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SCHOOL OF BUSINESS, ECONOMICS AND LAW

# Cloud Manufacturing: Implementation & Challenges in a Swedish automotive firm

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# Abstract

During the last century, the idea of industry 4.0 has evolved, based on the rapid development of the industry as well as all the necessary components that are required. As a key component of industry 4.0, cloud manufacturing is emerging as an enabler for a new possible manufacturing paradigm. Within the manufacturing segment, researchers are recognizing the development of the cloud and its implications within manufacturing. Cloud manufacturing enables organizations to increase both resource utilization, and flexibility as well as respond to the versatile needs of customers.

The purpose of this paper is to identify the current state of cloud manufacturing implementation and provide guidance on overcoming potential challenges for a Swedish automotive company. Cloud manufacturing in the automotive industry is selected for this thesis, as it is an industry that is currently undergoing several changes, such as the transformation into electric vehicles and technical developments. Moreover, there is a lack of research in the area of cloud manufacturing for the Swedish automotive companies specifically, which calls for further knowledge to be obtained. . A single case study was performed to obtain the information for the thesis purpose. The empirical findings consist of themes that are derived from various interviews with field- as well as academic experts, the examples of themes consist of the integration of cloud & data and security issues. The study concludes with several recommendations for the automotive company to increase the effort of working towards a cloud manufacturing system, creating a clear cloud implementation strategy, reallocating resources for a full-time implementation, joining data transmitting initiatives, and convincing management. However, as the organizational strategy is not to implement cloud manufacturing, further research could study the potential cloud manufacturing implementation process on a global level.

**Keywords:** Cloud Manufacturing, Cloud Manufacturing Implementation, Cloud Manufacturing Challenges, Manufacturing Security

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# 1. Introduction

*This chapter presents a background to cloud manufacturing and the development of industrial revolutions that lead to its expansion. The applications and definition of cloud manufacturing as well as the adaptation of large organizations. Thereafter, a problem discussion is presented where the aim is to define the current issues of implementation and understand the research gap. This leads to the purpose of the research as well as the research questions. Lastly, a description of the case study, delimitations, and thesis structure are presented.*

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## 1.1 A new industrial age

Society is always developing, and this era of humanity is no different. Technological advancements are one of the key areas people think will be playing a larger part in our lives. The advancements made during the last century have had a larger impact on our daily lives than ever before. Indeed, the information era has resulted in development that is unparalleled to any other era of civilization. One key technological development that has caught the eyes of scientists, politicians, and managers is the emerging transformation into the 'fourth industrial revolution.

The first industrial revolution occurred around the 1830s with the introduction of new technological advancements such as the wind turbine and steam engine; this resulted in the utilization of new materials such as coal and oil for energy, as well as the greater production capacity of a wide range of materials. The second industrial revolution - which occurred between the late 19th and 20th centuries - is famously known for Ford's assembly line, allowing for the standardization of products. The revolution meant that production capacity could be increased further since parts were no longer hand-made. During the 1950s, the start of the third industrial revolution took form - advancement within the semiconductor industry made automation within production lines possible. The fourth industrial revolution, while still in its infancy, is not only argued to increase efficiency but to create fundamental challenges to what it means to be human in the age of robots (Marr, August 13, 2018). The emergence of micro transistors within the fourth industrial revolution has been a key component of building computers (Investopedia, 2022). According to Moore's law, the number of transistors on a microchip is doubled every two years, whilst costs are halved; increasing the efficiency of computers at an exponential rate (Investopedia, 2022).

Industry 4.0 has seen several definitions and explanations; the phenomenon does not have a generally accepted definition (Schneider, 2018). It is however at its core the integration and increased relation between physical and digital technologies in the industrial landscape (Deloitte, 2020). It is a combination of several different aspects: Internet of Things (IoT), System integration, Cloud computing, Artificial Intelligence (AI), and Big Data to name just a few key technologies that have been identified in this potential shift (Deloitte, 2020). Since automation was established in the third industrial revolution, the need for human interaction between systems has been a requirement. Industry 4.0 has the potential to create value for companies (Kagerman, 2014); managers and scholars have put an increased focus on how factors such as automation, optimization, and reduced energy usage can be integrated into their operations (Schneider, 2018).

A key difference of Industry 4.0 is the enablement of integrated systems to communicate throughout the supply chain, enabling an adaptable manufacturing process. This flexibility means that the process can be proactive within the supply chain, planning for downtime or taking alternative routes based on weather or traffic information. The integration may therefore decrease the potential delays within production as well as schedule the downtime at the optimal moment. The increased flexibility of implementing industry 4.0 can result in manufacturers being able to accommodate direct orders, and process and ship them to the consumer more directly (Zhang et al., 2012).

Cloud manufacturing is described as a “smart networked manufacturing model that embraces cloud computing, aiming at meeting growing demands for higher product individualization, broader global cooperation, knowledge-intensive innovation, and increased market-response agility” (Ren et al., 2014). To meet the demands of increased personalization of products, manufacturers have increased the possibilities of customizing previously standardized products (Mai et al., 2015). Cloud manufacturing may also enable a sustainable approach to the manufacturing process, allowing for low material usage as well as enabling the users to share information cross-platforms and geographical locations (Velling, 2019). The main enabler of cloud manufacturing is argued to be the emergence of cloud computing, which allows the manufacturing process to transition from a production-oriented process into a service-oriented process (Mourtzis, 2020). The development of academic articles since the conception of cloud manufacturing in 2010 (Li et al., 2010) is illustrated in Figure 1. While the concept of cloud manufacturing has been developing at a significant pace, neither implementation nor the automotive industry is commonly being studied; in 2021, there were 9223 studies containing specifically cloud manufacturing, whilst 1075 studies contained specifically ‘cloud manufacturing implementation automotive industry’. It is therefore deemed valuable to study the topic in order to determine if such an implementation is underway in contrast to academic literature. The specific search terms ‘cloud manufacturing implementation automotive industry’ were selected in order to determine the implementation in the specific industry, as well as potential challenges that could be unique for the industry.

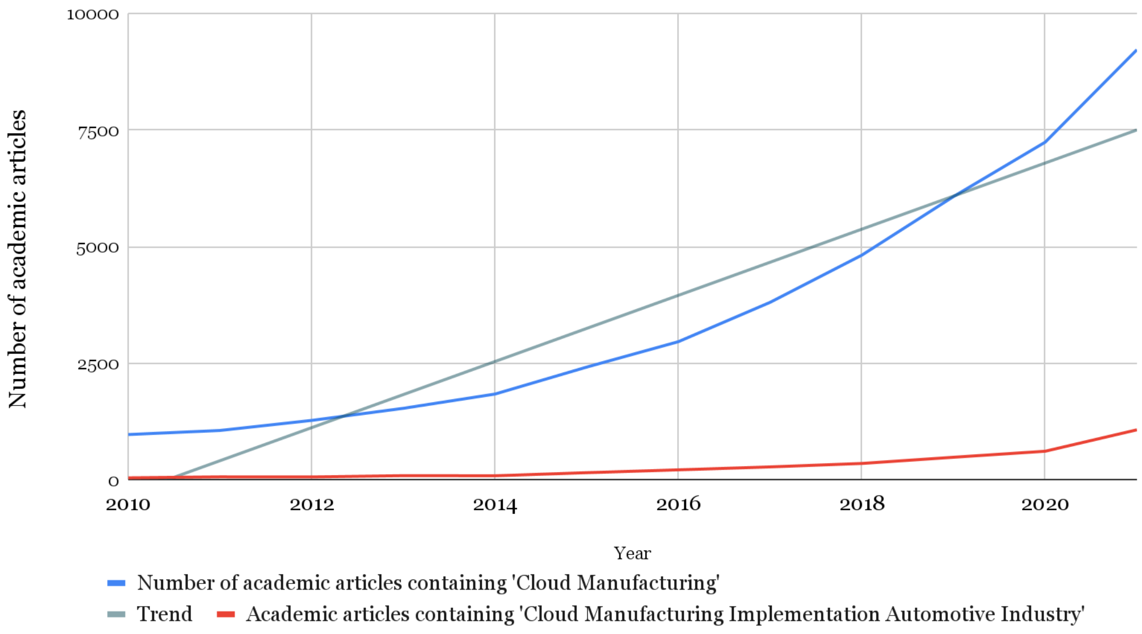


*Figure 1: Number of academic articles published each year, based on the search term 'cloud manufacturing' with a supporting trend line as well as the specific search terms 'Cloud Manufacturing Implementation Automotive Industry', at Gothenburg University's Library Search Engine Supersök*

## 1.2 Problem Discussion

While Industry 4.0 is still in its early inception, there are several dimensions of risks that are being discussed in the media and the academic world. Technology may provide several benefits; improved healthcare, increased efficiency, and new jobs may be examples of how technology can be argued to have improved society as a whole (Scott, 2020). During the still ongoing global pandemic, the global manufacturing industry faced unprecedented challenges, the well-prepared organizations within the manufacturing sector were able to showcase their flexibility and responsiveness to these new challenges, highlighting the potential that cloud manufacturing may have on scheduling in Industry 4.0 (Ivanov, 2020; Ivanov & Dolgui, 2020; Ivanov & Das, 2020).

Establishing an automated well-functioning supply chain may mitigate the need to relocate production toward low-wage countries (Deloitte, 2020). In addition to this, several organizations do not have the infrastructure or the competence to transition to industry 4.0 (Deloitte, 2020); essential success factors that have been identified are technical skills and IT infrastructure (European Commission, 2020). Firms that do not have the required skills to implement the changes can consequently not reap the potential rewards of implementing an Industry 4.0 strategy (Basl 2017). An example of this is OEM SMEs, which are typically labor-intensive and located at the low-end of the supply chain and consequently do not necessarily have sufficient staff education to reap the potential benefits that cloud manufacturing can offer (Adamson et al., 2017).

Cloud manufacturing allows for transforming the manufacturing industry from production-oriented manufacturing to service-oriented manufacturing (Ren et al., 2014). This enhances the impact of industry 4.0 within the organizational transformation, implementing the changes to the manufacturing process and therefore evolving the business model to maintain a competitive advantage (Lee et al., 2014).

While cloud manufacturing has the potential to fundamentally change the manufacturing process entirely, there may be issues with changing the status quo (Tao et al., 2011; Ghomi et al., 2019). Issues such as willingness-to-adopt cloud manufacturing, as well as knowledge and trust management, are argued to be major difficulties when making the case for implementing cloud manufacturing. (Tao et al., 2011) The uncertainty in demand that can occur when adopting cloud manufacturing requires different factories of a product to have interoperability, which can create difficulties with scalability (Ghomi et al., 2019). The hesitation is not necessarily only due to social factors, however, as deployment costs for phasing out legacy systems may be high; security and legal issues around the handling of data can also create significant business risks (Ghomi et al., 2019).

While cloud manufacturing implementation may have several advantages, such as higher flexibility, real-time market response, and higher visibility into the supply chain (Beeson, 2021), the increase in customization can however present the challenge of cost and speed within production (Ford & Despeisse, 2016). This is in part due to the lack of standardization. Additionally, finding the correct skill set within engineers and designers to implement these changes could potentially present a problem for firms (Ford & Despeisse, 2016).

## 1.3 Purpose

Cloud manufacturing in the automotive industry is selected for this thesis, as it is an industry that is currently undergoing several changes, such as the transformation into electric vehicles and technical developments. Moreover, there is a lack of research in the area of cloud manufacturing for the Swedish automotive companies specifically, which calls for further knowledge to be obtained. Therefore, the purpose of this thesis is formulated as follows:

The purpose of this paper is to identify the current state of cloud manufacturing implementation and provide guidance on overcoming potential challenges for a Swedish automotive company.

## 1.4 Research Questions

In order to reach the purpose of the thesis, the following research questions have been formulated:

### RQ 1

*What is the current cloud manufacturing implementation state of a Swedish Automotive Company?*

### RQ 2:

*What are possible challenges of working towards cloud manufacturing for a manufacturer in the Swedish Automotive industry?*

## 1.5 Short Description of Case Study

To study how an automotive company may work towards implementing cloud manufacturing and consequently its potential challenges, the thesis will study and analyze how Volvo Car Group currently approaches a potential implementation. Volvo Car Group will henceforth be referred to as ‘Volvo’. The reason for selecting Volvo for this thesis is to study and understand why and how a large industrial automotive manufacturer may approach the cloud manufacturing phenomenon. Additionally, the automotive industry is currently undergoing several transformations, which includes electric vehicles, improved technology and sustainability aspects. Conversely, there is a lack of cloud manufacturing implementation studies in the automotive industry, specifically in the Swedish industry. The selection of the company was due to both geographical location, as the company is located in Gothenburg, and its presence in Europe, as Volvo argues to have a 10 percent market share of premium cars in the region (Volvo Car Group, 2021).

## 1.6 Delimitations

During the research, the study faced some delimitations with the scope of the empirical findings as well as the scale of the study. As the study is based on a single case study, the findings are therefore unique for this particular research and organization. Additionally, the findings from the research are therefore not applicable for generalization for a wider scope. Furthermore, as the study is focused on the Swedish market, the implications of the findings are unique to this specific market. The research was also limited to the implementation of cloud manufacturing within a Swedish automotive firm. The technical aspects of the implementation will therefore be excluded, as the researchers are lacking the technical expertise. In addition to this, manufacturing models will be excluded from the research, this is mainly due to the timeframe of the conducted thesis.

## 1.7 Thesis Structure

After the introduction chapter, the literature review used is presented followed by the method used to conduct the study. Additionally, empirical findings are presented; the abductive approach allows for an iterative process, whereas the literature review can be adjusted in accordance with the findings. When the empirical findings have been presented, an analysis will be conducted which compares the literature review with the findings in order to strive to create new knowledge. Lastly, a conclusion will be presented, where the research questions will be answered and a recommendation can be formulated. The structure of the thesis is outlined as shown in figure 2.

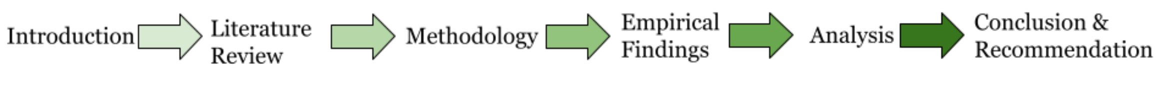


*Figure 2: Illustration of thesis structure*

# 2. Literature Review

*The Literature Review chapter forms a deeper understanding of the subject, that revolves around the authors' choice of research questions. The review is divided into three different parts: Cloud Computing, Cloud Manufacturing, and Supporting Technologies, with a summary of challenges presented at the end.*

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## 2.1 Cloud Computing

Cloud computing is being defined differently by various authors, Mell and Grance (2011) define cloud computing as the following: "a model for enabling ubiquitous, convenient on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and realized with minimal management effort or service provider interaction". While Paul and Ghose (2012) defines it as "a model for enabling convenient, limitless, on-demand network access to a shared pool of computing resources". Cloud computing is argued to be a core enabling technology for cloud manufacturing and a major difference compared to other advanced networked manufacturing paradigms (Adamson et al., 2017.

Cloud computing could be described as a large-scale paradigm of computing (Foster et al. 2008). This paradigm is driven by economies of scale and offers customers an online platform where they can access services, storage, and platforms on demand. The increased access for consumers is argued to not only change computing but may also give rise to a new business paradigm (Ren et al., 2014). Cloud computing resources are virtualized in a pool that allows the sharing of resources. In addition to this virtualization, the sharing of resources allows for multiple operating systems to run from a coherent host, utilizing the resources further (Figueiredo et al., 2005). Virtual computing resources enable the sharing of computing memory, storage, I/O, and compute capacity; this enables the end-user to compile and configure these resources to their specific demand (Ren et al., 2014). The end-users are therefore able to customize and utilize an on-demand service for themselves, without requiring any form of IT assistance (Hayes & Morgens, 2008). This is achieved by creating predefined templates that allow the end-user to customize while remaining within the framework, allowing for a convenient solution for the end-user (Ren et al., 2014). Cloud computing is currently not only being utilized by various private organizations, the implications are wide enough to include state and government institutions (Schartz et al., 2010). The enablement to process large datasets is argued to be a valuable tool for many different industries, for instance, the bioinformatic industry has specially developed applications and resources for managing large datasets (Schartz et al., 2010).

The architecture of cloud computing is suggested to be divided into three main layers; Infrastructure, Cloud management, and Service delivery (Dong et al., 2018). The first layer is the infrastructure one, this is the machines, the hardware, software, storage, and the underlying assets (Dong et al., 2018). This layer poses the highest security risk when experiencing an attack, as the risks are suggested to be higher for the lower layers and lower for the higher layers (Hussain et al., 2016). The second layer is Cloud management; this layer's task is to realize the objective of the cloud service and is connected to the infrastructure layer (Dong et al., 2018). The last and highest layer is the Service delivery layer, which consists of the service models, this layer is the one that is seen by the user and where they can interact (Dong et al., 2018). This layer is also suggested to pose the lowest security risk for the organization (Hussain et al., 2016).

### 2.1.1 Service models

Buyya et al. (2009) argue that cloud computing is a combination of three different fundamental service models: Infrastructure as a Service - IaaS, Platform as a Service - PaaS, and Software as a Service - SaaS. These service models are based on the different levels of virtualization (Huang et al., 2013), and are consequently divided into three different layers: The hardware and infrastructure layer, the platform layer, and the application layer (Salas-Zárate & Colombo-Mendoza, 2011).

The initial service model that enables the latter ones is argued to be IaaS, which has also been referred to as Hardware-as-a-Service (Xu, 2011). A key component of IaaS is the focus on usage-based payment schemes, i.e. customers paying as they use (Rimal et al., 2010). The service model is argued to create benefits for manufacturing firms as the need for investing in the construction and managing of their own IT systems is removed; other systems can be used with greater flexibility (Rimal et al, 2010). In addition to this, IaaS can benefit the manufacturing firms' technological capabilities, as the latest technology will be adopted by the firm (Xu, 2011).

PaaS, the platform layer service model, "provides abstractions and services for developing, testing, deploying, hosting, and maintaining applications in the integrated development environment" (Xu, 2011). Rimal et al. (2010) argue that the general application area for PaaS is for developers to operate within a platform that provides an end-to-end life cycle of the development process. PaaS may have various different application areas for development and integration (Salas-Zárate & Colombo-Mendoza, 2011), for instance, integrated-oriented platforms, i.e. a platform that strives to assist e-businesses and apps; development-oriented platforms, i.e. engines used to develop various applications; infra-oriented platforms, which offer developers a platform for scalability of infrastructure (Rimal et al., 2010).

SaaS is part of the application layer and enables already created applications to run on cloud-established infrastructure (Salas-Zárate & Colombo-Mendoza, 2011). The service model consequently eliminates the need to locally install applications on a device and can thus be accessed from different clients, i.e. web browsers and smartphones. SaaS is argued to be referred to as the Application Service Provider; a major component of SaaS is the integration requirement of additional applications (Xu, 2011). An example of SaaS services is Google's Apps which include word processing and spreadsheets, with the key focus on online availability, which enables the apps to be accessed from various smart devices (Salas-Zárate & Colombo-Mendoza, 2011).

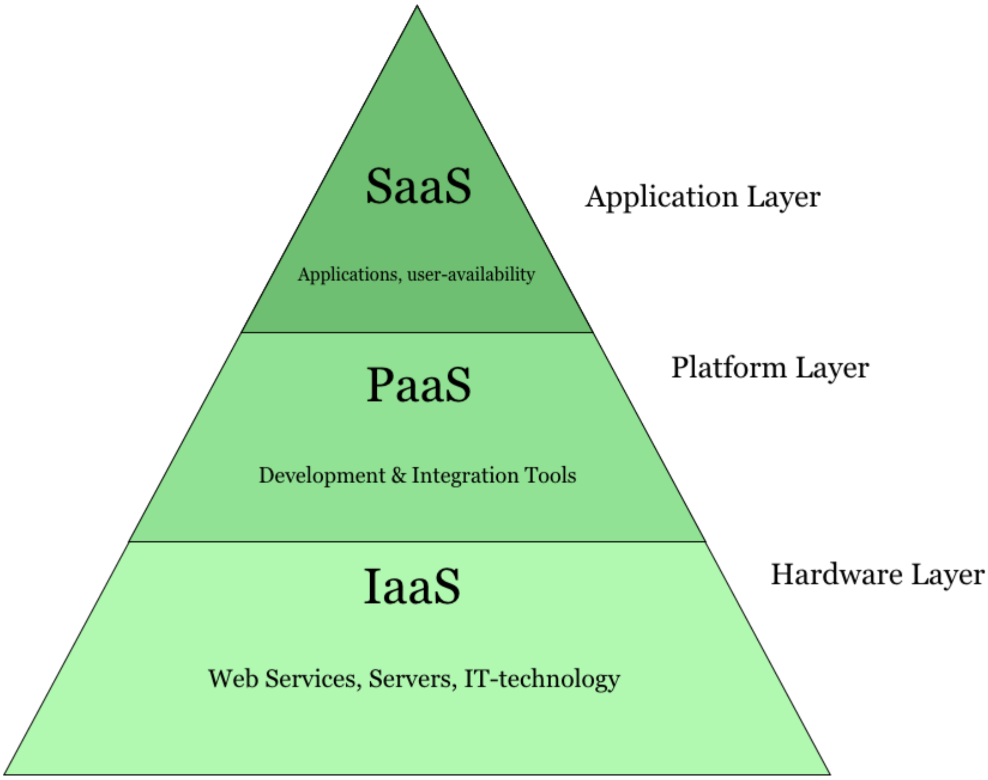


*Figure 3: The cloud computing service models, based on Xu (2011), Salas-Zárate & Colombo-Mendoza (2011) & Rimal et al. (2010)*

While the emergence of cloud computing is argued to be the main enabler for cloud manufacturing (Mourtzis, 2020), cloud manufacturing is in turn argued to elevate Manufacturing-as-a-service (MaaS) (Grassi et al., 2020). MaaS is described as a marketplace that may "connect clients requiring manufacturing services to suppliers providing those services" (Grassi et al., 2020). The idea of MaaS was discussed in academia already in the 1990s, however, it is argued that the concept was not fully grasped due to the still-emerging information technology (Adamson et al., 2017). The platform is suggested to remove friction in the manufacturing marketplace by providing decision-making tools, whereas quotations and order acceptance decisions are exemplified (Pahwa & Starly, 2021). MaaS is argued to be shifting the generally production-oriented manufacturing process into a service-oriented network through the enablement of offering manufacturing assets as services (Grassi et al., 2020). MaaS is argued to create possibilities for customer customization and small-batch purchases (Rauschecker et al., 2011).

### 2.1.2 Cloud platforms

The emergence of cloud platforms is suggested to enable smaller organizations to expand, while still maintaining their profit margins (Kamal et al., 2020). As the organization leases the cloud computing service, they are not needed to heavenly invest in the development of their own service i.e investing in IT infrastructure, training and educating staff, and licensing software (Power & Weinman., 2018). These cloud service models consist of IaaS, SaaS, and PaaS (Kamal et al., 2020). These service models come with different access and security levels, based on the customers' demands. However, the main component of each model is mainly storage, computation, and infrastructure services (Benlian et al., 2018). One of these systems is Amazon Web Service, AWS, which provides an on-demand service with the business model. Coppolino et al., (2017) explain that a client is able to pay for a virtual AWS PC or a physical one, the client is also able to combine both. Furthermore, AWS also provides security for the client's framework. Google also has its own service platform, called Google Cloud Platform, GCP (Kamal et al., 2020). Unlike AWS, GCP is a set of different cloud computing administrations that work on the same platform (Irani et al., 2019). GCP enables the clients to store and stockpile information as well as perform administrative tasks such as examining data and machine learning. Microsoft also launched its own cloud system, Microsoft Azure Cloud, Microsoft Azure (Kamal et al., 2020). Microsoft Azure offers the clients Saas, PaaS, and IaaS as well as supports a large range of programming languages (Ranjan et al., 2015). Microsoft Azure is able to process analysis, manage applications, and deployment of Microsoft data centers (Aljamal et al., 2018).

By contrast, firms may opt to develop private clouds in order to optimize IT resources in terms of monitoring and controlling business-critical applications (Vikas et al., 2013). By implementing a private cloud, the security aspect of a private cloud becomes dedicated to a single source and consequently argued to create a design that assures a higher security level (Aryotejo et al. 2018; Vikas et al., 2013). Furthermore, the customization of the system is also in the organization's control, as well as compliance (Vikas et al., 2013). The drawback would be the limited scalability of the service system as well as the high development cost of the entire system (Aryotejo et al. 2018; Power & Weinman., 2018). On the other hand, using public cloud services with the pay-per-use model lowers the cost of the investment as well as the high scalability, the public cloud is argued to be the more attractive option for some organizations (Aryotejo et al. 2018). Public clouds are generally based online through the Internet and managed by a third-party operation center offering access to the Internet and may consequently not be used as a single dedicated source (Ren et al., 2015). This is mainly due to costs, as firms may not have the resources to build the required IT infrastructure (Dhar, 2012). A hybrid cloud is presented as a combination of private and public cloud, providing the organization a combination of scalability from the service provider while still maintaining some in-house functions in order to increase security, maintain scalability, and decrease costs compared to private clouds (Aryotejo et al., 2018). For certain societies or clusters, a community cloud could also be used, whereas computing resources are being shared with members who have similar concerns (Ren et al., 2014)

### 2.1.3 Competence challenge

As cloud technology continues to emerge, a challenge has been highlighted; finding the right competence is suggested to be a struggle for corporations, as they don't have the skillset and organizational structure (Oredo et al., 2014; Wang et al., 2015). Furthermore, Tao et al. (2011) present that organizations might not have the knowledge cloud, resulting in an unwillingness to adapt. Lin and Chen (2012) further emphasize that the current personnel within IT will face some challenges with the emerging cloud computing phenomenon. Oredo et al., (2014) suggest that this is due to the phenomena of technological advancements usually being faster than the adaptation by the business world. Before the emergence of cloud computing, Wang et al., (2015) argues that systems were isolated and that the emergence of cloud computing bridges this gap and connects systems on both the technical and non-technical aspects. Wang et al., (2015) continue to explain that education and life-long learning are some examples of non-technical aspects. As the development of cloud computing unfolds, organizations are suggested to look for assistance to develop technological roadmaps (Oredo et al., 2015).

## 2.2 Cloud manufacturing

Cloud manufacturing is a concept that has emerged as a potential new service-oriented paradigm from cloud computing (Mouritz, 2020). The concept's definition has been subject to several academic studies (Li et al., 2010; Ren et al., 2015; Lu & Xu, 2018; Mouritz, 2020), however, it does not have a universal definition (He & Xu, 2015). Furthermore, there are no reports of a fully developed cloud manufacturing system (Adamson et al., 2017). Li et al. (2010) are argued to be one of the first studies to introduce the concept (Mouritz, 2020), in which the concept is defined as "an advanced manufacturing paradigm that is capable of improving resource utilization while efficiently responding to diverse customer needs" (Li et al., 2010). This diverse customer needs concern meeting the increasing demands for product customization, individualization, and collaboration (Ren et al., 2015). Xu (2011) elaborates on the definition of cloud manufacturing as a "model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g., manufacturing software tools, manufacturing equipment, and manufacturing capabilities) that can be rapidly provisioned and released with minimal management effort or service provider interaction". The new paradigm is therefore argued to organize the variety of on-demand manufacturing via cloud service platforms (Lu & Xu, 2018).

Cloud manufacturing is described as a computer- and service-oriented manufacturing model that has been enabled by developments in enterprise information technologies as well as existing advanced manufacturing models (Mouritz, 2020; Adamson et al., 2017). The main components of cloud manufacturing are argued to be networked manufacturing, cloud computing, Internet of Things (IoT), big data, virtualization, and service-oriented technologies to support collaboration, sharing, and management of manufacturing resources (He & Xu, 2015; Tao et al., 2011; Ghomi et al., 2019). The core of cloud manufacturing is virtualizing the physical manufacturing assets as virtual assets and utilizing them as a cloud service (Lu & Xu,2018; Ghomi et al., 2019).

The cloud manufacturing system is argued to primarily consist of manufacturing resources and capabilities as well as three main user types: Cloud providers, Cloud users, and Cloud operators (Zhang et al., 2012). The cloud provider refers to an entity that provides the manufacturing service to the cloud users based on their requests (Ren et al., 2014). The Cloud user refers to a customer that makes customized demands for different manufacturing applications of the product life cycle (Zhang et al., 2012). The cloud user is provided with on-demand support from the cloud platform and may consequently gain competitiveness through cost reduction, higher productivity, and business agility (Ren et al., 2014). The cloud operator manages the cloud manufacturing platform by setting up operations mechanisms and rules of technical processes and business strategy. In practice, the operator connects the supply and demand of cloud services business transactions, service delivery, and social networks of cloud providers and cloud users and can be benefited by creating values between provider and user (Ren et al., 2014). The general operating principle of cloud manufacturing is illustrated in figure 4.

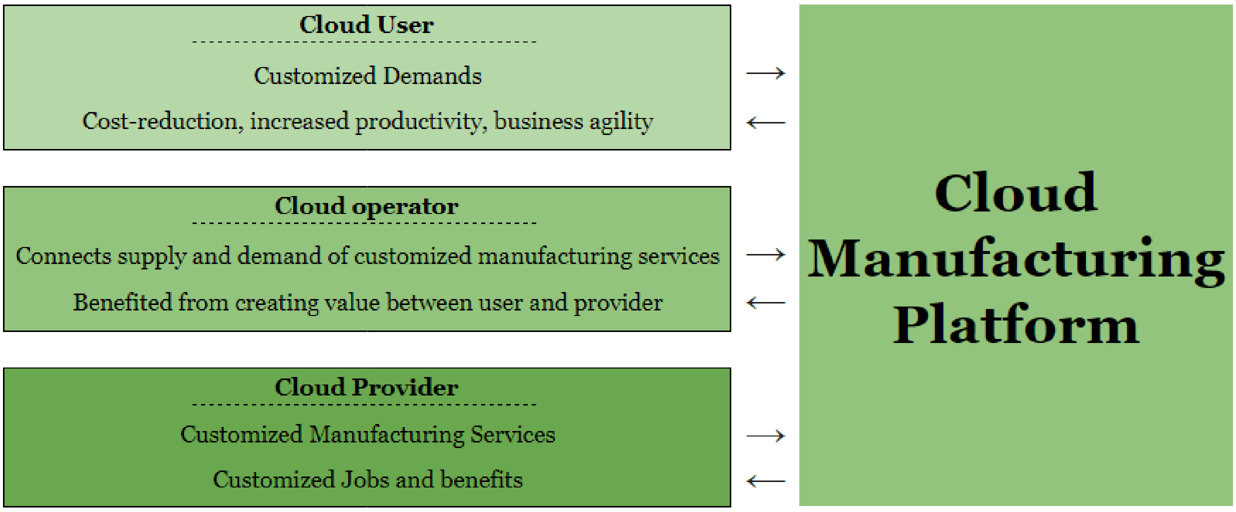


*Figure 4: Illustration of the general operating principles of cloud manufacturing, based on Ren et al. (2014) and Zhang et al. (2012)*

The emergence of cloud manufacturing is suggested to increase the flexibility of the production process, especially through the usage of cyber-physical systems and highly customized assemblies that allow manufacturers to deliver their services on-demand (Ivanov et al., 2020). The increased flexibility to processes and machines is argued to create a new entity for scheduling in manufacturing, whereas the cloud manufacturing service paradigm creates dynamically based services based on the availability of the machines and operations (Ahn et al., 2019). Cloud manufacturing is therefore shifting the scheduling of processes and machines from a fixed and rigid state, into a flexible use of services in which the previous focus of scheduling shifts is argued to emerge as a process and service composition that is performed simultaneously to deliver these manufacturing services on-demand (Ivanov et al., 2020).

Adaptation of cloud manufacturing is suggested to increase resource utilization within the manufacturing process (Rosenthal et al., 2009). In addition to this, the barriers to entry within the manufacturing industry are argued to be lower, mainly due to the reduced up-front investment cost of new enterprises (Tao et al., 2011). Connectivity is proposed to make the investment into machinery more feasible, mainly due to the instant access of these resources via cloud manufacturing (Tao et al., 2011). With a lower up-front investment cost and increased efficiency, cloud manufacturing is also suggested to increase the scalability of production to meet the customer's demand (Marston et al., 2011; Rosenthal et al., 2009). Moreover, with the suggested increase in customization, the end-user is able to request specific services that are personalized for their individual requirements (Ren et al., 2015).

The manufacturing equipment is suggested to have some certain characteristics to succeed; these are argued to be Connectedness, Context-awareness, Intelligence, and Metered Service

(Lu & Xu, 2018). Connectedness needs to be partly to the cloud and partly to other elements within the organization. This is suggested to enhance collaboration and cooperation throughout the services available. Context-awareness gives the manufacturing process the ability to recognize the intentions of the user; analyze these inputs and make a decision based on the current situation, status, and options. Cloud manufacturing intelligence provides the process insight from a large dataset of past engineering data; utilizing this knowledge to make decisions and actions. Furthermore, development within AI is suggested to assist in the development of adaptive decision-making and calculating action plans. Metered service enables the organization to charge the end-user for the amount of usage of the equipment, monitoring progress and resources that are being utilized (Lu & Xu, 2018). To increase the efficiency of cloud manufacturing and thus meet the characteristics, Lu and Xu (2018) remark on the development of autonomous driving as an area that is being utilized for research within cloud manufacturing. The decision-making based on adaptive input from autonomous driving is seen as a more complex task and could be simplified and implemented within cloud manufacturing (Ibid.). Interconnectivity of the manufacturing process also brings forward new users that can utilize the manufacturing process; the user can search for qualified cloud manufacturing services and complete the manufacturing task under the support of cloud computing (Tao et al. 2011). This creates a dynamic manufacturing system that is more service-oriented rather than order-oriented, which also is aligned with the modern automotive industry (Gopu, 2016). The automotive industry is suggested to adopt a more service-oriented architecture (SOA), which is argued to be more flexible and efficient (Gopu, 2016). By adopting an SOA, the manufacturing organization is not limited by the more traditional production ways, SOA is suggested to cover all stages of the life cycle of the product: Design, production, testing, maintenance, logistics, and integration (Ren et al., 2015).

Ghomi et al. (2019) argue that, while cloud manufacturing is showing the potential of improving the current manufacturing paradigm, there may be several issues with implementing a cloud manufacturing system in organizations: A key issue that affects the cloud manufacturing industry is security and is argued to hamper the growth of a wider cloud manufacturing implementation. Furthermore, the authors suggest that demand uncertainty could pose a major issue for firms. Since cloud manufacturing is an on-demand service, and customers are not predictable, it could pose a significant challenge to product planning (Ibid.).

The increasing integration of machines into production and manufacturing systems is suggested to strongly increase a machine's reliance on other machines, similar to an assembly line with human workers (Yang et al., 2016). The authors argue that there are three challenges arising when developing and integrating machines into smart manufacturing: Firstly, status, i.e. if the machine is currently busy performing a task or not, as well as the state of the machine and maintenance status, that is if the machine can be expected to perform the task. A common solution to this challenge is to use sensors to process data from the machine. Secondly, to make use of the status of different machines to distribute tasks to each machine, scheduling for dynamic changes alongside potential malfunctions, in order to distribute production tasks dynamically. Thirdly, communications and coordination between machines may present a challenge to the manufacturing process due to collaborations between systems and outside control can be limited, even with a two-way information flow due to technical limitations.

## 2.3 Supporting Technologies

The supporting technologies chapter presents the supporting technologies for cloud manufacturing, the Internet of Things, and Big Data (Ren et al., 2015; Tao et al., 2011; Ivanov, et al., 2020). These supporting technologies are crucial factors for the cloud manufacturing spectrum and will therefore be explained further.

### 2.3.1 Internet of Things

The increasing advancements in wireless communication and networking - a paradigm referred to as the Internet of Things (IoT) - have received increasingly higher attention in academia and management (Bandyopadhyay & Sen, 2011). A main enabler of the concept has been the installation of mobile transceivers between gadgets and everyday items - i.e. the 'things' (Mouritz, 2020). The business implications of the IoT concept are argued to advance the developments of areas such as automation, industrial manufacturing, logistics, business process management, and intelligent transportation of people and goods due to the increased connection (Bandyopadhyay & Sen, 2011).

IoT is argued to be one of the crucial factors in the development of cloud manufacturing, enabling smart connectivity and ubiquitous sensing (Gubbi et al. 2013). Differentiating the main two manufacturing resources that are cloud-connected, the two categories are hard- and soft resources (Ren et al., 2015). The hard resources are the physical machinery and the soft, e.g. software, data, and other intellectual elements are tasked to be integrated. The integration between hard and soft resources has been difficult in the past due to technological limitations, however, the development of IoT has made this possible in a range of applications (Ren et al., 2015). A common technique that is being utilized within the integration is Radio Frequency Identification - RFID, which enables the identification of hard resources and wireless data connection (Buckley, 2006). While RFID tends to be more favored within transfer techniques such as supply chain management (Ren et al., 2015), there are several other integration elements used for manufacturing such as QR-codes, barcodes, Near Field Communication, digital watermarking (Sgarbossa et al., 2020) and wireless sensor network (Akyildiz et al. 2002). The interconnectivity that RFID may enable is argued to be applicable in the manufacturing process (He & Xu, 2015). RFID may be integrated into both the searching and integration of resources, generating further knowledge for decision-making in the manufacturing process (Sgarbossa et al., 2020).

With the development of IoT, security issues have risen; privacy, communication, and storage of data are some of the key security problems that have developed (Zarpelão et al., 2017). The development of the new interconnected devices has led to a vulnerability due to the fast growth and deployment (Conti et al., 2018). In addition to the vulnerability of the fast development, further suggested challenges pose to the security question for IoT; authentication, authorization & access, privacy, and secure architecture (Conti et al., 2018). The deployment and management of the authentication are proposed as a major challenge within the IoT spectrum (Yang et al., 2016). The lack of a guaranteed Certificate Authority (CA), other authentication keys are required to ensure integrity (Conti et al., 2018). To ensure access to the right resources, a mechanism called Access control needs to be implemented within the devices, in combination with an authorization that specifies the access rights (Bertino et al., 2016). Due to the limitation of the devices within IoT, they might not be able to support the full access network of authorized resources, these limitations could potentially also differ from device to device (Moosavi et al., 2016). To compensate for this, a management system of different access control mechanisms and authentication controls needs to be customized for each and every single device, this is suggested to pose a major challenge within the IoT network (Li et al., 2017). The development of autonomous devices that collect data on potentially private information is also suggested as a challenge, especially for individual privacy, this is especially problematic due to the fact that this is being done without the individual even noticing (Lopez et al., 2017). The devices that are collecting the data autonomously require an object-oriented privacy model (Conti et al., 2018). The recent development of GDPR has been implemented to combat the issue of personal data protection (Cornock, 2018). The architecture of the system is also proposed to pose a challenge, previous challenges within the security architecture still exist, however, new challenges are introduced by deploying connectivity throughout the system (Raza et al., 2017). The detection of malicious traffic over the network and thus hunting for these medication actors is also suggested to be a challenge in the creation of secure architecture systems (Haddad et al., 2016).

The cloud manufacturing concept has seen several references to IoT (Zhong et al., 2017; Mouritz, 2020), in which interconnection and interoperability are identified as key elements (Grassi et al., 2020). Interoperability is suggested as a challenge within the cloud computing sector, even with the advancements in the industry (Rimal et al., 2011). Interoperability is the framework that enables integration as well as migration to the system, this is why it is considered essential for both the service providers and the enterprises that utilize IoT (Rimal et al., 2011). Increasing the interoperability between systems is suggested to have both financial impacts, but also increase the operational efficiency as well as the quality of service within cloud manufacturing (Camagnola et al., 2010).

### 2.3.2 Big Data

Big data is a term that is referring to a large amount of complex data which can be used as an analytical tool for managerial decision-making (Bashir & Gill, 2016; Dubey et al., 2019). The increase in computational power has led to this becoming a phenomenon, as previous computers could not analyze the large datasets (George et al., 2014). In the more recent years, Big Data has become a key concept in an organization's standard practice. In addition to this, the organizations are trying to implement larger datasets to create and capture value for their customers. One of the implications of Big data is analyzing patterns; George et al., (2014) describe search behavior, predicting actions of individuals, traffic patterns, and consumer choice as some of the examples that organizations utilize big data. Additionally, Big Data is also being utilized to predict the possibility of an event. The collection of the data is usually done through various inputs, some of these inputs originate from the sensors that are connected to IoT (Ahmed et al., 2016). The devices that are being utilized collect a large amount of data, this dataset can thereafter be analyzed via data-analytic tools (Bashir & Gill, 2016). Collecting and analyzing data has various implications, one of the implications where IoT devices and sensors could be utilized is within the traffic management system in which low-cost sensors manage traffic and collect large amounts of data (Rizwan et al., 2016). This is analyzed via an analytics tool to get a traffic prediction and other useful information that can be utilized for improvements (Rizwan et al., 2016). In addition to this, Big data predictive analytics is also suggested to improve cost performance and product quality within manufacturing (Dubey et al., 2019). The skillset of big data analytics is, therefore, more attractive to organizations, especially since the data is suggested to become easily accessible and cheap (McAffee & Brynjolfsson, 2012). The people that possess the skill sets to analyze large amounts of data as well as the ability to communicate and assist business leaders with their challenges are suggested to be difficult to find and are therefore in great demand (McAffee & Brynjolfsson, 2012).

## 2.4 Summary of Literature Review

The concept of cloud manufacturing that has been presented in the literature review consists of several potential challenges in its implementation; these challenges do not necessarily present solutions, but rather an indication of what current and future challenges may present to organizations. The main challenges that have been presented in the literature review are security, platform development, machine integration, and interoperability. Security refers to issues such as privacy and authorization, which are concerns presented by Zarpelão et al. (2017) and Conti et al. (2018). Platform development focuses on the approach to developing cloud services; the advantages and challenges of using private or public clouds, which have been argued by Aryotejo et al. (2018). Machine integration refers to potential challenges that can arise when developing a cloud manufacturing system, in terms of the integration between machines in order to create a real-time response to changes in for instance machine status (Yang et al., 2016). Lastly, interoperability concerns the integration and migration of systems; this could be presented as integration on a system level and is derived from IoT technology (Rimal et al., 2011). The main challenges presented in the literature review on implementing cloud manufacturing are presented in table 1.

*Table 1: Main challenges of implementing cloud manufacturing based on the literature review*

| Challenges | Area of concern | Function/ Technology | Key Reference(s) |
|---|---|---|---|
| | | | |
| Security | Privacy, Communication, Authentication, Authorization & Access | Cloud Computing, Internet of Things | Zarpelão et al. (2017), Conti et al. (2018) |
| Platform Development | Private Cloud, Public Cloud | Cloud Computing | Aryotejo et al. (2018) |
| Machine Integration | Machine Status, Task distribution, Communication and coordination | Integration | Yang et al. (2016) |
| Interoperability | Integration & Migration of systems | Internet of Things | Rimal et al. (2011) |

# 3. Methodology

*The Methodology chapter presents information regarding how the research was conducted. The chosen method was a qualitative and abductive approach. In addition to this, the data collection consisted of interviewees with both industry and research experts as well as personnel from Volvo.*

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## 3.1.1 Research worldview

Creswell (2014) suggests that there are four distinct research paradigms that are directly intertwined when it comes to selecting research methods and research designs. The paradigms are argued by the author to be related to different worldviews that are found in research; these are postpositivism, constructivism, transformative, and pragmatism. Postpositivism concerns a traditional type of research; it is usually associated more with quantitative research than qualitative. A researcher following postpositivism starts with a theory and finds data that either supports or refutes the theory, similar to a deductive approach. The constructivist worldview tends to study individual's and individuals' views on the situation that is being studied. It is more common to use a constructivist research paradigm in qualitative research, in which the researcher generates or inductively develops a framework based on the findings. A key point of constructivism is according to Creswell (2014) to seek understanding of the world and individuals. The transformative worldview is argued to be a philosophy that arose in opposition to structural laws of the postpositivist structural laws and is consequently a research paradigm that focuses on politics and change-oriented perspectives. Lastly, the pragmatism paradigm is suggested to put less focus on research methods themselves, but rather to use all available approaches in order to be able to understand the problem; it is consequently not specifically bound to any philosophy (Ibid.).

With the research paradigms in mind, the thesis indicates to be following the constructivist paradigm. This is due to several reasons: Firstly, this thesis is exclusively qualitative and does not use quantitative tools for data collection. Secondly, while there was a literature review conducted prior to the interview, the authors chose the option to have an iterative abductive process of the findings, indicating that the research paradigm that is mainly followed in this thesis is the constructivist paradigm. Thirdly, this thesis aims to understand the individuals' perception of cloud manufacturing, both in terms of implementation and potential challenges that may arise.

## 3.1.1 Research Strategy

Given that the purpose of this paper is to identify the current state of cloud manufacturing implementation and provide guidance in overcoming potential challenges for Swedish automotive firms, a qualitative research approach will be adopted. Bell et al. (2019) argue that qualitative research emphasizes the behavioral themes and perspectives of the studied subjects as well as attempting to understand the subjects' context in which the research is being conducted. Additionally, the qualitative research approach that has a focus on contextual results can be argued to provide deeper data than a quantitative approach as well as more flexibility for the researchers (Bell et al., 2019). Bearing in mind that the purpose strives to identify challenges based on companies' representatives, a qualitative is deemed to be the most appropriate approach.

The approach adopted for this thesis is an abductive approach. An abductive approach enables the researchers to initially create a framework that can be adjusted based on empirical findings in an iterative process (Patel & Davidson, 2019). Based on the literature studies, a literature review has been created, which has then been recalibrated based on the empirical findings. The iterative process is illustrated in figure 5. Furthermore, the overarching goal of this study is to study potential patterns that can contribute to frameworks or create new knowledge around the topic, rather than test an existing framework's applicability.

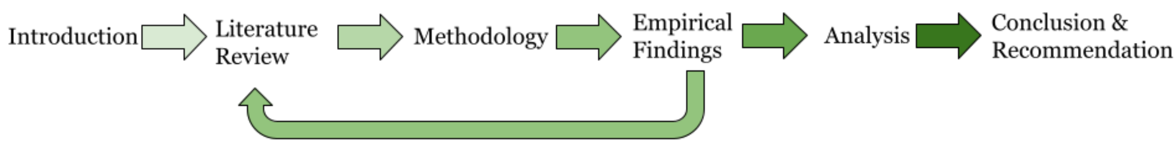


*Figure 5: Illustration of the abductive iterative process of the literature review*

## 3.2 Research design

The research design enables the study to formulate a framework for the collection of data and therefore the analysis. Gray (2019) argues that the research design is the guideline for the implementation of research methods and the analysis of the underlying data. Bell et al. (2019) suggest that there are five different archetypal research designs: experimental, cross-sectional, case study, longitudinal and comparative. The choice of research design is based on the purpose of the study and consequently the questions. For this thesis, a case study is selected as the most suitable for including several actors in the industry. The case study design chosen is a single case, meaning that the case will be studied within the isolation of its context and contrasted with previous research (Patel & Davidson, 2019). Case studies are subsequently used to develop theoretical frameworks, depending on the degree of the discoveries' possibilities of generalization (Bell et al., 2019). The authors chose a single case study for this report, which is due to the purpose of identifying company-specific issues. It is therefore deemed necessary to utilize a case study within the automotive industry to meet the purpose and answer the research questions of this paper.

As additional arguments for the choice of a case study design, explanations for the rejection of other designs should be stated. The experimental design would not be suitable mainly due to the lack of variables to be analyzed. Cross-sectional would not be suitable as the study aims to identify a challenge for a single company and not interview various stakeholders. Longitudinal could be argued for, as a one-subject observation. This would however not be suitable as the research is aimed to identify the current challenges and not observations over time. The comparative design requires at least two cases, alternatively more, as it requires a need for comparison. As the study only utilizes a single case, this research design would not be suitable (Gray, 2019)

### 3.2.1 Case study

A case study design allows the researchers to investigate and therefore obtain in-depth knowledge of a specific case with the natural environment (Bell et al., 2019). The case study (i. e. A Swedish automotive firm) is in the process of implementing cloud implications within its manufacturing division. The automotive firm is argued to transform to cloud services, especially within their various divisions such as manufacturing. A single case study, therefore, offers an exclusive view of how the implementations are compared to the academic literature, how the internal processes and perception of the transformation, but also the current strategy and vision of the implementation and its challenges. Hence, the Swedish automotive sector is a relevant case for the researchers where they can contribute with more practical recommendations. Rowley (2002) suggests that the design of a case study is preferable when the given case is exclusive and therefore has something special to declare. This can be linked to a Swedish automotive firm that are are facing specific challenges in implementing cloud manufacturing

According to Bell et al. (2019) during business research, the case usually consists of an organization and is, therefore, able to answer how and why something occurs. It is therefore deemed appropriate for the design of this thesis, which aims to identify the challenges of a Swedish automotive firm and compare the academic literature with the challenges that the specific firm is facing. The reasoning behind a case design is to gain a deep understanding of the case, in contrast to a more generalized view (Bell et al., 2019). The Swedish automotive firm has undergone a large transformation towards a more sustainable approach, indicating that the organization is rapidly adapting to new circumstances and market prerequisites. In addition to this, the firm is also a global actor with a long history in car manufacturing, which sparks an interest to study how this knowledge can be applied to gain a competitive advantage.

## 3.3 Data collection

To answer the research questions, both primary data and secondary data were obtained. Firstly, the primary data were collected by conducting interviews. Secondly, the secondary data was collected by conducting a literature review. As the thesis will utilize an abductive approach, the literature review can be adjusted according to revelations from the interviews.

### 3.3.1 Primary data collection

For the assembling of primary data, interviews were conducted. The interviewees consisted of a research expert, an industry expert, an product owner within manufacturing, a smart factory engineer and an digital strategy & coordination manager within the automotive industry. The interview will be recorded and transcribed in order to minimize the risk of misinterpretation and to improve credibility. The interviews were referred to as primary sources, as they will be aligned with Patel & Davidson’s (2019) requirements for a primary source. Before the interviews, a guide was formed. This consisted of open-ended questions that are non-leading to not compromise the objectivity of the study. Furthermore, the interviews were semi-structured for this reason, this enables additional information and insight into potential new questions.

When conducting this thesis, the research ethics requirements of Patel & Davidson (2019) were taken into account. This includes that the researchers presented themselves, the representing institution, and the purpose of the study. Furthermore, the respondents for the thesis had no obligation to partake in this study and will decide for themselves to be a part of the study. If confidential information were to be presented during the interview, the information would be up to the respondent's judgment to its relevance if it is to be included. The information that was gathered through the interviews was only gathered for this thesis and for no other purpose.

#### 3.3.1.1 Sampling

The sampling process for gathering respondents was conducted through purposive sampling, meaning that the respondents were selected on a subjective basis of having the experience of reaching the purpose of the paper (Bell et al., 2019). As a result of this, the selection was chosen by screening the participants beforehand, as prior knowledge of the subject at hand is vital due to the research topic still being relatively new. As the research question handles the implementation of cloud manufacturing, the selection process was focused strongly on finding the right competence, which in this case is argued to be both cloud and manufacturing, or cloud integration into the manufacturing process. Therefore, an industry expert and a research expert were chosen to give an unbiased opinion on the subject.

The sampling process of the Volvo employees was made through a snowball sampling process, meaning that the authors reach out to an initially small group of people that are selected based on the relevance of the purpose (Bell et al., 2019). Snowball sampling is useful when the researchers are unable to reach the subjects with the desired characteristics (Naderifar et al., 2017). The first small group thereafter recommends other people that are knowledgeable in the area. The sampling selection was initiated by contacting manufacturing managers at Volvo and thereafter being redirected to relevant staff members of the organization.

The first interviews proved valuable for the findings, whereas the last interview was reaching a theoretical saturation, meaning that the findings were no longer providing new information regarding the topic (Bell et al., 2019). This was mainly due to the limited staff on Volvo that was working specifically within the areas of cloud as well as manufacturing. Additionally, the topic of cloud manufacturing requires specific knowledge in the area, which means that the respondents have to possess knowledge of the combination of cloud and manufacturing. Moving further down in the organization was therefore deemed to not benefit the thesis, in terms of new empirical findings. Consequently, there are only three interviews with Volvo staff that were deemed valuable and enriching of the results.

### 3.3.1.2 Interviews

As per the interview questions, a semi-structured design was chosen as the method for structuring the questions. The approach of semi-structured was preferred over an unconstructed approach due to the risk of not gathering the correct information from the interviewees (Bell et al., 2019). In addition to this, the semi-structured approach allows the authors to gather a wider scope of information while still maintaining the information on the research topic. To enhance this wider scope, the questions were not standardized for all the respondents. This resulted in two different interview guides; one was used for the staff at Volvo (Appendix B) regarding questions that could exclusively be answered by people in the organization, as well as an interview guide for the experts (Appendix C) which focused on their experience in industry and research. This enhanced the relevance of the information while also allowing the interviewees to respond and elaborate on areas that they were most knowledgeable in. This is a crucial part of the thesis since it allows for deeper knowledge and different perspectives within a single case study. In contrast, the authors chose an industry expert as well as a research expert to provide additional perspectives as well as mitigate the risk of potential biases. Some of the questions were standardized, this allows the authors to compare the response and analyze the answers to a higher extent. Furthermore, questions were also specific to the respondents and therefore adapted based on the information that was provided. This was done to cover the aspects that might otherwise not have been knowledgeable from the data gathering before the interviews. Patel & Davidson (2019) suggests that the interviews should start with a broader view and questions before progressing towards the more specific and detailed ones. To make sure that the respondents understood the questions, the authors verified the respondent's understanding of the questions before the start of the interview. Table 2 provides an overview of the parameters of the interviews, whereas the title of the respondents and representing companies or institutions are illustrated. The interviews lasted between 45 minutes and an hour each, which was deemed to provide sufficient data for the empirical findings.

*Table 2: Interview Overview Table*

| **Referred to as** | **Professional Title** | **Company/ Institution** | **Date** | **Interview Duration** |
|---|---|---|---|---|
| Research Expert (RE) | Associate Professor Production Engineering | KTH Royal Institute of Technology | 7/3-2022 | 48:42 |
| Industry Expert (IE) | Capability Lead Smart Factory | Capgemini | 11/4-2022 | 1:02:05 |
| Smart Factory Engineer (SFE) | Smart Factory Engineer, Plant Strategy Engineering | Volvo Car Group | 21/3-2022 | 53:23 |
| Product Owner Manufacturing Analytics (POMA) | - | Volvo Car Group | 21/3-2022 | 1:04:13 |
| ME Digital Strategy & Coordination Manager (DSCM) | - | Volvo Car Group | 13/4-2022 | 46:34 |

Prior to the interviews, the respondents were asked for permission to be recorded, following the research ethics of confidentiality presented by Patel & Davidson (2019). The recordings were then the base of the transcriptions. As per Bell et al. (2019), the reasoning behind transcriptions is to contrast and compare differences between the interviews and academic theory. All of the interviews were conducted in English as this was decided to be the optimal form of communication, this also corresponds with Bell et al., (2019) who suggest that to ensure dependability, all communication should be on the same premises.

The interviews were conducted via Microsoft Teams and Zoom. This was mainly due to geographical distance to the respondents, as some respondents were not in proximity to the Gothenburg area and consistency was desired for the interviews. Additionally, the authors suggested having the meeting over Teams/Zoom as an alternative due to the Covid-19 recommendations. An alternative to the Teams/Zoom interviews is by conducting the interviews over the phone, however, this alternative could potentially lead to misunderstandings and thus decrease the transferability of the study (Bell et al., 2019).

### 3.3.2 Secondary data collection

Secondary data were obtained through a literature review. Bell et al. (2019) argue that it is important for researchers to establish the existing literature on the subject, as well as current knowledge, previously used methods, and what theories have been applied. Additionally, the importance of creating a literature review to link the research questions, findings, and discussions to previous knowledge. By linking the previous findings to the findings of the paper, the literature review helps to strengthen credibility (Bell et al., 2019).

The secondary data were accompanied by academic research and connecting literature within the designated field of study. The literature was systematically collected via reviews and correlations towards the topic. This decreased the likelihood of bias towards specific papers/research. Relevant keywords were therefore used to scope out relevant articles via exclusion and inclusion (Bell et al., 2019). These keywords were sorted on relevance and thus narrowed down to a specific view, for a more narrow scope to find significant sources of information. In addition to this, a simplification process was developed by having general keywords as well as specific keywords, to find relevant articles which could be applied in the data collection process.

To establish an overview of the subject, scientific reports, peer-reviewed articles, and books will be used for secondary data collection. These were obtained at databases such as Gothenburg University Library, the Gothenburg University search engine Supersök, as well as Google Scholar. Furthermore, relevant references that were examined within academic journals were an addition to gaining further exposure to the field.

*Table 3.1: General Search Terms used*

| **General Search terms** |
|---|
| |
| Cloud Computing |
| Cloud Manufacturing |
| Industry 4.0 |
| Manufacturing Strategy |

*Table 3.2: Specific Search Terms used*

| **Cloud** | **IT** | **Cloud Manufacturing** |
|---|---|---|
| - Cloud Platforms | - Big Data | - Paradigms |
| - Service Models | - IoT | - Machine integration |
| - Competence | - Cyber Security | - Cloud Manufacturing implementation |
| - Cloud Infrastructure | - Cyber-physical systems | - Challenges |
| | - Virtualization | - Scheduling |

As the data collection elements were done digitally, some general keywords were initially presented to ensure the relevance of the study as well as the relevance of the source material that the researchers utilized. The general keywords are presented in table 3.1. In addition to this, as the scope and relevant literature were still deemed large, more specific keywords were defined to narrow the scope of the research even further. These specified keywords are showcased in figure 3.2.

The inclusion and exclusion criteria were set as guidelines regarding what was deemed as relevant literature as well as the ability to answer the research question and therefore fulfill the purpose of the research (Bell et al., 2019). Table 4 presents criteria and exclusion of what the researchers deemed relevant for the research, these criteria are therefore also in alignment with the delimitations of the thesis. The inclusion criteria are presented as Implementation of Cloud Manufacturing, Different types of Cloud Platforms, The role of competence within cloud manufacturing implementation, Security challenges within cloud & data, Cloud manufacturing's supporting technologies' roles, Cloud manufacturing's future, and Peer-reviewed articles. Where the exclusion criteria are: Technological Perspectives, Digital Twins, Topics of Industry 4.0 that have not been mentioned, and Supply chain implications.

*Table 4: Inclusions & Exclusions of the thesis*

| **Inclusion** | **Exclusion** |
|---|---|
| Implementation of Cloud Manufacturing | Technological Perspectives |
| Different types of Cloud Platforms | Digital Twins |
| The role of competence within cloud manufacturing implementation | Topics of Industry 4.0 that have not been mentioned |
| Security challenges within cloud & data | Supply chain implications |
| Cloud manufacturing's supporting technologies' roles | |
| Cloud manufacturing's future | |
| Peer-reviewed articles | |

## 3.4 Data analysis

The data collecting process consists of both secondary- and primary empirical data. This research aims to understand and identify the current state of cloud manufacturing implementation and provide guidance for overcoming potential challenges. To achieve a theory on the subject, a thematic analysis was chosen. This provides identifications through different patterns when structuring the empirical findings (Patel & Davidson, 2019). The qualitative data, which naturally is unconstructed, cannot be grouped directly (Patel & Davidson, 2019); a thematic analysis can, by coding together patterns and contrasts, create themes to perform qualitative data analysis (Bell et al., 2019). To achieve this, a transcription of the interviews was constructed, this enabled the researchers to get an overview of the empirical findings. In addition to reviewing the transcripts, concepts and keywords were formed to increase the objectivity of the study and thus increase the transferability, credibility, dependability, and confirmability of the report. Furthermore, the keywords are then formed into codes which are combined into themes (Appendix A). The first-order codes represent statements made in the interviews, which are then grouped with the second-order codes, which are grouped into the themes of the thematic analysis. During the last stage of the process, the themes are reviewed and verified by the respondents to increase objectivity and credibility. An example of the thematic analysis is illustrated in figure 6; the thematic analysis is located in Appendix A.

| First-order Codes | Second-order Codes | Themes |
|---|---|---|
| Unnecessary Data Gathering | Process Challenges | Cloud & Data in the Manufacturing Process |
| Determining Scope | | |
| Securing Quality | Motives for Implementing Cloud | |
| Improving Data Stream | | |
| BI Reporting | | |

*Figure 6: Example of Thematic Analysis*

## 3.5 Research Quality

Bell et al. (2019) argue that two key aspects to take into consideration while researching business and management are transferability, credibility, dependability, and confirmability, which in turn parallels the terms transferability, credibility, dependability, and confirmability. This section will thus discuss the author's efforts to ensure high transferability, credibility, dependability, and confirmability.

### 3.5.1 Transferability

The term transferability is used to determine if the findings apply to other contexts (Bell et al., 2019). For qualitative studies, it is argued that validity is sought after throughout the entire research process (Patel & Davidson, 2019). External validity covers the generalization that will be made during the study. For this study, there will be some limitations in ensuring generalizability due to the thesis only focusing on specifically Swedish automotive firms. In addition, Bell et al., (2019) argue that there may be difficulties in ensuring high generalizability on small samples of cases. Therefore, the generalization of the results will have to be carefully made and should be considered low. Nonetheless, the risk of overgeneralization will be difficult to ensure, mainly due to different approaches to different markets within the same organization.

### 3.5.2 Credibility

Credibility concerns how believable the findings are, and parallels internal validity (Bell et al., 2019). Credibility is the relationship between the observations and the developed framework the researchers have proposed. To ensure credibility, the methodological choices that have been presented in this chapter have been explained and argued for. There are primary and secondary data obtained as well as theory to compare to the findings (Lincoln & Guba, 1985). Additionally, to ensure that the social context was properly understood, the transcriptions of the interviews were sent to the respondents to validate the correct interpretation of the data (Cope, 2014).

### 3.5.3 Dependability

Dependability is used to determine how replicable the empirical findings are if they were to be repeated multiple times (Lincoln & Guba, 1985). This is done by ensuring that the results are not achieved by chance or specific phenomena (Bell et al., 2019). By ensuring high dependability, a study can therefore be classified as having reliability and the findings are consequently likely to apply at other times (Lincoln & Guba, 1985). To ensure high dependability, i.e. a high level of conformity between the researchers' observations (Bell et al., 2019), both authors were present at the interviews. Moreover, both authors participated in the writing and reading process of the transcriptions made from the interviews to ensure that the understanding of the interviews was agreed upon (Cope, 2014).

### 3.5.4 Confirmability

Confirmability is used as a parallel to objectivism, that is that the author's own opinions or personal values are not manifested in the thesis findings (Bell et al., 2019). While it is argued that confirmability should be a primary goal for the authors to establish (Lincoln & Guba, 1985), it is difficult to fully ensure confirmability in business research (Bell et al., 2019). A method of enhancing confirmability is for the authors to demonstrate how conclusions and interpretations were made, as well as clearly illustrate where the data of the findings were derived from (Cope, 2014).

## 3.6 Ethical considerations

Patel & Davidson (2019) suggest that there are four different ethical requirements when conducting research: Information requirements, confidential requirements, consent requirements, and usage requirements. Information requirements require the researchers to provide the concerned respondents with the study's purpose. The confidential requirements require the researchers to provide the respondents the possibility of being anonymous and include the handling of confidential information. The consent requirements require the respondents of the study to have the right to decide if they want to participate in the study. Confidential information disclosed by respondents will not be published. The usage requirements require information gathered from individuals to only be used for research purposes (Patel & Davidson, 2019).

When conducting this thesis, the research ethics requirements of Patel & Davidson (2019) were taken into account. Before the interviews, the researchers presented themselves, the representing institution, and the purpose of the study. This is to increase transparency and remove potential deception of the research conducted by the authors (Bell et al., 2019). Moreover, the respondents for this thesis had no obligation to partake in this study and were voluntarily taking part in the study. When confidential information was presented during the interview, the information was decided not to be included. The respondents were allowed to be anonymous, as well as the company or institutions that the respondents represented. The information gathered in the interviews was only gathered for the empirical findings of this thesis and served no other purpose.

## 3.7 Summary of Methodology

In the previous sections of the methodology chapter, the research strategy and design as well as the data collection and analysis have been presented and criticized. This includes the presentation of the research strategy; a research worldview in which the constructivist worldview is selected, an abductive approach for the literature formulation, and a qualitative method. The research design is presented as a single case study. The data collection consists of conducted interviews and how the interviews were conducted as well as a literature review. The data is then analyzed using thematic analysis, in which first-order codes, second-order codes, and overarching themes are presented. There are remarks and arguments presented to ensure high research quality to the extent that it is possible, in which processes and arguments are made for transferability, credibility, dependability, and confirmability. Lastly, there are ethical considerations in the methodology section that are presented and taken into consideration when conducting the research of the thesis. Table 5 illustrates a summary of the selections made concerning methodology.

*Table 5: Summary of the methodology chapter*

| Theoretical Summary | |
|---|---|
| | |
| **Research Strategy** | Contructivistic Worldview |
| | Abductive approach |
| | Qualitative |
| | |
| **Research Design** | Case Study |
| | |
| **Data Collection** | Interviews |
| | Literature Review |
| | |
| **Data Analysis** | Thematic Analysis |
| | |
| **Research Quality** | Transferability |
| | Credibility |
| | Dependability |
| | Confirmability |
| **Ethical considerations** | |

# 4. Empirical Findings

*The chapter on Empirical findings consists of the data findings from the various interviews that were conducted. The structuring and presentation of the findings were based on the codes that were processed into themes that were identified in the thematic analysis in Appendix A. The interviews were conducted with various staff from Volvo as well as an Industry and Research Expert. The themes that have been identified are the state of manufacturing, integration into the cloud, manufacturing strategy, implementation, security, and cloud manufacturing in the future.*

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## 4.1 Cloud & Data in the Manufacturing Process

Volvo has been working with the implementation of data gathering for their cloud service for the past five years; POMA argues that Volvo has been aware of the implementation at other organizations but has chosen not to investigate it, until five years ago. The ambition of the implementation was to secure the quality of a product throughout the production process. However, the POMA argued that they quickly realized that this was too difficult and required too much work for the potential gain due to the scope of the implementation being too wide. The decision was made to start small-scale and focus on the more cost-effective solutions; bottlenecks and troublesome equipment were identified and data analysis could be done on a smaller scale to achieve results while not pooling too many resources. This also meant that the production teams started to investigate the root causes of problems that were encountered.

*"(...) we are trying to see where and how we can extract the most amount of value for the least time. In the beginning we were trying to predict the total quality in the product. This was extremely difficult, because it required an immense amount of data from a large part of the production process. As the product goes through a lot of different steps and stations before its finished. To extract valuable information from that kind of analysis requires extreme amounts of input data."*

*- POMA (2022)*

The maturity of data collection was also realized within the production teams. SFE explains that during the initiation of the data-gathering project, all the available data was collected. This led to a lot of unnecessary data getting collected and thus analyzed. This was at the beginning of working with the raw data, however, SFE argues that this experience created improvements in the data collection process. The new data collection process and mapping are consequently slower. However, the results are suggested to be more valuable than previously. The improvements in data handling are partly due to pilot projects with universities and different suppliers, but also the maturity of Volvo and the improvements to the process.

*"Initially we talked a lot about big data and tried to add all the input we could find. This meant that we added data that wasn't that relevant, but this is something that is now recognized in hindsight. Which means that now that we have matured, we understand*

*what types of data that we should utilize and what data is unmercenary for this improvement. This has resulted in us working more efficiently and getting a better result."*

- *SFE (2022)*

During the past three years, the collection of data is argued to have been drastically improved. The implementation of a cloud system enabled all engineers within the organization to seamlessly stream raw data to the cloud. AWS was chosen as Volvo's platform and this is where the construction of a private cloud could be done. POMA explains that before the cloud platform, all the data gathering was done manually by a collaboration between the production teams and the POMA's department. This process usually took two months to gather all the data, then another one to twelve months before analysis could be conducted. This has now been avoided, when the cloud platform allows real-time streaming of data to be uploaded into the cloud. Volvo is calling this system "self-service", which was introduced during the last quarter of 2021. The introduction of self-service did not only allow all the engineers at Volvo to transmit the data, but this also allowed for a standardized way of working, throughout the organization.

*"After the introduction of self-service, we noticed a larger data stream of information from our engineers. As they were able to send it to us so that me and my team could manually process it. The process of data gathering usually started 2 months after we received a request from the production personnel, we started to gather all the necessary data that was available, and it usually took 1-12 months before they received anything back. This is an extremely long process. Therefore, we introduced self-service (...)"*

*- POMA (2022)*

RE argues that cloud computing can be used at three different levels in manufacturing businesses or as a manufacturing utility: The entry-level, which is explained as inserting the manufacturing data into the cloud, which allows for sharing of data. This is exemplified by services such as Gmail or iCloud. The second level is argued to be centered around cloud manufacturing itself, which calls for a deeper use of cloud computing. 'Deeper use' refers to using cloud computing to precise the manufacturing process by connecting the manufacturing machines to the cloud. By utilizing a service-oriented architecture, SOA, alongside the integration of cloud computing, the company's operations and assets, such as machines, robots, and data, are seen as a service. Consequently, SOA is argued to connect the manufacturing services to cloud computing. The third level is presented as the implementation level and scope. This level includes selecting to which extent cloud manufacturing will be implemented into either the manufacturing operations or cloud computing in general. Furthermore, it is argued that it should be determined if the company should develop a private cloud or utilize public clouds as the implementation process of integrating cloud manufacturing.

The application areas for data and cloud in Volvo's data platform architecture are presented as the 'golden path'; the process is explained as the process of moving and receiving data from the factory into business intelligence reporting. The process is initiated by obtaining data in the factory through applications data, IoT data, databases, and third-party data. The factory data is thereafter uploaded to cloud service platforms, AWS and Azure are explicitly mentioned. The data contains structured as well as unstructured data. The data is then transferred into a data warehouse, in which data sets and meta-data may be created. The data is used for self-service applications, which is argued by DSCM to allow for the creation of Business Intelligence reports. The reports can consist of ad-hoc data analysis, alerts, real-time data, and data science for the physical and digital production plants.

## 4.2 Integration of Cloud & Data

The RE suggests that the general implementation of cloud manufacturing can currently be possible from a technological perspective. It is however the integration and connectivity that are argued to be the main challenges to implementing a cohesive cloud manufacturing process.

*"(...) from the base level, the technology level, the basic technologies are there. Computing, sensing, big data (...) - we have the knowledge and technology already. The thing is that I think that what the technology needs is integration for connecting - we have big data, but how do we connect it to the machine, your company or your robot? So you have the methods, you have the algorithms and the machines, but how do you connect them together in a stable and robust way? I think that's where we are today."*

- RE (2022)

Conversely, Volvo's implementation of connectivity throughout the manufacturing equipment is ongoing; SFE argues that the best result would be obtained by building a new factory. The main reason for this is suggested to be the avoidance of legacy systems and equipment, as these systems and equipment are difficult to integrate. POMA does not share this view and believes that the integration is possible with legacy systems and equipment, but is however agreeing that there is a larger challenge with these systems. The IE also believes that the integration of legacy systems is possible and that organizations are not required to update their systems for cloud integration. In addition to this, the RE argues that the integration of robots and machines is a major challenge. Big data, methods, algorithms, and machines are present and viable, but the RE suggests that the current challenge is how to integrate them stably and robustly.

*"Legacy systems are a challenge, but normally it should be fine. Because they are producing, they are well designed, developed and really customized in a professional way."*

- *IE (2022)*

Another challenge that is identified by both SFE and POMA is the resource allocation, as this is argued to be a key component for the cloud manufacturing integration. The resources are argued to consist mostly of competent personnel, POMA argues that the resources that are required for a full-scale implementation and integration would be considerably high, which is not something that the senior management is currently willing to allocate. This does not only apply within POMA's team, the manufacturing division is argued to also face this issue. SFE argues that every manufacturing team needs a person that will work full time with the integration of cloud services. This is however argued to not be possible with the current resource allocation in the manufacturing department.

The issue of finding the competence and technical skills for the transition into cloud manufacturing and data-driven decision-making is argued to be a significant challenge for companies, according to RE. The transition is suggested to require many different competencies such as production planning, data scientists, and programmers. It is therefore argued to be crucial for companies to assemble diverse teams to create a solution that covers the areas that a cloud manufacturing implementation could potentially require. POMA argues that finding the right people with the required competence is a constant challenge for all divisions and not specifically a challenge for the cloud operations division alone. The main vacancies that are challenging to find are argued to be engineers, web developers, front-end, back-end, and full-stack.

The IE argues that there are mainly three different layers within cloud adaptation that organizations may utilize: The first layer is the equipment layer. The equipment layer is suggested by the IE to utilize a private cloud network that can transmit data from each machine or equipment to the production layer. The second layer is the production layer where the production systems are controlled. This layer is also the most difficult one to implement, as the current service providers do not have a good solution currently, according to the IE. AWS outposts are exemplified as an infrastructure solution that is being developed as a solution to the on-prem challenge. Since the solution is still under development, the IE, therefore, recommends organizations either develop their cloud systems within the production facility or wait for on-prem systems to develop further from the major cloud service providers. The third and final layer will be the cloud service that is utilized by the organization, this could be utilized for analytics and daily operational use. This layer could be exemplified as the Self-Service that Volvo utilizes. The cloud service allows Volvo, according to DSCM, to collect information that is being transmitted from the production for analytical and improvement purposes. The IE also argues that a challenge that automotive is facing is having these cloud platforms communicating with each other while still maintaining their security.

*"(...) The main challenge that I think is renewing their central applications, in terms of controlling their manufacturing processes. This is also what a lot of these organizations aren't doing at the moment; they are building these systems in parallel to their existing IT landscape (...), which means they aren't fully integrated into the legacy world and they aren't starting with a clear roadmap and view of how the full transition will take place. This is for me the largest challenge that the automotive industry faces; they build up a lot of use-cases that are not linked or integrated into their legacy systems (...)"*

- *IE (2022)*

## 4.3 Manufacturing Strategy

The overarching strategy that is being implemented throughout Volvo's manufacturing process is based on a legacy system that was developed for one single factory; this system has since been scaled up. This system was based on the principles of lean manufacturing, with sequencing and planning within production from 12 weeks forward. POMA argues that there have been major challenges with upscaling this system to multiple factories, as the design was only intended for one specific factory. In addition to being built around the core principles of lean, the production system is pull-oriented. POMA and SFE argue that the senior management is still focused on this strategy and not trying to implement any radical changes to the manufacturing process. POMA recognized another manufacturing strategy that favors a more adaptive approach. However, the method might be a more philosophical one, rather that one is better than the other. Volvo has therefore chosen the more static approach, where the focus lies on fewer variations within the manufacturing process. This theory was tried at one of Volvo's close partners, Polestar. By having less variation within processes and production material, the margins would increase. Along with fewer components and better material planning. SFE argues that the fluctuation in staff requirements could also potentially be improved. POMA argues that lowering the customization of the hardware within the end-product could be complemented by software customization. By enabling customization within the software of the Car, the implications on the manufacturing process are non-existent. At the same time, the customers are still able to have a unique product, suited for their specific demands. This implementation showcased by Polestar was successful, therefore, Volvo is argued to be implementing the same strategy with lesser variations.

This strategy might be prone to change according to POMA and SFE, if some positions within senior management would be replaced, the strategy might change drastically. Mainly due to the wide recognition of adaptive manufacturing within the Volvo and the possible advantages that this might have.

*“ (..) it is so expensive with variation, this is not only variation of the product, but also within processes. The impact of the Covid-19 has made us think over the variation of products within the cars. As we are having a shortage of semiconductors and other suppliers are closing.”*

*- POMA (2022)*

Furthermore, it is argued by DSCM that Volvo’s current software portfolio does not provide enough support for emerging advanced manufacturing processes. This has given rise to the mechanical engineering digital strategy, which plans for a digital production plant in real-time. The digital production plant will be combined with IoT and digitalization and aims to be a natural part of the manufacturing process. This is argued to improve data integrity, data exchange as well as streamlining of data flow without disruption.

The IE argues that automotive companies are usually controlled by the production process, the main focus is therefore to secure production processes and minimize stops. This is suggested to be one of the major reasons for lower variation within the production process and therefore the strategy that some automotive organizations implement. The benefit of an adaptive production system might therefore not be the focus area as the manufacturing department is still trying to automate processes and are still not finished with implementing industry 3.0 improvements.

*"The production in the factories are still working on getting manual processes automated and to move away from paper, to get all the data in a digitalized way. To have it transparent for all the relevant people, so production is still dealing with the simple stuff(...) I don't see IoT or AI changing this drastically within the near term future. It will be more of an evolution, step by step"*

- *IE (2022)*

RE strongly believes that the adaptation of cloud computing within manufacturing will be a matter of time. Stating that within the coming five years, the implications of cloud computing and thus the adaptation will grow larger. Within the next ten years, the full-scale implementation will be a fact, within most automotive firms, this is also something that is emphasized by the IE, which also believes that the next five to ten years will be the timeframe for cloud manufacturing implementation. In addition to this, the IE suggests that the implementation is part of an industrial revolution, therefore, the adaptation will take a significant amount of time before it could be fully incorporated.

Volvo also recognizes the importance of a futuristic perspective, POMA defines one of the major challenges for the organization as connectedness and datastream that the 10 000 manufacturing robots. This is mainly because every robot needs to be connected for the organization to fully implement the cloud solution within manufacturing. Additionally, each workstation needs to be connected through a private machine of the network when uploading the data. POMA, therefore, argues that the scaling of the operation could pose a major challenge as this would require Volvo's supplier to also implement the cloud adaptation for their robots.

*"So we have over 10 000 robots across the globe, which means, if we are to have every station send data via their network then we would have a much better and more secure datastream. So at the moment, if we are trying to gather data from a single robot, this requires a person to do this. But this isn't viable for all the 10 000 robots. Which means, that we need to find a solution for this"*

- *POMA (2022)*

The RE argues that a bridge of cloud manufacturing gaps with IoT, this gap isn't agreed on by the IE. As the IE believes that IoT could be considered more of an enabler within the subject. The IE continues to argue that the production lines are quite far behind the academic literature on the subject since production is still trying to digitize and move away from paper. AI or IoT is not something that the IE believes will change drastically within the near-term future, rather something that will be an evolution and be implemented step by step. Similar arguments are made by POMA and SFE, as the implementation process is still small-scale but Volvo is expanding its implementation of cloud solutions.

In the future, the cloud is argued to play a large part in the entire IT landscape and manufacturing platform, the IE suggests that all the automotive manufacturers are shifting the manufacturing IT to a more platform-centric approach. It is argued that many organizations have initiated large implementation programs for this, continuing that the future is more of a when the full-scale adaptation will be implemented rather than if. As the technology is getting better by the day, the IE argues the target state where 80 percent of all applications will be running in a cloud environment. This is implied by the IE that Microsoft and Amazon predicted, hence why the development of their on-prem solutions is already within the development. The requirement of an on-prem solution is argued to be due to latency and as well as more specific requirements. The IE suggests that the manufacturing divisions possess significant dependency on legacy systems, which indicates that change from the current IT landscape to cloud could take more than ten years.

*"It's not a question of if, but a question of when and how fast they will transform their application landscape towards the cloud direction. The production personnel are going this direction but this is the breaking-point at the moment, because of the technology that is getting more resilient and less prone to failure(...) The public cloud providers like AWS and Azure, understood that there will always be a need for an on-prem part. You always need to have the possibility to have cloud technology on prem in the plant."*

- *IE (2022)*

## 4.4 Security Issues

RE argues that one of the main challenges of working towards cloud manufacturing is security, in particular of what information is safe to put on the cloud such as data, knowledge, and applications. It is argued that the security issue is not necessarily a challenge specifically to Sweden, but rather a global challenge for companies.

SFE emphasizes that the different pilot projects are based on data that has been collected by Volvo and that the sharing of this data is an issue. The main problem is argued to be when the data is going outside of the company, which means that Volvo's in-house projects are less complicated than when data is being shared outside of the organization. The possibility of leakage of data or a cyberthreat is something that Volvo is aware of; SFE argues that threats have been realized now more than ever before. This was not the case before, SFE argues that five years ago, the IT department had little collaboration with SFE's department. However, the IT department is now the main component of the initiation of every single project. During the initial meeting, IT is a part of the negotiations from the first day. If the security requirements cannot be fulfilled by a supplier, the collaboration with the supplier will be terminated. In addition to the possibility of leakage of data, cyberthreats also pose a large risk of access to the entire Volvo network, SFE argues that this is their largest concern, as this poses a risk for the entire organization. To combat the security issue, Volvo has developed a requirement framework which is to prevent any type of data breach. Moreover, to gain access to Volvo's data, the operator is required to use Volvo's IP addresses. This is argued to create difficulties when sharing data with suppliers, as the supplier may not always have access to the correct IP addresses.

*"The main problem is when data is going outside our network or factories, when the data leaves our secure network, our main concern is the cyberthreat. So, when we have the Pilots within our network, this is usually never a large issue. We have a huge amount of respect for the cyberthreat that could pose for us as a company, so we are reluctant to share our data, since we don't want it to end up in the wrong hands. It's not just about data either, having an outsider get access to our Volvo Network poses a huge risk for us. There are a lot of things that they can accomplish by having access to our secure network."*

- *SFE (2022)*

The IE suggests that security poses different types of challenges, the main challenge that is argued to be within the final product. However, the IE continues to argue that the security within the production plants themselves also poses a challenge. The security within the manufacturing plants usually consists of two to three layers. These are suggested to already be in place, which is something that SFE and POMA agree on, as the collaboration with suppliers is more difficult when data is shared outside the manufacturing plants. The IE describes that one of the first challenges an organization overcomes is to have the different layers of security communicating with each other; transmitting data internally from the manufacturing plants to the concerned departments for analysis.

*"You have kind of a demilitarized zone where it's very difficult to access from the outside. But they have a good security system in place at the moment. Even with cloud computing, there is no issue to have an end-to-end security concept, even if you have a datacenter like AWS or Microsoft."*

- *IE (2022)*

The RE suggests that there are methods to mitigate technical risks concerning data sharing with suppliers; consequently arguing that it can be mitigated on three different levels: The first level concerns the improvement of the security mechanism. This is exemplified by using blockchain technology as a means of having private keys with restricted public access to improve security on a cyber-level base. The second level is argued to be the demonstration and convincing of management to illustrate how data security may be improved. The third level concerns the amount of data shared, arguing that a general misconception with cloud manufacturing is that all of the data shared is public and exposed, which the RE argues is not the true meaning of cloud, and that there are security measures in place for public cloud usage.

Integrating the suppliers is a challenge that the IE defines, arguing that this is solvable. During the last years, an initiative called Catena-x was formed by German automotive manufacturers and their suppliers. One of the objectives of this initiative is suggested by the IE to implement a standardized way of transmitting data between suppliers and OEMs. Furthermore, the IE argues that there are custom-made solutions in place between every supplier and OEM at this moment, however, one of the initiative's goals is to set an industry standard for formatting and transmitting data along the value creation process. SFE states that during their supplier integration, there are some requirements that Volvo needs to be fulfilled before a collaboration might occur. These requirements are partly to protect the data that Volvo shares, but also to have the systems aligned with Volvo's own.

# 5. Analysis

*The chapter on Analysis consists of the Empirical Findings in relation to the literature review. The thematic codes that were identified and applied in the empirical findings are also applied within the analysis. The structure is therefore presented in the same way as the empirical findings. The analysis discusses the discrepancy of the academic literature compared to the findings of the study as well as the similarities that are presented below.*

## 5.1 Cloud & Data in the Manufacturing Process

The cloud manufacturing concept is still generally unknown to the respondents at Volvo, which suggests that Volvo does not explicitly work toward cloud manufacturing. However, Volvo is currently integrating data into a cloud service system. The integration indicates that Volvo is currently located at the 'first level' of cloud integration that the RE presents. The current level of integration is thereby not included in the other levels, which include the virtualization of physical assets such as robots and machines in the production process (He & Xu, 2015; Tao et al., 2011; Ghomi et al., 2019). As this is argued to be one of the core features of an implemented cloud manufacturing infrastructure (Lu & Xu, 2018), it is therefore not possible to claim that Volvo is currently having a cloud manufacturing infrastructure in place. Furthermore, it is argued by POMA that Volvo is lagging in the development and integration process of the cloud, which can be argued to be an underlying cause for the current implementation level.

The empirical findings indicate that there may be a discrepancy between the academic literature and the Swedish Automotive industry. While cloud manufacturing was firstly introduced in 2010 (Liu, 2010), Volvo started to create and utilize cloud services from 2019 and onwards. The integration process is therefore not necessarily completed and implemented. Volvo acknowledges the late adaptation of the cloud within their IT landscape and the implications that it might have. While there are no fully implemented cloud manufacturing systems in 2017 (Adamson et al., 2017), the findings illustrate that Volvo has not fully implemented a cloud manufacturing system in 2022. This reasoning is reinforced by the RE and the IE, which argue that the application areas and cloud transition will be more prominent in five years and fully implemented in ten years.

The IE proposes that the core challenge for the implementation of cloud within manufacturing is that the systems that are being developed are parallel to the existing ones, meaning that the central application is not being reviewed. A result of this is that the legacy systems are therefore not fully integrated. The IE also suggests that vague roadmaps for the full transition could also pose a major challenge for automotive manufacturers. This correlates with the empirical findings that are being suggested by the RE, as the tools for implementation are currently present, however, the implementation of the equipment or machines is argued to be a challenge. Conversely, Rimal et al. (2011) suggest that a challenge within the implementation is interoperability, even with the current state and advancement. Interoperability and the framework for both integration and migration to the new system correlate with the challenge suggested by the IE. The empirical findings argue that Volvo is not currently working on a mass migration of clouds within their manufacturing system, merely to fulfill specific tasks and functions, as exemplified by Volvo's 'Self-Service'.

Yang et al. (2016) present three core challenges with integrating and developing equipment or machines into cloud manufacturing. The first challenge is suggested to identify the current status of the machines, the authors propose that this could be solved with sensors. The IE does not believe that this is the reality, however, as the current step within the manufacturing process is implied to still be automating processes, arguing that sensors and AI into machines are a bit far from the actual reality of manufacturing processes. The empirical findings also suggest that Volvo focuses on data collected from the machines/manufacturing equipment. Arguing that the more adaptive approach is not in line with the current organization's manufacturing strategy. The second challenge is suggested by the authors to relate to scheduling and distributing tasks, additionally planning for potential malfunctions, the reasoning behind this is argued to be the distribution of dynamic production tasks. As per the empirical findings, this is also not aligned with the current strategy of Volvo, the RE, and the IE also argues that the implementation of adaptive manufacturing is still within the future, that the current implementations are within their infancy and the first challenge has not been solved. The third and final challenge that is presented is the communication of the equipment. The empirical findings are indicating that Volvo is currently working on this, gathering data from the equipment to be analyzed and processed. This implementation is also argued to be within its infancy, as the authors propose the challenge to also include communication and coordination between different machines. Currently, Volvo is utilizing its public cloud element to gather data and optimize downtime, however not necessarily with a communication and coordination system between machines in the production system (Ibid.).

The RE suggests that competence is a major challenge for the organizations during the transformation toward cloud manufacturing; locating personnel that is competent within both manufacturing and cloud services is argued to be a problem. The RE, therefore, suggests that organizations utilize a team of special competencies to implement the organizational adaptations for cloud manufacturing. This argument is however not shared by the Volvo representatives. In addition to this, the study finds that competence always poses a challenge, therefore stating that this challenge is not exclusive to the implementation of cloud. The findings suggest that engineers and full-stack developers are some of the core competencies that Volvo is searching for. Contrasting this to the literature, which is not agreeing with this, Lin and Chen (2012) argue that the current IT personnel will face challenges as the cloud implementation emerges.

The lack of further integration of cloud may create a discussion of the new manufacturing paradigm that cloud manufacturing is suggested to institute (Li et al., 2010; Mouritz, 2020). The findings do not necessarily indicate that there is currently a manufacturing paradigm transition towards the components of cloud manufacturing, rather towards cloud computing in terms of services, storage and resource utilization (Ren et al., 2014; Figueiredo et al., 2005). It may be important to note that this thesis concerns a single case study isolated at a current time state in which a cloud manufacturing system still is not have a implemented system (Adamson et al., 2017), which may affect the argument of a potentially new manufacturing paradigm.

## 5.2 Integration of Cloud & Data

The empirical findings indicate that Volvo is using data gathered from the manufacturing process in the operations. Currently, the organization is working with an adapted lean approach, which has resulted in less desire for variation and consequently less customization and individualization of products. This has been the organization's strategy since the implementation of lean manufacturing within their factories. Furthermore, the Volvo respondents argue that there is a cost-benefit of following this approach, rather than a more diverse and adaptive one. As the adaptive approach would demand a large-scale change within their core manufacturing system. In addition to the substantial change, Volvo also suggests that the two different approaches could be seen as philosophical, arguing that one method might not necessarily be better than the other.

When Volvo started with its optimizing plans and data collection, Volvo noticed that the scope was too wide, furthermore, the ambitions of what Volvo wanted to accomplish is argued to be too difficult to implement. Both POMA and SFE argue that Volvo quickly realized the immense scope of the project and decided to shift focus in a more cost-efficient manner, having learned that small improvements are still able to achieve the desired outcome. This leads to the current state of data collection, which is focused on optimizing downtime and bottlenecks within the factories. This is strongly correlated with the lean-manufacturing approach and is therefore the main focus of the data gathering system that Volvo launched.

The gathering system is a cloud platform that utilizes AWS during the development of its platform, which is called Self-Service. The service enabled the various manufacturing teams to transmit their data directly, this increased the efficiency of the entire operations and consequently enabled POMA's team to utilize their personnel more proactively. Furthermore, the increase in efficiency also transmits to the manufacturing divisions, which is argued to spark interest within new teams. SFE argues that more teams are recognizing the need for these types of implementations within the production system, this also increases the amount of data that is being gathered for POMAS team. The reasoning behind the utilization of AWS meant no requirements to invest in personnel, IT infrastructure, or the remaining cost that a large-scale platform development requires (Power & Weinman, 2018). The discussion of developing their platform or utilizing a provider was a rather easy choice for Volvo, as POMA argues that Volvo knew that they will receive a better end product if they outsource to one of the large service providers. Therefore, utilizing an IaaS or HaaS according to (Xu, 2011) from AWS. Power and Weinman (2018) also argue that scalability, as well as high development cost, are some of the benefits that utilizing a public cloud platform provides, which is also the reasoning behind Aryotejo et al. (2018) argument of the public platforms to be the favorable option for organizations. This solution could be contrasted with the academic literature that suggests a private cloud development to increase the organization's security level (Aryotejo et al. 2018; Vikas et al., 2013). Additionally, the control of the development and full customization of the cloud system, which the organizations are not able to receive when utilizing a cloud service provider like AWS or Azure.

This public cloud solution is however not a holistic one but a quite specific one for the designated task. In this case, the task of Self-Service is to have a public cloud platform where data can be collected to then further analyzed by POMA's team. The self-service platform is considered to be a public cloud platform that would enable Volvo a high form of scalability which is suggested by Aryotejo et al. (2018). This argument correlates with the view of the IE, which believes that the majority of applications will be running through a cloud platform within the coming years; continuing that most of the large automotive organizations have implemented projects for the large-scale implementation of cloud within their organization.

## 5.3 Manufacturing Strategy

The strategies that Volvo are following are aligned with the manufacturing strategy that they have been utilized since the implementation of lean manufacturing. The empirical finding suggests that Volvo is striving for less variation within its products and processes. This directive stems from the strategy that Polestar has implemented within their production process, as Polestar showcases that lesser variation and more standardized products are beneficial. Not only for the production process but also the whole value chain according to POMA. This strategy is also visible in Polestar and its manufacturing process. Clear differentiation from the more customizable alternatives that are usually being offered. Volvo does however recognize the value of consumer customization and therefore implement this within their software instead. The study finds that this achieves two major things, the production is still able to lesser their variation of products and processes. Therefore lowering their cost and standardizing their way of working, additionally, the consumers can customize according to their specifications without the strain on the manufacturing department. Meaning that Volvo can follow the example of Polestar with less variation, maintaining their manufacturing strategy while still offering a partly customizable product to their end customer.

While benefits of cloud manufacturing are described as customization (Ren et al., 2015), interoperability (Rimal, 2011), and machine communication (Ivanov et al., 2020; Yang et al., 2016), Volvo has deliberately chosen to not implement a dynamic production process that meets the customer's needs of product customization and individualization, instead opting for a lesser variation approach where customization will be offered through software. Volvo and the IE argue that the choice of adaptive manufacturing or lean manufacturing strategies could be a philosophical approach, rather than an improvement over the other. Tao et al. (2011) identify this unwillingness to adopt cloud manufacturing, based on knowledge and trust. that organizations might. Additionally, the concept of cloud manufacturing is not widely implemented. The study finds that changing the entire production system might also pose a major challenge, as legacy systems are required to be updated and integrated. Additionally, the empirical findings showcase a discrepancy of opinions regarding the legacy system integration. SFE believes that a new factory could be a solution to the challenge, therefore, developing new systems, while POMA and the IE argue that the legacy systems could be integrated with their current form and do not therefore require a new factory to solve the legacy challenge.

The current manufacturing strategy is defined by senior management, the empirical findings indicate however that several people within Volvo cars favor a more adaptive approach. This approach could however change, as Volvo states that during organizational changes, the strategy could alter and therefore favor a more adaptive manufacturing approach. TheIE suggests that the automotive organizations are mostly following the directions of the manufacturing process, thereby deciding the strategy for the entire organization. A challenge that has not been discussed in the findings is demand uncertainty as described by Ghomi et al. (2019). With Volvo's manufacturing strategy of avoiding variation and uncertainty as well as the production strategy's influence over the organization, it would therefore seem that a cloud manufacturing implementation may not be beneficial to implement before such a challenge could be resolved. As the manufacturing division aims for stable production and to minimize downtime, the production process is usually not willing to try new concepts. Mainly due to that the production process is still trying to implement the changes of Industry 3.0, with automating processes, therefore indicating that the manufacturing process is behind the development of cloud integration as the study finds. As the manufacturing divisions are suggested to be behind the rest of the organizations with cloud implementations, the RE and the IE argue that within the coming five years, the cloud implementations will play a larger part in the organizational strategy. Additionally, the full-scale transition of cloud is suggested to take place within the coming ten years. As the study finds, the transition towards the cloud is only suggested to be a matter of time.

The emerging topic of cloud manufacturing has increased during the last century as figure 1 shows. This shows the growing interest in cloud solutions, outside the scope of everyday usage. These implications are well understood by automotive manufacturers, which is why the IE states that all the major automotive manufacturers are developing strategies for cloud integrations. Furthermore, arguing that the IT landscape will have 80% of its applications in a cloud-based environment. This transition into the cloud is argued by both the RE and the IE, additionally, the larger service providers have also understood this transition. The IE suggests that Amazon and Microsoft are already predicting what the manufacturing industry needs, which is an on-prem solution. Even if the manufacturing division has not fully committed to cloud adaptation, the future will require these types of solutions, according to the IE.

It has been argued by the IE and the RE that cloud manufacturing implementation may take between five to ten years to see full application. This may however not necessarily hold for Volvo; POMA argues that the implementation of cloud services to store data alone was a process in which Volvo is lagging compared to other competitors. It may therefore be raised that a cloud manufacturing implementation at Volvo could potentially require more time than what was suggested by the RE and the IE. Additionally, the IE argues that the transition into the cloud could be categorized in terms of a revolution.

## 5.4 Security Issues

Volvo's development of the cloud platform was made on AWS. This is argued by POMA to be a 'private cloud', in which suppliers are obliged to use a Volvo IP address to gain access to the stored data. The security demand for a Volvo IP address is argued to have increased challenges surrounding data sharing within the organization, especially concerning data sharing with partners and suppliers. This is however not the true definition of a private cloud, whereas the underlying ownership determines what type of cloud is being used (Ren et al., 2015). For this particular case, Amazon is the underlying owner; Volvo's cloud is therefore likely a private cloud by definition.

The IE identifies that the organizational IT-security landscape is usually based around two or three main layers within the organizations and that these layers are already in place. Continuing, this enables the organizations to have a form of a demilitarized zone, where the security is very high. The findings illustrate that implementing a cloud platform within this IT infrastructure is possible, even if operated on a larger service platform such as AWS or Azure. This aligns with the current implementation of Volvo's Self-service platform, which is based around the public cloud platform from AWS.

It is argued by Volvo staff that security and IT have been playing a larger role in the organization, which may be a result of the development of security issues for businesses regarding privacy, communication, and data storage Zarpelão et al. (2017). It is suggested that security threats such as data leakage and cyber-threats are increasing risks for the company. The increase in cyber-threats has resulted in larger security demands within the organization as well as the information that is being shared with other actors. The empirical findings suggest that Volvo has taken action to combat this, during the initial meetings with collaborators or other stakeholders Volvo has started to incorporate their IT division. Additionally setting up a list of requirements, as the realization of a data breach could have severe effects on the entire organization. These requirements have caused Volvo to lower its flexibility within its negotiations. However, to retain some flexibility within the negotiations the study suggests that the IT divisions are attending to solve any potential requirements that the suppliers are unable to meet.

One of the largest challenges that Volvo identifies, is to share the data outside of the organization. This has proven to be quite difficult as the organization is highly aware of the possible security implications that this poses, the study suggests that Volvo is, therefore, more prone to initiate pilots and other collaborations within the organization. The risk of sharing sensitive data outside the organizations is a problem. This communication risk is also highlighted by Zarpelão et al. (2017) and aligns with the risk identified by Volvo.

The IE argues that the automotive manufacturers currently have a high-security system in place and that the challenge of collaboration with various suppliers poses minor challenges. Continuing that as the collaboration is initiated, the sharing of data is usually solved by tailored solutions between the different parties. The main challenge that is being suggested would be a standardized way of data sharing, across suppliers and automotive manufacturers. The empirical findings indicate that this issue is currently being investigated by the Catena-x initiative. This initiative could solve some of the issues that Conti et al. (2018) argue for; authorization and authentication could have a possible solution if the communications could be standardized. Additionally, the highlighted issue that Yang et al. (2016) propose, management and deployment are also solvable with a more standardized way of communicating.

# 6.0 Conclusion & Recommendations

*The conclusion chapter provides a summary of the study, as well as recommendations for the Swedish automotive manufacturer. This is achieved by providing answers to the research questions set out in 1.4. Lastly, there are concluding remarks made regarding potential future research on the topic at hand.*

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The purpose of this thesis has been to identify the current state of cloud manufacturing implementation and provide guidance in overcoming potential challenges for a Swedish automotive company. The delimitations of the paper have been to specifically study a manufacturer in the Swedish automotive industry as well as technical aspects and manufacturing models. The research questions were formulated to study the current implementation phase of cloud manufacturing, which is found to be a question of when, and not if, it will be embraced by the manufacturing industry. While the findings do not indicate an explicit implementation plan for a cloud manufacturing system, the first research question aims to present and explain how certain elements may be derived from components of the cloud manufacturing concept. The second research question aims to identify current and future challenges that may affect a possible cloud manufacturing implementation, while the third presents possible methods of meeting these current or potential challenges based on the analysis. The research questions are answered below:

## 6.1 Answering the Research Questions

### RQ 1

*What is the current cloud manufacturing implementation state of a Swedish Automotive Company?*

The study did not identify that the current strategy was to follow the large-scale implementation of cloud manufacturing. Instead, to continue the path of lean manufacturing and therefore lower the amount of differentiation within the manufacturing process. The empirical findings suggest that currently, the organization is utilizing data collection to decrease the amount of stop time and increase efficiency as well as to schedule various service tasks on the manufacturing equipment. The implementation of cloud usage within manufacturing is also suggested by the findings to have been derived late. As the organization was aware of cloud integration and data collection sometime before the Swedish automotive company started the implementation. This is recognized by the organization as well as that the current scale of implementation is relatively low. The organizational reasoning behind this strategy has been to follow the pilot project of Polestar, where the variation within processes as well as products has been low. Volvo is therefore standardizing its manufacturing process while offering customization via its software.

The current organizational focus of the data collection started with a team of analysts manually collecting the data from the equipment. This system proved to be quite inefficient, as it required the analysts to collect the data they were supposed to analyze. Volvo, therefore, developed a cloud system to allow manufacturing personnel to submit the data directly from the manufacturing division. This cloud system was initiated during the last quarter of 2021 and is called Self-service. Self-service was developed on a public cloud platform that is being provided by a PaaS - in this case, AWS. This public platform enables IoT and sensors to collect the data within the manufacturing division which is then uploaded to the public cloud platform for business intelligence reporting. This is being referred to as the 'Golden path' according to the findings. Additionally, Volvo is also able to make decisions based on the raw data that is being collected and analyzed, which they are currently implementing in terms of increasing the efficiency of the machines and equipment.

### RQ 2

*What are possible challenges of working towards cloud manufacturing for a manufacturer in the Swedish Automotive industry?*

This thesis has presented several factors that may be potential challenges for a possible cloud manufacturing implementation. The challenge that is identified as one of the major is security and the issue of sharing data between suppliers. Moreover, cyber threats and potential data leaks have been acknowledged as significant security risks, which has called for further involvement of Volvo's IT functions.

Furthermore, there is no indication of a clear cloud platform strategy, which may result in an unclear transition process of cloud integration into manufacturing, and there may be a challenge in developing such a strategy parallel to the existing IT landscape. Moreover, a holistic cloud platform implementation process proved to be a challenge in terms of scope and scalability within the organization, which resulted in small-scale implementations. This coincided with challenges of determining the quantity of data being collected, which has resulted in unnecessary data gathering.

Additionally, competence is suggested to pose a challenge for the implementation of cloud manufacturing. However, this issue is argued to not be specific when working towards cloud manufacturing, but rather to be defined as a broader organizational issue that transcends multiple divisions and industries.

The management of the organization could also potentially pose a challenge when working towards cloud manufacturing. As the empirical findings suggest, the management is defining the strategy of the organization, therefore if the management is opposed to full integration of the cloud, the integration might not occur. The current organization strategy is also suggested to decrease the amount of resources that are allocated for cloud manufacturing implementation, which is also defined as an organizational challenge. The study also identified the current manufacturing system as a challenge, where legacy systems need to be integrated or reviewed to promote a full transition. Additionally, the technological advancement of connectivity is argued by the findings existing, however, the implementation of connectivity is suggested as a major challenge.

## 6.2 Recommendations

The findings of this thesis have resulted in several recommendations for Volvo to increase the effort of working toward a cloud manufacturing system: Firstly, it may be advantageous for a cloud manufacturing transition to create a clear cloud implementation strategy to create a future transition. Secondly, reallocating resources to create a dedicated full-time implementation team for the cloud as well as determine if the cloud system will be developed within the existing legacy systems or if a new system should be developed. The study has identified that there may be a significant challenge in developing cloud systems parallel to the rest of the organization, which calls for further integration of the development process with existing IT functions. Thirdly, data sharing and lack of data standardization could potentially be navigated by joining data transmitting initiatives, such as Catena-X. Lastly, convincing management of how private and public clouds could be used to increase security could be a key factor in continuing the cloud integration process.

## 6.3 Limitations and Future Research

For future research, it may be valuable to study the potential cloud manufacturing implementation process on a global level or actors with higher market share in the automotive industry. It would be key to determine if the automotive industry has a future in cloud manufacturing, or if the concept does not apply to this industry specifically. It may additionally be important to study which types of manufacturing industries may benefit from a cloud manufacturing implementation; that is, benefiting from increased customizability and a more dynamic manufacturing process. Further, and although outside the scope of this thesis, studying how security mechanisms may be improved in a cloud manufacturing implementation with the usage of blockchain technology could be valuable in convincing managers to implement a cloud manufacturing transition from a security perspective.

This study can be used for future research when researching cloud manufacturing implementation. Due to this study's nature of a single case study, the generalizability should be considered low. Therefore, it would be valuable for future researchers to use a different research design - a cross-sectional design and multiple case studies could be used for comparing implementation stages or implementation strategies. The authors argue that the results could differentiate between the organization chosen in this paper compared to other actors in the same or similar industry. It is therefore argued by the authors that selecting a firm that is proactively working towards a cloud manufacturing implementation could provide nuance to the research field and its role in the future.

There are additional challenges presented in this paper that were not necessarily resolved but may be researched in the future. For instance, creating standardized data sharing - both between suppliers and other actors in the industry that are engaged in collaborative efforts. Lastly, the cloud manufacturing implementation process itself, whereas the potential scalability and scope may be recommended. This is however likely to be a few years away, considering the estimated ten years until a fully implemented cloud manufacturing system may be implemented.

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# Appendix A

| Thematic Analysis | | |
|---|---|---|
| First-order Codes | Second-order Codes | Themes |
| Unnecessary Data Gathering | Process Challenges | Cloud & Data in the Manufacturing Process |
| Determining Scope | | |
| Securing Quality | Motives for Implementing Cloud | |
| Improving Data Stream | | |
| BI Reporting | | |
| Reliable machine integration | Integration Challenges | Integration of Cloud & Data |
| Cloud Platform Communication | | |
| Developing Systems Parallel to the legacy systems | | |
| Connecting Robots and Machines | Navigating Integration Challenges | |
| Improving Legacy Systems | | |
| Building a new or updating a current factory | Resources | |
| Finding the right Competence | | |
| No dedicated full-time integration of Cloud Services | | |
| Lean manufacturing | Employed Strategies | Manufacturing |

| | | |
|---|---|---|
| Less customization with a static approach | | Strategy |
| Organizations controlled by manufacturing process | | |
| Management is reluctant to integrate Cloud services | Organizational Aspects impacting Strategy | |
| Convincing Management | | |
| Determining Cloud Platform Strategy | Strategy Challenges | |
| Creating a clear roadmap of the Transition | | |
| Scaling up the Implementation Process | | |
| Using Blockchain Technology to Improve the Security Mechanism | Navigating Security Challenges | Security Issues |
| Increasing Communication between Security Layers | | |
| Involving the IT-function as a result of increased cyberthreats | | |
| Data Transmission Initiatives | | |
| External Data Sharing | Security Challenges to overcome | |
| Cyber Threats | | |
| Standardized Data Sharing | | |

# Appendix B

**<u>Interview Guide - Volvo Employees</u>**

**Introduction**

- Introduction of the authors and the purpose of the study
- Asking permission for recording the interview
- Checking if there are any questions before the interview is initiated

**Interview Questions**

1. Can you describe your current role at the company?

2. How do you/your division work towards cloud manufacturing?

3. What is the reasoning for implementing cloud into your organization?

4. How do you work towards cloud manufacturing internally?
    a. The team/division
    b. The board
    c. Collaborative efforts

5. Have there been any internal challenges so far with implementing cloud into the manufacturing process?
    a. How have these challenges been resolved?

6. How do you work towards cloud manufacturing externally?
    a. Supplier Relationships
    b. Information & Data Sharing
    c. Stakeholders

7. Have there been any external challenges so far with implementing cloud into the manufacturing process?
    a. How have these challenges been resolved?

8. What is your reasoning of developing your own, private cloud versus outsourcing through public cloud?

9. How would you describe Volvo's approach towards data-sharing within your cloud system?
    a. How is this view compared to external actors such as suppliers?

10. What are your thoughts regarding the role of cloud manufacturing in your organization for the future?

11. How are you planning for future potential challenges of implementing cloud manufacturing?

**Closing Remarks**

- Thanking the respondents for participating in the interview and the thesis
- Asking if the respondents would be interested in reading the thesis once completed
- Asking if there may be further communication in order to clarify potential misunderstandings

# Appendix C

**<u>Interview Guide - Experts</u>**

**Introduction**

- Introduction of the authors and the purpose of the study
- Asking permission for recording the interview
- Checking if there are any questions before the interview is initiated

**Interview Questions**

1. Can you describe your current role in your organization?

2. How would you describe the term 'cloud manufacturing'?
    a. What do you believe to be its main components?

3. What is your previous experience in cloud manufacturing?
    a. How long have you been researching/working within the area?

4. What do you currently believe to be the main challenges of implementing cloud manufacturing in automotive companies?
    a. Are there any industry-specific challenges within the Automotive industry, if so, which?
    b. Do you believe there may be specific challenges for Swedish companies in the automotive industry, if so, which?

5. How do you believe that legacy systems may affect the implementation of cloud manufacturing?

6. How do you believe that security risks can be mitigated when it comes to sharing data to stakeholders?

7. What are your thoughts regarding transparency between the automotive manufacturer and their suppliers?

8. What could the reasons be for developing the cloud platform on public platforms?

9. What could the reasons be for developing the cloud platform on private platforms?
    a. How much of a common occurrence do you believe this to be?

10. In what ways do you believe the automotive industry's views on customizability affects the implementation of cloud manufacturing?

11. What are your thoughts regarding the role of cloud manufacturing in the automotive industry for the future?

12. What do you believe to be challenges for a future implementation of cloud manufacturing?

**Closing Remarks**

- Thanking the respondents for participating in the interview and the thesis
- Asking if the respondents would be interested in reading the thesis once completed
- Asking if there may be further communication in order to clarify potential misunderstandings