rare**.
3) Resources must be hard to **imitate**.
4) Resources must be **non-substitutable**.

To sum up the RBV of a firm, a company needs to hold tangible and intangible resources which are heterogeneous and have VRIN character to achieve a sustained competitive advantage. Competitive advantages are mandatory to remain successful in an everyday changing business environment. By strengthening relationships and utilizing new technologies as 3DP in new and efficient ways, companies can have a lead over their competitors.

Before getting into detail regarding the several relationship types, the actors in a simplified supply chain are introduced.

The production process starts with raw materials and ends with the end consumer who is using the finished product (The Logistics & Supply Chain Management Society, 2016). Recently, the reverse flow of goods gained more importance and therefore an entire supply chain consists not only of the forward flows (product/services, information, and finances) (Coyle, Langley Jr., Novack & Gibson, 2013) but also of the backward flows (e.g. recycling, re-use).

Figure 3 shows a very simplified model of a supply chain where the backward flow is completely excluded because it is irrelevant for the purpose of this study. The supply chain shown consists of four actors: supplier, manufacturer, TPL, and customer.

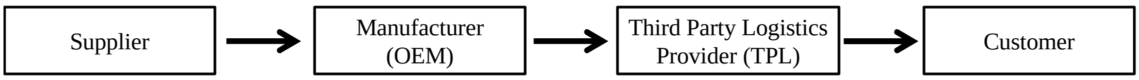

Figure 3: Simplified Supply Chain (Own Illustration)

The first actors within a production process are the suppliers. They provide the resources and raw materials a firm needs to build the offered products and services (Law, 2009). Depending on the position in the supply chain some suppliers deliver not only materials but entire components for the finished product to the manufacturer. For this study only the actual raw material providers are classified as suppliers whereas producers of sub-components are manufacturers.

Manufacturers are those companies which actually produce the goods and the sub-components of an automobile. In the automotive industry they are called OEMs and well-known companies are BMW, Daimler, and Volkswagen (Hundertmark, 2013). Besides those car manufacturer brands, the big sub-component makers such as Bosch, Johnson Controls and Continental (Automobil Industrie, 2015) are seen in this study as OEMs even if they could also be seen as suppliers.

A TPL is '*an external provider who manages, controls, and delivers logistics activities on behalf of a shipper*' (Hertz & Alfredsson, 2003, p. 140). Those activities are not only the pure transportation of goods but can include a variety of VASs like warehousing, assembly or customs clearance. To gain competitive advantages a supply chain has to be fully integrated. Hence, TPLs are getting more and more important due to the trends of '*globalization, lead time reductions, customer orientation, and outsourcing*' (Hertz & Alfredsson, 2003, p. 139). As the prior introduced outsourcing is often performed by TPLs, these firms should be classified in detail. Two characteristics of such firms are their problem solving ability and their ability of adapting to customer needs. Hertz and Alfredsson (2003) developed a framework in which every logistics service provider can be classified (figure 4).

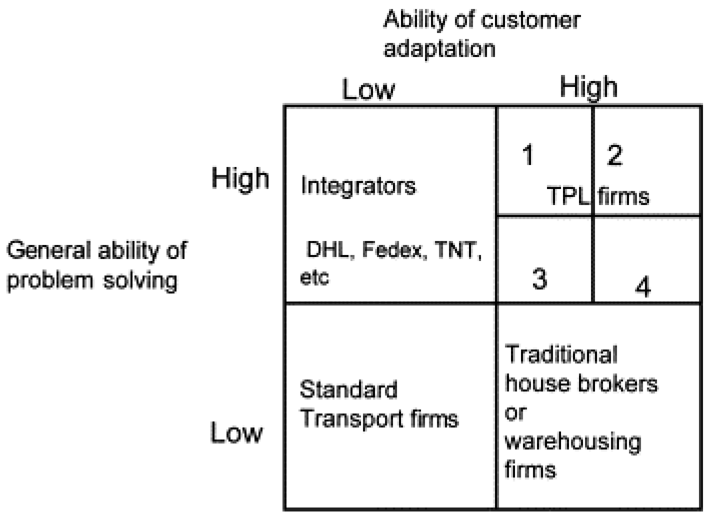

Figure 4: Logistics companies framework (Source: Hertz & Alfredsson, 2003)

For this research study the TPLs are of interest which are subdivided into four categories (figure 5). The needed level of trust, integration into the other firm, investments, and several more factors raise when a logistics company will reach the ‘customer developer’ stage. Performing the production via 3DP for a client needs high customer adaptation and the companies need to be able to solve all the new arising problems regarding the new technology. Therefore, TPLs may switch positions within the four categories. The investigated logistics companies are located in the ‘standard TPL provider’ field as they are offering their set of standardized services to their customers.

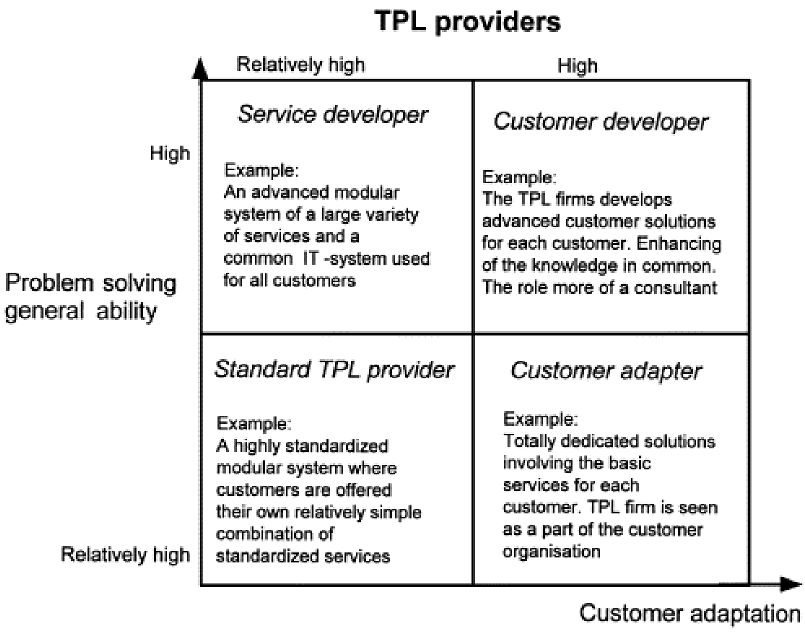

Figure 5: TPLs framework (Source: Hertz & Alfredsson, 2003)

When excluding the reverse logistics flow, which is done in this study, and the maintenance and repair business the supply chain ends with customers that purchase the product or service.

Between all actors relationships exist which for example are affected by changes in the manufacturing technology (Song, Dai & Song, 2006). Suppliers may have to be changed, TPLs have to perform other tasks or have to stop tasks they already perform, and customers will receive products which should be of the same or even better quality than before. A good relationship management is needed to be able to respond to the ever and fast changing business environment (Hoyt & Huq, 2000).

Several perspectives of relationships exist which range from transactional relationship to relational ones (figure 6). In transactional relationships companies are at 'arm's length' which means that there exists '*a relatively low or nonexistent level of involvement between the parties*' (Coyle et al., 2013, p. 110). One-time purchases and multiple purchases of standard products are typically for transactional relationships.

The other extreme are relational relationships which are embodied in strategic alliances. Hereby, the involved actors cooperate over a long time and modify their businesses voluntarily to achieve a mutual goal (Tjemkes, Vos & Burgers, 2012). Regarding the growth of firms, knowledge acquisition, cost reduction, and innovativeness, strategic alliances become more and more important (Zoogah, Vora, Richard, & Peng, 2011).

In-between collaborative relationships exist where the companies also work together but the duration of the collaboration is not as long and the involvement not as intense as in strategic alliances (Coyle et al., 2013). Deep strategic alliances are harder to switch than transactional, arm's length relationships as companies are in alliances more intertwined and the switching costs very high (Hertz, 1996; Weiss & Anderson, 1991).

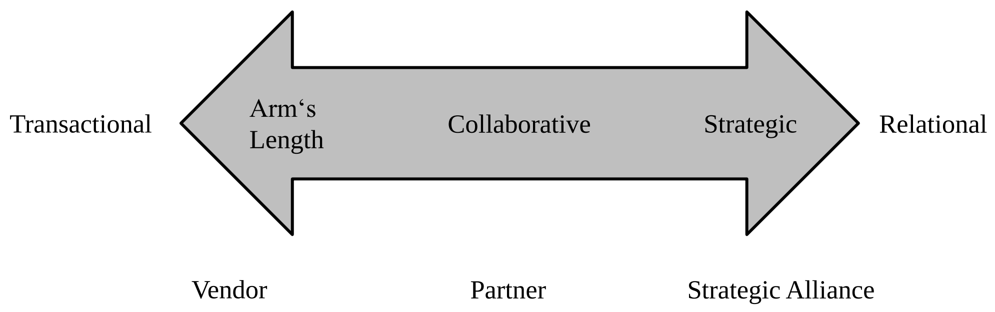

Figure 6: Perspectives of Relationships (own illustration, Source: Coyle et al., 2013, p. 110)

Collaboration between companies is very important in today's competitive markets. Collaboration means '*two or more independent companies work jointly to plan and execute supply chain operations with greater success than when acting in isolation*' (Simatupang & Sridharan, 2002, p. 19). As shown in figure 7, one can distinguish between three different types: 1) vertical collaboration, 2) horizontal collaboration, and 3) full collaboration (Mason, Lalwani & Boughton, 2007; Saenz, Ubaghs & Cuevas, 2015; Coyle et al., 2013).

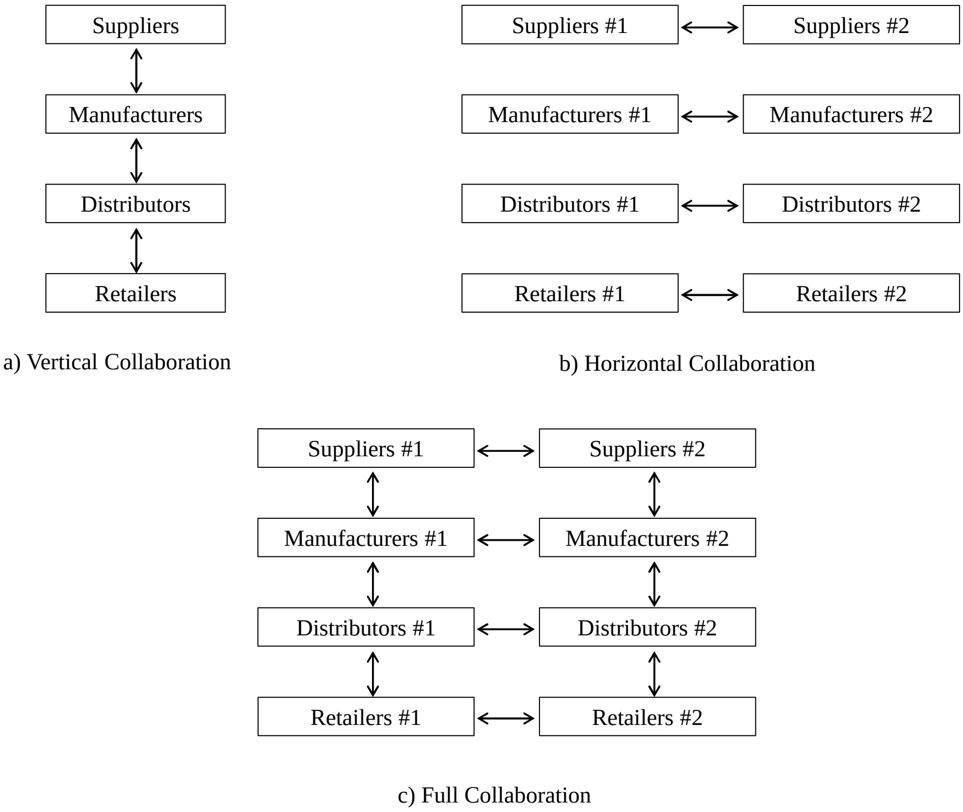

Figure 7: Types of Collaboration (own illustration, Source: Coyle et al., 2013)

Vertical collaboration takes place between buyers and suppliers within one supply chain (Barratt, 2004). This means the collaboration goes upward or downward in the flow of a product and is therefore the traditional form of supply chain collaboration. Customer relationship management or collaborative demand planning including also forecast are only two typical initiatives within vertical collaboration.

Horizontal collaboration takes place between companies which are in the same position in different supply chains, sometimes even between competing firms (Coyle et al., 2013). The aim of horizontal collaborations is to '*identify and achieve win–win situations among two or more firms operating at the same level of the supply chain*' (Pomponi, Fratocchi & Rossi Tafuri, 2015). Those situations could be joint product design or joint sourcing to achieve better prices.

Full collaboration is the combination of both before mentioned types. When introducing full collaboration, the efficiency of all members can be increased dramatically as the benefits of vertical and horizontal collaboration can be used (Coyle et al., 2013).

Therefore, collaboration is directly connected with relationships. When the relationships between companies are strong the level of collaboration between the actors is also high.

Good relationships to other supply chain actors are inevitable in today's globalized world. Without the support and the cooperation along the value chain no single company is able to become and stay successful as no competitive advantages and the needed VRIN attributes can be developed.

2.4 The Future of 3D Printing

Experts and several companies see a bright future for 3DP (Lipson & Kurman, 2013; DPDHL, 2012; Niemeyer, 2014). Industry analysts even say that '*the sky is the limit*' (Ludwig & Harvey, 2013) for this manufacturing technology. Even President Obama in 2014 launched three big projects that investigate the use of 3DP in several departments, e.g. Department of Defense and Energy (White House, 2013). But there are also some misconceptions about the technology and its use. 3DP will impact every industry sector in a certain way. Therefore, an outlook about potential opportunities in several business sectors will be given.

In their yearly report about 3DP, Wohlers Associates increased their expectations of the revenue of the worldwide 3DP industry. In the Wohlers Report 2013 they stated that the industry will have revenue of 10.8 billion USD by 2021 (Wohlers Associates, 2013). Only one year later, in the Wohlers Report 2014, the consultants expect that the additive manufacturing industry will grow dramatically and achieve more than 20 billion USD revenue by 2020 (Wohlers Associates, 2014). Figure 8 shows the estimated revenues out of both mentioned reports; yellow bars represent the Wohlers Report 2013 and blue bars represent the Wohlers Report 2014.

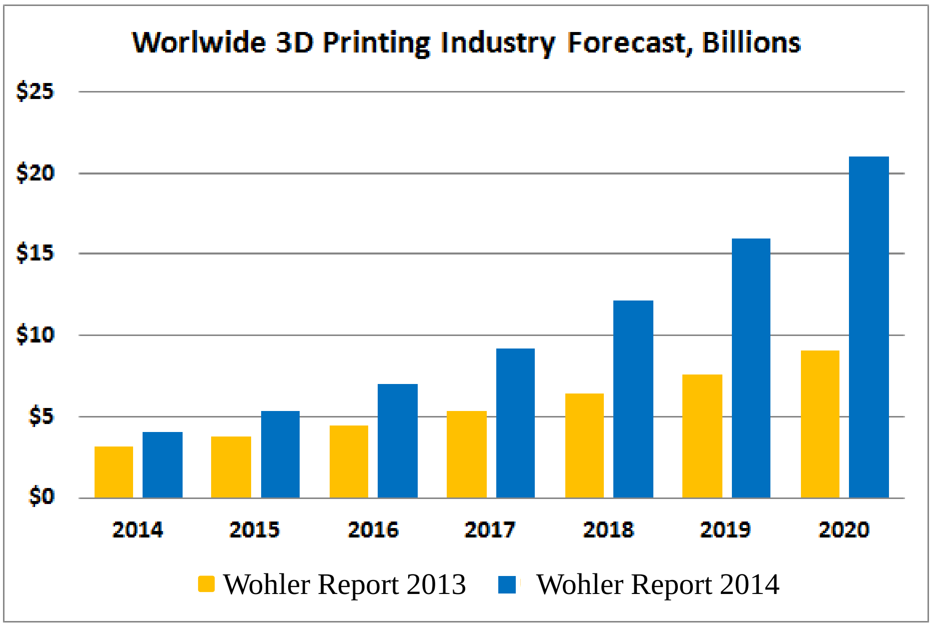

Figure 8: Estimated Revenue of the Worldwide 3D Printing Industry (Source: Columbus, 2015)

The University of Southern California has developed a new procedure within the additive manufacturing which is called 'contour crafting' (Fastermann & Ciric, 2014). This technique can revolutionize the construction sector by constructing buildings or sub-components of houses with huge 3D printers layer-by-layer (Mudholkar, 2006; Sculpteo, 2011). The first 3D printed building area was created in Suzhou, China, within only two days. The entire surface is 1100 square meters big and the buildings have up to five stories (Sculpteo, 2015b; 3ders.org, 2014). As 3DP needs no additional material or expensive construction equipment like cranes, the actual building costs are significantly lower than building houses with conventional techniques (Ankenbrand, 2015; Dambeck, 2014).

As shown earlier, the medicine sector is highly benefiting from 3DP. Researchers were able to print tissues with a quality level that allowed those organs to be transplanted into humans (Murphy & Atala, 2014; Melchels, Domingos, Klein, Malda, Bartolo & Hutmacher, 2012). A long-term project, which is conducted in the United States, aims at printing fully functioning hearts to engraft them into human beings (Fastermann & Ciric, 2014). This technique is called ‘tissue engineering’ and has the potential to revolutionize the entire organ donation process (Marga, Jakab, Khatiwala, Shepherd, Dorfman, Hubbard, Colbert & Forgacs, 2012). No patient has to wait for a suitable organ but doctors can 3D print it out of own or stem cells. 3DP makes it is also possible to be more exact with the dosage of drugs resulting in more personalized medicine and better recovery of patients (Rybicki, 2015). To reach those ambitious goals it is still a long way to go. Especially regarding applicable materials which can be implanted into a body and the needed vascularization to survive are still challenges that have to be solved before 3DP can achieve its highest capability (Murphy & Atala, 2014).

Within the food sector substantial progress is going on. At the Universal Exposition 2015 in Milano the Italian food company Barilla in collaboration with the Netherlands Organization for Applied Scientific Research TNO 3D printed pasta (TNO, 2015a). Besides research institutions as the Massachusetts Institute of Technology a lot of other industrial companies (e.g. National Aeronautics and Space Administration, Hershey’s, Mondeléz, Philips, and Nestle) are active in 3D food printing (TNO, 2015b). This is an indicator that researchers as well as the industry see a high potential with regards to producing food via 3DP. This has two enormous advantages: first, only the needed amount would be printed which will reduce wasted food and second, individual meals for persons with intolerances could be produced in an easy way (Fastermann & Ciric, 2014).

All three mentioned areas in combination with 3DP can contribute to improvements in catastrophe areas (BSR, 2015; Fastermann, 2014; Fastermann & Ciric, 2014). Instead of using tents, real buildings could be created within a relatively short time frame, medicine could be produced at the place where it is needed and does not have to be shipped under temperature control to the disaster region, and nutrition shortages could be solved by 3DP food.

In 2013 Foster+Partners, an international architecture and design studio, has established a consortium with the European Space Agency (Foster+Partners, 2013; ESA, 2013). The two companies want to build a lunar base via 3DP. Carry 3DP material to the moon would be very expensive and no one can estimate if these materials will be usable on the moon. Therefore, the already available lunar soil and rocks will be used as printing materials (Ceccanti, Dini, De Kestelier, Colla & Pambaguian, 2010; Fastermann, 2014). 3DP on the moon will change the aerospace business significantly and brings the space agencies a step further to a moon base. As space mission durations are getting longer and longer, astronauts will be able to 3D print food or medical instruments on demand. First tests show that there is no significant quality decrease when printing under pressure (Wong & Pfahnl, 2014). The lunar base will not be built before the 2030s but 3DP in remote areas like the moon is feasible. However, a lot research and development in this field has to be undertaken to reach this goal.

All those examples draw a shining picture of the new technology 3DP but there are also some misconceptions which can be found in the media, the general public but also among people who are familiar with the technology. The most common misbelief is concerned with the ownership of 3D printers. It will not be possible that everyone owns his or her 3D printer at home to print spare parts whenever something is broken (Forbes/Wolfe Emerging Tech, 2011). Reasons for this are on the one hand the lack of material knowledge which is needed to print all kinds of parts in proper quality and on the other hand the need for more than just one printing machine to produce everything. It is not possible to produce all products with the same procedure and therefore different printers would be needed. This means as a consequence that one would need to have a huge train of machines at home (Fastermann, 2014).

Another area which needs urgent modifications is concerned with regulations and laws right now in place when it comes to the production via 3DP. Legislation has to be pro-active to utilize additive manufacturing to its best and not to harm people. Until now it was more often re-active and laws were changed after an incident. This happened for example in the United States when the company Defense Distributed released the first 3D printed fire gun (Greenberg, 2013; Lewis, 2014). Further issues of concern are related to patents, copyrights as well as intellectual property rights. 3DP is expected to have the potential to impact several business sectors. Therefore, '*legislators and advocates in the realms of patent, copyright, and firearm law will need to keep pace to ensure that 3D printing brings more good than harm*' (Lewis, 2014, p. 318).

The demand for 3D printers and associated materials and software will continue to rise. The world demand will reach over 5 billion USD by 2017 (The Freedonia Group, 2013). The main focus will shift from prototyping to the direct production of parts or finished products. The acquisition costs of 3D printers decline dramatically and home printers are available below 1,000 USD (McKinsey Global Institute, 2013). Commercial 3D printers for enterprises are expected to cost less than 2,000 USD by 2016 (Basiliere, 2014).

Additive manufacturing can be utilized in several business areas but there exist several barriers and misconceptions regarding the technology. When these mentioned barriers and concerns can be overcome, 3DP will impact the world even more than it does today.

2.5 Summary

Based on the three aspects introduced – 3DP, outsourcing, and supply chain actors and their relationships – a conceptual model is developed in which the three research questions are also illustrated.

3DP is a concept which will have an impact on the economy and may cause changes in the manufacturing industry. Manufacturing strategies can be more diverse when additive manufacturing technologies are introduced in a proper way. This will, as stated earlier, alter the relationship between supply chain actors.

This study deals with the German automotive industry. Within this business sector, the OEMs are the owners of the three-dimensional CAD files and therefore in the position to undertake a make-or-buy decision regarding the production of parts via 3DP. It could be outsourced to all three other actors within the simplified supply chain introduced. But it is most likely that – if outsourced – TPLs will be in charge of this production step. These companies already perform VASs on behalf of the manufacturers (e.g. assembly) and 3DP could be a new service.

In figure 9 the conceptual model is presented. OEMs possibly use 3DP directly to produce parts or even final products (Audi, 2014). TPLs could offer additive manufacturing as VAS and hereby extend their portfolio (DHL, 2014). Suppliers may become unneeded as OEMs could produce the delivered components themselves or use different raw materials than today (Handelsblatt, 2016). And finally, customers could have their own 3D printers for certain products and they will have higher expectations with regard to individualization (Fastermann, 2014). It can be seen that 3DP will impact all supply chain actors but to focus this study only the relationship between manufacturers and TPLs is investigated.

The first research question deals with potential relational changes when additive manufacturing is implemented, whereas the second and third question investigate whether the new technology has the potential to be outsourced by manufacturers and why TPLs should add additive manufacturing to their portfolio.

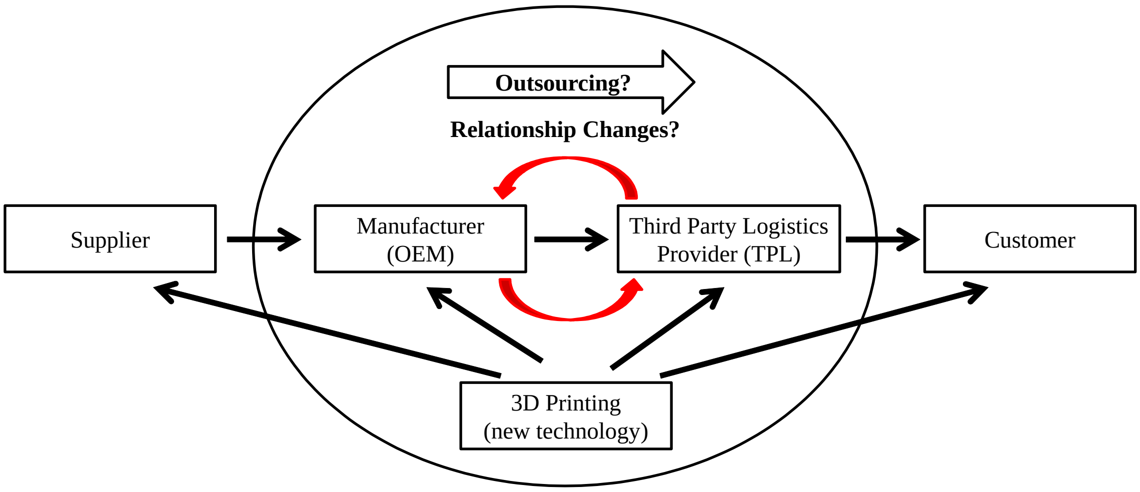

Figure 9: Conceptual Model (Own Illustration)

3 Methodology

In this section the used research methodology will be presented which is according to Saunders, Lewis and Thornhill (2012, p. 674) '*the theory of how research should be undertaken, including the theoretical and philosophical assumptions upon which research is based and the implications of these for the method or methods adopted*'. Besides this, the quality of the conducted research will be evaluated.

3.1 Research Philosophy

The process of generating new knowledge by gathering data through different methods to answer certain questions is called 'research' (O'Leary, 2010). But every research study is different and diverse research philosophies can be applied. By choosing a specific research philosophy, I set certain assumptions regarding my view of the world. The term 'research philosophy' is an overarching term which relates to the development of knowledge and its nature (Saunders et al., 2012). Four different research philosophies are well known in business research: positivism, realism, interpretivism, and pragmatism.

For this research study the best suitable approach is interpretivism as specific details of a business situation are the focus and the researcher wants to look behind these details (Saunders et al., 2012). Interpretivism is '*a research philosophy which advocates the necessity to understand differences between humans in their role as social actors*' (Saunders & Lewis, 2012, p. 106).

An interpretivistic research philosophy argues that the business world is too complex to explain everything by law-like generalizations like it is done in the positivistic philosophy (Saunders et al., 2012). As this study deals, amongst other things, with relationships between companies, generalization of results is only in certain ways possible. This is also mentioned as one downside of the research philosophy with regards to the research quality.

Another reason for choosing interpretivism as research philosophy lies in the contextual depth which will be gained by using this approach (Saunders, Lewis & Thornhill, 2009). To answer the constructed research questions, deep knowledge of the process of 3DP and its implications on the relationship between car makers and logistics companies is needed.

Saunders et al. (2012) recommend to use small samples and qualitative research when adopting an interpretivistic research philosophy. As this study focuses on six companies and data will be gathered by semi-structured interviews the research strategy is in line with the research philosophy.

To outline the entire research design, I use the 'research onion' by Saunders et al. (2012). The next chapters are structured according to the different layers of the onion (figure 10).

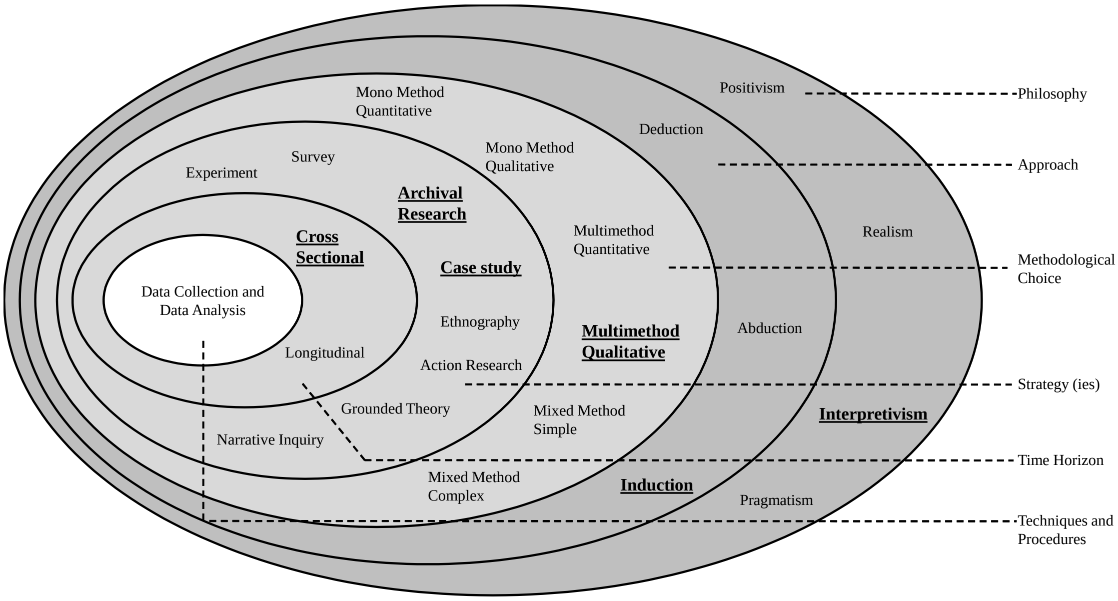

Figure 10: Research Onion (own illustration; Source: Saunders et al., 2012)

3.2 The Nature of the Research

According to Kumar (2011) three different perspectives exist from which you can look at research: 1) application perspective, 2) objectives perspective, and 3) mode of enquiry perspective. For this study, I use the objectives perspective because the aims of this study are clearly stated in the introduction section. The purpose of a research study can either be exploratory, descriptive, explanatory or a combination of the aforementioned (Saunders et al., 2012).

When conducting a descriptive research study, the researchers attempt to describe a specific behavior or a certain situation in a systematic way (Kumar, 2011). As this study copes with potential changes in the business environment and a new technology, it is not possible to have '*a clear picture of the phenomenon on which you wish to collect data prior to the collection of the data*' (Saunders et al., 2012, p. 171).

In explanatory studies the researchers focus '*on studying a situation or a problem in order to explain the relationship between variables*' (Saunders & Lewis, 2012, p. 113). As I want to investigate how the relationship between several supply chain actors will change when additive manufacturing technologies are introduced, it is possible to identify cause-and-effect relationships. This is one aim of exploratory research purposes (Zikmund, Babin, Carr & Griffin, 2010).

An exploratory research purpose '*aims to seek new insights, ask new questions and to assess topics in a new light*' (Saunders & Lewis, 2012, p. 110). An exploratory study should be undertaken when only a bit is known in the specific area (Kumar, 2011). 3DP is a fairly new concept and especially with regards to its impact on the relationship between OEMs in the automotive sector and logistics companies in Germany, nothing is written in the academic literature. Also about the potential to outsource some part of the core-business of a company (in this study producing parts) not much is done in academia.

A combination of explanatory and exploratory research is the best suitable approach for this research study.

3.3 Research Approach

The second layer of the research onion contains the different research approaches researchers can use for their studies. Saunders et al. (2012) identified three different approaches: deduction, induction, and abduction. Those approaches deal with the availability of theory at the beginning of the research project.

When using a deductive approach the researchers clarify their theory at the beginning of the study, set hypotheses and test them to examine whether the theory is true or false (Saunders & Lewis, 2012). The opposite approach is induction. Hereby theory is developed '*as a result of analyzing data already collected*' (Saunders & Lewis, 2012, p. 109). As there is nothing written about additive manufacturing in combination with changes of the relationship of supply chain actors, this approach is applicable to my master thesis. I will use the gathered data to develop a theory in the specific field. The third approach, abduction, is a combination of the other two approaches. The researcher is going forth and back between data and theory (Saunders et al., 2012). One could now argue that this approach is better fitting to this study. But within abduction the researcher has to analyze the gathered data and make sense of it before going back to the field and gather new data based on the new findings. Data has to be revised and integrated in theory again and again (Saunders et al., 2012). This is an iterative process which has to be conducted several times which is nearly impossible within the given time frame.

As noted earlier, 3DP is fairly new and not highly present in the academic business literature, therefore the best suitable approach is induction.

3.4 Research Design

By research design the '*general plan of how you will go about answering your research question(s)*' (Saunders et al., 2012, p. 159) is meant. This includes the choice for appropriate methods, the strategies undertaken within the study, and the time horizon within which the research study takes place. The research design has two main goals. First, it should help the author to identify and develop the procedures she or he will undertake during the research and second, the quality of those procedures regarding credibility, dependability, confirmability, and transferability should be ensured (Kumar, 2011).

3.4.1 Methodological Choice

The gathered data within a research study can be either numeric or non-numeric, meaning words and images or a mixture of both. Therefore, you have to distinguish quantitative research from qualitative research. To collect quantitative data researchers have to use standardized procedures (e.g. questionnaires) whereas for qualitative data non-standardized ways are appropriate (e.g. interviews) (Saunders & Lewis, 2012).

As stated earlier an interpretivistic philosophy is applied. This suits to a qualitative research design because the researcher has to '*make sense of the subjective and socially constructed meanings expressed about the phenomenon being studied*' (Saunders et al., 2012, p. 163). The data gathered in this research study are expressed by words to gain in-depth knowledge about the studied phenomenon. This excludes all quantitative research strategies and therefore I chose a multi method qualitative approach which is explained further in the next section.

3.4.2 Research Strategies

Choosing an appropriate research strategy is the fourth layer of the research onion. Researchers have to take several aspects of their research project into consideration when selecting the research strategy. Amongst others, the most important aspects are the specific research questions, the research purpose, the amount of existing knowledge and time available to conduct the study as well as the access to potential participants (Saunders et al., 2012).

3.4.2.1 Case Study

By using the exclusion principle an appropriate research strategy is selected. An experiment strategy should be used when causal links between variables are studied (Saunders & Lewis, 2012). As my study does not have dependent and independent variables, this strategy is not suitable. Another strategy is ethnography. Hereby, the researcher has to take active part in the studied population (Zikmund et al., 2010). Due to time constraints as well as access issues it is not possible to become a part of the studied companies. Therefore, ethnography will be neglected. The same reasons apply to the exclusion from action research as used strategy. For conducting action research there has to be a close collaboration between the researchers and the practitioners as well as the acting of the researchers as insiders within the change process (Saunders & Lewis, 2012). This research study will be conducted by questioning several companies and therefore it is not possible to be part of every organization. The survey strategy is neglected because the data collection techniques connected to this are highly structured (Saunders & Lewis, 2012). In this study, respondents should answer freely and without any given borders to present their actual thoughts about the topic. Taking all this into consideration the best suitable research strategy is the case study.

Case studies are '*the preferred strategy when 'how' and 'why' questions are being posed, the investigator has little control over events, and the focus is on a contemporary phenomenon within a real-life context*' (Yin, 2009, p. 2). Case studies also are very useful '*when exploring an area where little is known or where you want to have a holistic understanding of the situation, phenomenon, episode, site, group or community*' (Kumar, 2011, p. 127). In explanatory and exploratory research case studies are most often used to gather data (Saunders & Lewis, 2012). By looking for changes in the relationship between supply chain actors as well as the potential of outsourcing the production via 3DP I need an understanding of the entire context of the phenomenon. This is supported by case studies (Saunders et al., 2012). A case study is an '*empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*' (Yin, 2009, p. 18). This overall understanding of the situation is needed to further develop old and establish new theories by gaining new insights about the topic. This suits to an inductive or an abductive research approach.

As one can see in figure 11, according to Yin (2014) investigators have to make decisions regarding two dimensions when choosing case study as research strategy:

1) single case vs. multiple case,
2) holistic case vs. embedded case.

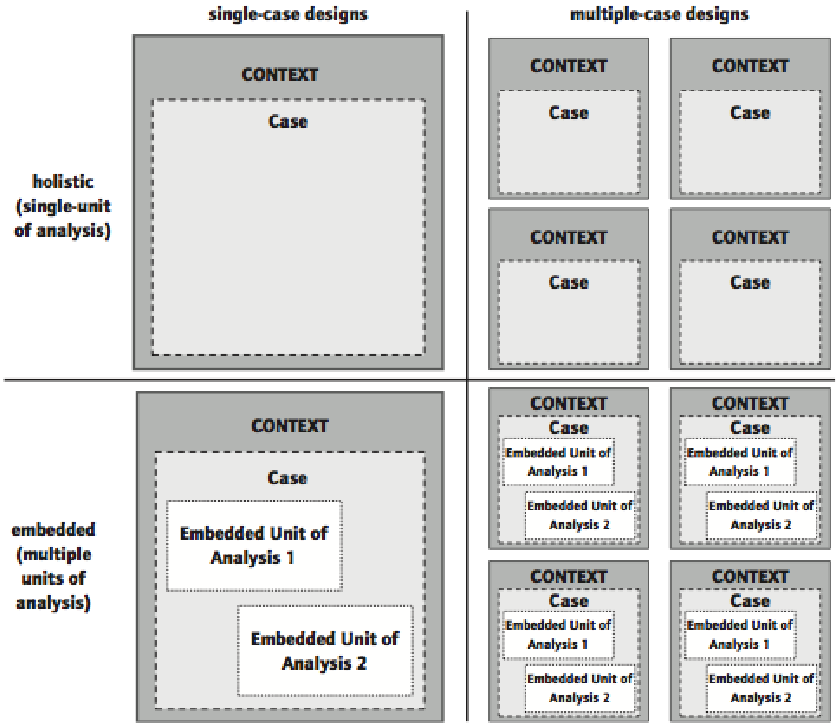

Figure 11: Basic Types of Designs for Case Study (Source: Yin, 2014, p. 50)

When researchers investigate critical or unique cases, the single case approach is applicable. This provides the opportunity to analyze a situation in-depth and drawing conclusions out of this rich understanding of the situation (Zikmund et al., 2010; Saunders et al., 2012). The biggest disadvantage is that it is not possible to generalize the findings as they only arise out of one single case. In single case studies, it can happen that the chosen case is not as critical or unique as the researcher thought before and hence the rational for choosing this approach is not given anymore (Yin, 2014). To avoid this, a multiple case study design can be conducted. Multiple cases can help to generalize findings out of different case studies and theory building can be performed. The findings out of a multiple case study design are more robust than when undertaking a single case study design (Yin, 2009). To illustrate a general understanding of the concept 3DP and the related research questions, a multiple case study will be conducted. The two cases used in this thesis are on the one hand the manufacturing companies and on the other hand logistics service providers. Each case will then be divided into different subunits – meaning more than one company in the specific sector is investigated and analyzed. Therefore, the study follows an embedded approach (Yin, 2009).

3.4.2.2 Archival Research

In archival research investigators use administrative documents and reports as a source of data and analyze those (Saunders et al., 2012). The expression 'archival' can be a bit misleading as one might think that only historical phenomena can be studied. But according to Bryman (1989) also recent administrative documents are suitable within this approach. As stated earlier, a lot of research within the field of 3DP is done by companies. Therefore, this strategy suits to the research study. Advantages of using such documents are that they are stable which means they can be reviewed by others and they fit to the specific topic chosen with a rich amount of details (Yin, 2014). Besides this, Yin (2011) states that document studies are suitable as a complement to interviews as they connect theory and real life cases. A negative aspect by undertaking this research strategy is that many reports and documents are confidential and therefore not accessible by researchers (Yin, 2014). Saunders and Lewis (2012) suggest using this strategy as a support approach to other strategies because they reflect a certain business' opinion. Archival research will be used to get a deeper understanding of the topic from a company's standpoint to answer the research question in a proper way.

3.4.2.3 Observations

To support the findings out of the cases, observations can be a good source of evidence. As this study does not only investigate a new technology but the context in which this manufacturing procedure will be implemented, direct observations will bring a better understanding of the phenomenon and its frame (Yin, 2014). A downside of observations is that they are time-consuming and the possibility that things are done in another way because an observer is present (Yin, 2009). '*[...] observations of the technology [...] are invaluable aids for understanding the actual use of the technology [...]*' (Yin, 2014, p. 114) when case studies are about the use or implementation of new technology. Especially the last point argues for using observations to strengthen the findings out of the case studies.

To sum it up, in this master thesis case study is the preferred research strategy. According to Yin (2009), I will use multiple cases with an embedded view. As one needs to use multiple sources of evidence in case studies, the results out of the semi-structured interviews will be backed up by archival research meaning document studies as well as direct observations. This use of multi methods will strengthen the findings as the concept of triangulation is applied. Triangulation is the use of '*more than one method or source of data in the study of social phenomena*' (Bryman & Bell, 2011, p. 397). This is especially needed when the gathered data are concerned with relationships between entities in the social world. By investigating the relationship between two supply chain actors this is the case. Therefore, combining different methods as it is done within this study is '*the most valid and reliable way to develop understanding of such a complex reality*' (Kanter, 1993, p. 337).

3.4.3 Time Horizon

In most books about research methods the authors differentiate between two kinds of study with regards to time (Saunders et al., 2012; Zikmund et al., 2010; Saunders &

Lewis, 2012). The first one is the cross-sectional study and the second one is called longitudinal study. Kumar (2011) points out that there exists also a third form of study which is between the two aforementioned, the before-and-after study design. Next, the characteristics of each of the three designs will be presented and the choice for the cross-sectional study design is justified.

Within a cross-sectional study, data are collected only once and by that the researchers obtain an overall picture of a certain situation or phenomenon (Saunders & Lewis, 2012). Undertaking such a study is relatively cheap and not difficult to analyze but the biggest disadvantage is that it is not possible to measure any change of a situation or phenomenon – only an estimation of the change is possible (Kumar, 2011). To study change or development over time, one has to conduct a longitudinal study. Hereby, the researchers contact the same respondents several times within a given time horizon (Saunders et al., 2012). The downside of this approach is that most research conducted by students is very time constrained and therefore it is not possible to investigate the same phenomenon over a certain period of time (Saunders & Lewis, 2012). Another disadvantage of a longitudinal study is that the respondents must be willed to answer your questions several times. Between those approaches is the before-and-after study design. Hereby, the researchers conduct two cross-sectional studies and compare their outcomes (Kumar, 2011). Thus displaying the change of a situation is possible and you have to contact your respondents only twice. But to undertake this study design researchers need enough time.

For my study I choose the cross-sectional study design. The main reason for this choice is the time constraints to conduct my research. Qualitative research is seen as appropriate for cross-sectional studies (Saunders et al., 2012).

3.5 Data Collection

Data can be collected by using either primary or secondary sources. Secondary data are data which are already collected and presented either as a summary in another paper or as a raw data set (Saunders et al., 2012). Hereby, the researcher is using the same set of data but she or he is interpreting them in a different way or even has an entirely different focus in the study. By investigating a new topic, which is not highly investigated until now, researchers have to collect fresh data. Those data are called primary data and can be collected by observations and/or interviews (Kumar, 2011). Regarding relationship changes due to the implementation of a new technology as well as the potential to outsource a part of the core-business (production) of a company no secondary data are available. Primary data need to be gathered. This is done by the introduced research strategies – archival research, observations and case studies. Within the latter one I will conduct semi-structured interviews to collect data.

Semi-structured interviews are '*a method of data collection in which the interviewer asks about a set of themes using predetermined questions […] The interviewer may choose to omit some topics and questions and ask additional questions as appropriate*' (Saunders & Lewis, 2012, p. 151). Such interviews are suitable for qualitative research as the answers have to be interpreted by the researcher and she or he can gain new insights through the answers of the respondents. Semi-structured interviews are very applicable in situations where complex phenomena are studied and in-depth information is needed to understand the entire situation (Kumar, 2011). The interviewer can explain everything when the respondent is not sure about the meaning of a certain question and interaction between both is possible which will lead to more and deeper insights. By utilizing observations as a second source of primary data the statements out of the interviews will be better understood because observations are '*a purposeful, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place*' (Kumar, 2011, p. 140). Observations of the process of additive manufacturing lead to a clearer view of the possibilities this technology will bring with regards to give it out of the firm or not. In my study, I set a clear focus on the relationship between supply chain actors with regards to the implementation of a new technology. When this is the case compared to a more general view, semi-structured interviews are suitable (Bryman & Bell, 2011). The interview guide which will be used for this master thesis can be found in the appendix A2.

3.5.1 Sampling Method

Within a research study it is not possible to ask the entire population what thoughts each and every one has on the research questions. Therefore, sampling, which is '*the process of selecting a few (a sample) from a bigger group (the sampling population)*' (Kumar, 2011, p. 193), is very important. Two groups of sampling methods exist: probability sampling and non-probability sampling (Saunders et al., 2012). As the entire population for this research study is not known, only non-probability sampling is appropriate. Within this category I will choose purposive sampling. This is a method '*in which the researcher's judgement is used to select the sample members based on a range of possible reasons and premises*' (Saunders & Lewis, 2012, p. 138). The premises are:

1) The type of company – only logistics companies and automotive producers are applicable for the study.
2) The companies have to operate in Germany.
3) The companies need to have a department in which 3DP is researched and/or considered to have an impact on the tasks performed.
4) The respondent has a connection to the development of 3DP in the company.
5) The respondent's position is on a strategic level within the company.

Kumar (2011) argues that researchers do not have a specific sample size in mind when undertaking qualitative research. The needed size is determined by the data saturation point. You collect data until the point is reached '*where you are not getting new information*' (Kumar, 2011, p. 213). Within the given time restrictions it is not possible to reach the saturation point and therefore as much interviews as possible are conducted.

Information regarding the interviews is provided in table 2.

Table 2: Interview Details

Company	Industry Sector	Position of interviewee	Date and Length of interview	Type of interview
Autobau	Automotive Sector	Vice President - Corporate Logistics	14.03.2016 50 minutes	Skype video-call
ProduCAR	Automotive Sector	Project Manager - Business Innovations	04.04.2016 45 minutes	Skype video-call
CarDrive	Automotive Sector	Project Manager Production Innovation and Business Solutions	05.04.2016 40 minutes	Skype video-call
ConsultLog	Logistics Sector	Consultant for Strategic Innovations	15.03.2016 45 minutes	Face-to-Face
Logistics ONE	Logistics Sector	Project Manager - Research & Innovation Management	23.03.2016 45 minutes	Face-to-Face
Forward Logistics	Logistics Sector	Vice President Research and Innovation	21.03.2016 60 minutes	Face-to-Face
		Key Account Automotive & Solutions	08.04.2016 50 minutes	Skype video call

3.6 Data Analysis

In qualitative research data are expressed through words. Therefore, the answers are not standardized (Saunders et al., 2012). After an interview had been conducted the recording was transcribed in order to eliminate the possibility to forget any important aspect. To ensure the research quality, those transcripts were sent back to the respondents and they could change or exclude parts which they do not want to have in the study. This procedure increases the research quality.

According to Saunders et al. (2009) three main processes are available to analyze qualitative data:

1) Summarizing (condensation) of meanings,
2) Categorization (grouping) of meanings,
3) Structuring (ordering) of meanings using narrative.

In this study the first two processes are applied after the interviews are conducted and transcribed. By summarizing the words spoken by the respondents, long statements are shortened down into fewer words and compressed to easy understandable information. The summarized information make further reference to the interview easier (Robson, 2002). This procedure helps me to understand the given information with regards to the research purpose. Grouping the data gathered out of the different sources makes it easier to compare the results. The categories arise automatically out of the research questions. Each category has to be connected to the purpose as well as having a relationship to the other categories (Saunders et al., 2012). By categorizing data out of different interviews, the realization of relationships between the gathered data will take place. The gathered data are compared to each other. Therefore, a comparative analysis is carried out in which divergent and common patterns can be identified (Castree, Kitchin & Rogers, 2013). Afterwards, the framework as well as theory can be developed to answer the research study's purpose.

3.7 Research Quality

In order to reach a research quality level which is accepted by others every study has to be assessed according to several criteria. For quantitative research, Yin (2009) suggests four tests which are commonly used in business research:

1) Construct validity,
2) Internal validity,
3) External validity, and
4) Reliability.

As these aspects cannot be used for qualitative research, Lincoln and Guba (1985) came up with new terms to test qualitative research quality. Such research is tested for trustworthiness which is divided in:

1) Credibility,
2) Dependability,
3) Confirmability, and
4) Transferability.

Those four aspects which are in line with the chosen interpretivistic research philosophy (Patton, 2002) as well as the ethics which are connected to this study are presented in the following subchapters.

3.7.1 Credibility

Credibility is associated with the researcher's acceptability of others and the truth of the gathered data and perspectives (Cope, 2014). To achieve credibility, researchers have to demonstrate which methods they used and how these where carried out (Bryman & Bell, 2011). Within the methodology section of this study, I presented my methods as well as how respondents were selected which enhances the thesis' credibility. Another way to raise the credibility level is called 'respondent validation' which is '*a process whereby a researcher provides the people on whom he or she has conducted research with an account of his or her findings*' (Bryman & Bell, 2011, p. 396). As all transcripts of the interviews are sent to and reviewed by the respondents this criteria also is fulfilled.

3.7.2 Dependability

Dependability in qualitative research is the parallel to reliability in quantitative research. Reliability is '*the extent to which data collection methods and analysis procedures will produce consistent findings*' (Saunders & Lewis, 2012, p. 128) if they were repeated by other researchers. The entire process is described within the study. The problem is stated, criteria for selecting the right respondents are given, the interview guide is attached in the appendix A2, and thus other researchers are able to ask the same questions. The procedure to analyze the data is also explained. Other researchers can come to similar results when undertaking the study in accordance to the given methodology (Cope, 2014). By definition semi-structured interviews have one downside regarding dependability: follow-up questions may be different in the event of duplicating the study. Therefore, within the framework of the chosen research strategy a high degree of dependability is given.

3.7.3 Confirmability

Confirmability is concerned with the objectivity and subjectivity of the researcher. Bryman and Bell (2011) state the entire objectivity in business research is not possible but researchers should show that they have '*acted in good faith*' (p. 398). This is especially difficult by conducting an interpretivistic research philosophy as the researcher and his or her research are value bound (Saunders et al, 2012). However, confirmability can be developed by explaining why certain conclusions were drawn and how the interpretation of the gathered data took place (Cope, 2014). Cope (2014) suggests also the use of '*rich quotes from the participants*' (p. 89) to show that the data present the respondents' and not the researcher's viewpoint. By presenting all underlying assumptions of the study, the thesis' confirmability is enhanced. Also confirmability is established in the Empirical Findings, Analysis as well as Conclusion sections of the master thesis.

3.7.4 Transferability

Transferability is closely connected to generalizability in quantitative studies which means that your findings are also valid in another research setting (Saunders et al., 2009). As some qualitative studies are not designed to generalize the findings but to illuminate a certain phenomenon in-depth, transferability is not an applicable measure for the research quality (Golafshani, 2003; Polit & Beck, 2010; Cope, 2014). This study tends to get a deep understanding of the emerging technology 3DP and its impact on a certain relationship between certain actors and therefore generalization of findings is only possible within borders. Therefore, transferability cannot be used as a measure in this thesis.

3.7.5 Research Ethics

During every stage of a research study ethical concerns will arise (Saunders et al., 2012). The rights of the studied people and the people that are affected by the study must be guaranteed at every point during the study.

The first ethical issues occur when trying to gain access to the interviewed people. Hereby, existing business contacts which are established through prior work experiences were used to develop new contacts to practitioners within the observed field. According to Saunders et al. (2012) this strategy is very successful. By establishing the relationship to the needed interview partners a clear statement about my research study was given in advance and the contacts had the chance to ask everything and bring up their concerns regarding for example the confidentiality of the data. As this study deals with a fairly new technology where not all outcomes are easy to anticipate and certain knowledge can bring a competitive advantage, respondents may do not want to talk about it. Therefore, participants have the freedom to choose whether they and their company want to stay anonymous. This all ensures that participants can '*make an informed decision about whether or not they wish to participate in a study*' (Bryman & Bell, 2011, p. 133).

Collected data are only used for this study and not provided to anyone else. Transcripts of the interviews are stored for a period of five years after the end of this study only on my personal computer with no access of anyone else. Therefore, confidentiality and anonymity of the participants within this study is guaranteed (Saunders et al., 2012).

Potential participants can request all information about the study they want to have. After studying all information and asking all questions they are free to decide whether they want to participate in this study or not. Also interviewees are allowed to quit the participation at any stage during the study. Therefore, it is secured that no coercion of any kind will affect the study's results (Saunders & Lewis, 2012). The privacy of participants is also ensured during the entire study by sticking to the interview guide as well as by putting no pressure on anyone (Bryman & Bell, 2011).

As only business relationships to the participants are developed, objectivity regarding the data collection as well as data analysis is secured. This will enhance the study's quality (Saunders & Lewis, 2012).

Through using the Harvard citing system all sources of evidence are clearly stated within this report. Using such a citing system will ensure that no intellectual property rights are harmed (Saunders & Lewis, 2012). If not other stated, the remaining conclusion and perspectives originate from my previous experiences as well as the analysis of the collected empirical data.

4 Empirical Findings

This section presents the findings out of the conducted semi-structured interviews. It is divided into the two cases introduced earlier – Original Equipment Manufacturers and Logistics Service Providers. All information given in this part of the master thesis arose from the conducted interviews. The stated quotations are given by the respondents who would like to stay anonymously. Besides this, the results of the document studies as well as the observations will be presented.

4.1 Case 1 - Original Equipment Manufacturers

Within the first case which deals with the OEMs in the automotive sector three interviews were conducted. The investigated companies are global players with huge power in the industry. Therefore, their perceptions can be seen as applicable for all companies in the automotive business area. Based on the respondents' request to remain anonymous fictitious names are used for each company.

4.1.1 Autobau

Autobau was founded more than 125 years ago. It has more than 350.000 employees worldwide whereof more than 130.000 are located in Germany. The company is not a well-known car brand but it produces several components and entire subassemblies for automobiles. Due to its long tradition, wide knowledge about manufacturing technologies as well as experiences with shifting technologies are available within Autobau. The respondent is active in the 'corporate logistics' sector of the company. Tasks of this area are besides others the creation of flexible logistics processes as well as the utilization of innovative logistics practices. The interviewee was involved in several outsourcing projects and in the development of several innovative solutions for the logistics area of Autobau. This makes the respondent a suitable candidate for this research study.

Relationships within Autobau are classified according to well-known terms like transactional-based relationship and strategic alliance. Relationships to logistics companies are highly important to the company and hence Autobau tries to have between 5 and 10 different logistics companies for their business.

> …'*Transactional relationships to a logistics company are an exceptional case for Autobau since the administrative costs would be too high.*' **[AB]**

The collaborations are called 'strategic' but in the respondent's opinion there are important parts for a real strategic alliance missing. Therefore, the interviewee calls them 'long-term partnership'. The most crucial part that is missing to name the partnership strategic alliance is the mutual investment and development for shared projects. Strategic alliances can be found at the interface between Autobau and its suppliers as joint projects where risk sharing components are given. To sum it up, relationships to the logistics sector are highly important and therefore long lasting but they are only limited strategic.

The process of ‘outsourcing’ is associated with all tasks Autobau did by themselves before and are now provided by an external party. The respondent stated clearly that outsourcing is only a brief phase in which

…‘*a company converts in-house production to external procurement.*’ **[AB]**

After the full implementation of the task at the third party company, Autobau does not talk about outsourcing anymore. Most often cost savings is the number one criterion why a company should outsource an activity. For Autobau the achieved flexibility is more important as it is a big company. The respondent stated that Autobau is not able to fire people even if the business gets down. When activities are outsourced contracts can be cancelled and Autobau does not need to fire people. Outsourcing was performed in several business units of Autobau with different results. The crux in the unsuccessful cases lies in the pain sharing prerequisite Autobau wanted to achieve. The respondent stated that

…‘*logistics companies are not interested in pain sharing when they can ruin their entire result of the year by just one performance problem*’. **[AB]**

In plant logistics a performance problem means that the production stops and idle times are very expensive.

3DP efforts are made within Autobau because

…‘*an omission of using this new technology would be grossly negligent.*’ **[AB]**

The respondent and his company see a bright future for this technology in the area of spare parts and small batch series production. An utilization for large-scale production is not imaginable by Autobau as the production via conventional methods is more efficient. But

…‘*for the extreme case ‘lot size of one’ as well as for individual customization of products 3DP will lower the costs dramatically.*’ **[AB]**

Regarding the two mentioned areas where 3DP can be advantageous, Autobau has two benefits in mind. First, a cost advantage as small batch sizes cannot be produced in an efficient way by current production technologies. Concerning costs another advantage is the decrease in warehousing costs as parts have not to be stored as spare parts in warehouses. The CAD files can be stored on PCs and spare parts are printed on demand. Secondly, the availability and the speed of delivery are increased. Parts will be produced where and when needed. Right now, the 3DP suitable areas are most likely the ones which are outsourced by companies like Autobau which are specialized in large-scale production. Therefore, the respondent thinks that the implementation of 3DP will foster insourcing instead of outsourcing. Insourcing these tasks will lower the dependability on suppliers and other parties as Autobau can produce the parts in own facilities in an efficient way. But Autobau also has two concerns which could foster the outsourcing of 3DP production. First, the parameters of 3DP will get more complex (geometry of parts, number of different materials of parts) and second the registration of existing parts without engineering drawings. In the respondent’s opinion, companies that specialize in those two fields and are able to protect their procedures and techniques by patent can achieve an

…‘*extensive advantage compared to others.*’ **[AB]**

Within the automotive industry there already exist places where logistics service providers perform several tasks like pre-assembly of cars. The respondent sees a possibility to cosign also some activities regarding 3DP to the centers but in his view the type of the company then shifts from a logistics company to a production firm.

Autobau thinks that it is possible that decentralized structures regarding the spare parts production will increase if 3DP is highly used in this sector and last mile logistics will become even more important than it is today.

> …'*The supply chain will undergo changes especially for spare parts and small batch series.*' **[AB]**

These products are responsible for approximately 7% of Autobau's logistics costs. The respondent estimates that out of those 7% only half can be produced via 3DP. This means that only around 3.5% of the entire logistics volume will get lost for the logistics companies. This should not be a problem for these companies and therefore, the relationship between Autobau and the logistics companies should not decline.

4.1.2 ProduCAR

ProduCAR is a German car maker of high-class and middle-class vehicles. It has over 80.000 employees worldwide and consists out of several sub-brands. The main brand where the respondent is employed produced more than 1.8 million cars in 2015. The company claims to be a pioneer in the field of producing automotive parts via 3DP. Within the Research and Development department the respondent is responsible for business solutions with regards to new technologies like 3DP.

ProduCAR already produced a smaller version of an old-timer based entirely on 3DP techniques. This was a big step towards their aim to

> …'*3D print metal parts for our regular cars in the middle and premium-class.*' **[PC]**

But this long-term goal is according to the respondent not achievable if they are not collaborating with a lot of other firms out of e.g. the logistics sector. These relationships are of strategic nature as they are aimed at strategic long-term and core business affecting visions.

> …'*We have a lot of research partners out of different business sectors and in collaboration with them we try to push the advances of the new technology. Without our partners we would not be in our current market position.*' **[PC]**

By building a competence cluster with actors out of a lot not coercively connected business areas, ProduCAR gained a lot of different perspectives on the possibilities and risks of the new manufacturing technology. For example, 3DP specialists offered insights regarding their newest advances by using the technology and logistics companies elaborated on the potential shift in their transport actions as well as on the possibility to integrate 3DP in the already existing logistics services.

As the biggest downside of 3DP the company identified the simplicity to replicate all parts and components when there is a leak in the data transfer or even by using 3D scanners to get a printable file of the part.

…‘*3DP is predestined for copycatting our products and copyright infringements will arise easily. Therefore, for our 3DP businesses we want to establish really close relationships to a few partners we can trust.*’ **[PC]**

They try to circumvent the potential dangers by establishing even closer relationships to the chosen partners and by reducing the number of partners to keep track of the distribution of the CAD files. This shows that ProduCAR can imagine to handover the 3DP process to business partners in order to use all the advantages outsourcing can bring for the company. The respondent stated that the

…‘*potential to outsource the 3DP process is given but we are not sure if it will go to specialists or logistics companies. And it will not happen within the next 10 to 15 years. First, we have to find out what the new technology will offer to us. Specialists have all the knowledge to use 3DP efficient and in a correct way but logistics companies have already a worldwide network of warehouses where we could locate our printers.*’ **[PC]**

ProduCAR will further develop their competencies in the technology and has to weigh how to factor certain partners into the research activities and to what extent it is possible to use others’ knowledge about the manufacturing technology.

4.1.3 CarDrive

CarDrive was founded 50 years ago and is nowadays a Europe-wide known producer of sub-components for several vehicles of different big automotive companies. CarDrive’s strength is the production of high-precise parts with complex structures. Parts with these two attributes are predestinated for 3DP. By utilizing several manufacturing technologies, the company is able to produce individual parts, pilot series, and in serial production. At CarDrive, the respondent is responsible for all developments regarding the manufacturing technology 3DP and its implication on CarDrive’s business relations. Hence, the interviewee is very knowledgeable in the technology’s consequences.

Regarding the state of the technology CarDrive’s 3DP Solution Manager states that

…‘*the technology is ready to 3D print parts with required stability and functionality to use them in end consumer products. We hear that especially in the aerospace industry it is already common for specific components. But within the automotive industry, a lot of internal barriers – for example the readiness to take a risk and make the investment – have to be overcome.*’ **[CD]**

A lot of research is done to enhance the process parameters to make 3DP more interesting as an alternative manufacturing technology within the automotive sector. But other procedures are still more advantageous for the car manufacturing. CarDrive thinks that the

…‘*development has to be undertaken by all involved actors and in a mutual way. Otherwise we will not reach the best outcome.*’ **[CD]**

This statement underpins the company’s effort to work in close relationships with their customers, suppliers, and logistics service providers. Those relationships are seen as critical for CarDrive.

Nowadays CarDrive is using 3DP not for the production of final products but for prototyping and tooling. First trials were conducted for components for cars and therefore

> …'*we at CarDrive see great potential for lot size one, small batches, and spare parts. Even if 3DP gets faster it will never be a technology for mass production. Big assembly lines are unbeatable regarding the number of cycles.*' **[CD]**

CarDrive also is aware of the possibility to outsource their future 3DP practices to specialists as well as logistics service providers which are already providing several VAS for them. The respondent highlighted also that

> …'*logistics companies are quite knowledgeable in the technology due to their research centers. Therefore, I think outsourcing to them will take place to a certain extent because they have a perfect global distribution network.*' **[CD]**

Relationships with the logistics sector are seen critical for CarDrive's business as they need the right amount of material at the right time at the right place to secure the production.

> …'*3DP brings the advantage that we can calculate our demands and production times better as our current printers tell us all those parameters when we induct the CAD file.*' **[CD]**

The relationship between those two actors can be improved when the data for the raw material demand are more accurate and the needed production time can be estimated in a better way. Better data can enhance just-in-time delivery which leads to more efficient supply chains.

4.2 Case 2 - Logistics Service Provider

The second case represents the opposite side of the OEM-TPL relationship which is investigated within this study – the logistics service providers. As in case 1, the researched logistics companies are big global players with large operations in Germany. Anonymity was favored by the respondents and therefore fictitious names will be used again.

4.2.1 ConsultLog

ConsultLog has a huge market share in the logistics sector in Germany. This market power was developed by operating in the logistics sector for more than 100 years. To ensure the position, innovations have to be used and generated. Therefore, ConsultLog has its own logistics innovation team. The respondent is employed in this team and therefore very knowledgeable in the area of new arising technologies and their potential use for logistics service providers. He is a consultant for several business units within the company.

Relationships with automotive companies are very important for ConsultLog as these customers are responsible for a huge share of the company's shipped volumes. Within ConsultLog, relationships are not classified according to the introduced terminology. According to the respondent's answer the relationships to car manufacturers are long lasting and not only transportation is performed for them. In the event of special shipments the company is connected only on a transactional basis with the customer.

ConsultLog provides already several VASs for the automotive sector which range from warehousing to pre-assembly of components to pre-delivery inspection (PDI). The respondent was involved in the outsourcing process of one car manufacturer's warehousing and plant logistics activities. These services were the first ones ConsultLog provides next to transportation to its customers. The innovation consultant stated that it is highly important to undertake economic efficiency calculations and risk analyses before offering new services.

> …'*There exist a lot of examples in the logistics industry where a firm lost a huge share of the annual profit by just one performance problem*.' **[CL]**

It is therefore fundamental that a logistics service provider can ensure a high service level.

ConsultLog realized that cost cutting for a lot of firms is not anymore the top criteria when outsourcing a task. Especially in the automotive sector the customers expect a high flexibility and security of supply. The customers want to

> …'*perform their core business' tasks in the best way while not wasting any resources for non-core tasks.*' **[CL]**

While performing some VASs, logistics service providers act as producers as well. To enhance the own portfolio of services and to stay competitive, ConsultLog is doing research in new technologies. 3DP plays a major role in future thoughts of the innovation department. The company estimates that around 5% of the world production will be 3D printable.

> …'*It is not possible to produce everything via 3DP. For example if a high number of items is needed other manufacturing technologies are more cost efficient*.' **[CL]**

The main field of application will be highly individualized products or components which means they are produced maximum five to ten times.

For ConsultLog 3DP will enable them to deliver those specialized parts with higher speed as they assume that the 3D printer is located closer to the point of consumption. The company is sure about a decrease in shipping volumes around the entire globe but they anticipate an increase in shipping volumes within continents or even countries.

> …'*We have warehouses all around the globe. Therefore, our infrastructure is set to build a global 3D printing distribution network. After printing only last mile logistics is needed.*' **[CL]**

ConsultLog sees the increase in speed, the shortening of the supply chain as well as higher flexibility as reasons to get 3DP business from their customers. In their worst case scenario ConsultLog believes that their business is not in danger because the volume of products that cannot be printed is high enough to remain profitable.

3DP will only be responsible for a low percentage of the world production and additionally transportation has to take place also for 3D printed parts. Therefore, the respondent states that

> …'*the relationship to our automotive customers should not be affected in a negative way.*' **[CL]**

But he could imagine that the relationship will change when ConsultLog has to focus even more on last mile logistics of the products.

4.2.2 Logistics ONE

Logistics ONE is a globally operating logistics service provider with its headquarter in Germany. It offers transportation via road, air, and sea as well as several other VAS like warehousing and PDI. The firm can look back on a successful history as it was founded over 130 years ago and is still a big player in the market. Worldwide more than 60.000 people are employed by Logistics ONE and the company is active in more than 125 countries. The interview participant is working in the innovation department of Logistics ONE and is the project manager for 3DP.

Logistics ONE generates innovations out of problems within the own operations as well as in collaboration with customers and research facilities. 3DP is a top issue on the agenda of the company and hence this technology and potential impacts for Logistics ONE are analyzed. The motivation for the research originates out of the fear of losing shipping volumes and having abandoned warehouses. The company started early to collaborate with automotive companies to build think tanks about 3DP in this business area.

> …'*Some companies are not able to identify the impact, while others are not willing to do so. Hence, right now no one can give precise numbers how the business area will be affected when 3DP is implemented.*' **[LO]**

However, Logistics ONE is aware of potential changes in the supply chain and tries to prepare themselves for it.

As the entire basic conditions of the 3DP field are really blurry, the respondent does not see a chance that logistics firms will perform the production via 3DP for the next 15 to 20 years.

> …'*The companies with engineering competencies have to clarify how 3DP can be used in their business before companies like Logistics ONE process the job.*' **[LO]**

This means that the company sees a chance that 3DP will be a new VAS and will expand Logistics ONE's service portfolio in the future. Without having 3DP as a VAS the company sees the risk of not getting business because it could be a future bid requirement of the customers.

Out of past experiences when adding a new VAS to the portfolio Logistics ONE expects a worsening of the relationship to the customers at the beginning as it has to broaden its own knowledge with the new technology before the service is performed smoothly and the relationship gets even stronger. On the other hand, the respondent states that

> …'*shared warehouses in which 3DP could be performed will enhance the relationship between all our partners.*' **[LO]**

Another reason for stronger relationships is seen in the current state of the technology and all the standards that need to be developed before 3DP can be used in an efficient way.

> …'*We need close collaboration, worldwide, with our customers to create standards, test methods, and other general conditions. Without working closely together, no one will benefit from the technology as it could be possible.*' **[LO]**

Overall, in Logistics ONE's opinion the relationship to the automotive customers will not worsen within the next 20 years as transportation is still needed for most of the components and products. They expect a shortening of the shipping distances and a higher importance of last mile logistics.

4.2.3 Forward Logistics

With more than 250.000 employees and operations in more than 200 countries and territories, Forward Logistics is the world leader in logistics. Besides the transportation of goods it also offers several other logistics operations and entire supply chain wide solutions for its customers. Forward Logistics consists out of several business units and the two respondents are working in two different business divisions. The first interviewee is responsible for innovations within the portfolio of Forward Logistics. Forward Logistics has its own center for innovation where they experiment with new technologies like drones, autonomous vehicles as well as 3DP and try to find out how Forward Logistics can benefit from those next generation technologies. The second interview partner is employed in a department which develops solutions for the entire supply chain of a customer. This means that not only pure transportation is taken into consideration but also several VASs that can be offered to achieve an efficient supply chain.

The German company Forward Logistics is one of the biggest logistics companies worldwide and the automotive industry is one the most important business areas within Germany. Hence, it is obvious that Forward Logistics sees the car makers as highly important and high potential customers.

> *…'The automotive sector is highly important for our entire company as we obtain a huge transportation volume for all of our means of transportation. Therefore, we do our best to deepen and enhance these relationships.'* **[FL2]**

Not only due to the size of the company and the industry sector, good relationships are crucial for Forward Logistics' business. Just the fact of being a logistics service provider that offers a wide variety of services for its customers makes relationships important.

> *…'As a logistics company we are the interface between several supply chain actors and need to take all requests and needs into account. Relationships and relationship management is crucial for us.'* **[FL1]**

These close relationships combined with a huge effort in developing new VASs and improving current business practices are the key for Forward Logistics' long lasting success.

> *…'We research a lot in the field of new technologies to expand our own product portfolio. Especially in one business unit we develop several VASs and 3DP, which will account for around 5-6 % of the world production, is seen to have the potential to become a new VAS that we will offer our customers soon.'* **[FL1]**

> *…'We try to get as much knowledge as possible about the 3DP processes so we are best prepared to offer this new VAS to our clients with a high service level.'* **[FL2]**

The company's own innovation center is cooperating in research clusters with universities as well as other companies. Those multilateral groups enhance the capability of each single firm and better outcomes are achieved. Within meetings with customers, potential uses of 3DP are discussed and outsourcing is playing a big role in everyone's considerations.

> …*'I have the feeling that the relationships to our customers within for example the automotive industry are stronger now. One reason for this is of course our close collaboration within several research projects regarding new technologies and their impacts on our businesses.'* **[FL2]**

> …*'We are talking with the auto makers about outsourcing and the feedback we are receiving is absolutely positive. We have all the logistics structure to integrate the technology in our already performed tasks.'* **[FL2]**

Forward Logistics is aware of changes in their businesses and their supply chains due to the introduction of new technologies. But as they are already a big player which has a high market share they are looking also forward to a bright future for the company. They assume that automotive companies will see them as perfect partners for their production via 3DP.

> …*'We already have a good relationship to car makers, we already have a worldwide distribution structure, we already did a lot of research on 3DP and gained a lot of knowledge - hence, we are a highly suitable candidate to perform 3DP for others.'* **[FL1]**

Forward Logistics states clearly that they want to be a player within the 3DP market and put much effort into the research and development of the technique as well as its application within Forward Logistics' product portfolio.

4.3 Findings out of the document studies

In this section I used several company documents to investigate their perspectives regarding this study's topic. Industry reports, white papers, press releases, company websites, presentations held by organizations, and future scenario studies are mainly used. Besides publicly available information on companies' websites and brochures some of the interviewed firms provided information out of internal protocols and reports. A lot of research institutions in Germany are researching additive manufacturing and its implications. Therefore, documents published by these facilities are also taken into consideration. To maintain the anonymity for all companies the alphabet is used to mark them. In justified exceptional cases, a reference list can be provided.

First of all it must be pointed out that all companies see 3DP as a great opportunity which will impact their business and associated relations to business partners. But all state that they will need at least 10 to 15 years more to fully utilize the technology. '*Limitations to 3D printing processes, such as restrictions on materials, speed, and a lack of working knowledge, could be the reasons why it might take longer for the process to be fully adopted*' (Company N, 2014). Especially legal concerns are named in several documents and should be addressed by all stakeholders who want to benefit from the new technology (Company J, 2014; Company A, 2014; Company P, 2015; Company R, 2014).

Additive manufacturing is performed by automakers since the 1990s (Company B, 2014; Company M, 2003; Company G, 2015). At the beginning it was used for rapid prototyping which is nowadays still a field of application for 3DP. Recently

Company D celebrated its 25th anniversary of the introduction of additive manufacturing within the company (Company D, 2015). This makes these companies to pioneers within the field of 3DP and out of these experiences they are very knowledgeable.

Logistics companies like Company J and Company H anticipate a diversity of manufacturing strategies and potential for more decentralized distribution structures (Company K, 2012; Company H, 2015; Company A, 2014). As they already have warehouses all over the world at strategic places like airports and seaports the logistics industry thinks that they are suitable candidates for taking over the 3DP services for companies in other industries (Company J, 2014). For example, Airbus is producing parts for a military airplane in one of their facilities by 3DP and Company H is responsible for the logistics of those parts (Company H, 2016). This collaboration could be a first step to handing over the production via 3DP. A shift to a more decentralized production structure will change the type of transportation needed. Parts and products do not need to be shipped around the globe but the need for transportation will still be in place (Company I, 2010). Even if everyone could print almost everything at home or near to the place of consumption, there have to be companies that ensure the last mile logistics (Company O, 2013).

Many companies expect the biggest change within the after sales market supply chains as storage costs can be cut down and parts can be produced on demand (Company F, 2014; Company A, 2014). This will lead to new business models, for example digital warehouses for CAD files, and a new market for 3DP raw materials will become highly important (Company J, 2014). But a fundamental change within the logistics industry is only possible when 3DP can fully substitute conventional manufacturing technologies like casting or forging (Company J, 2013).

In 2015, Company H established an 'Enterprise Lab for Logistics and Digitization' in collaboration with the Fraunhofer Institute for Material Flow and Logistics in which they want to '*develop solutions for tomorrow's logistics together*' (Company H, 2014a). Company B engaged in a competence center with Company Q where research regarding the production process of vehicles is done (Company C, 2016). Another department of Company Q produced individual orthoses for assembly operators at Company D's plant in Munich. Those highly individualized tools protect the joints of the workers by excessive pressure (Company Q, 2014; Company D, 2014). Those three examples show that there already exist deep official relationships between logistics service providers or automotive companies and research institutions in Germany regarding the development of 3DP. In other areas, for example the delivery of packages, automotive companies and logistics firms (Company J and Company B) collaborate even directly (Company B, 2015). Regarding the core business of the logistics companies, transportation, strong and long lasting relationships are in place today which are expanded to a big extent (Company J, 2010; Company H, 2014b). The automotive sector produces a huge amount of volume which has to be shipped around the globe and hence they need strong partners with the best solutions. Due to the logistics competences and good collaboration within the relationship entire supply chains become more effective and efficient (Company J, 2015). This leads in turn to even better relationships and an extension of the collaboration (Company O, 2012). Cooperation exists also between different logistics companies in so called clusters, for example 'Cluster for Logistics Luxembourg'. In those work groups logistics firms exchange their thoughts about future trends and how they could develop their skills even more (Company E, 2016). To extend the own service portfolio, logistics firms also are going together as can be seen in the example of Company H which is collaborating with a parcel delivery service (Company L, 2015). Especially in fields of new innovations like e-mobility also automotive companies work closely together (Company S, 2015).

4.4 Findings out of the observations

To understand the manufacturing technology 3DP better and to achieve more knowledge about the advantages and disadvantages of 3DP, I organized some observations. These observations were undertaken at four different companies respectively research institutions whereof two companies, ConsultLog and Forward Logistics, were also respondents for the semi-structured interviews. The other two institutions are specialized in the field of 3DP or have huge research projects about this technology. For these companies anonymity as well as confidentiality are ensured as well. Therefore, no company names are given in this section at all. All four institutions are still researching the technology and its opportunities and see a great future for additive manufacturing. The firm specialized on 3DP is active for more than 20 years within the field of additive manufacturing.

All four observations proceeded in the same way. First, a short explanation what is researched was given; secondly, the 3D printer was shown and its specifications named; thirdly, an active 3DP job was shown and last I had the opportunity to ask questions about the demonstrated steps and its implications.

The first thing that came always in my mind when seeing the printers was the very limited installation space for the objects. This is a big limitation with regards to building end-products and not only sub-components or small parts. Besides this, the procedure of building just one layer of an object takes really long. It is possible to change the process parameters to higher pace but this would result in lower quality of the component and in the end higher costs for postproduction steps. The pace of production is also one barrier on 3DP's way to potential mass production.

In all observations it was obvious that the machines are not able to produce for example engine hoods which are needed in large quantities in the automotive production in a cost efficient way. Another topic which needs to be addressed is the diversity of materials that one needs to produce end-products. Nowadays, only a few materials are applicable for producing end products via 3DP. To make cars lighter and more efficient components are built out of carbon and glass fiber. These materials for example are not printable in good conditions. Especially the visited research institution puts a huge effort in the development of new 3D printable substances.

By observing the procedure not only the downsides of the technique were visible. Products can be as complex as possible but are still producible with 3DP. Complexity means not only the outer shape but also the inside structures of the products. For example, internal cooling channels can be 3D printed. Disturbances of the material which occur when milling those channels are reduced. All shapes of coolant ducts are possible with 3DP as they are also built layer by layer.

For 3DP one needs no big plant where several parts are forwarded along a production line and the final product is assembled step by step. In the extreme case – meaning using a 3D printer only with one single material - a company needs only one machine to 3D print the product and a bit space for the post production steps. When a company is using different materials, different additive manufacturing techniques should be applied and therefore several machines are needed. But several 3D printers need still less space than a huge production line. Smaller plants are possible as well as less workers as the 3D printers can work without any supervision. 3DP seems to be an easy technology after all parameters are adjusted for the first time. During one observation it was said that an operator using state of the art 3DP software does not need any special knowledge about the technology. After applying the CAD file to the 3D printer the software is calculating all needed parameters and especially the most fitting position of the object within the building space by itself. Operators can change parameters but most likely the machine has found the best suitable option.

5 Analysis

The analysis section combines the theoretical framework with the empirical findings. First, the findings out of the cases are summarized; second the case findings, document study findings and observation findings are connected and finally compared to the theory part of this thesis.

To analyze the gathered data first all empirical findings are summarized and compared. A summary of the data out of the automotive sector is given, followed by a summary of the data gathered from the logistics companies. By comparing these data with the findings out of document studies and out of the observations, certain aspects are confirmed or rejected. The comparisons result also in the identification of relationships between the findings out of different sources. In qualitative research, comparative analysis is performed through description (Castree et al., 2013). Afterwards, those aggregated findings are combined and compared with the introduced theory. Also my own opinion and view on the given topic is added. The analysis is concluded by the presentation of the new theory that should be applied on new technologies.

Within the first case, three OEMs in the automotive sector as defined prior in this study were interviewed. First to mention is that all three companies are highly involved in the development of 3DP techniques and are aware of its huge future impact for their industry.

From the perspective of the automotive sector, relationships to the logistics industry are very important, if not even strategic. One reason for this is of course that car makers need a lot of transportation between their plants and hence they are to a certain extent dependent on logistics companies' activities. But they also realized that those firms do a lot of research in new emerging fields to extend their portfolios. Sharing and exchanging knowledge is helpful for both sides. Whereas one respondent stated that the relationship is only 'long-term' but not strategic because mutual investment and development for shared projects is missing, the other two respondents said clearly that 3DP efforts have to be undertaken in a mutual way with shared resources. This points in the direction that the relationship to logistics firms has to become closer and reach a strategic level. A strategic partnership is also preferable when two companies share knowledge about core business affecting innovations. The automotive sector assumes that it will need some more years until 3DP has the biggest effect on their businesses. Based on all parts being manufactured, the proportion of parts and components in which 3DP can be efficiently applied is very little. This means that already existing transportation volumes will not get lost. Hence, out of the Case 1 findings it is not expected that the OEM-TPL relationship will be affected in the near future. Another possibility which I estimate is even an improvement of the connection. The companies will collaborate in research clusters and will do research together and invest together. Also they have to be aware of the effortlessness to copycat their products when CAD files get public. These two aspects enhance the close collaboration and will bring tight interdependence.

All three interviewed companies are experienced in outsourcing tasks and services within their production cycles. Regarding the technology of 3DP the companies were not consistent in their answers as they could imagine both, outsourcing and insourcing. For both scenarios reasons exist. Cost savings, higher flexibility in economically difficult periods, better knowledge of specialists, and the already existing worldwide distribution network argue for outsourcing the production via 3DP. On the other hand, a shortening of the entire supply chain as well as lower dependability on external service providers are main reason for OEMs to keep the production via 3DP in-house or bring several production steps back to countries near to the end-consumers. All respondents stated clearly that 3DP will impact their business and change their supply chains in a certain way.

3DP also is a hot topic for logistics service providers, therefore all of the three investigated companies are conducting research in this field. Logistics firms are dependent on the shipping volume their customers are giving to them and as the automotive sector is highly relevant in Germany the relationships to these firms have to be strong and are of high importance. The firms are not only connected through the pure transportation of goods but also through several performed VASs out of the diverse portfolio logistics companies have in place nowadays. As no one can exactly estimate how the own company will be impacted by introducing 3DP, the logistics service providers assume that their volumes will not decrease dramatically if at all as 3DP raw materials have to be shipped then. Logistics companies expect also a potential shift in transportation from long distance global transportation to an increase in last mile logistics. Transportation is always needed. This will ultimately result in no negative changes in the OEM-TPL relationship.

As mentioned, the logistics companies are highly engaged in researching 3DP to expand their product and service portfolio. Hence, all respondents think that their company is knowledgeable in the field of additive manufacturing and see the possibility that the 3DP production of small batch sizes can be outsourced to them. A new VAS will not only bring new profit but in the future it can also be mandatory to win new business. As logistics companies already have global distribution networks and expertise in the transportation of goods – independently by which manufacturing technology produced – these firms are appropriate outsourcing partners. Logistics companies are aware of the importance that 3DP can only be beneficial if close collaboration between all involved supply chain actors is available. They also anticipate that this technology can just be outsourced after engineering companies have clarified what is possible and how this will change their production processes. This will need at least 5 to 10 years.

The document studies support the findings about the relationship between logistics companies and the firms being active in the automotive sector. The relationships have a long history and the companies need each other not only on a short term basis. Collaborative activities are already in place. These include mutual development of supply chain solutions as well as joint research of new technologies and their impacts. Some of the relationships between OEMs and TPLs are facilitated by research institutions which are state-owned. This makes it easier for competitors to work closely together as they are engaged in state-owned projects for the aim of making the entire country more competitive.

The automotive companies claim that all of them are pioneers and very knowledgeable in the field of additive manufacturing but the logistics sector is making great progress in the development of 3DP solutions. Regarding the already existing supply chain activities both company types expect the biggest changes in the after sales market and in small batch series. A diversification of manufacturing strategies will be a consequence. But also the appearance of new business models, like digital warehouses, will take place. Firms that move first of all into the new arising fields and that find the best solutions to protect the 3DP CAD files and store them in the most efficient way, can receive a tremendous competitive advantage compared to competitors and second movers. This is called the first mover advantage which leads to a technological leadership.

In the documents it is also stated that the big impact of the new technology will be present in 5 to 15 years, hence all actors that want to get a slice of the pie need to engage today to be competitive when 3DP will change the entire supply chain. Knowledge about the technology is an intangible resource which cannot be easily imitated by others and which can be of high value for the future success of the company.

The conducted observations provide a clearer picture of the additive manufacturing technique and its feasibility to perform the production by different companies. Regarding supply chain actor relationships, no investigations could be done as the presenters were not able to give any answers to this. Practical advantages and disadvantages of the current 3DP jobs were shown. This confirmed that the technology reached already a high level and is able to produce certain parts but it will take at least five years more until its full capacity is reached. Within this time frame companies need to engage in constant development to take advantage out of the technology.

The questions that now have to be answered deal with potential changes in the OEM-TPL relationship and the possibility to offer 3DP as an additional VAS. RBV as well as the introduced types of relationships within the supply chain in connection with the characteristics of 3DP and outsourcing will be used to conduct the analysis.

5.1 Changes in Supply Chain Relationships

Right now automotive manufacturers and logistics companies have long lasting and deep relationships. TPLs are performing several VASs for the automakers and the car companies are responsible for a huge share of the logistics shipping volumes around the entire globe. Working together brings mutual benefits for the actors. Collaborative partnerships are in place where at least two companies have an agreement about sharing resources such as knowledge to achieve a mutual goal. The mutual goal for logistics firms and car makers is a seamless supply chain which means that the supply of all needed components is ensured at all times. As in most cases also VASs are performed by the TPLs, the relationship is even more than a collaborative partnership but less than a strategic alliance. Strategic alliances are directly connected with joint development and especially mutual investments for innovations and new projects. Automotive companies have collective development projects with their components suppliers as those parts need to fit into their systems perfectly. Performing also VAS like PDI needs knowledge sharing and potentially sharing of workers. If 3DP will expand the portfolio of TPLs, these firms appear not only as logistics service providers but also as manufacturers and they will be at the same level as the component suppliers are already today. Therefore, the relationship between TPLs and OEMs will reach a higher level and is probably seen as a strategic alliance as the logistics companies will not make all the investments for 3DP machines and associated needs alone.

As stated before, TPLs provide a lot of VAS for the OEMs. Depending on the amount and the type of tasks and services performed, the logistics firms are according to the introduced framework (figures 4 and 5) either ‘integrators’ or ‘standard TPL provider’. By adding new services to the portfolio, TPLs develop their customer adaptation further as they can satisfy more requested tasks. This will lead to a shift of the TPLs to either ‘customer adapter’ or ‘customer developer’. The logistics companies move closer to the OEMs for which they perform the tasks. This is another sign that the OEM-TPL relationship will get better by performing 3DP as a VAS. A side effect of extending the portfolio is a stronger and more competitive position on the market for the TPLs.

Automakers and logistics firms are not on the same level within a supply chain but they are collaborating a lot. Hence, vertical collaboration is already in place. When TPLs become a manufacturer due to the production via 3DP a shift of their position within the supply chain will occur. TPLs are then regarding some tasks and services on a different level but for others tasks on the same level than the OEMs. Next to the already existing vertical collaboration, horizontal collaboration occurs. Depending on the remaining supply chain actors, which are not part of this research study, this might lead to full collaboration. In a full collaboration situation the entire supply chain benefits from the know-how and resources each single firm owns. Everyone can reach a higher outcome with less input than working alone. Reaching full collaboration is directly connected with tight relationships between all supply chain actors. A full collaborating supply network is a resource that is valuable, rare, inimitable, and non-substitutable – meaning it is a resource that has everything which is needed to achieve a sustainable competitive advantage. Such a characteristic is not unique for one single network. But other networks consist out of different companies and have different values, different cultures, and different company histories. Hence, they can achieve also a sustainable competitive advantage but this will differ from other networks.

Extending the position of TPLs within a supply chain – being also manufacturers – can also lead to destruction or at least a worsening of the relationships to a certain extent. Logistics companies will be in direct competition to current suppliers and component makers which may be current customers of the logistics companies and have good relationships to the car makers. This can lower vertical relationships within a supply chain as the supply chain can be shortened and some actors are redundant.

When 3DP is established in the manufacturing industry also 3D scanners are not far. 3D scanners have the ability to produce easily a very accurate image of an object and convert this into a CAD file. This file in turn can be used to 3D print the object without the need of all the engineering efforts for designing it. Total costs can be reduced because development costs are several times higher than the costs for scanning an object. Products and components are getting easy imitable when 3DP and 3D scanning are common technologies. Therefore, companies need to establish a close relationship to all partners that have access to their CAD files to protect their products.

Nowadays, car makers procure a lot of components from external partners as these are specialized in the production of the certain part. As the sub components need to fit perfectly into the final products of the car maker, the development and engineering effort is done in a mutual way. With this in mind and the possibility to print everything via 3DP when a CAD file is available, suppliers of sub parts can become needless.

When the technology reaches a stage where products can be produced in high quantity via 3DP the automotive companies are able to produce the parts without the need for the specific knowledge. This can have a negative effect on the relationship between the OEMs and their suppliers. As soon as car makers produce more parts by themselves the suppliers will lose production volume and in the end profit.

5.2 Outsourcing 3D Printing – or better In-House Production?

As with all other technologies and services not every single company will perform the tasks. Thus also 3DP will not be executed by all firms on the market. As it is clear that additive manufacturing will change several production steps and even entire supply chains, all companies in the production sector should consider the technology as a 'must-use' if there will not arise any new and better technology. Utilizing 3DP can be done by owning own 3D printers or by outsourcing the service to partners. After conducting an economic efficiency calculation each company has to decide whether in-house production or outsourcing is suitable for them.

As customers expect more functions within a single product the complexity level of each component will rise. 3DP is suitable for the production of final products with high complexity at lower costs than conventional production methods like casting (figure 12).

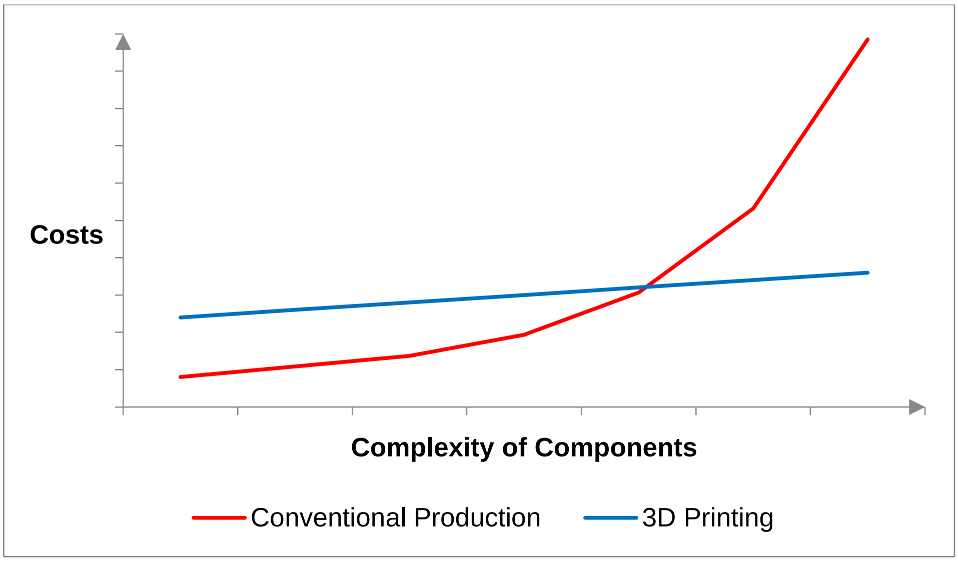

Figure 12: Costs and Complexity of components (own illustration)

Customer satisfaction is very important for long lasting success of a firm and for maintaining market share. Today, no other technology than 3DP is able to produce multifunctional parts with high quality to relatively low costs, hence there is no alternative to utilize the technology when a company wants to stay competitive.

Building more complex parts means in turn that a company is able to integrate several functions into one continuously produced element. A result is a smaller number of single parts that have to be combined by for example soldering. Joints of parts are from a technical point of view always weak points of an entire product. Hence, 3DP can increase the quality of the parts by reducing costs. Producing at lower costs than competitors always brings a competitive advantage as consumers want to pay as little as possible. In summary, OEMs should try to build the knowledge about 3DP themselves to utilize this advantage or outsource their 3DP business to the most knowledgeable partner. A make-or-buy decision has to be undertaken by the car makers.

In-house 3DP has tremendous advantages that will make a company more competitive. The time from a design to actual production can be reduced as no new molds are needed when the model is changed and designs can be kept confidential as no drafts have to leave the company. A leak regarding an innovative product design has huge negative implications for a company. On the other hand, outsourcing also has positive aspects. 3DP specialists have even better knowledge what is possible with the new technology and they are also more knowledgeable with regards to printable materials. If a company is not able to acquire this knowledge within a certain financial frame it should consider outsourcing.

The big logistics companies are well-informed about 3DP as they research this field a lot. All expect that they will gain at least some business by providing this VAS to their customers. But as building just one product by 3DP takes really long today – several hours to several days – it has to be questioned if it is economically feasible for TPLs. TPLs have to establish a broad knowledge base about printable materials, all the different additive manufacturing technologies as well as acceptance of possible customers to become players in the 3DP field. This can be very costly and hence the benefits for offering the service have to be much higher than the occurring preparation costs.

Independently of the manufacturing technology transportation is always needed. By utilizing 3DP the production facilities may come closer to the consumer markets as no cheap labor force is needed to undertake all the single production steps. Costs for worldwide transportation can be cut down. The time to market (TTM) can be shortened by developing near to the production and the not needed production of for example molds. TTM is the time starting at the concept phase of a product until it is finally placed in the market place (Doyle, 2011). This argues for insourcing the production via 3DP. But if companies can integrate their 3DP activities for spare parts into the transportation activities still needed, outsourcing gets more interesting. The concept could be called ‘the 3DP truck’ and it operates as follows: A consumer – private person or repair shop – needs spare parts for a broken car. The order is placed via phone or an online system and in cooperation with a logistics company the car maker immediately sends out a truck which has a 3D printer on its loading space. The trucks are operated by a TPL. The parts are printed during the tour to the customer and are just in time finished when the truck arrives. Delivery times are decreased while the flexibility of the supply chain is increased which was named as one of the top reasons for outsourcing a service. By integrating also other new technologies (e.g. autonomous vehicles) this concept can have a big future impact on the production and delivery of spare parts.

According to the study’s findings, 3DP is nowadays and most like also in the future only economically feasible for small batch sizes (figure 13).

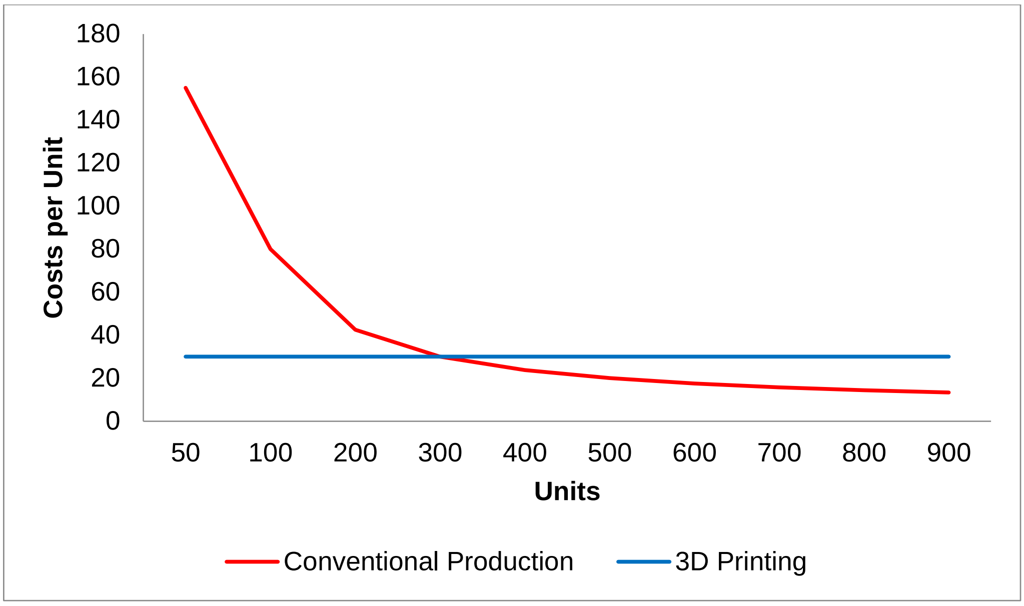

Figure 13: Lot Size & Costs (own illustration)

Conventional manufacturing technologies have high set-up costs when producing ‘lot size one’ respectively lot sizes below a critical number of products. A mold for casting costs several hundreds or even thousands of Euros. This investment pays off only when a company produces a lot of products with this single form. For 3DP no molds or similar are needed and hence the set up costs are low. This argues from a cost perspective for owning an in-house 3D printer but the OEMs considered in this study are specialized in producing high quantities of products. Within one single firm a ‘lot size one’ production is an exceptional case and therefore the amortization of the initial investment will take long. Also the degree of capacity utilization will be low. This makes an entire assembly line inefficient and outsourcing 3DP tasks become more attractive. The capacity utilization can be increased when for example several firms which have only a limited amount of small batch size production use the same 3D printers at different times. Shared printing centers will be the consequence which can be integrated in the already existing shared warehouses of multiple car makers. The warehouses are operated by logistics companies which could also overtake the supervision of 3DP processes as the printers need almost no operator. In total, automotive companies can use all the advantages additive manufacturing offers by sharing the investment with competitors and partners. Outsourcing could lead to new horizontal relationships within the industry as well as strengthen the already existing vertical relationships.

Besides the consolidation of different printing jobs from different companies at one place (shared warehouse) another advantage for outsourcing is in place. 3DP has the potential to shorten the shipping distances as the production moves closer to the end consumers. This has a more distributed plant structure compared to centralized facility structures as consequence. TPLs have already a global distribution structure at strategic locations like seaports and airports. These well-functioning global networks are rare and so they can lead to a superior position of the company which uses this structure. Upgrading the facilities at these locations by adding 3D printers can establish a worldwide 3DP distribution center without the need of any new buildings or new space.

This already existing network advocates for TPLs being the best partner when it comes to outsourcing.

A decrease in shipping volume is to a certain amount expected as well as a decrease in the need of warehousing. Both are business fields of TPLs which will affect their profits and hence their competitiveness. To remain successful, TPLs have to adapt to these changing conditions by for example offering additional services. Being directly engaged in the production via 3DP is one possibility to absorb the decrease in volume and warehouse activities. To gain this business, TPLs have to reach an expert level with regards to the technology – meaning broad knowledge about the process as well as the printable materials, a good infrastructure to ensure a high service level, and efficient production. Another chance to lower the negative impacts of the technology is to engage in the procurement and development of printable raw materials. Having more knowledge in the indirect processes of 3DP can lead to a superior position and could be a potential springboard to receive even the actual 3DP process. In sum, TPLs have to absorb the effects of the implementation of 3DP by for example winning and performing outsourced 3DP business.

If a company outsources a service or a task, the partner selection process is always extensive. Right now, OEMs do not feel certain to whom they might outsource their 3DP production. TPLs are performing several VASs for them and hence they are suitable partners for the execution of an additional task. But as few 3DP specialists exist within the industry it is also thinkable that these companies will perform the additive manufacturing processes for the OEMs. They have better knowledge than other companies. Knowledge is a valuable resource which is hard to imitate as no other company can learn about a process as another firm already did. Sharing these competences in a close relationship can lead to a competitive advantage for the OEM as it can produce via 3DP in the best possible way.

3DP has the potential to be performed by an external partner after outsourcing the service. At the current state of the technology it is a gamble to make a final statement whether outsourcing or in-house production is the best option. The most important aspect in this decision is the economic feasibility of performing the service as well as of gaining all the needed knowledge within the own company. When in-house production is not an option, several kinds of companies have to be taken into consideration in the outsourcing partner selection process of an OEM. According to the respondents most suitable partners are TPLs and specialized firms. Both types have advantages as well as disadvantages which have to be assessed by every single company.

To sum up, depending on a company's knowledge, financial capacity, and utilization level, in-house printing or outsourcing of 3DP activities is the preferred way. The future development of the technology will decide which path should be favored by OEMs.

5.3 Summary

Out of the analysis of findings from several sources it is obvious that the relationships within a supply chain will be affected by the implementation of 3DP. Depending on the future movement of 3DP and its acceptance within the industry several shifts within a supply chain are possible which have different effects on the OEM-TPL relationship. The three most likely shifts are illustrated in figure 14 and explained below.

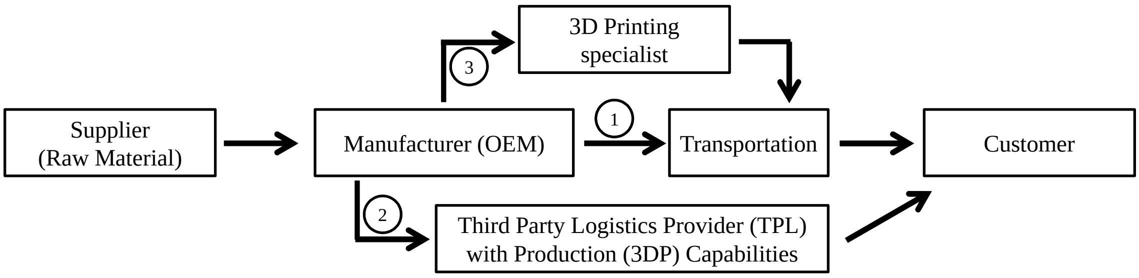

Figure 14: Possibilities of Supply Chains when implementing 3DP (own illustration)

The first scenario is that OEMs produce everything which is possible by 3DP near to the point of consumption and only last mile logistics is needed. This path within the supply chain is connected with the decision to possess own 3D printers – in-house production. This will lower the TPLs' global shipping volumes but the magnitude of printable parts compared to total volumes is expected to be not really high. Producing in-house will shorten the supply chain and makes it more efficient as less errors can occur at the interface between companies. But as transportation needs still to take place only a little worsening of the relationship but most likely no change at all is the expected outcome.

Outsourcing is the concept which is associated with the other two scenarios. The difference lies in the party which is performing the 3DP.

The second path in the supply chain is the outsourcing of 3DP to TPLs. These companies have already good relationships to OEMs and perform a lot of VASs next to their core business 'transportation'. 3DP is just another service in their portfolio which can be ideally connected with already conducted activities like pre-assembly of components. As OEMs need 3D printers only for a few orders it is possible that more than one OEM collaborate with one TPL to use the 3D printers in the most economical way. The relationship between OEM and TPL will become stronger and deeper as the TPL has to learn more about the engineering knowledge behind the components that should be printed. But also the relationship between several OEMs will be increased as they need to coordinate in collaboration with the TPL who is using the 3D printers at which point in time. Vertical and horizontal relationships are improved and strengthened. Knowledge clusters need to be established to ensure that all partners are always up to date regarding the state of the art. Clusters make an entire supply network more efficient as risk, investments, and opportunities are shared amongst all.

The third path is an outsourcing of 3DP to specialized companies. The rationale behind this decision is their broad and deep knowledge base regarding the technology. OEMs do not need to acquire the know-how, but can buy it in. At the end of the printing a transportation to the OEM is needed which has to be performed by a logistics company. As it does not matter for transportation companies from which origin to which destination they have to bring the goods a relationship change is not expected.

Summing up, at least within the next years a change within the OEM-TPL relationship is not anticipated. Reasons for this are on the one hand that transportation is still needed and on the other hand the fact that only a small share of all products can be 3D printed in an economical feasible way.

The early and successful implementation of 3DP will give companies a competitive advantage if they consider all characteristics of the technology when introducing it.

With regards to the presented VRIN model, 3DP in combination with outsourcing will be assessed. The VRIN model states that a company needs resources that are valuable, rare, imperfectly inimitable, and non-substitutable to gain a sustainable competitive advantage. A new technology like 3DP changes some of these attributes as they cannot be applied in the given form.

Additive manufacturing and its associated knowledge about the processes are the resources which need to be taken into consideration when applying the VRIN model. Obviously, the technique has to be of value for the company, otherwise it is senseless to invest into machines and know-how. As shown above, 3DP is of high value for the automotive sector as certain parts can be produced more efficient and the degree of complexity can be increased. Therefore, 'valuable' will remain a component of the competitive advantage model with regards to the technology additive manufacturing.

3DP is for most applications new and therefore 'rare' which is the next component of the VRIN model. A competitive advantage can only be achieved if something is not done by everyone or a company is doing it with a higher quality. Using 3DP to gain a competitive advantage is only possible if a company performs it extraordinary well or it uses the technique in a way no one else does. Hence, next to valuable, rare will also stay within the concept.

The third component is 'imperfectly inimitable'. 3D scanning in combination with well-performed 3DP leads to perfect copies of products. CAD files are stored in digital warehouses which need good protection that no leaks can occur. Those two aspects are responsible for the first change within the VRIN model. 'Imperfectly inimitable' should be changed to 'protectability'. For companies using 3DP it is important to protect their CAD files and designs in a way that only authorized persons or companies have access to. Also their engineering skills need to be protected and developed so that 3D scanners are not able to copy the product without any damage of the product.

With the addressed 3D scanners reverse engineering is possible. Reverse engineering is the '*process of extracting the knowledge or design blueprints from anything man-made*' (Eilam, 2005, p. 3) and re-producing it. This is an easy process by utilizing 3D scanners and 3D printers. Products can be substituted easily by re-engineered products which have slightly changes to circumvent patents. Therefore, the fourth component of the VRIN model, non-substitutability, should be changed to 'innovativeness'. Companies need to put much effort and financial resources in their Research and Development units to stay ahead of the competition which can easily re-produce parts.

Figure 15 shows the altered VRIN model which is more suitable for achieving sustainable competitive advantages by utilizing the new technology of 3DP.

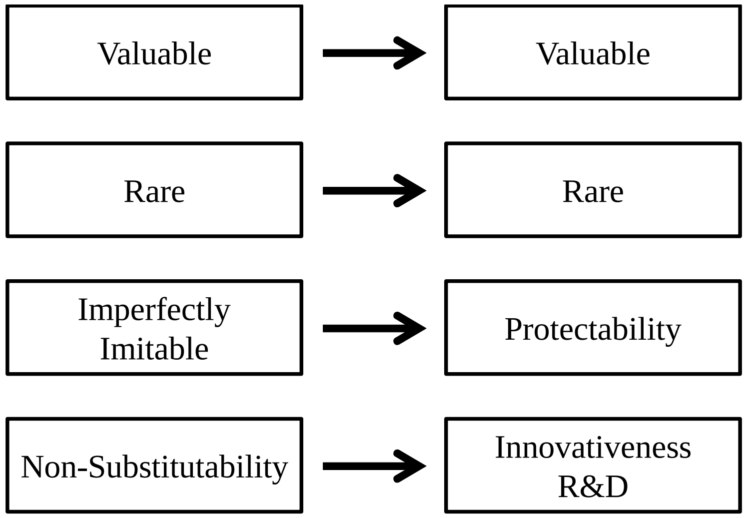

Figure 15: Altered VRIN Model (own illustration)

Especially the two changed attributes, protectability and innovativeness, are highly important when the 3DP activities are outsourced. The involved firms need to innovate together so that everyone is on track how far the technology and its applications within the company are and they need to find ways to protect their knowledge, CAD files, and 3DP practices in a mutual way.

To put everything in a nutshell, 3DP will not make all other conventional manufacturing technologies redundant for the next 10 to 20 years as for example casting is unbeatable when it comes to high output quantities. With regards to all possible manufacturing technologies it will never be ‘black or white’ – meaning only 3DP and no 3DP at all. A mutual existence of 3DP and conventional manufacturing technologies is the most likely scenario. Therefore, transportation is always needed which makes TPLs indispensable. A diversification of manufacturing technologies makes the distribution of raw materials, components, and final products more complex and this results in a higher importance of the relationship to logistics companies. To fully catch 3DP’s impact on the economy and its relationships, one needs to wait few more years. A lot of general conditions need to be in place before a final judgement can be made about 3DP’s impact. Depending on the arrangement of these rules, standards, and laws, all supply chain members need to consider their relationships and potential changes within their processes.

6 Conclusion

This chapter will draw the conclusions of the study by answering the research questions stated in the introduction as well as the purpose of the master thesis.

The purpose of this study has been to explore the relationship changes between automotive OEMs and logistics service providers in Germany by investigating the possibility of outsourcing the production via 3DP. By answering the outlined research questions and combining findings and theory, final conclusions can be drawn.

Until 3DP will reach its full capacity several years will elapse, hence no changes in the supply chain actors' relationships – especially the OEM-TPL relationships – are expected to occur in the near future. Thereafter, shifts within supply chains will emerge. But nowadays – as 3DP's full impact can only be roughly estimated – it is not possible to make a clear statement about the direction this change will have. One thing is certain: Independent of the deployed manufacturing technology transportation is always needed. Hence, TPLs are always needed and OEMs need good relations to them. The relationship between OEMs and TPLs can get even deeper as they research the potential of 3DP in common and TPLs may perform tasks associated to additive manufacturing. But worldwide shipping will decrease and total transport volumes are getting lower. A consequence may be a shift backwards in the relationships from a nearly strategic partnership to only collaborative activities. In summary, relationships will not change within the next couple of years. Afterwards, depending on the acceptance and the final use of 3DP huge changes are possible.

OEMs are using additive manufacturing for prototyping for several years and hence they are very knowledgeable within this field. Therefore, outsourcing is not really obvious. When it comes to the production of final parts via additive manufacturing, specialized 3DP companies are ahead of the OEMs and hence potential outsourcing partners. Another outsourcing area is the combination of 3DP and transportation by using the concept of the 3DP truck. Within the next years OEMs have to decide if they want to put a lot of effort and money in the development to perform 3DP in-house or if they want to utilize specialists or providers of certain VASs. Outsourcing the 3DP activities is of high interest when it is combined with other services or if the company lacks knowledge about additive manufacturing and acquirement of this know-how is too costly.

Logistics service providers are offering already several VASs and have to expand their portfolio to stay competitive. As especially the big TPLs are researching new technologies, its impact on their businesses, and potential new opportunities they gained a lot experiences in the field of additive manufacturing. By adding 3DP to their portfolio it is possible to obtain new and enhance existing business. A well-performed new VAS makes TPLs more competitive and as 3DP will be used by a lot of companies it is highly recommended to offer this service in combination with other services to customers.

By answering the three given research questions the purpose of this study is fulfilled.

7 Discussion

The final chapter of this thesis presents the implications 3DP will have on organizations and their relationships as well as the study's limitations and suggestions for further research within the investigated area.

7.1 Contribution

This study contributes to the academic research at the interface between technical and economic aspects as it combines business theories with new technology that is just investigated with regards to technical impacts. The study should be seen as a starting point of a long-term study about the shift that may occur when 3DP is implemented in most companies.

As all respondents and experts state that it will need at least five to ten years until additive manufacturing reaches the final status for final products production its implications will occur even later. But already today companies and their executives have to consider all effects the new technology can have on their business and their business relations. New business models will occur, new firms will enter the market, and new regulations will be in place. Hence, without being aware of all upcoming topics successful companies may lose market share or customers. This study helps to understand the importance of new innovative manufacturing technologies for future business plans.

This study presents also a broad summary of the state of the art in 3DP as well as activities that are planned in the future, e.g. 3D printers on the moon. This gives managers who just started to get involved in additive manufacturing technologies a good overview about the status quo.

This master thesis contributes also to companies' considerations whether they should perform 3DP in-house or utilize an external partner. Potential paths of the development are shown and possible consequences when choosing one or the other way are illustrated.

7.2 Limitations

This master thesis had a predetermined time horizon and hence only seven interviews with six companies could be conducted. Additionally, all interviewed companies are global players within their industry sector. This small sample size as well as the characteristics of the firms limit the ability to generalize the findings. Therefore, this study should be seen as a starting point that gives first insights about this field of study.

The analysis of the empirical findings is also limited by the fact that only two actors of the entire supply chain are taken into consideration. This was needed to make the entire master thesis feasible but restricted in turn certain actors' perspective on the topic. These may have a completely different attitude towards the future impact of 3DP.

With regards to the already existing literature one can argue that another limitation lies in the extensive use of company studies and reports. These institutions show in their publications often just the potential benefits. But as the technology is new and research regarding its non-technical implications just started, academic papers are rare in this field. This will change in the next years and may alter some assumptions.

The biggest limitation of this study is the current hype around additive manufacturing technologies. All respondents as well as academic papers expect a bright future for and a broad implementation of additive manufacturing technologies in the daily life. After a few more years of research in the field new downsides may arise and the hype will die away. As a result the given answers could be different – meaning not as positive as they are nowadays.

7.3 Suggestions for Further Research

This study was focused on the logistics and automotive industries. 3DP is considered to affect all existing industry sectors. Therefore, it is highly recommended to perform studies focusing on for example the military or textile sector to broaden the knowledge about potential 3DP effects on the global trade.

Since only interviews with German companies were conducted, the study's results may not be transferable to car makers and logistics companies in other countries. Hence, it is needed to conduct the study in other countries preferable other continents with a different progress in the technology. Additionally, only big companies which are specialized in large scale batch production were taken into consideration. 3DP will most likely change lot size one and small batch production. A study about the impact on the relationship between logistics companies and small or medium size enterprises should be performed to get a clearer picture of potential changes in the industry.

In general a bigger study with participants from different industries and different company sizes should be conducted to establish knowledge about 3DPs impact across industries. This study should also follow a longitudinal time horizon to identify changes over time as the technology will be further developed in the next years.

Another future study should distinguish between car maker brands like Audi, BMW or Volvo and car component suppliers like Bosch, Continental or Johnson Controls. By utilizing 3DP, car makers are able to produce all the sub-components which are bought from the suppliers right now in an easy way. Therefore, the relationship between these two types of companies can be affected dramatically by the extensive introduction of 3DP.

Also other theories than RBV and competitive advantage should be used in other studies. A suggestion is to use the concept of first mover advantages and disadvantages. Herewith researchers could investigate why companies should put high effort in the development of 3DP to achieve benefits in the future compared to competitors.

Also the impact on existing distribution networks as well as the last mile logistics should be researched in-depth. 3DP will change the routes and distances of transportation which will in turn alter global transport volumes.

As 3DP is relatively new for most of the common business research fields, the list of suggested further research can be continued. The topics range from logistics issues to legal concerns (e.g. protection from copycatting and imitated components) to marketing strategy about the new manufacturing technology to consequences for entire organizational strategies. In addition, research should also be conducted in non-business areas to further explore technical attributes.

List of References

3ders.org. (2014, April 1). *10 completely 3D printed houses appear in Shanghai, built under a day*. Retrieved March 11, 2016, from http://www.3ders.org/articles/20140401-10-completely-3d-printed-houses-appears-in-shanghai-built-in-a-day.html

AEB. (2014). *Six theories about how 3D printing will change logistics*. [White Paper]. Leamington Spa: AEB.

Airbus. (2015). *Airbus APWorks - High Quality Metal 3D Printing* [Press Release 22.05.2015]. Munich: Airbus APWorks GmbH.

Amit, R., & Schoemaker, P. (1993). Strategic assets and organizational rent. *Strategic Management Journal, 14*(1), 33-46.

Ankenbrand, H. (2015, March 6). Eine Villa aus dem 3D-Drucker. *Frankfurter Allgemeine Zeitung*. Retrieved March 11, 2016, from http://www.faz.net/aktuell/wirtschaft/unternehmen/innovation-eine-villa-aus-dem-3d-drucker-13466157.html

Audi. (2014). Passt wie gedruckt. *Audi Blog*. Retrieved March 26, 2016, from http://blog.audi.de/2014/07/18/passt-wie-gedruckt/

Automobil Industrie. (2015). Die Weltweit Grössten 100 Automobilzulieferer. *Automobil Industrie, 4*, 36-37.

Bak, D. (2003). Rapid prototyping or rapid production? 3D printing processes move industry towards the latter. *Assembly Automation, 23*(4), 340-345.

Bardi, E.J., & Tracey, M. (1991). Transportation Outsourcing: A Survey of US Practices. *International Journal of Physical Distribution & Logistics Management, 21*(3), 15-21.

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management, 17*(1), 99.

Barratt, M. (2004). Understanding the meaning of collaboration in the supply chain. *Supply Chain Management: An International Journal, 9*(1), 30-42.

Basiliere, P. (2013). *How 3D Printing Disrupts Business and Creates New Opportunities* [Report]. Stamford, CT: Gartner, Inc.

Beckett, G. (2013). *Reflections of Time*. Singapore: Trafford Publishing.

Bennett, D., & Klug, F. (2012). Logistics supplier integration in the automotive industry, *International Journal of Operations & Production Management, 32*(11), 1281-1305

Berman, B. (2012). 3-D printing: The new industrial revolution. *Business Horizons, 55*(2), 155-162.

Black, J., Hashimzade, N., & Myles, G. (2012). Outsourcing. *A Dictionary of Economics,* A Dictionary of Economics.

BMW. (2015). *25 years of 3D printing at the BMW Group: Pioneers in additive manufacturing methods*. [Press Release 18.11.2015]. Munich: BMW.

Bruch, H. (1998). *Outsourcing: Konzepte und Strategien, Chancen und Risiken*. Wiesbaden: Gabler.

Bryman, A. (1989). *Research Methods and Organisation Studies*. London: Unwin Hyman.

Bryman, A., & Bell, E. (2011). *Business research methods* (3.rd ed.). Oxford: Oxford University Press.

BSR. (2015). *3-D Printing: Sustainability Opportunities and Challenges*. [Report]. Copenhagen: BSR.

Campbell, T., Williams, C., Ivanova, O., & Garrett, B. (2011). *Could 3D printing change the world. Technologies, Potential, and Implications of Additive Manufacturing,* Atlantic Council, Washington, DC.

Castree, N., Kitchin, R., & Rogers, A. (2013). comparative research. *A Dictionary of Human Geography*. Oxford University Press.

Ceccanti, F., Dini, E., De Kestelier, X., Colla, V., & Pambaguian, L. (2010). 3D printing technology for a moon outpost exploiting lunar soil. In *61st International Astronautical Congress, Prague, CZ, IAC-10-D3* (Vol. 3).

Chorafas, D. (2002). *Outsourcing insourcing and it for enterprise management Business opportunity analysis*. Basingstoke: Palgrave Macmillan.

Cohen, D., George, K., & Shaw, C. (2015). *Are you ready for 3-D printing?*, McKinsey Quarterly, February 2015.

Cohen, D., Sargeant, M., & Somers, K. (2014). *3-D printing takes shape*. McKinsey Quarterly, January 2014.

Columbus, L. (2014, December 18). Gartner Forecasts The 3D Printer Market Will Be $13.4B By 2018. *Forbes*. Retrieved March 07, 2016, from http://www.forbes.com/sites/louiscolumbus/2014/12/18/gartner-forecasts-the-3d-printer-market-will-be-13-4b-by-2018/#d74f0212552d

Columbus, L. (2015, March 31). 2015 Roundup Of 3D Printing Market Forecasts And Estimates. *Forbes*. Retrieved March 14, 2016, from http://www.forbes.com/sites/louiscolumbus/2015/03/31/2015-roundup-of-3d-printing-market-forecasts-and-estimates/#307640b91dc6

Cope, D. (2014). Methods and meanings: Credibility and trustworthiness of qualitative research. *Oncology Nursing Forum, 41*(1), 89-91.

Coyle, J.J., Langley Jr., C.J., Novack, R.A., & Gibson, B.J. (2013). *Managing Supply Chains: A Logistics Approach* (9th ed., International ed.). South-Western/Cengage Learning.

Dambeck, H. (2014, April, 8). China: 3D-Drucker fertigt zehn Häuser an einem Tag. *Spiegel Online*. Retrieved March 11, 2016, from http://www.spiegel.de/wissenschaft/technik/china-haus-mit-3-d-drucker-hergestellt-a-963249.html

DB Schenker (2014). *Enterprise Lab for Logistics and Digitization*. [Corporate News]. Essen: DB Schenker. Retrieved March 26, 2016, from http://www.dbschenker.com/ho-en/news_media/press/corporate-news/news/8613962/2014-11-10-dbschenker-enterpriselab.html

DB Schenker. (2015). Traum eines Ingenieurs. *DB Schenker PROJEKTpraxis, 14*, 10-11.

Desai, D. R., & Magliocca, G. N. (2014). Patents, meet Napster: 3D printing and the digitization of things. *Georgetown Law Journal*, *102*, 1691-1841.

Deutsche Post. (2010). *Delivering Tomorrow: Towards Sustainable Logistics*. [Report]. Bonn: Deutsche Post AG.

DHL. (2013). *LOGISTICS TREND RADAR 2013: Delivering insight today. Creating value tomorrow!*. [Report]. Troisdorf: DHL Customer Solutions & Innovation.

DHL. (2014). *LOGISTICS TREND RADAR 2014: Delivering insight today. Creating value tomorrow!*. [Report]. Troisdorf: DHL Customer Solutions & Innovation.

DHL. (2016). *LOGISTICS TREND RADAR. - Delivering insight today. Creating value tomorrow*. Retrieved April 25, 2016, from http://www.dhl.com/en/about_us/logistics_insights/dhl_trend_research/trendradar.html#.VzCTdUZy40Y

DHL Freight. (2016). *Automotive Logistics with top marks for Strength and Flexibility*. [Company Brochure]. Bonn: DHL Freight Automotive.

Doyle, C. (2011). Time to market. *A Dictionary of Marketing*, A Dictionary of Marketing.

DPDHL. (2012). *Delivering Tomorrow: Logistics 2050 - A Scenario Study*. [Scenario Study]. Bonn: Deutsche Post DHL.

Eilam, E. (2005). *Reversing secrets of reverse engineering*. Indianapolis, Ind.: Wiley Pub.

Ellram, L., & Billington, C. (2001). Purchasing leverage considerations in the outsourcing decision, *European Journal of Purchasing & Supply Management, 7*, 15-22.

ESA. (2013, January, 31). *Building a Lunar Base with 3D Printing*. Retrieved March, 14, 2016, from http://www.esa.int/Our_Activities/Space_Engineering_Technology/Building_a_lunar_base_with_3D_printing

Fastermann, P. (2014). *3D Drucken: Wie die generative Fertigungstechnik funktioniert*. Berlin Heidelberg: Springer Verlag.

Fastermann, P., & Ciric, D. (2014). *Fabucation. 3D-Druck in der Schule: Die revolutionäre Technologie und ihre Folgen einfach erklärt*. Norderstedt: BoD – Books on Demand.

Forbes. (2016, January, 15). Top 10 Technology trends for 2016. Retrieved March 09, 2016, from http://www.forbes.com/sites/gartnergroup/2016/01/15/top-10-technology-trends-for-2016/2/#2a8fb0315830

Forbes/Wolfe Emerging Tech. (2011). Terry Wohlers: Manufacturing The future of 3D Printing. *Forbes/Wolfe Emerging Tech Report, 10*(11), 6-7.

Ford Motor Company. (2016). *The evolution of mass production*. Retrieved February 3, 2016, from http://www.ford.co.uk/experience-ford/Heritage/EvolutionOfMassProduction

Foster+Partners. (2013). *Foster + Partners works with European Space Agency to 3D print structures on the moon* [Press Release]. London: Foster + Partners.

Fraunhofer Institut. (2015). Druck mir das mal eben aus!, *Logistik entdecken: Magazin des Fraunhofer-Instituts für Materialfluss und Logistik IML Dortmund, 16*, 40-41.

Fredriksson, A. (2011). *Materials Supply and Production Outsourcing*. PhD Thesis, Chalmers University, Gothenburg, Sweden.

Friedrich von den Eichen, S.A. (2002). *Kräftekonzentration in der diversifizierten Unternehmung: Eine ressourcenorientierte Betrachtung der Desinvestition*. Wiesbaden: Gabler Edition Wissenschaft: Strategisches Kompetenz-Management.

Gartner. (2014). *Gartner's Top 10 Strategic Technology Trends for 2015*. [Analysis Report]. Stamford, CT: Gartner, Inc.

Gebler, M., Uiterkamp, A., & Visser, C. (2014). A global sustainability perspective on 3D printing technologies. *Energy Policy, 74*, 158-167.

Ghausi, N. (2002). Trends in outsourced manufacturing – Reducing risk and maintaining flexibility when moving to an outsourced model. *Assembly Automation, 22*(1), 21-25.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. (Report). *The Qualitative Report, 8*(4), 597.

Greenberg, A. (2013, May 5). Meet The 'Liberator': Test-Firing The World's First Fully 3D-Printed Gun. *Forbes*, Retrieved March 14, 2016, from http://www.forbes.com/sites/andygreenberg/2013/05/05/meet-the-liberator-test-firing-the-worlds-first-fully-3d-printed-gun/#127484de511e

Hagberg-Andersson, Å., & Grønhaug, K. (2010). Adaptations in a supplier-manufacturer network: A research note. *European Journal of Marketing, 44*(1/2), 34-41.

Handelsblatt. (2016, January 19). 3D-Drucker sollen Zulieferer ersetzen - Airbus stellt Produktion um. *Handelsblatt*, Retrieved March 13, 2016, from http://www.handelsblatt.com/unternehmen/industrie/airbus-stellt-produktion-um-3d-drucker-sollen-zulieferer-ersetzen/12853248.html

Hertz, S. (1996). The Dynamics of International Strategic Alliances. *International Studies of Management & Organization, 26*(2), 104-130.

Hertz, S., & Alfredsson, M. (2003). Strategic development of third party logistics providers. *Industrial marketing management, 32*(2), 139-149.

Holmström, J., Partanen, J., Tuomi, J., & Walter, M. (2010). Rapid manufacturing in the spare parts supply chain: Alternative approaches to capacity deployment, *Journal of Manufacturing Technology Management, 21*(6), 687-697.

Hoyt, J., & Huq, F. (2000). From arms-length to collaborative relationships in the supply chain: An evolutionary process. *International Journal of Physical Distribution & Logistics Management, 30*(9), 750-764.

Hundertmark, H. (2013). *Beziehungsmanagement in der Automobilindustrie: OEM Relationship Management als Sonderfall des CRM*. Wiesbaden: Gabler.

Kanter, R. (1993). *Men and women of the corporation* (2.nd ed.). New York: BasicBooks.

Kedia, B. L., & Lahiri, S. (2007). International outsourcing of services: A partnership model. *Journal of International Management, 13*(1), 22-37.

Ketler, K., & Walstrom, J. (1993). The outsourcing decision. *International Journal of Information Management, 13*(6), 449-459.

Khajavi, S.H., Partanen, J., & Holmström, J. (2013). Additive manufacturing in the spare parts supply chain. *Computers in Industry, 65*(1), 50-63.

Kieviet, A., & Alexander, S. (2015). Is your supply chain ready for additive manufacturing? *Supply Chain Management Review, 19*(3), 34-39.

Kumar, R. (2011). *Research methodology: A step-by-step guide for beginners* (3.rd ed.). Los Angeles; London: SAGE.

Law, J. (2009). *A Dictionary of Business and Management* (5th ed.). Oxford University Press.

Lee, C.W., Kwon, I.G., & Severance, D. (2007). Relationship between supply chain performance and degree of linkage among supplier, internal integration, and customer. *Supply Chain Management: An International Journal, 12*(6), 444-452.

Lewis, A. (2014). The Legality of 3D Printing: How Technology Is Moving Faster than the Law, *Tulane Journal of Technology & Intellectual. Property, 17*, 303-318.

Lincoln, Y.S., & Guba, E.G. (1985). *Naturalistic Inquiry*. Beverly Hills, CA: SAGE.

Lipson, H., & Kurman, M. (2013). *Fabricated: The new world of 3D printing*. Indianapolis, IN: John Wiley & Sons, Inc.

Ludwig, A., & Harvey, S.E. (2013). 3D Printing Affects Every Industry, Even Homebuilding (Interview with Terry Wohlers). *Techonomy Exclusive*, July 19, 2013.

Marga, F., Jakab, K., Khatiwala, C., Shepherd, B., Dorfman, S., Hubbard, B., Colbert, S., & Forgacs, G. (2012). Toward engineering functional organ modules by additive manufacturing. *Biofabrication, 4*(2), 1758-5082.

Mason, R., Lalwani, C., & Boughton, R. (2007). Combining vertical and horizontal collaboration for transport optimisation. *Supply Chain Management: An International Journal, 12*(3), 187-199.

McAlister, C., & Wood, J. (2014). The potential of 3D printing to reduce the environmental impacts of production. *ECEEE Industrial Summer Study Proceedings 2014*. 213-222.

McGrath, R., MacMillan, I. & Venkataraman, S. (1995). Defining and developing competence: A strategic process paradigm. *Strategic Management Journal, 16*(4), 251-275.

McKinsey Global Institute. (2013). *Disruptive technologies: Advances that will transform life, business, and the global economy*. [Report]. Seoul: McKinsey Global Institute.

McNulty, C. M., Arnas, N., & Campbell, T. A. (2012). Toward the printed world: Additive manufacturing and implications for national security. *Defense Horizons, 73*, 1-16.

Melchels, F.P.W., Domingos, M.A.N., Klein, T.J., Malda, J., Bartolo, P.J., & Hutmacher, D.W. (2012). Additive manufacturing of tissues and organs. *Progress in Polymer Science, 37*(8), 1079-1104.

Mellor, S., Hao, L., & Zhang, D. (2013). Additive manufacturing: A framework for implementation. *International Journal of Production Economics*, 149, 194-201.

Mourdoukoutas, P. (2015). How 3D Printing Changes The Economics Of Outsourcing And Globalization. *Forbes*. Retrieved March 03, 2016, from http://www.forbes.com/sites/panosmourdoukoutas/2015/07/18/how-3d-printing-changes-the-economics-of-outsourcing-and-globalization/#7c66b3a66b8c

Mudholkar, N. (2006). Paradigm Shift. *Time Journal of Construction and Design*, March 2006, 33-36.

Müller-Dauppert, B. (2009). *Logistik-Outsourcing: Ausschreibung, Vergabe, Controlling* (2.nd ed.). München: Verlag Heinrich Vogel.

Murphy, S.V., & Atala, A. (2014). 3D bioprinting of tissues and organs. *Nature Biotechnology, 32*(8), 773.

Murthi, S. (2002). Build versus buy - making the right decision, *Free Information Builder's Whitepaper*, Retrieved March 03, 2016, from http://www.developer.com/java/other/article.php/1488331/Build-Versus-BuymdashMaking-the-Right-Decision.htm

Niemeyer, A. (2014). *Picking winning supply-chain technologies*, McKinsey & Company, June 2014.

O'Leary, Z. (2010). *The Essential guide to doing your research project* (2nd edition). Sage Publications.

Panalpina. (2013). The Future of Logistics. *Connect – The Panalpina Magazine, 02,* 6-7.

Patton, M. (2002). *Qualitative research & evaluation methods* (3.rd ed.). London: SAGE.

Penrose, E.T. (1959). *The Theory of the Growth of the Firm*. New York: Wiley.

Petschow, U., Ferdinand, J. P., Diekel, S., & Flämig, H. (2014). Dezentrale Produktion, 3D-Druck und Nachhaltigkeit. *Schriftenreihe des IÖW, 206*(14).

Polit, D. F., & Beck, C. T. (2010). Generalization in quantitative and qualitative research: Myths and strategies. *International Journal of Nursing Studies, 47*(11), 1451-1458.

Pomponi, F., Fratocchi, L., & Rossi Tafuri, S. (2015). Trust development and horizontal collaboration in logistics: A theory based evolutionary framework. *Supply Chain Management, 20*(1), 83-97.

Porter, M. (1980). *Competitive strategy: Techniques for analyzing industries and competitors*. New York: Free Press.

Power, M., DeSouza, K., & Bonifazi, C. (2006). *The Outsourcing Handbook: How to Implement a Successful Outsourcing Process*. London and Philadelphia: Kogan Page.

Prahalad, C.K., & Hamel, Gary. (1990). The core competence of the corporation. *Harvard Business Review, 68*(3), 79-91.

PWC. (2013). 3D printing: A potential game changer for aerospace and defense. *gaining altitude with PwC, 7*.

Quinn, J.B., & Hilmer, F.G. (1994). Strategic Outsourcing. *Sloan Management Review 36* (Summer), 43-55.

Reiss, B. (2015). Outsourcing. *Agency Sales, 45*(5), 36-40.

Rifkin, J. (2012). The third industrial revolution: How the internet, green electricity, and 3-d printing are ushering in a sustainable era of distributed capitalism. *World Financial Review, 1*, 8-12.

Rifkin, J. (2014). The third industrial revolution is here. *Director*, 67(7), 30.

Robson, C. (2002). *Real world research: A resource for social scientists and practitioner-researchers.* (2.nd ed.). Oxford: Blackwell.

Ruffo, M., Tuck, C., & Hague, R. (2007). Make or buy analysis for rapid manufacturing. *Rapid Prototyping Journal, 13*(1), 23-29.

Ryan, B., & Delgado-Sanchez, A. (2010). Outsourcing relationships: A case of accounting surveillance. *Journal of Accounting & Organizational Change, 6*(1), 52-71.

Rybicki, F. (2015). 3D Printing in Medicine: An introductory message from the Editor-in-Chief. *3D Printing in Medicine, 1*(1), 1.

Sachs, E., Cima, M., & Cornie, J. (1990). Three-dimensional printing: rapid tooling and prototypes directly from a CAD model. *CIRP Annals-Manufacturing Technology, 39*(1), 201-204.

Saenz, M.J., Ubaghs, E., & Cuevas, A.I. (2015). Enabling Horizontal Collaboration Through Continuous Relational Learning. Heidelberg: Springer.

Saunders, M., & Lewis, P. (2012). *Doing research in business and management : An essential guide to planning your project*. Harlow: Financial Times Prentice Hall.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students* (5.th ed.). Harlow: Financial Times Prentice Hall.

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students* (6.th ed.). Harlow; New York: Pearson.

Sculpteo. (2011, March 17). *Contour Crafting: build entire houses, the 3D printing way*. Retrieved March 11, 2016, from http://www.sculpteo.com/blog/2011/03/17/contour-crafting-build-entire-houses-the-3d-printing-way/

Sculpteo. (2015a). *3D Printing Volume*. Retrieved March 24, 2016, from https://www.sculpteo.com/en/glossary/3d-printing-volume-definition/

Sculpteo. (2015b, October 7). *3D printing construction & architecture: building the home of the future*. Retrieved March 11, 2016, from http://www.sculpteo.com/blog/2015/10/07/3d-printing-construction/

Sculpteo. (2016). *3D Printing*. Retrieved April 21, 2016 from https://www.sculpteo.com/de/glossar/3d-druck-definition/

Seitz, H. (2008). Dreidimensionales Drucken von patientenindividuellem Knochenersatz. *RTejournal-Forum für Rapid Technologie 5,*(1).

Sharma, R. (2014). The Future Of 3D Printing And Manufacturing. *Forbes*. Retrieved March 14, 2016, from http://www.forbes.com/sites/rakeshsharma/2014/01/15/1255/#3d5663642246

Simatupang, T.M., & Sridharan, R. (2002). The Collaborative Supply Chain. *The International Journal of Logistics Management, 13*(1), 15-30.

Sitel. (2014). *Top 5 Reasons Companies Outsource*. [White Paper]. Nashville, TN: Sitel.

Song, J.B., Dai, D.S., & Song, Y.Q. (2006). The Relationship between Change of Organizational Structure and Implementation of Advanced Manufacturing Technology: An Empirical Study, *Management Science and Engineering, Proceedings of the International Conference on Management Science and Engineering*, 782-786.

Stratasys. (2015). *In-House or Outsource? – Six Business Advantages of Owning an In-House 3D Printer*. [White Paper]. Eden Prairie, MN: Stratasys Ltd.

Tayauova, G. (2012). Advantages and disadvantages of outsourcing: Analysis of outsourcing practices of Kazakhstan banks. *Procedia - Social and Behavioral Sciences, 41*, 188-195.

The Economist. (2012a, April 21). The third industrial revolution. *The Economist, 403*(8781), 15.

The Economist. (2012b, April 21). Solid print; Additive manufacturing. *The Economist, 403*(8781), 14-18.

The Freedonia Group. (2013). *World 3D Printing (Additive Manufacturing): Industry Study with Forecast for 2017 & 2022* [Industry Study]. Cleveland, OH: The Freedonia Group, Inc.

The Logistics & Supply Chain Management Society. (2016). *Supply Chain*. Retrieved February 6, 2016, from http://lscms.org/scm-dictionary/s/

Tjmkes, B., Vos, O., & Burgers, K. (2012). *Strategic Alliance Management*. New York: Routledge.

TNO. (2015a). *World first for Barilla and TNO 3D pasta printer at EXPO2015* [Press Release 13.05.2015]. The Hague : TNO.

TNO. (2015b). *3D Food printing: Creating shapes and textures*. [Presentation held by van der Linden, D.]. The Hague: TNO.

USPTO. (2016). *Apparatus for production of three-dimensional objects by stereolithography*. Retrieved February 4, 2016, from http://patft.uspto.gov/netacgi/nph-Parser?Sect2=PTO1&Sect2=HITOFF&p=1&u=/netahtml/PTO/search-bool.html&r=1&f=G&l=50&d=PALL&RefSrch=yes&Query=PN/4575330

Volkswagen. (2015). *Volkswagen treibt digitalen 3-D-Druck im Autobau voran* [Press Release 26.02.2015]. Wolfsburg: Volkswagen Konzern.

Wang, W., Wang, T.Y., Yang, Z., Liu, L., Tong, X., Tong, W., Deng, J., Chen, F., & Liu X. (2013). Cost-effective printing of 3D objects with skin-frame structures. *ACM Transactions on Graphics (TOG), 32*(6), 177.

Weele, A. (2010). *Purchasing & supply chain management: Analysis, strategy, planning and practice* (5.th ed.). Andover: Cengage Learning.

Weiss, A., & Anderson, E. (1991). *The effects of switching costs on the termination of distribution channel relationships*, 91-109, Cambridge, Mass.: MSI.

Wernerfelt, B. (1984). A Resource-Based View of the Firm. *Strategic Management Journal*, *5*(2), 171-180.

White House. (2012, August 16). *We Can't Wait: Obama Administration Announces New Public-Private Partnership to Support*. Retrieved March 12, 2016, from https://www.whitehouse.gov/the-press-office/2012/08/16/we-can-t-wait-obama-administration-announces-new-public-private-partners

White House. (2013, February 12). *Remarks by the President in the State of the Union Address*. Retrieved March 24, 2016, from https://www.whitehouse.gov/the-press-office/2013/02/12/remarks-president-state-union-address

Wißkirchen, F. (1994). Logistik-Outsourcing – Neue Wege in der Logistikkostensenkung, *Logistik Heute*, *16*(6), 33-35.

Wohlers Associates. (2013). *Wohlers Report 2013: Additive Manufacturing and 3D Printing State of the Industry - Annual Worldwide Progress Report*. [Report]. Colorado: Wohlers Associates.

Wohlers Associates. (2014). *Wohlers Report 2014: 3D printing and Additive Manufacturing State of the Industry - Annual Worldwide Progress Report*. [Report]. Colorado: Wohlers Associates.

Wong, J. Y., & Pfahnl, A. C. (2014). 3D printing of surgical instruments for long-duration space missions. *Aviation, space, and environmental medicine, 85*(7), 758-763.

Yin, R. (2009). *Case study research: design and methods* (4.th ed.). London: SAGE.

Yin, R. (2011). *Qualitative research from start to finish*. New York: Guilford Press.

Yin, R. (2014). *Case study research: Design and methods* (5.th ed.). London: SAGE.

Zikmund, W., Babin, B. J., Carr, J. C., & Griffin, M. (2010). *Business research methods* (8.th ed.). Mason, Ohio: South-Western Cengage Learning.

Zoogah, D., Vora, D., Richard, O., & Peng, M. (2011). Strategic alliance team diversity, coordination, and effectiveness. *The International Journal of Human Resource Management, 22*(3), 510-529.

Appendix

Appendix A1: Explanation of several 3DP techniques

This is an excerpt out of the 'Disruptive technologies: Advances that will transform life, business, and the global economy' report by the McKinsey Global Institute (2013).

Selective Laser Sintering (SLS). In this technique, a layer of powder is deposited on the build platform, and then a laser 'draws' a single layer of the object into the powder, fusing the powder together at the right shape. The build platform then moves down and more powder is deposited to draw the next layer. SLS does not require any supporting structures, which makes it capable of producing very complex parts. SLS has been used mostly to create prototypes but recently has become practical for limited-run manufacturing. General Electric, for example, recently bought an SLS engineering company to build parts for its new short-haul commercial jet engine.

Direct Metal Laser Sintering (DMLS). DMLS is similar to selective laser sintering but deposits completely melted metal powder free of binder or fluxing agent, thus building a part with all of the desirable properties of the original metal material. DMLS is used for rapid tooling development, medical implants, and aerospace parts for high-heat applications.

Fused Deposition Modeling (FDM). A filament of plastic resin, way, or another material is extruded through a heated nozzle in a process in which each layer of the part is traced on top of the previous layer. If a supporting structure is required, the system uses a second nozzle to build that structure from a material that is later discarded (such as polyvinyl alcohol). FDM is mainly used for single- and multipart prototyping and low-volume manufacturing of parts, including structural components.

Stereolithography (SLA). A laser or other UV light source is aimed onto the surface of a pool of photopolymer (light-sensitive resin). The laser draws a single layer on the liquid surface; the build platform then moves down, and more fluid is released to draw the next layer. SLA is widely used for rapid prototyping and for creating intricate shapes with high-quality finishes, such as jewelry.

Laminated Object Manufacturing (LOM). A sheet of material (paper, plastic, or metal) is fed over the build platform, adhered to the layer below by a heated roller, and a laser cuts the outline of the part in the current layer. LOM is typically used for form/fit testing, rapid tooling patterns, and producing less detailed parts, potentially in full color.

Inkjet-bioprinting. Bioprinting uses a technique similar to that if inkjet printers, in which a precisely positioned nozzle deposits one tiny dot of ink at a time to form shapes. In the case of bioprinting, the material used is human cells rather than ink. The object is built by spraying a combination of scaffolding material (such as sugar-based hydrogel) and living cells grown from a patient's own tissues. After printing, the tissue is placed in a chamber with the right temperature and oxygen conditions to facilitate cell growth. When the cells have combined, the scaffolding material is removed and the tissue is ready to be transplanted.

Appendix A2: Interview Guide

JÖNKÖPING UNIVERSITY
International Business School

Interview Guide for the semi-structured Interviews

Master's Thesis within Business Administration
Study Program: International Logistics and Supply Chain Management

Working Title of the Master's Thesis: **Impact of 3D printing on the Relationship of Supply Chain Actors**

Name: Felix Eckes
Contact Address: 3dprint.eckes@gmail.com

Date:	DD-MM-YYYY
Starting Time:	HH:MM
Ending Time:	HH:MM
Location:	
Interview Type:	Face-to-Face Web-based with video Web-based without video
Confidentiality	Strictly Confidential Public
Company Type	OEM Logistics Company
Company:	
Respondent:	
Position of Respondent:	

1. Section: Introduction/Context

Interviewer: Introduction of the research project including explanations of the scope, purpose, research questions as well as delimitations of the study; clarification of the interviewee's rights during the project and the applied research ethics

Interviewee: Opportunity to introduce the company and the own position

Start of Semi-structured interview: Not all questions have to be asked and additional questions can be asked whenever necessary.

Do you consent that I record the interview?
Would you and your company like to remain anonymous in the study?
Which position do you hold in this company?

2. Section: Relationship to OEM/to Logistics Company

Are you familiar with the terms like 'transactional relationship' or 'strategic alliance'?
How are business relationships classified in your company?
How many different relationships do you have to OEM/logistics companies? Approximately?
Are you in direct contact with an OEM/a logistics company?
How would you describe your company's relationship to OEM/logistics company?

3. Section: Outsourcing

Do you have any connection to the topic 'outsourcing' in your working life? If yes, what?
Do you use outsourcing in your company?
How is outsourcing in your company defined?
Have you been involved in any outsourcing process within your company? How? Which task was outsourced?
What is necessary for a firm to get an outsourced task?
What could be/is your advantage compared to other companies to gain a new task that should be outsourced?

4. Section: 3D Printing

Do you have any connection to the topic '3D printing' in your daily working life? If yes, what?
Do you use 3D printing in your company? In which areas?
How can your company gain benefits by utilizing 3D printing?

5. Section: 3D Printing and Outsourcing

Why is 3D printing a technology that could be outsourced? Why not?
Which companies are suitable candidates to outsource production via 3D printing to them?
Would you outsource the entire production via 3D printing? Or only parts? Why?
Do you think 3D printing can be outsourced to logistics companies?

6. Section: Follow up Questions

Opportunity to ask additional questions

7. Section: Closure of Interview

Interviewer: Do you want to receive a copy of the final Thesis?
Thank you for your time!