Organizational Changes and Barriers Related to The Implementation of Additive Manufacturing

Kousha Torabi 22449 & Nawar Al-Ebadi 22907

Abstract

This study examines the organizational changes occurring in the implementation of additive manufacturing and identifies the barriers related to it. Since additive manufacturing is but recently being implemented on a large scale, there exists very little research on how it affects a company on an organizational level. Hence, we have conducted a qualitative study where we interview four different companies regarding their work with additive manufacturing. Further, we analyze our collected data together with complementary secondary data on the basis of theories regarding implementation of new technology. Our findings show several changes - both at an organizational and operational level - that occur in relation to the implementation of additive manufacturing. Furthermore, multiple barriers associated with individual unlearning have been identified. The findings of this research contributes to the field of new technology management by evaluating existing theories and to some extent extending them to be more applicable to this specific technology.

Keywords: Rapid prototyping, 3D printing, Additive Manufacturing, Rapid Manufacturing, Operations management, Contingency theory, Product development, New technology management, Process design

Stockholm School of Economics
Bachelor Thesis in Management, 15 ECTS
Department of Management & Organization
Supervisor of the Bachelor Thesis: John Söderström
Date of presentation: 2015-06-02

Table of Contents

1. Introduction

The following part describes Additive Manufacturing and how it works. Further, it discusses the purpose of the study and previous research conducted on the area. Finally, the scope and research question of the study is presented.

1.1 Background

For decades, contingency theory has been one of the major areas within management research. It is the theory that there is no single best way to structure an organization. Instead, the optimal way for each organization is dependent on the internal and external situation. Ever since the birth of contingency theory, researchers like Joan Woodward have contributed with research regarding how organizations may have to reorganize based on the technology that they are using (Orlikowski, 2015). With modern IT-systems being implemented and changes in digital infrastructure, the 90:s was a very interesting decade for this field. There was a lot of research published on what is called Advanced Manufacturing Technologies (AMT) and the organizational changes it could imply.

Today, additive manufacturing (AM), a rather disruptive technology, is being implemented. Almost all research regarding new technology management and contingency theory is based on subtractive manufacturing and traditional methods. Consequently, there is a need to update the research within these areas in order for it to be applicable on AM. Hence, we find it immensely interesting to explore what implications this disruptive technology has for the field of new technology management.

AM is a technology that has been elaborated with for decades. However, it is not until recently that the technology has reached a level of effectiveness and accuracy enabling organizations to utilize it on a broader scale (Berman et. al. 2012). It is currently being used in a wide range of industries such as the development and production of medical devices, fashion/sports items and vehicle components. An extensive survey conducted by PWC (2014) shows that 66.7% of manufacturing companies are adopting AM in some way and that only 6.7% have no plans of doing so. Thus, there is clearly an upward trend in the number of organizations utilizing the technology. Furthermore, PWC found that that 25% of manufacturers are currently

implementing AM solely for prototyping and 10% are using it for both prototyping and manufacturing final products (PWC, 2014), which indicates that the technology is applicable to both prototyping and manufacturing processes.

This trend of increased implementation of the technology is further confirmed by an estimation by General Electric, stating that by 2020, approximately 50% of their products will in some way have been touched by a 3D-printer, either in prototyping or final production. (Investor's Business Daily, 2013) Another large manufacturer that has applied AM into their processes is Ford Motor Co., who was earlier using a method of designing sand molds and cutting castings from them. They have mentioned that they saved up to two months thanks to using AM when designing a particular cylinder head (Wall Street Journal, 2013).

AM uses layer-by-layer manufacturing by adding material continuously in order to build a component or a finalized object rather than subtracting it from a larger block. The 3D-printers used in AM are connected to a Computer-Aided-Design (CAD) software, which supplies the information on what to print. This implies that AM in many cases enables organizations to almost eliminate delivery time for physical goods, the same way the internet did with information (Campbell et. al. 2011). The digital object is virtually sliced into layers and manufactured by the printer by adding these layers on top of each other (Berman et. al. 2012). This enables a wide range of new possibilities when it comes to how objects are produced. For instance, one can now produce hollow components in one piece instead of adding two or more parts together. Since everything is constructed by thin layers, it is also possible to print whole constructions consisting of multiple components with full mobility. Consequently, structures that earlier had to be built by assembling parts can now be produced in one piece and many products can now be made lighter and more durable.

1.2 Previous Research

Since AM is a technology that has recently been implemented, there is almost no research about the organizational changes and challenges associated with implementing it into the manufacturing and prototyping processes. The current research mainly concerns the

technology itself and its possible applications. In other words, there is practically no research on additive manufacturing methods from an organizational perspective. There are however speculative articles discussing the potential organizational changes that AM can cause (Petrick & Simpson, 2013)

However, an extensive amount of research has been conducted on the implementation of Advanced Manufacturing Technologies (AMT). This includes computer controlled or microelectronics based equipment used in the design, manufacturing or handling of a product. Today, most of these technologies can be considered to be outdated and we believe that the theories aren't completely applicable to AM since they are based on different types of advanced technology.

There is however a significant amount of research regarding the implementation of new technology and how this affects companies as well as what the barriers to implementation might be. However, these studies are usually based on subtractive manufacturing and IT related systems, which has different characteristics compared to AM. Hence, there is a need to complement this previous research with studies conducted on the implementation of AM and the changes and barriers to implementation associated with it.

1.3 Purpose

The innovation survey conducted by PWC (2014) clearly indicates an almost exponential growth in the implementation of AM into manufacturing and prototyping processes. Thus, it is clear that there will be an extensive need for research on the subject. When such a disruptive technology is implemented, there are several management-related aspects that need to be taken into consideration. Since the existing research on this area mainly concerns older technology with characteristics largely different from AM, we aim to conduct an exploratory study to examine what organizational changes and barriers to implementation are associated with this specific technology, as well as evaluate the applicability of previous theories regarding new technology implementation. Furthermore, this is a relatively young and unexplored

subject, which gives us the opportunity to contribute to the field of management with new conclusions and inspire for further research on the subject.

1.4 Scope

We have chosen to look specifically at companies or departments within companies that use AM in their manufacturing and/or prototyping processes, primarily since this is where the technology is being applied as of today. In particular, we focus on the changes and barriers to implementation implied by implementing AM into these processes. This includes organizational, cultural as well as operational aspects of the implementation process.

Due to the nature of the topic, we consider that the geographical aspect of the scope is irrelevant when studying the implementation of a specific technology. Therefore, the study includes companies from various regions, both within and outside of Sweden.

1.5 Research Question

Based on the previously described background and purpose of our thesis, our research question is as follows:

What are the organizational changes and barriers related to the implementation of additive manufacturing technologies?

Below follows a definition of organizational changes and barriers to implementation that we have had in mind when conducting our research.

Organizational change: the process in which an organization changes its operations, technologies, organizational culture or strategies in order to achieve a greater output or become more effective and efficient.

Barriers to implementation: what makes it difficult for the necessary changes to happen in the implementation process.

1.6 Abbreviations & Definitions

In this thesis, a certain terminology is used that might not be familiar for all. Hence, we have chosen to summarize the most recurring and relevant terms and abbreviations in this section.

3DP - 3D-Printing or additive manufacturing.

AM - Additive manufacturing or 3D-Printing.

AMT - Advanced Manufacturing Technologies - A computer-controlled or microelectronics based equipment used in the design, manufacture or handling of a product.

CAD - Computer Aided Design - Softwares used for designing and prototyping digitally.

NPD - New Product Development - The complete process of creating a product and bringing it to the market.

2. Methodology

The following part describes and justifies our chosen scientific approach to the study. Further, we discuss our primary and secondary data collection. Finally, we make a quality assessment of the study and discuss its applicability and trustworthiness.

2.1 Scientific Approach

2.1.1 Inductive vs Deductive Method

The methodology implemented for our research is based on the notion of induction. That is, the study uses the collected empirical data in order to build a theoretical framework used to analyze the data (Bryman, Bell, 2013). The main reason for why an inductive methodology is preferable is the fact that this research area does not provide an adequate, clear theoretical framework on which we could base the empirical data collection on. Thus, it is not optimal to use a deductive approach. Instead, we continuously build the theoretical framework on an iterative basis by using the collected empirical data.

2.1.2 Positivist vs Interpretivist Epistemology

Recall that this study aims to investigate the changes and barriers of implementing AM into the manufacturing and prototyping processes. This implies that the collection of primary data needs to put emphasis on how individuals within the investigated organizations perceive the changes and barriers of implementing AM. For this reason, an epistemology based on the notion of interpretivism is preferable for this study. Although the positivist approach has dominated organizational research throughout the years, it would not be optimal in our case since it implies only taking into account non-subjective information such as numerical data on changes within the investigated organizations (Duberley et al, 2012). Although such data is highly relevant for answering the research question, it does not provide an exhaustive view of the changes and barriers of implementing AM. Thus, we need to dig deeper to answer our research question.

2.1.3 Qualitative vs Quantitative Research

Due to the nature of the research question investigated in this study, we have chosen to conduct a qualitative research. A qualitative research enables a higher degree of flexibility when collecting data since it allows for the inclusion of subjective information regarding how individuals perceive certain changes and phenomena. For this reason, qualitative research is more in line with an interpretivist epistemology (Bryman, Bell, 2013).

2.2 Conducting a Qualitative Case Study

We have conducted a case study by interviewing managers at various organizations that have implemented AM. The case study method implies several advantages for this particular research. One of the main advantages is the ability to ask questions of why, what and how regarding a specific phenomenon. This is essential in order answer our research question since it allows us to dig deeper into the experiences of organizations that have implemented AM. Furthermore, the case study method is an effective way to investigate relatively unexplored areas since it allows a less restricted way of collecting different types of information. Thus, it does not require a high level of prior knowledge regarding the subject (Meredith, 1998).

Upon deciding the number of organizations and interviewees to include in our study, we faced two significant limitations. These consisted of a narrow time scope of conducting this research as well as limited accessibility to organizations. Moreover, we faced a dilemma when trying to identify the ideal number of cases to include. As discussed by Voss et al (2002), there is a trade-off between the depth of observation and the generalizability of a case study. While having a low number of case studies allows researchers to provide a deep and thorough understanding of the investigated phenomenon, it limits the generalizability of the findings derived from the case study. To manage this tradeoff, we decided to include four organizations and a total of seven interviewees. These organizations vary in terms of size and industry, which allows us to sort for any size or industry-specific changes and challenges of new technology implementation that is not directly linked to the specific characteristics of AM. This increases the generalizability without needing to reduce the depth-of-observations of our study.

In regards to the number of interviewees, we found that the implementation of AM within an organization is usually managed by 1-4 individuals. Consequently, the possession of relevant information is limited to very few people, which makes the inclusion of a larger number of interviewees an inefficient utilization of our time and would not add value to the study. This is supported by other researchers such as Rowler (2012), who found that conducting few, longer interviews is preferable if a researcher can identify specific individuals who are in key positions to understand a certain phenomenon.

2.2.1 Interviewee Profiles

	Interview object	**Position**	**Location**	**Date**
1	Andreas Graichen, Siemens	Team Leader & Senior Specialist Manager of AM	Swedish HQ, Finspång	2015-04-22
2	Pajazit Avdovic, Siemens	Innovation Coordinator of 3D-printing team	Swedish HQ, Finspång	2015-04-22

3	Jonas Eriksson, Siemens	Laser Specialist of 3D-printing team	Swedish HQ, Finspång	2015-04-22
4	Håkan Brodin, Siemens	Materials Engineering Specialist	Swedish HQ, Finspång	2015-04-22
5	Anonymous, Global Car Manufacturer	Senior Principal Engineer at the AM department	Telephone	2015-03-13
6	Torbjörn Åkesson, Torbjörns Team	Founder & CEO	Telephone	2015-04-14
7	Mikael Schuisky, Sandvik	Operations Manager at the AM-department	Telephone	2015-04-14

2.2.2 Interview Design & Structure

The interviews conducted in this study have been performed in a semi-structured manner. In other words, they have been based on an interview guide, which highlights several important, broad subjects that are used to guide the interviewer (See Appendix A). This is more suitable to the context of this study than other types of structures since it helps us moderate the content into relevant areas without asking leading questions. This is particularly important in our case since the relevance between management and AM is often unclear to the interviewees. Therefore, it might not be easy for them to independently identify what information is of relevance to us.

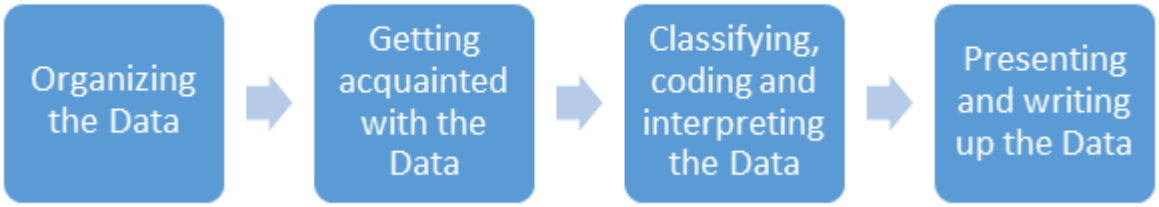
The interview guide has been formulated in accordance with the recommendations provided by Bryman and Bell (2013). To begin with, we used the research question as a main starting point in order to evaluate what subjects that are essential. Further, we have formulated a number of questions for each of the subjects in order to help the interviewer keep up the flow of the interview. When formulating these questions, it has been important to keep in mind not to ask the interviewees leading questions, since it would generate a bias towards the perceptions of the interviewer. Finally, the interview ends with repeating to the interviewees the responses that have been noted for a chance to correct any misconceptions.

Due to the geographical distance, three of the interviews were conducted via telephone. This creates several issues that need to be highlighted, among them the inability to perceive and analyze the body language of the interviewees, which is often of high relevance since it communicates implicit information about their perceptions. In order to assess this issue, we recorded and transcribed all interviews (with the approval of the interviewees). Tape recordings has been proven to be an efficient tool in mitigating personal biases associated with the interviewer, such as the tendency to only register information that the interviewer himself agrees with (Voss et al, 2002).

2.2.3 Interview Data Analysis

The data analysis has been conducted in accordance with a model, which includes four key components (Rowler, 2012).

Figure 1: Four-component analysis model for qualitative interview data



Organizing the Data

To begin with, we organized transcribed data collected from the interviews by dividing it into the different subjects that were included in our interview guide. This simplifies identifying the relevance of the data as well as to which part of the analysis it belongs to. For instance, by collecting all data regarding any changes in process layouts and placing it in the same category, we can easily identify any patterns between the changes in process layouts experienced in the different organizations.

Getting Acquainted with the Data

Since all interviews were transcribed, it became natural to get acquainted with the data using a structured reading. That is, we thoroughly read the data while at the same time annotating patterns, key findings and quotes that were of interest for the analysis.

Classifying, Coding & Interpreting the Data

The activities of classifying and coding data were conducted in parallel with previous stages by dividing the data into subjects used in the interview guide as well as conducting a structured reading. The interpretation of the data was however done through multiple discussions with our supervisor and other researchers. By involving various individuals in the interpretation process, we reduced any personal biases related to any preconceived ideas we had regarding the subject.

Presenting & Writing up the Data

The findings derived from the data analysis are presented in the same subjects that were used in the initial stage of organizing the data (see section 4.0). Since these subjects are based on the interview guide, which was constructed in a conversational-friendly manner, it helps presenting the data in an order that is easy to follow.

2.2.4 Complementary Secondary Data

For some of the organizations included in our study, we have analyzed short films demonstrating how the organizations utilize AM technology. These have provided us with clear descriptions of the processes in which the technology is implemented, which is especially important in the cases where we have not had an opportunity to visit the organizations.

PWC have conducted an extensive survey containing rather detailed answers from a large number of firms regarding if they are using AM and if so, how and for what. This survey provides us with sufficient information in order to draw conclusions on the number of organizations planning to implement the technology and how the ones that already have are using it. This data was used in the background section (see section 1.1)

2.3 Quality Assessment of Research

Traditionally, the quality measurements used to evaluate research studies are reliability and validity. However, many researchers have reached the conclusion that these measurement tools are not fully applicable for qualitative research (Bryman, Bell 2013). In the case of reliability, it is problematic to use it as a quality measurement tool because of the difficulty to repeat a qualitative study and reach the same findings. This is due to subjective factors that affect the outcome of a qualitative study, such as the behavior of the interviewer as well as the data interpretation process. When it comes to validity, it is often measured using quantitative tools such as assessing the correlation between various variables, also known as internal validity. This is problematic for a qualitative study since the data collected is not numerical and therefore cannot be assessed using quantitative tools. Therefore, we have chosen to use alternative quality assessment tools that are more adapted to the nature of qualitative studies. These are credibility, transferability and authenticity (Bryman, Bell 2013).

2.3.1 Credibility

Credibility concerns whether the research have been conducted in accordance with the prevalent rules and agreements with stakeholders involved in the research, particularly the interviewees. We have ensured achieving a high level of credibility by maintaining a continuous exchange of information with the individuals that have been interviewed. The empirical results included in our findings have been sent to the interviewed individuals in order to give them the possibility to make any necessary corrections and add additional information, a technique commonly known as respondent validation (Bryman, Bell, 2013). Furthermore, all interviews included in our study have been recorded after an agreement with the interviewed individuals. By using transcripts of the interviews, we enhance the credibility of the study by ensuring that no parts of the interviews are forgotten.

2.3.2 Transferability

The notion of transferability assesses whether the findings of a study holds in different contexts. Having a high level of transferability is essential in order to make valuable contributions to the research field and enable the readers to use our findings for their specific

context. One technique we have used to increase the level of transferability is the inclusion of various organizations and individuals from different organizational levels in the empirical data. This diversification of our empirical data increases the applicability of our findings on different contexts.

2.3.3 Authenticity

Authenticity is assessed in the same way that we ensure a high level of credibility, namely by using the technique of respondent validation. Furthermore, authenticity concerns whether organizations involved in our study are able to extract recommendations and take appropriate measures based on our findings, i.e. tactical authenticity (Bryman, Bell 2013). To increase the tactical authenticity of our study, we have ensured to share our research findings with the involved organizations and highlight any potential key takeaways relevant to them.

3. Theoretical Framework

In this section, we describe the theoretical framework used for the study and its limitations. In addition, we explain how the theoretical framework is used in the analysis of the empirical data.

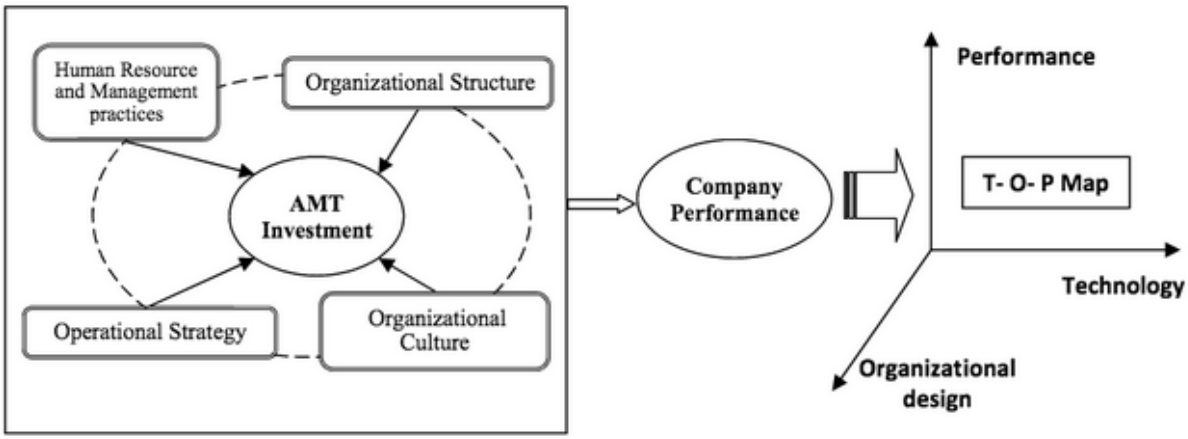
3.1 Organizational Changes Related to Implementing New Technology

This section includes research regarding organizational changes associated with implementation of new technology into an organization. By applying the theories emerging from this research area, we can create an understanding regarding the contingencies associated with the exploitation and implementation of Additive manufacturing into the processes of a modern organization.

An article by Saberi and Yusuff (2011) discusses a strategic framework for implementing AMT and how it should be handled to optimize the performance of a firm. In the article, they present a model (see figure 2) where four different organizational factors are taken into account concerning the AMT investment. First, they discuss the importance of using the correct organizational structure. Secondly, they talk about the impact of organizational culture on the implementation process. Thirdly, they discuss the organizational and manufacturing strategy and lastly they view it from a human resources and management perspective. These factors are

related to the company performance and to a three-dimensional T-O-P map that describes the relation between performance, organizational design and technology.

Figure 2: Framework for understanding organizational changes in AMT investment



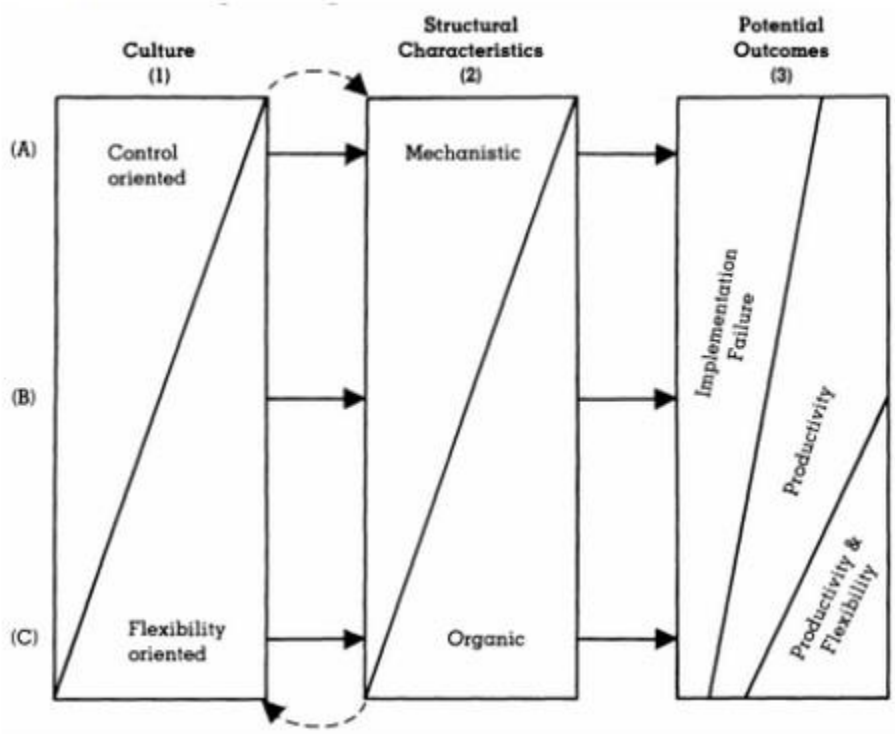
Organizational Structure

The structural perspective in this model is divided into the three dimensions often used in research and practice (Ghani et. al. 2002). These are centralization, formalization and complexity. Centralization refers to the delegation of power in the jobs regarding the technology. Formalization refers to goals and visions that are written and communicated, while complexity concerns a number of factors such as the number of dissimilar departments or different job titles. Furthermore, the authors argue that these three dimensions need to adapt in accordance with the implemented technology. It states that flexible and computer based technologies require more organic and less hierarchical structures. The classical hierarchical pyramid thus needs to turn more into a diamond shape with more middle managers. One of the main reasons for having a good internal structure is that implementing new technologies often results in a need for increased communication and knowledge transfer between two or more departments. Finally, Saberi and Yusuff state that companies with less complex structures with maximum administrative decentralization will have better success rate in implementing new technology than organizations with higher formalization and complexity.

Organizational Culture

In this context, organizational culture is defined as "*the shared values and beliefs of an organization's members, which manifests itself in the ends the organization seeks and the means it uses to attain them"* (Saberi and Yusuff, 2011). In their study, two types of organizational culture are identified, namely control oriented and flexibility oriented. The connection between these cultures and the implementation of AMT is illustrated in figure 3.

Figure 3 - Relationships among culture, Structure and AMT Outcomes



Consider company A in figure 3, who has a highly control-oriented culture. This culture manifests itself through high power centralization, formalization and complexity. This creates obstacles for company A to implement AMT into the organization since it hinders the employees working with the technology to fully exploit the benefits of increased flexibility (Saberi and Yusuff, 2011). Consequently, employees are demotivated, making them likely to reduce their effort and dedication to their work. This creates an environment where a successful implementation of AMT becomes very challenging (Saberi and Yusuff, 2011).

In contrast to the case described above, company C in figure 3 would experience an easier AMT-implementation process due to its flexibility-oriented culture, which manifests itself through an organic structure with high power decentralization and generalist job descriptions. Consequently, the organization has values advocating high employee commitment. Such commitment enables a much higher level of trust, which in turn simplifies the management of fear and insecurity among workers associated with the perceived risks of implementing AMT. This model thus proposes that changing the cultural dynamics of an organization toward a much more flexibility-oriented culture is a highly likable due to its correlation with success rate of implementing new technology.

Operational & Manufacturing Strategy

In this context, strategy is defined as actions carried out in the purpose of reaching a specific goal. Saberi and Yusuff use the general agreement that a firm's strategy consists of a combination of four key competitive priorities: cost, quality, flexibility and dependability/delivery. Further, the article argues that the fit between an organization's key competitive priorities and its decisions regarding technological investments is a significant factor in determining the implementation success (Spanos and Vodouris, 2009).

Human Resources & Management

A successful implementation is unlikely to occur without having the human resources onboard (Malhotra and Heine, 2001). Saberi and Yusuff mention that the scope and responsibilities of the employees working with new technology will most likely increase after the implementation. (2011). Further, it will be necessary to adopt effective management practices and to hire managers with relevant experience, the right competence and suitable characteristics for the technology that is to be implemented.

The Role of Design-Manufacturing Integration

There is research discussing the possible effects of implementing AM on the integration between design and manufacturing (Patrick, Simpson, 2013). This research concludes that there will be a much higher integration between the design and manufacturing processes due to the

implementation of AM. Furthermore, researchers argue that the economies of scale will matter less as AM is becoming more commonly used since it enables companies to produce single, highly customized products, at a low cost. However, these findings are merely conceptual and are not based on any empirical data.

Using this research, we examine the role of design-manufacturing integration within the organizations in our qualitative study. By doing so, we can create an understanding regarding the importance of design-manufacturing integration when implementing additive manufacturing.

Applicability

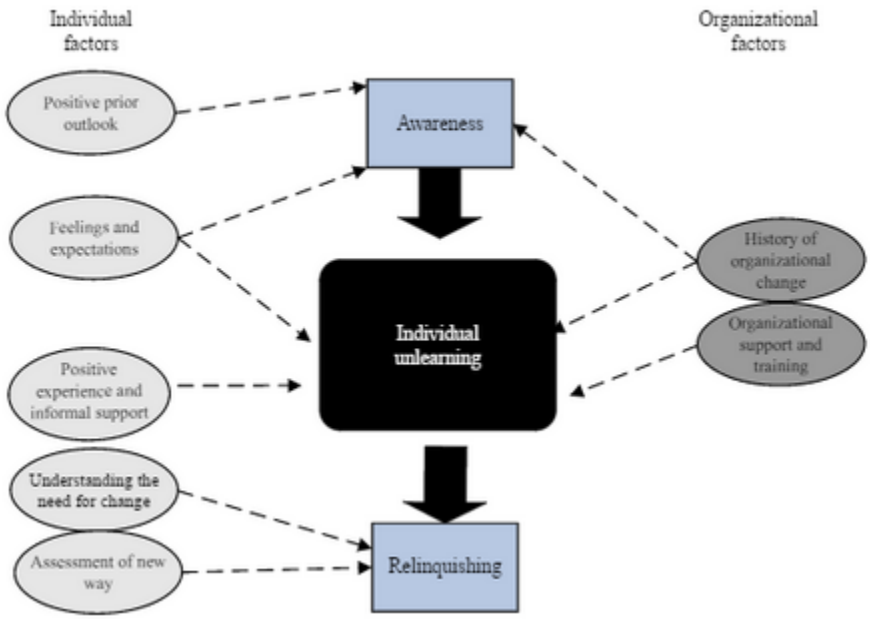
The studies on which the theories above are derived from are based on implementation of relatively old and outdated advanced manufacturing technology. Therefore, there is an uncertainty regarding the relevance of these findings to additive manufacturing. Thus, the model is used in our study to assess whether the implementation process of organizations who have implemented AM creates the organizational changes brought up in these studies. By doing that we can create an understanding regarding the role of the four perspectives in figure 2 in regards to the implementation of AM and the organizational changes related to it.

3.2 The Challenges Associated with Implementing New Technology

A significant amount of research has been dedicated to illustrate the fact that projects, which aim to implement new technology, often end in failure (Cozijnsen et al, 2000). In an extensive quantitative research discussing the challenges of implementing new technology, Becker found that failure in implementing new technology is often caused by major challenges associated with facilitating unlearning within the organization. In this context, unlearning is defined as *"the process by which individuals and organizations acknowledge and release prior learning, in order to accommodate new information and behaviors"* (Becker, 2005). Based on these findings, Becker manages to develop a model (see figure 4) explaining factors influencing individual unlearning within an organization during the new technology implementation process. The

model divides these factors into two categories, namely individual factors and organizational factors.

Figure 4: An model explaining individual unlearning during the technology implementation process



Individual Factors

In her study, Becker identifies five individual factors that can impose challenges to the unlearning process when implementing new technology (2010). The first factor concerns the outlook regarding the new technology that employees have prior to the implementation. If a negative prior outlook hinders the implementation, the implementers will face the challenge of communicating the importance of the new technology early in the implementation process.

The second factor concerns the feelings and expectations of employees regarding the new technology. Becker found that terms such as “worried”, “anxious” and “uncomfortable” often came up when assessing how the employees felt during the implementation process. These feelings expressed by employees can in many cases lead to an internal resistance hindering the implementation process.

The third factor concerns positive experience and informal support during the implementation process. If individuals receive informal support for the change from their supervisors, they are

more likely to be much more committed to the change. If, however, the supervisors perceive the new technology as a ”temporary management fad” that is unlikely to become a permanent change, they will discourage employees to engage actively in the implementation process and unlearn their past practice. This sets a barrier for the implementers to convince employees that the change is permanent and encourage them to take on an active role through informal support.

The fourth factor included in Becker’s model is the importance of creating an understanding regarding the need for change. Becker’s empirical study indicated that the process of understanding the need to implement a new technology is continuous and does not end in the initial phases of the implementation process. The same goes for the fifth individual factor, which concerns the assessment of the new technology. Thus, a main challenge associated with new technology implementation is to provide the necessary tools to continuously assess the efficiency of the new technology.

Organizational Factors

Becker identifies two main organizational factors affecting individual unlearning during the new technology implementation process. The first one concerns the history of organizational change within the organization, which can become a barrier to implementing new technology if previous organizational changes were poorly managed. This can lead to a strong reluctance towards change among individuals and a high level of inertia.

The second organizational factor identified by Becker concerns the organizational support and training provided to individuals during the implementation process. The provision of support and training to the employees is essential in order to tackle the challenge deriving from the accommodation of previous technology with the new one since, in many cases, the change from existing technology to a new one is performed gradually and cannot be done instantly.

Applicability

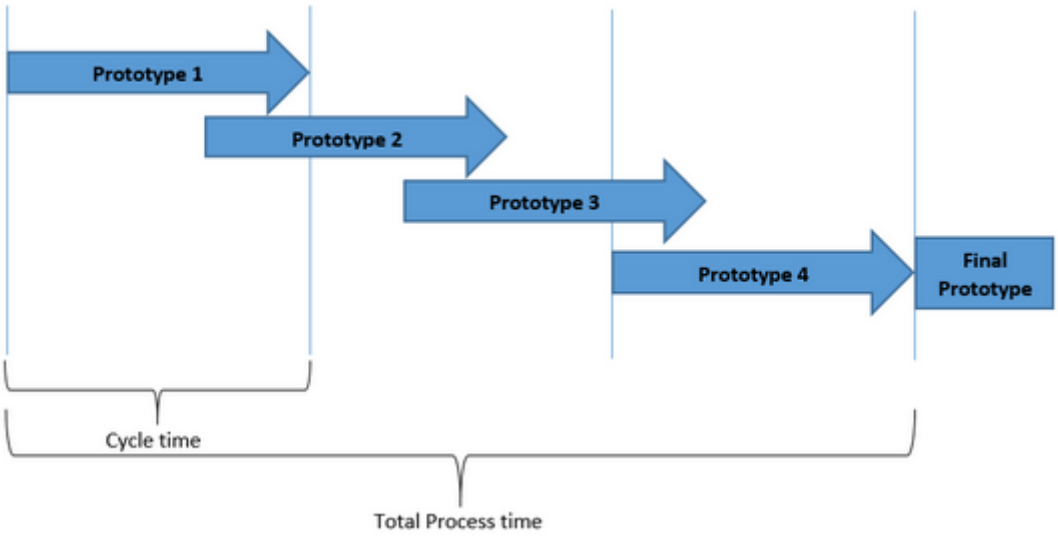
The model developed by Becker provides us with a theoretical framework, which we can utilize in order to analyze the barriers of implementing AM. This allows us to create an understanding regarding the individual and organizational factors causing these barriers. Furthermore, our analysis can provide an extension to Becker's model by assessing the limitations of her research. Firstly, her research is based on the assumption that technology is subtractive rather than additive. Therefore, we evaluate the applicability of her research on the basis of our findings. Secondly, the model developed by Becker is based on a study of only one single organization. This implies limitations in regards to the transferability of her findings. Since our study is conducted on several organizations, we can assess this lack of transferability.

3.3 Optimization of Manufacturing & Prototyping Processes

This section presents research regarding different tools and strategies to improve prototyping and manufacturing processes. In our study, we use this research to analyze the possible effects of implementing AM on the organization's processes and whether it can optimize these processes.

A research paper by Bare and Cox (2008) discusses that organizations in many cases have inefficient routines when it comes to working with prototyping. The study analyzes a company using a prototyping method where the prototypes are produced in parallels in order to save time (see figure 5). The production of prototype 2 commences before prototype 1 is finished and tested. Consequently, the errors in prototype 1 will be taken care of in prototype 3, and so on. This is suboptimal in regards to reducing waste as it creates ineffective knowledge transfer between different prototypes.

Figure 5: Prototyping process with Ineffective knowledge transfer



Using these findings, we analyze the impact of the AM technology on prototyping processes and whether it can optimize the prototyping process by improving knowledge transfer between different prototypes.

When it comes to the manufacturing process, there is previous research stating that implementation of AM optimizes the process by reducing total throughput time (Berman, 2011). However, some researchers argue that the technology requires more time and resources to be put into quality control due to limitations in the used material (Mellor et al, 2012). Thus, based on this contradictory research and our empirical data, we evaluate whether implementing AM can in fact optimize the manufacturing process.

The Process Layout Model

This model describes four different process layouts (fixed position, functional, cell and product) and shows how these should reflect the characteristics of the products produced such as volume and variety as well as the technology used to produce them. In addition, it presents methods for choosing the most appropriate layout (Groover 2007). Whether the process technology is appropriate or not is decided by the degree of automation, the scale/scalability and the coupling/connectivity of the technology.

Although there is a vast amount of research confirming the validity of this model, there is no proof of the applicability of this model on processes using additive manufacturing technology. Thus, we apply this model in order to create an understanding of how the operations processes changes when AM is implemented, while at the same time evaluating the applicability of this model on processes based on additive technology.

4. Empirical Data

In the following section, we present primary data that has been acquired in the interviews as well as secondary data that we have found to be relevant.

4.1 Background of how the Interviewed Companies use AM

Sandvik

Sandvik is in the very early stages of using AM and they are currently evaluating how it can be used in both prototyping and manufacturing. According to Michael Schuisky, they implemented AM because of the great potential of the technology. He stated that it has many areas of use where both Sandvik and their customers can benefit. The AM division within Sandvik believes that it is the future and that they might risk falling behind if not keeping up with the high-paced technological development.

Furthermore, they have created a new unit that operates closely to the board, and focuses solely on AM. This unit is currently focusing on R&D regarding how and where the technology can be implemented into their processes. Since they are already one of the major suppliers of the metal powder used for metal 3D-printers, this is the technology that they are focusing on. Since they have use of the components themselves and many years of experience regarding the raw materials, they hope to be able to realize important synergies over different areas and departments by expanding their usage of AM. In addition, they have many decades of experience when it comes to engineering and working with different technologies.

Global Car Manufacturer

For the Global car manufacturer, the main reason for implementing AM was to improve their current NPD-processes by increasing their efficiency. They are primarily using it for prototyping

and manufacturing test parts to assess their fit and compatibility. Also, the senior principal engineer interviewed mentioned that they couldn't use the current technology directly in their production since they produce too large volumes.

As of today, their most successful use is for injection molding, where they are able to combine CAD and AM. Injection molding is a process of manufacturing components by injecting material into a mold. This used to take a lot more time since it earlier needed to be crafted manually. Thanks to AM, they are now able to optimize the production of tools and molds, thereby simplifying the entire process.

Earlier on, the company used to sculpture their prototypes by hand from a sand-based material. This method is still being used but not to the same extent. The different methods for prototyping complement each other and it seems unlikely that AM will completely replace it in the short run, partially because designing a CAD file requires a lot of time.

Torbjörns Team

Torbjörns Team is a dental-technician laboratory that uses AM primarily to make molds for plaster. They are currently elaborating with different materials and colors by designing prototypes and turning ideas into physical realities.

Torbjörns Team bought the printer with the purpose of preparing dentists for intra-oral scanners and scans. Nowadays, dentists and dental technicians no longer get these in physical models mailed to them. Instead, they receive digital files, which saves both time and money. Hence, it is a big advantage to be able to print the model in order to prepare the dentists. Another reason for acquiring the printer was to avoid falling behind larger and more international competitors.

Siemens

Siemens utilizes AM both for prototyping and manufacturing. The technology was first introduced when they needed increase the efficiency of the repair process of a certain burner. By implementing AM into the repair process, they decreased the lead-time by 90%. This lead to

curiosity regarding where else they could benefit from this technology. Now they have a specific department dedicated to working with it. Today, additive manufacturing at Siemens is based on three main pillars: rapid prototyping, rapid repair and rapid manufacturing.

Rapid prototyping is the pillar described as the easiest, primarily since a prototype only needs to fulfill minimum requirements when it comes to the material and usage. Since it only needs to hold for a few hours or even just stand on a table, there are no specific long term standards to be met material- and quality-wise. The second pillar, rapid repair, is a way of repairing components significantly faster than with traditional methods. Processes that used to take up to 30 weeks can now be done in 3-4 weeks. The final pillar, rapid manufacturing, concerns production of goods and final components.

4.2 The Perceived Organizational Changes of Implementing AM

The changes that managers and engineers from the AM departments within the interviewed organizations have mentioned can be divided into two main categories. The first category includes changes connected to the organizational structure and culture. The second category includes changes related to the prototyping and manufacturing processes.

4.2.1 Organizational Structure & Culture Related Changes

The AM departments within organizations usually started out as more informal groups of people responsible for a new area in addition to their current ones. Some firms realize the potential of this technology for their processes, consequently decentralizing power and giving them more flexibility.

The combination of complex digital processes of the AM technology together with the analogous processes of traditional methods has been a recurring subject. Managers have needed to find ways to be able to combine these two types of technologies. This results in a need of a much higher level of variety in competence and skills.

In almost all cases, the ultimate solution for finding relevant and competent staff has been to combine the reallocation of current employees with recruiting new ones. The fact that the

printers are so automated will also lead to the reallocation of labor to some extent. The larger firms are looking for younger designers and engineers who preferably have been working with AM at their universities. The smaller firms often have a niche area where they cannot just hire an AM specialist since they need their designers to have a certain basic and more specific understanding of what they do. This has lead to some firms educating their staff further to adapt to the new technology and to learn the new design principles.

A majority of the firms are convinced that they will keep having a certain group within the R&D department that are focused on additive processes since the technology will keep evolving. This group will work closely with the departments or sections where the printers are being used for prototyping or manufacturing. Future recruitments for these departments are also expected to be aimed at people who have additive methods as a standard in their way of working.

It has been necessary to create a new manager position in order to properly monitor the work with AM. In some cases, employees have also been appointed project leaders for different units or areas. For instance, it is common that one is a laser specialist, another is a CAD/CAM designer that checks the new designed models printability etc. Another necessity has been to further develop the communication concerning the specific processes containing AM technology in order to meet the resistance caused by fear and insecurity regarding the new technology. For instance, Sandvik have considered arranging internal seminars for their employees in order to build awareness.

At Siemens, they have experienced a much higher degree of integration between the design and manufacturing processes. The constructors and designers need to communicate more. Since they are seeing a trend where almost all the prototypes are produced by AM, they find it important to increase the design-manufacturing integration in order to ensure that their prototypes can be produced with their traditional methods as well if necessary.

4.2.2 Operations & Process Related Changes

The organizations that have had the technology implemented the longest have experienced a change in the types of problems that can occur in the product development process. For instance, in Torbjörns Team, the problems associated with the traditional, subtractive methods often circulated around the speed and quality, since they often needed to redo their prototyping process if the customer was unsatisfied with the quality, leading to a much slower time to market and a high sunk cost. Now, problems are much more computer related and require a higher level of analytical problem-solving skills.

Almost all organizations experienced a much faster time to market as well as shorter cycle time. The technology also allows the organizations to develop more prototypes in the product development process, which in turn decreases the risk of default products and allows a more extensive and thorough testing of product designs before they are released. However, since the production technology and the used material are different, the properties of the components will also change. Hence, the quality control procedure needs to change. Consequently, some firms have had to add a step of quality control for printed parts. Further, the AM technology enables a higher degree of automation since the printers work overnight and on weekends.

It is difficult to see how the process layouts of the prototyping and manufacturing processes have changed and will change, mainly since most firms haven't gotten far their implementation of AM. At Siemens however, they are building a large 3D-printing facility where they have chosen a cell-layout. The reason being that the building needs to have a very strong ventilation system because of the residue and heat. Since the printers that Siemens will primarily work with metal powder and laser technology, it could cause a major health risk if a spill gets up into the ventilation system.

Furthermore, interviewees at Siemens state that the total number of steps in the design and production processes has decreased and that they are able to create more functionality in fewer steps. Since you are building your component while creating the material simultaneously,

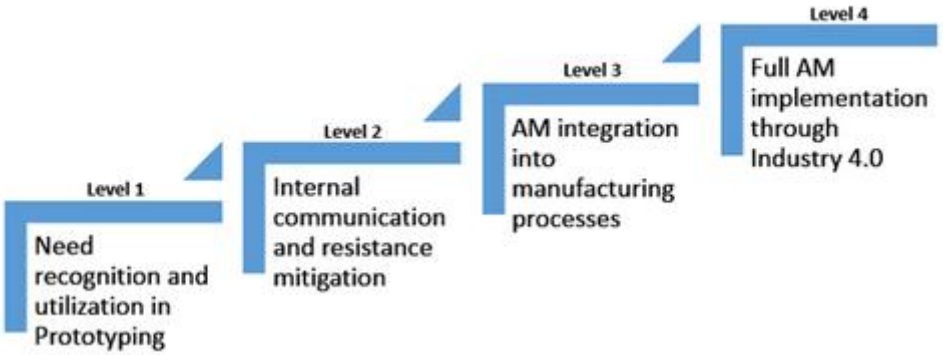
they've had to outsource their quality control which in its turn increases the lead time with a couple of weeks.

None of the companies believe that AM will replace all the traditional methods in either prototyping or manufacturing. Rather, it needs to be combined to achieve the best result possible. At Siemens, they've started using hybrid machines that combine different types of manufacturing technologies. Their main limitation is that it needs to work with material that can be handled by both a printer and traditional techniques.

4.3 The Barriers of Implementing AM Technology

Based on the data collected from interviews, we noticed a variation of hinders depending on what level of AM implementation an organization had reached. These can be illustrated by a model developed by Siemens (Figure 6) that identifies four main levels of AM implementation, each with their own set of barriers.

Figure 6: The AM four-level implementation model



Level 1 - Need Recognition & Utilization in Prototyping

For all organizations in our study the implementation of AM began in the prototyping processes since these processes have less stakeholders than the manufacturing or repair processes. At this stage, the implementation did not require taking into account any direct input from customers or other units in the organization outside the prototyping process. Furthermore, as mentioned earlier, the requirements for prototypes are not as formal and strict as the standards and requirements that manufactured products need to fulfill.

However, one challenge that arose at this level was to acquire the resources necessary for initiating the utilization of AM. This proved to be problematic for many of the organizations mainly due to fear and skepticism expressed from decision-makers towards the new technology. Håkan Brodin at Siemens described this skepticism as a very significant challenge that needed to be handled: *"Many of our managers didn't want us to put too much effort into implementing Additive Manufacturing because they were afraid of the risks and opportunity costs. It forced me to work with implementing the technology on overtime, in addition to my regular assignments."*

Level 2 - Internal Communication & Resistance Mitigation

At this stage, the implementation of AM reached the next level as it involved more co-workers within the organization from various divisions. In addition to prototyping, the technology began to be used in multiple areas such as product design and repair. Consequently, several of the implementation initiators within the organizations were faced with heavy resistance from individuals affected by the new technology. For instance, at Sandvik as well as in Siemens, the new technology was resisted by individuals with a high level of internal influence due to their conservatism regarding the traditional methods that they have used throughout the years. Due to ignorance regarding the properties and advantages of AM, many feared that using the technology would imply unnecessary work and effort.

The main resistance experienced at all organizations concerns the properties of the material used in AM. For instance, at Torbjörns Team and Siemens, many were not used to working with powdered material. This raised concerns regarding the sustainability and compatibility of the material. Furthermore, many individuals in the product design processes were used with working within clear frameworks. This complicated the implementation process since people were stuck in their traditional mindset characterized by explicit rules and standards. Andreas Graichen at Siemens explains:

"People are used to the fact that there are clear limitations for how you should design new products. They cannot fully let go of this way of thinking, which hinders us from being able to fully exploit the benefits of Additive Manufacturing".

The expansion of AM implementation with the organizations required the inclusion of individuals from several units. In the cases of larger organizations such as Siemens and the global car manufacturer, it caused challenges associated with coordinating the workload of individuals from various units and redefining their tasks. This required the implementation to be conducted by cross-sectional units including materialists, technicians, quality managers and communicators. This in turn created the importance to take into account different interests and perspectives.

Level 3 - Integration & Formalization of AM into Manufacturing

Organizations at this level have managed to integrate the AM technology into their manufacturing processes. Although only few organizations in our study had reached this level, we managed to identify several interesting barriers.

Firstly, a main obstacle experienced by Siemens was the increased requirements on the output produced by AM, since it began to be included in the final products. To ensure that these requirements were met, Siemens needed to find ways to evaluate the quality of the components produced by AM. This created the challenge of identifying how to include quality assessment into the operations processes, which requires a high degree of process flexibility.

Secondly, one of the major challenges emerged from the fact that no organization could fully replace traditional technology with AM. Consequently, implementers needed to find ways to combine AM with the traditional technology, which became problematic in cases where materials used in AM and traditional technology were not compatible.

Thirdly, the advantage of being able to construct highly complex structures created barriers when attempting to manufacture products that were designed using AM technology. Very

often, designers constructed structures too complex for the traditional manufacturing technology to produce. Moreover, difficulties emerged in limiting the freedom of design due to the high customization of AM technology. This challenge was however much less prevalent in organizations with a high level of design-manufacturing integration.

Level 4 - Full Implementation Through Industry 4.0

The final stage in the AM implementation process concerns full digitalization throughout the entire supply chain, also called industry 4.0. This would enable machines to communicate with each other and with humans. Although Siemens are gradually approaching this level, no organizations included in our study had fully reached industry 4.0, since it requires complete digitalization of the activities and transactions performed within the supply chain, including everything from concept generation to producing and delivering the end-user product. A main challenge experienced by Siemens when attempting to reach this level is the fact that there are multiple stakeholders who need to actively implement the technology and undertake necessary organizational changes.

5. Analysis

In this section, we will analyze the empirical data presented in section 4 using the theoretical framework presented in section 3.

5.1 Reviewing the Organizational Changes

This part of the analysis is based on the model from section 3.1 regarding organizational changes in AMT investment. The model is very broad and general since it aims to be applicable to all AMT investments. Hence, this part of the analysis sets out to pinpoint which are the most characteristic of these changes that are important to bear in mind when implementing AM. In other words, to what extent does this model hold for AM. These claims are supported by our findings presented in 4.1 and 4.2. In figure 7 below, the changes experienced by the interviewed firms have been categorized based on the different management perspectives presented in the model.

Figure 7: the organizational changes of implementing AM

Orgnizational Structure	Human Resources & Management	Operational Strategy	Organizational Culture
•New departments •More decentralization •Less formalization	•New managers positions •Increased responsibility •Re-allocation of staff	•Different view on the four key competetive priorities: cost, quality, flexibility and delivery	•More organic •Need for innovativeness and creativity

Organizational Structure

Just like the model of Saberi and Yusuff states (2011), our interviewed companies experienced a more decentralized structure where the managers of the AM department successively gained more influence on decision-making. Most of our interviewed companies also started a new department that works explicitly with the new technology. These departments were generally, just like the theory suggests, much less formal than the rest of the organization and there existed more space to deviate from current routines. The reason for this is that less formalization gives the specialized team a better opportunity to fully explore the potential of the AM technology. What Saberi and Yusuff do not mention however, is the fact that all our interviewed firms experienced a need for increased cross sectional communication. Most often, the purpose was to keep cross sectional compatibility of the products and to initiate a closer cooperation between the design and manufacturing department so that the competence regarding the new technology could be transferred effectively. In conclusion, based on the empirical data that we have collected, the main structural changes occurring when implementing AM into an organization are similar to the ones expressed by Saberi and Yusuff, with the exception of increased cross-sectional communication.

Human Resources & Management

Since AM is a new area for the companies implementing it, naturally there will be a need for someone to manage it. Most of our interviewed companies have eventually created a new managerial position and in one way or another either recruited new or reallocated existing staff. When it comes to the increase in responsibility for the staff, this only occurred at Siemens where AM was implemented and the responsibility added to the already existing tasks of

material engineer Håkan Brodin. However, from another point of view, there was a clear emergence of many new areas of responsibility. For instance, the current CAD designers need to learn the new way of working and the quality controllers need to establish new routines. Overall, our findings in this area are in line with what the theory suggests.

Operational Strategy

According to Saberi And Yusuff, a company's fit between the four key competitive priorities cost, quality, flexibility and dependability/delivery is a significant factor in determining its success with implementing an AMT. For AM specifically, we have found that the optimal fit differs in regards to if you are focusing on prototyping or manufacturing. In the case of prototyping, the main benefits are related to cost and flexibility. In most cases, the cost of prototyping decreased significantly. The flexibility of the process increased due to the multiple settings and options of the materials and the printers. Also, the new hybrid machines make it possible to both subtract from, and add to, earlier manufactured prototypes. The quality is not as much of importance since a prototype only needs to last during a test run or even stand still on a table as a model. On the other hand, when manufacturing a product that will be included in a machine or exposed to a higher degree of stress than a prototype, all four priorities are of similar importance. However, when AM has been implemented, firms experience a much higher degree of flexibility. This positive change is however somewhat countered by the increased need for quality control due to the fact that the material and the component is manufactured simultaneously.

Organizational Culture

In general, the interviewed companies have realized that a more flexibility oriented culture with less centralized decision-making and complexity is the best way to adopt a new technology, just like the theory suggests. Even though it would be optimal, this is not the way many companies work, especially larger companies like Sandvik and Siemens who need more established routines and structural control to be able to monitor their work. What the theory does not mention however, is that even a more complex company with more structural characteristics

can partially simulate this type of cultural environment by giving more power to the department in charge of implementing the technology. This is something that we have seen at Siemens for instance, who seems to be doing great progress with their implementation process. The smaller firms are more affected by the technology when it comes to how the organizational culture evolves around it. We have seen that they experience a shift towards a more organic and less hierarchical structure, just as what Saberi and Yusuff suggest is optimal.

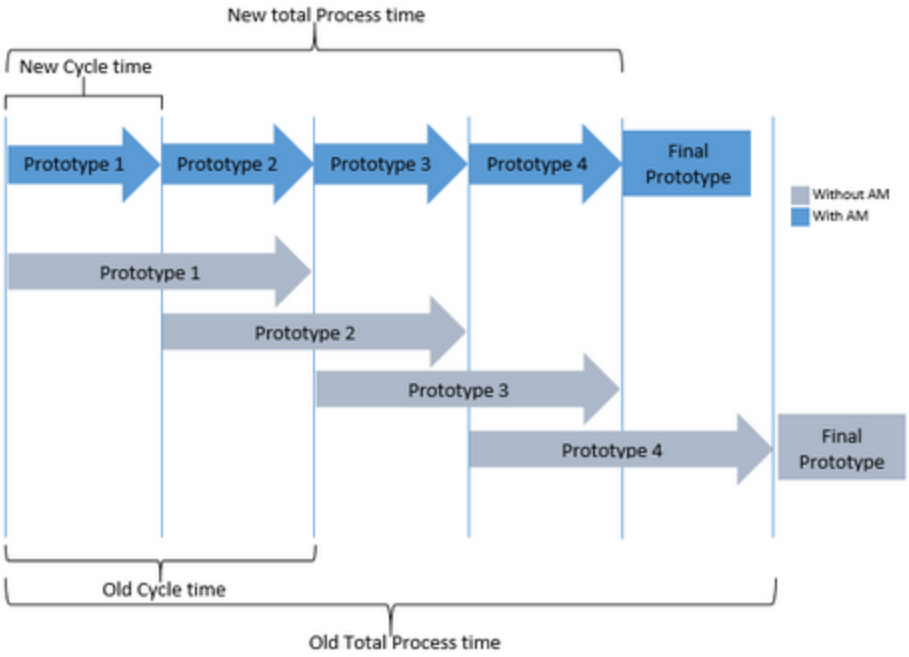
5.2 Reviewing the Process-related Changes

In this section, we analyze the changes of implementing AM related to managing the processes where the technology is being implemented. To begin with, we examine the changes, which occur in the prototyping process by applying the theory of Cox and Bare regarding optimization of prototyping processes (see section 3.3). Furthermore, we analyze the empirical findings of our study regarding the changes in production processes by relating it to conceptual theories presented in previous research. Finally, we apply the process layout model by evaluating its applicability on operations processes based on additive technology.

Changes in the Prototyping Process

It is clear from our empirical findings that implementation of AM into the prototyping process reduces the cycle time of each prototype as well as the total process time it takes to produce a final prototype. As depicted in the figure below, this enables organizations to produce prototypes sequentially instead of simultaneously without having to increase total process time. By relating these findings to the research of Cox and Bare, we find that implementing AM into the prototyping process can increase process optimization since it eliminates the inefficient knowledge transfer caused by simultaneous production of prototypes. The technology allows the process to experience continuous improvement of the quality of prototypes since the production is based on knowledge transferred from all previous prototypes. According to Cox and Bare, this continuous improvement reduces the risk of default in the future manufacturing of a prototype. This is supported by our empirical findings since several organizations experienced a reduced risk of default in the manufacturing process due to improvements in the prototyping process.

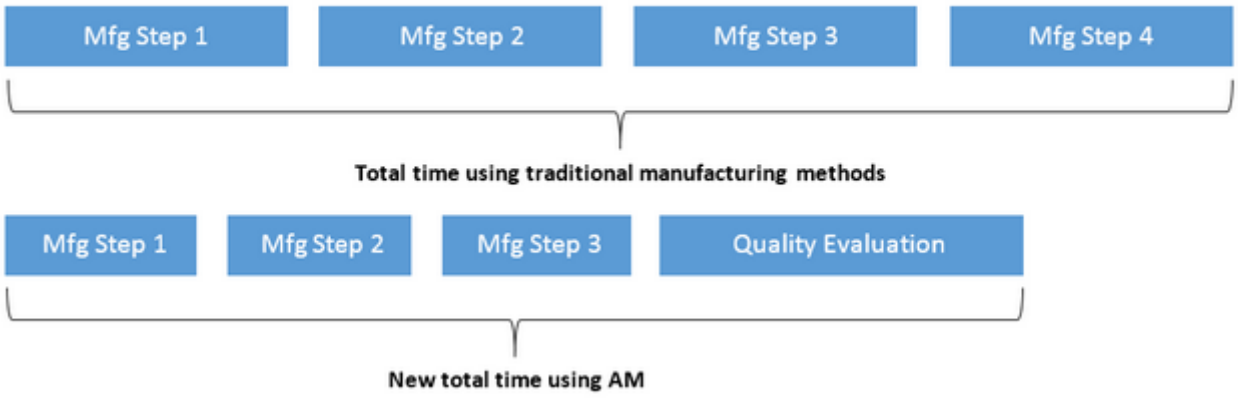
Figure 8: Changes in the prototyping process



Changes in the Manufacturing Process

Most research suggests that the overall production time for a certain component decreases when using AM in the processes. Not only do the steps in the production get shorter, some can even be eliminated. We have also seen these patterns in our empirical data. However, it is important to bear in mind that the quality evaluation of the produced component is different when it has been touched by a 3D-printer. This results in an additional step that could vary time-wise depending on the complexity of the product and the material used. This is illustrated in figure 9 below.

Figure 9: Manufacturing process with and without AM



In figure 9, one of the production steps has been eliminated and a new quality evaluation activity has been added. What it does not show is that depending on how long and extensive this evaluation step becomes together with the risk of the material not passing the test, there is a risk that the whole process becomes longer than with the traditional methods. For this reason, some companies - in our case Siemens - are looking for ways to outsource this part of the process to a more specialized company. This might not be profitable for a smaller company that as a result has to examine the quality in house.

Changes in the Process Layout

According to the process layout model, the operations processes using AM technology should be of project or jobbing type, since the AM technology produces very varied products at usually lower volumes. However, a project process is usually suitable when the production time of an item is relatively long, which is not the case with AM. Hence, the jobbing process is more suitable. Based on these two process types, the AM facility should have a so-called functional layout or a cell layout. This implies that the layout decision is dominated by the functional needs and convenience of the transforming resources.

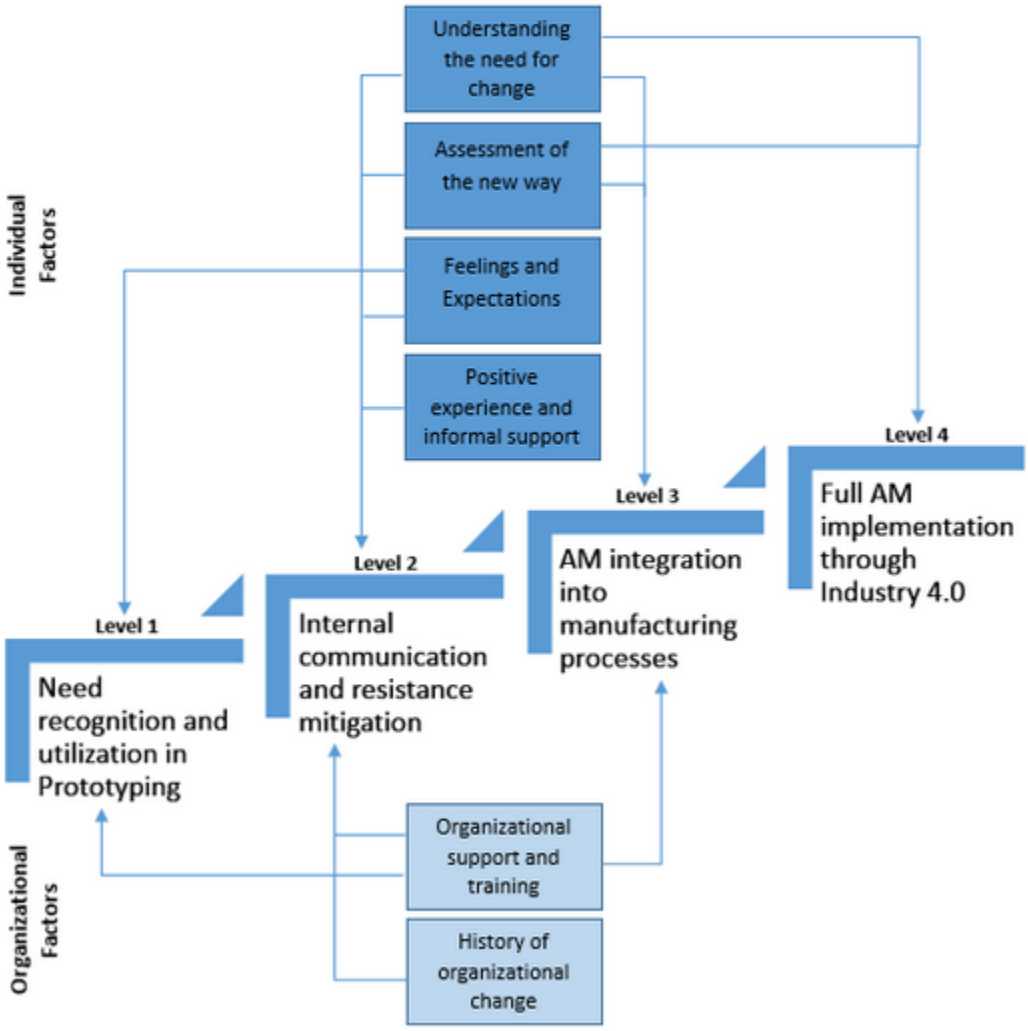
At Siemens, they have chosen to use a cell layout. Their decision is not based solely on what is optimal from an operations management perspective, but rather from a health risk point of view. They have chosen to place the printers in isolated cells to avoid that the metal powder gets into the strong ventilation systems if a spill accident would take place. In other words, this type of layout would have to be used regardless of what would be optimal from a production perspective. From our interviews with the other companies, we have learnt that they have not fully decided what process layout to use. Hence we can draw the conclusion that the different layouts need to be experimented with and that in the case of AM, decisions based on the process layout model might not be as obvious as in other cases.

5.3 Reviewing the Barriers to Implementing AM

By applying Becker’s model regarding individual unlearning (figure 4), we analyze in this section the role of Becker’s individual and organizational factors in the context of AM implementation

and how they can help explaining the perceived barriers when implementing AM. To do so, we integrate Becker's model into the four-level AM implementation model (figure 6). This integration is illustrated in the figure below.

Figure 10: The role of factors affecting individual unlearning in AM implementation process



5.3.1 The Role of Individual Factors

Based on our empirical findings, we conclude that the positive prior outlook of individuals is an irrelevant individual factor in the context of AM implementation, due to the fact that there is inadequate information for individuals to build a prior outlook on regarding AM. However, this lack of information enhances the importance of the other individual factors. To begin with, the barriers of acquiring resources in the first level of implementation can be directly linked to the factor of feelings and expectations, since the resistance of top management to delegate

resources is mainly due to a feeling of uncertainty regarding the risks and sustainability of the technology.

Furthermore, we find that much of the resistance experienced in other levels of implementation was related to a lack of understanding regarding the need to implement AM. Thus, there is strong evidence that the individual factor regarding the understanding of the need for change is essential. Moreover, evidence shows that organizations were faced with the challenge of finding methods to assess the performance and quality of AM in order to mitigate the internal resistance. This indicates that assessing the new way is a significant individual factor affecting the AM implementation process, and remains important throughout the process when other stakeholders than designers and prototypers enter the process.

In her study, Becker emphasizes the role of expectations and informal support during the implementation of new technology. Empirically, this factor proved to be highly important in the context of AM in order to manage the conservatism regarding the traditional methods used in the organizations implementing AM, which can be a major barrier in the implementation process.

5.3.2 The Role of Organizational Factors

We found evidence emphasizing the importance of both organizational factors identified by Becker. However, their importance varies in regards to which implementation levels they affect. To begin with, the history of organizational change within organizations implementing AM tended to play a more significant role in the second level of implementation. This is due to the fact that it is at this stage that the implementation is spread within the organization and requires the endorsement of various stakeholders. Furthermore, in the case of Siemens, who have experienced several organizational changes throughout the years, there was a much stronger resistance derived from insecurity, in comparison to younger organizations such as Torbjörns team, which indicates that this factor plays a significant role in the context of AM implementation and can become a major barrier.

However, the importance of this factor phases out as it is mitigated through organizational support and training, a factor that plays a significant role throughout the process. The empirical data showed that a lack of organizational support and training enhances the barriers to acquiring resources to implement the technology at the first level of implementation and mitigating the internal resistance towards the technology.

6. Conclusion

In the conclusion, we summarize the main findings from the analysis in section 5.

It is evident that successful AM implementation requires a more decentralized and less formal structure, since this allows full exploitation of the technology and enhances necessary cross-sectional communication. New managerial positions will emerge and the reallocation of staff and redefinition of tasks are likely to occur. Furthermore, the trade-off between the four key competitive priorities, cost, quality, flexibility and dependability/delivery will change. For prototyping, more focus will be on cost and flexibility while for manufacturing they will be of more equal importance. Finally, the organizational culture will become more flexibility-oriented and organic with less centralized decision-making and less defined tasks.

In prototyping processes, AM reduces cycle time and increases flexibility in design and modeling. The possibility to create more prototypes faster and at a lower cost than before can be expected to speed up product innovation and increase the quality of the final products. Regarding the manufacturing processes, our findings imply that the total time to market decreases. However, depending on the material, the new quality assessment step that needs to be added can in fact increase time to market. Hence, the effect of AM on the manufacturing process is not yet a given fact.

The process layouts for both prototyping and manufacturing varies between companies and it is evident that we are at a stage where different layouts are being experimented with and that there seems to be no clear perception of what is optimal for AM.

Using Becker's research on individual unlearning in new technology implementation, we identified four main individual factors affecting the barriers associated with implementing AM. One factor concerns the feelings and expectations of individuals, which hinders the unlearning process of the old way of working. Furthermore, the importance of understanding the need for change and being able to assess the new technology were experiences as two highly significant factors affecting AM implementation throughout the implementation process. Finally, informal support in the organization was proven to be useful for managing conservatism regarding what technology to use and skepticism regarding AM.

In regards to organizational factors, two were identified as the most relevant ones: the company's history of organizational change and organizational support and training. Somewhat counter intuitively, we found that companies with a history of organizational change met more resistance due to insecurity than smaller and younger firms due to negative experiences in the past. Additionally, companies that lacked organizational support and training had a more difficult time handling uncertainty amongst staff and willingness to adapt to AM.

7. Discussion

In this section, we will discuss our contributions to the field of management, the generalizability of the study and finally, we make suggestions for further research related to this topic.

7.1 Contributions of this Study

As discussed before, previous research on the area of new technology management is based on subtractive technology, which differs greatly from AM. Thus, there is a need to reevaluate the theories within this research area and extend them order to build a bridge between existing theory on implementing new technology and the characteristics of AM. Through this qualitative study, we contribute to building this bridge by applying existing theory to the organizational changes and challenges identified in our empirical data. We do not only identify the possibilities and limitations imposed by AM, but we also create an understanding regarding how different parts of an organization are contingent on this new technology. Through these contributions, this study helps initiate the exploration of a technology that is rather disruptive and can lead to significant changes in how prototyping as well as manufacturing is managed.

Furthermore, with an increasing amount of organizations utilizing AM, there is a growing need to provide research that helps organizations gain an insight into the implementation process of this technology. Thus, a major contribution of our study is providing managers with a framework for understanding the changes that are likely to occur when implementing AM. Moreover, we increase the understanding about the challenges imposed in each level of implementation, thereby preparing managers for what they can expect when expanding their use of AM.

7.2 Generalizability of this study

In regards to the research generalizability, we recognize the limitations imposed by only having four organizations included in our empirical data, since the inclusion of a larger quantity of data is an efficient tool to enhance the generalizability of a study. However, as discussed before (see 2.2), increasing the number of organizations would reduce the research depth of observation, thus limiting us from being able to thoroughly investigate the implementation of AM within these organizations. Furthermore, the data collected from each organization in our study is relatively similar, thus indicating that increasing the number of organizations would not necessarily imply a higher level of generalizability.

We have ensured that our study is generalizable through the high variety between the four organizations included in our study. Through this variety, we enhance the applicability of our findings into organizations with various sizes and industry types, without having to reduce the level of depth-of-observation.

7.3 Suggestions for Further Research

It is clear that the increasing utilization of AM is creating a large hole in research within the area of new technology management. This hole needs to be filled with empirical studies regarding the implementation of AM in order to thoroughly understand the changes and challenges associated with this technology, as well as how these challenges can be mitigated. Moreover, the ability to conduct extensive case studies on this research area will be much easier in the future due to the increasing use of AM. Apart from this, we see possibilities to research the

strategic implications of AM and the role it plays in companies' competitive strategies. This is very interesting since the choice of technology is often done on the basis of the competitive advantages the technology enables. Another area of interest is to investigate the role of AM in the context of supply chain management and how the technology can affect structure and transactions within a supply chain.

Bibliography

Academic References

Bare, M., Cox, J., 2008, *"Applying principles of Mass Customization to improve the Empirical Product development process",* Springer Science + Business Media, LLC, Volume 19

Becker K., 2010, "*Facilitating unlearning during implementation of new technology*", Journal of Organizational Change Management, Vol 23 Iss 3 pp. 251-268

Becker K., 2005, "*individual and organizational unlearning: directions for future research*", International journal of organizational behavior, vol 9, No 7, pp 659-670

Bell, E., Bryman, A., 2013, "*Företagsekonomiska forskningsmetoder",* Liber, Sweden

Berman, B., 2012, *"3-D printing: "The new industrial revolution",* Business Horizons, Volume 55

Campbell, T., Williams C., Ivanova, O,. Garrett, B., 2011, *"Could 3D-printing change the world?"* Atlantic Council, Strategic Foresight initiative

Cozijnsen, A., Vrakking W.J. and Ijzerloo, M.v., 2000, "*Success and failure of 50 Innovation projects in Dutch companies*", European Journal of Innovation Management, Vol 3 No 3, pp 150-159

Dean W. J., Yoon Joon SE., Susman I. G., 1992, *"Advanced Manufacturing technology and Organization structure: Empowerment or Subordination?"*Organization Science, Vol 3, No 2, USA

Duberley, J., Johnson, P., Cassell, C., 2012, "*Philosophies Underpinning Qualitative Research*", In Symon, G., Cassel, C., (Eds.) Qualitative Organizational Research: Core Methods and Current Challenges (pp. 15-34). London: SAGE Publications Ltd.

Ghani, K.A., V. Jayabalan, and M. Sugumar, 2002, "*Impact of advanced manufacturing technology on organizational structure*". Journal of High Technology Management Research. 13: p. 157-175.

Groover, Mikell P. (2007). *"Work Systems: The Methods, Measurement & Management of Work."* Prentice Hall

Gupta A., Chiang D., Chen I., 1997, *"Determining organizational structure choices in Advanced Manufacturing Technology management"* Omge, INt. J. Mgmt Sci. Vol 25, No. 5, pp 511-521

Hao, L., Mellor, S., Zhang, D, 2013, *"Additive manufacturing: A framework for implementation",* International Journal of Production Economics

Malhotra, M.K., M.L. Heine, and V. Grover, 2001, "*An evaluation of the relationship between management practices and computer aided design technology*". Journal of Operations Management 19 p. 307–333.

Meredith, J., 1998, "*Building operations management theory through case and field research*", Journal of Operations Management, Vol. 16, pp. 441-454

Nair, A., Swink, M., 2006, *"Capturing the competitive advantages of AMT: Design-manufacturing integration as a complementary asset",* Journal of Operations Management, Volume 25

Petrick, I., Simpson, T., 2013, *"3D Printing Disrupts Manufacturing"*, Point of View, Volume of Nov-Dec 2013

Rowler, J., 2012, *"Conducting research interviews",* Management Research Review, Vol. 35 Iss 3/4, pp. 260 – 271

Saberi, S., Yusuff, R.M., 2011, *"Advanced manufacturing technology implementation performance: Towards a strategic framework",* Department of Mechanical and Manufacturing Engineering, University Putra Malaysia

Schilling, A. Melissa and Hill, W. L. Charles, Aug 1998, "*Managing the new product development process – Strategic imperatives",* The academy of management executive; Aug 1998

Spanos, Y.E. and I. Voudouris, 2009, *"Antecedents and trajectories of AMT adoption: The case of Greek manufacturing SMEs"*. Research Policy. 38: p. 144–155.

Swamidass, P.M. and W.T. Newell, 1987, *"Manufacturing strategy, environmental uncertainty and performance: a path analytic model"*. Management Science. 33 (4): p. 509 - 524.

Voss, C., Tsikriktsis, N., Frohlich, M., 2002,*"Case research in operations management"*, International Journal of Operations & production management, Vol 22 Iss 2 pp. 195-219

Wanda J. Orlikowski. "Technology and organization: Contingency all the way down" *In* Technology and Organization: Essays in Honour of Joan Woodward. Published online: 08 Mar 2015; 239-246.

Zammuto R. F., Krakower, J, Y, 1991, "*Quantitative and qualitative studies of organizational culture"* Research in organizational change and development, P. 83-114

Zammuto R. F., O'Connor E. J., 1992, "*Gaining Advanced Manufacturing Technologies' benefits: The roles of organization Design and Culture"* The academy of management review, Vol 17, No 4, pp 701-728

Web Pages and Articles

"3D printing and the new shape of industrial manufacturing", 2014*,* PriceWaterHouseCooper, viewed 2015-02-15, <https://www.pwc.se/sv_SE/se/verkstad/assets/3d-printing-and-the-new-shape-of-industrial-manufacturing.pdf >

"Contingency Theory", 2015*,* 12manage Encyclopedia, viewed 2015-02-17, <http://www.12manage.com/methods_contingency_theory.html>

"GE: 3D-printers to "touch" half of its manufacturing." Investors Business Daily, October 7, 2013.

"Printing Out Barbies and Ford Cylinders" Wall street Journal, June 5, 2013.

Appendix

Original Interview Guide (in Swedish)

- **Introduktion (Mjuka frågor)**
  - Kort presentation av vårt arbete
  - Presentera syftet med intervjun
  - Fråga om anonymitet
  - Fråga personen om hans/hennes arbetsuppgifter, bakgrund.

- **Nuvarande användning av 3D-Printing**
  - Varför implementerade man det?
  - I vilka processer/områden?

- **Hur gick man tillväga när man implementerade detta?**
  - Hinder/utmaningar för att implementera det?
  - Använde man modeller/ramverk för implementering av ny teknik?
  - Tänkte man på att det är ny teknologi?
  - Hur bestämde man på vilka områden man ska implementera den?

- **Vilka organisatoriska förändringar upplevde man?**
  - Vad har ni behövt förändra rent konkret?
  - Reallokering av resurser?
    - Omdefiniering av arbetsuppgifter?
    - rekrytering av ny personal?
  - Ny managerposition?
  - Process layouten, Förändrades den?
  - Time to market? Work-In-progress? Några ändringar där?

- **Hur tror du att det kommer påverka er i fortsättningen?**
  - strukturellt
  - ledarskapsmässigt

- **Avslutning**
  - Sammanfattning av respondents svar och det man har kommit fram till för att undvika missförstånd.
  - Fråga ifall denne har några frågor/övrigt att tillägga

Interview Subjects - detailed:

The following organizations and individuals are included in our primary data:

Sandvik

Mikael Schuisky - Operations manager of Additive Manufacturing: Mikael Schuisky is head of a team responsible for the research and implementation of AM at Sandvik.

Torbjörns Team

Torbjörn Åkesson - Founder & CEO: Åkesson initiated the implementation of AM technology into the operations at Torbjörns team, a dental technician laboratory situated in Stockholm.

Siemens industrial Turbomachinery

Andreas Graichen - Team leader of 3D-printing team & Senior specialist manager of AM:

Graichen was one of the initiators of the implementation of AM technology into the prototyping as well as manufacturing processes at Siemens.

Pajazit Avdovic - Innovation coordinator of 3D-Printing team: As innovation coordinator, Avdovic is responsible for the acquiring and internal communication of information regarding different aspects of AM technology.

Jonas Eriksson - Laser Specialist of 3D-Printing team: With many years of experience with laser-based technologies, Eriksson has an extensive knowledge regarding technical aspects and challenges associated with implementing such technology as AM.

Håkan Brodin - Specialist within Material Engineering: Together with Andreas Graichen, Brodin initiated the implementation of AM into Siemens and had the main responsibility over it prior to the formalization of the 3D-printing team.

Global car manufacturer

We have interviewed the Senior Principal Engineer from the AM department of a global car manufacturer. The company as well as the engineer chose to be anonymous.