CHALMERS
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The impact of Cloud PLM on smaller manufacturing companies

An exploratory study to assess the challenges of smaller manufacturing companies and their relationship to Cloud PLM systems

Master's thesis in Master Program Quality and Operations Management & Master Program Production Engineering

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Department of Industrial and Materials Science
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Abstract

The purpose of the study is to understand how Cloud PLM will affect smaller manufacturing companies and the study aimed to achieve this by answering three research questions:

- What product related challenges are smaller manufacturing companies facing?
- How can Cloud PLM aid manufacturing companies in overcoming their challenges?
- What manufacturing companies are likely to adopt Cloud PLM?

To answer the research questions, a literature review, two series of interviews, and a survey was performed. The interviews where performed with experts and smaller manufacturing companies to gain qualitative data to compliment the literature review and provide a background for creating the survey. The survey aimed to provide quantitative data which in combination with the qualitative data was utilized to answer the research questions.

The study found that the challenges for smaller manufacturing companies can be divided into three main categories being: External, Administrative, and Innovative. Cloud PLM systems can aid smaller manufacturing companies in overcoming most of their product related challenges yet depends greatly on the adoption rate within a company. The most likely company segments to adopt a Cloud PLM system are companies with highly standardized products and companies with 250-400 employees. The adoption likelihood is seemingly correlated to the amount of knowledge within PLM systems.

Keywords: PLM, Cloud PLM, Manufacturing, SMEs, Challenges, Benefits, Adoption.

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Rahul Gowda Bangalore Rudre Gowda, Max Lundström, Gothenburg, May 2021

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Nomenclature

AF1	First survey statement in adoption factors section of the survey
AF2	Second survey statement in adoption factors section of the survey
AF3	Third survey statement in adoption factors section of the survey
AF4	Fourth survey statement in adoption factors section of the survey
AF5	Fifth survey statement in adoption factors section of the survey
AF6	Sixth survey statement in adoption factors section of the survey
AF7	Seventh survey statement in adoption factors section of the survey
AF8	Eighth survey statement in adoption factors section of the survey
AF9	Ninth survey statement in adoption factors section of the survey
B1	First survey statement in benefits section of the survey
B10	Tenth survey statement in benefits section of the survey
B11	Eleventh survey statement in benefits section of the survey
B2	Second survey statement in benefits section of the survey
B3	Third survey statement in benefits section of the survey
B4	Fourth survey statement in benefits section of the survey
B5	Fifth survey statement in benefits section of the survey
B6	Sixth survey statement in benefits section of the survey
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B8	Eighth survey statement in benefits section of the survey
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C1	First survey statement in challenges section of the survey
C10	Tenth survey statement in challenges section of the survey
C11	Eleventh survey statement in challenges section of the survey
C12	Twelfth survey statement in challenges section of the survey
C13	Thirteenth survey statement in challenges section of the survey
C2	Second survey statement in challenges section of the survey
C3	Third survey statement in challenges section of the survey
C4	Fourth survey statement in challenges section of the survey
C5	Fifth survey statement in challenges section of the survey
C6	Sixth survey statement in challenges section of the survey
C7	Seventh survey statement in challenges section of the survey
C8	Eighth survey statement in challenges section of the survey
C9	Ninth survey statement in challenges section of the survey
CAD	Computer Aided Design
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CSP	Cloud Service Provider

EDM	Engineering Data Management
ERP	Enterprise Resource Planning
IaaS	Infrastructure as a Service
ICT	Information Communication Technology
IP	Intellectual Property
IT	Information Technology
OEM	Original Equipment Manufacturer
PaaS	Platform as a Service
PDM	Product Data Management
PLM	Product Lifecycle Management
R1	First survey statement in risks section of the survey
R2	Second survey statement in risks section of the survey
R3	Third survey statement in risks section of the survey
R4	Fourth survey statement in risks section of the survey
R&D	Research and Development
ROI	Return on Investment
SaaS	Software as a Service
SME	Small to Medium sized Enterprise

1
Introduction

The introduction provides the background, purpose, limitations and approach for the thesis.

1.1 Background

The rapid development of Information and Communication Technology (ICT) has augmented the expectations put on companies to perform more with less. The trend of digitization is influencing all industries and a great deal of companies are working to improve their digital maturity [1]. The degree of digital maturity can vary greatly depending on the industry, company, and geography being everything from conceptual to truly transformed. One of the main influences to the trend of digitization is globalization which is increasing the need of competitiveness in industries around the globe. Companies need to develop their competitiveness in order to survive in today's world where companies need to constantly invest in innovation, developing better products or solutions to outperform their competition [1]. For manufacturing industries, this implies designing, manufacturing, testing, and validating new products which generates enormous amounts of data increasing the complexity of managing their product portfolio. For companies to successfully compete in a global environment they need to do more, manage more, both with less resources. To do this companies can look to ICT systems to enhance their efficiency.

Product Lifecycle Management (PLM) systems is one ICT system which is focused around the product related processes within a company. Implementation of PLM systems within manufacturing companies has the ability to increase their digital maturity and enhance their efficiency. When successfully implemented in an organisation a PLM system integrates a product's complete life cycle from birth to death and also the interlinks the business aspect of managing all products across the organisation [2]. A PLM system forms the *product information backbone of the company and its extended enterprise* [2]. Successful implementation of PLM systems can undoubtedly affect the entire value chain of a product and the company. Yet, whilst there are benefits to be reaped there are also multiple barriers to overcome [3]. Companies considering implementing these systems often find it difficult to know what to focus on due to the complexity of what a PLM system can offer. Implementing PLM systems can be a tentative process which requires technical resources, managerial resources, and financial resources which are mainly within the reach of large companies. The benefits of a PLM system have therefore often been out of

reach for smaller manufacturing companies due to the accompanying complexity and cost.

Cloud PLM is a recently developed type of system based on the advancements in ICT and cloud computing, which provides a more accessible solution compared to the traditional PLM systems. Cloud computing can be defined as *a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (eg, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction* [1]. The Cloud PLM solution requires comparatively less resources in terms of investment and maintenance to traditional PLM systems. Cloud PLM can introduce the benefits of a PLM system with lessened complexity and cost to smaller manufacturing companies. Cloud PLM is a relatively new concept and it is unclear if and how Cloud PLM could aid smaller manufacturing companies. The uncertainty of Cloud PLMs future within smaller manufacturing companies, and the lack of research within this area, provides the knowledge gap which this thesis aims to help fill.

1.2 Purpose and Research Questions

The study's purpose is to understand how Cloud PLM will affect smaller manufacturing companies. The following research questions were posed to fulfill the study's purpose and has guided this study:

RQ1: What product related challenges are smaller manufacturing companies facing? The product related challenges faced by smaller manufacturing companies are interesting to discover since if these match with the benefits provided by a PLM system that is likely a driver for adoption. Product related challenges concern anything that is related to the product or solution the company produces from the beginning of Research and Development (R&D) to the end of the product's life cycle.

RQ2: How can Cloud PLM aid manufacturing companies in overcoming their challenges? Comparing the benefits of a Cloud PLM system with the challenges of the smaller manufacturing companies would show where this system could be of assistance and provide insight to where the effect of Cloud PLM may be located.

RQ3: What manufacturing companies are likely to adopt Cloud PLM? Understanding what type of companies are likely to adopt provides further insight into where Cloud PLM will have an impact. The type of companies could be segmented by for example industry, size, or whether they own the Intellectual Property (IP) of their products or solutions.

1.3 Limitations

The project will be limited to manufacturing companies within Sweden with a head count greater than 30 and lesser than 400. A lower limit was set since the advantages of PLM is better suited for companies with some form of organizational complexity which is created the more employees a company hires. An upper limit was set since the thesis' aim is to investigate the impact upon smaller manufacturing companies. The thesis will mainly focus on Cloud PLM systems which can be tailored towards the smaller industries and not enterprise PLM systems which would fit larger industries. Due to time constraints the thesis will not follow-up with investigated companies in the future seeing which companies actually has adopted Cloud PLM but rather aims to provide what criteria affect the probability of adoption.

1.4 Study Approach

To answer the research questions the thesis aimed to perform an exploratory case study by gathering qualitative and quantitative data through interviews and a survey. The qualitative data is used to increase the understanding within this area and the survey is used to quantify interesting factors. The thesis first conducts a literature study establishing a foundation of published material regarding PLM, PLM systems, Cloud PLM, adoption factors for new systems, and the product related challenges that smaller manufacturing companies face.

Interviews were conducted with experts and smaller manufacturing companies. Interviews with experts aimed to provide a generalized knowledge of PLM, Cloud PLM, and smaller manufacturing companies. The gained knowledge from these interviews provided together with the literature review the basis for the interviews with smaller manufacturing companies. These interviews aimed to focus more on the specific experiences of the companies regarding their challenges and how they adopt new systems.

The findings from the literature review and the interviews established the basis on which the survey was developed. The key points of interest discovered were covered and quantified with no intent to gather new key points from the survey.

Finally, the qualitative and quantitative data was analysed and used to draw conclusion regarding the research questions.

2
Theory

The theory section provides a compilation of the literature used during the exploratory case study. The theory includes a definition and origin of PLM systems, the benefits of PLM systems, the current adoption of PLM systems, the relationship between SMEs and PLM systems, and a description of Cloud PLM.

2.1 PLM Systems

The first question that needs to be addressed is *What is PLM?*. Several authors and industrial experts have attempted to define PLM taking its multidimensional characteristics into account. The PLM community in the University of Salento [2] has compiled definitions from several authors and experts condensing it into a set of three features with underlying dimensions. The three features are *Managerial, Technological, and Collaborative* [2]. The table compiled by them can be seen in Figure 2.1. They further arrive at the definition of PLM as *a strategic business approach that supports all the phases of product life-cycle, from concept to disposal, providing a unique and timed product data source. Integrating people, processes, and technologies and assuring information consistency, tractability, and long-term archiving, PLM enables organizations to collaborate within and across the extended enterprise.* [2]. A PLM system digitizes this working method providing a system to efficiently interconnect the aforementioned aspects.

The origin of PLM systems begins with the Engineering Data Management (EDM) system, an EDM system is an electronic vault to store documents in an efficient mechanism which indexes and accesses the drawings and documents [4]. The EDM systems evolved to Product Data Management (PDM) systems in the late 1980s which emanated due to the requirement of handling large design files generated from Computer Aided Design (CAD) in the manufacturing industries [5]. A PDM system is a computer application which is used to manage product data. The system ensures efficient handling of product data to make it available in the right place to provide easy access, retrieval and facilitates reuse of data [4]. PLM systems are systems that creates a single digital touch-point for companies to handle their PLM work. This is an expansion of the EDM and PDM systems which focuses on the handling of data. The early versions of PLM systems were primarily used in the product development phase of the product's life-cycle. The emergence of PLM systems provided the capability of standardizing the process within the entire life cycle of a product, no longer limited to just the product development phase [5].

Set of features	Key dimensions	Description
Managerial features	Integrated approach	It means the act of dealing with PLM considering its different related aspects (e.g., information, technology, and strategic points of view).
	Business strategy	It is how an organization takes decisions and manages resources to gain and maintain a competitive advantage over a period of time.
	Creating value	It is the primary goal of every business; it means performing activities that increase the value of organization's goods or services, generating wealth for its shareholders, and satisfying customers' expectations.
	Design, production, and maintenance phases	They refer to the different stages of the entire product lifecycle from its conception, through design and manufacture, to service and disposal.
Technological features	Product information backbone	It means a central hub storing different data distributed among heterogeneous systems; it creates a single view of product information that can be leveraged across the whole organization and its network.
	IT tools (CAX, PDM, etc.)	They encompass a board range of software and IT systems used in all the aspects of product lifecycle (design, analysis, manufacturing, production planning, product testing, collaboration, etc.).
	Secondary information	It is all the information indirectly connected to the specific product knowledge (e.g., vendor application notes, catalogs, customer feedbacks, marketing plans, archived project schedules, etc.).
	Traceability	It means the ability to chronologically interrelate product lifecycle information and to track all accesses and changes to the data.
	Long-term archiving	It refers to the organizational need for long-term retention of older data; it helps an enterprise to maintain information integrity and demonstrate regulatory compliance and transparency.
Collaborative features	Integrating people, and process, data	It means combining in a unique approach different aspects related to PLM (business processes, human resources, data, etc.) so that they work together to better product lifecycle management.
	Sharing	It means using or enjoying data and information jointly with others in order to enable knowledge integration during collaborations in the product lifecycle.
	Within and across extended enterprise	It means a borderless organization whose processes are transformed and integrated with the ones of its partners, based on cooperative and collaborative relations.

Figure 2.1: Features, key dimensions and description of PLM

Presently, there are two overarching types or deployment methods for PLM systems, *Cloud PLM and On-Premise PLM*. An on-premise system limits access to the PLM system to a specific location and requires an on site implementation with dedicated servers and Information Technology (IT) personnel. On-premise systems tend to be more customised for the specific company's processes. Cloud PLM systems on the other hand enable companies to use their PLM systems independent of location and the IT-infrastructure for a Cloud PLM system will vary depending on the implementation solution [6].

On-premise PLM system implementation requires not only an established IT infrastructure along with maintenance but also the necessary technical expertise [7]. Lack of advanced infrastructure, lack of interoperability, complex licensing policies, and the considerable investment in IT infrastructure limit the usage of on-premise PLM systems. In order to unite all the geographically scattered stakeholders, on-premise PLM systems are insufficient. Hence, this leads to the adoption of internet-based systems for real-time connectivity, and that can be fulfilled only with Cloud PLM systems [6].

2.2 Benefits of PLM

The benefits for an organization in successfully managing their products' life cycle is that the organization gains a competitive advantage by being able to create better products in shorter time, at lower costs, and with less quality defects [2]. A PLM system enables organizations to structure their work with PLM allowing them to create a standardized method of working by collectively using a PLM system in the place of multiple heterogeneous information system environments [5], thus aiding the organization in gaining a competitive advantage. The advancement of communication within the organisation, both directly and indirectly is one of the main benefits of a PLM system [5]. Direct communication is enhanced due to efficient transfer of files, conversions between different file formats, using a common data bank to facilitate transfer of CAD data directly to Enterprise Resource Planning (ERP) systems, etc [5]. This further enhances indirect communication by improving quality of work, reducing mistakes due to bad communication, inaccurate information, and overall increasing the speed of work by reducing unnecessary data transfers and increasing effective reuse of information [5].

It is clear that there are large benefits to increasing the efficiency in a manufacturing company. Figure 2.2 [5] shows the engineers' use of time where only 29 percent of his time is used for actual engineering work and most of it is wasted in finding, sharing and recreating information that already exits.

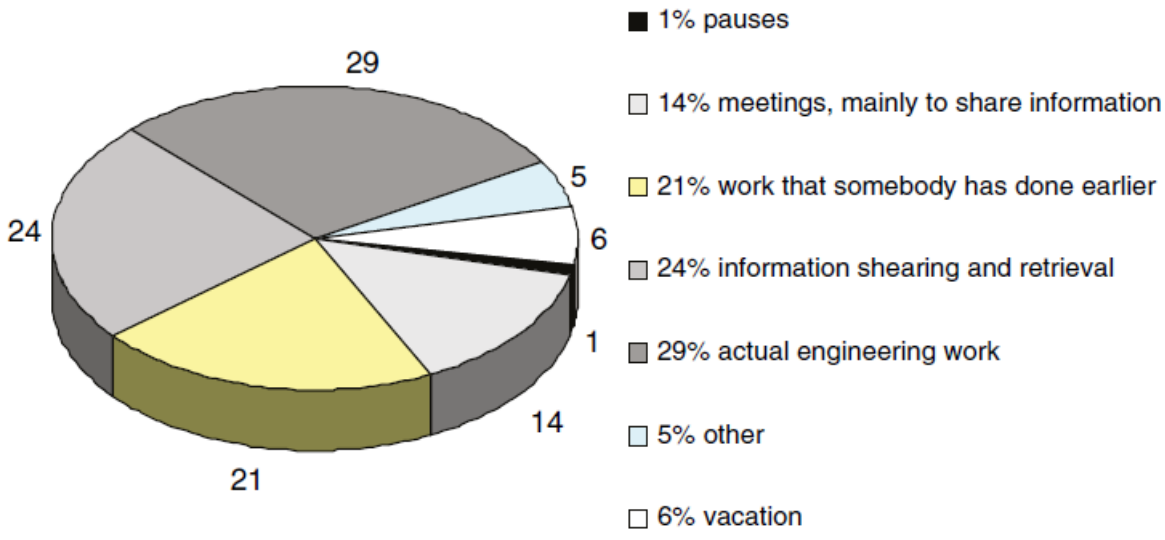

Figure 2.2: The engineers' use of time

The gaining of these benefits may however be hampered because the use of some features in a PLM system is voluntary [8]. With only a small amount of adopters companies may be prevented from experiencing the aforementioned benefits [8]. Since PLM systems are spanning an increasing amount of departments and one key benefit being communication (which requires both sending and receiving party to be active) the involvement of all employees becomes of ever increasing importance

for the benefits of PLM. However, it is unsurprising that companies fail to engage the entire organization towards a common goal considering that they are used to traditional ICT systems which take a traditional or concurrent approach limiting the degree of collaboration [9]. In the traditional approach, each department is a separate silo where there is no or little communication between the various departments within an organization which can lead to miscommunication and inefficiency in work processes. The concurrent approach involves the use of collaborative tools such as design of manufacturing or earlier manufacturing involvement to increase the collaboration and communication between different departments in an organization to improve the work processes [9]. These approaches are still insufficient due to lack of effective communication in today's world where there is cut-throat competition between industries. There is a need to use a more collaborative approach by using PLM systems to increase the communication between departments in an organization through standardized work processes [9].

It is evident that the successful implementation of a PLM system clearly can be beneficial to an organisation. These benefits are however difficult to measure directly in terms of monetary value. As the main benefit of PLM systems is the increasing efficiency in daily operations throughout the company [5]. These benefits can appear as declining quality costs, reduction in tied up capital, faster time-to-market of products, higher margins of profit, faster reaction time to changes in market and better collaboration between suppliers and customers [5].

2.3 Adoption of PLM systems

To gain the aforementioned benefits of PLM the entire organization needs to collaborate and work together towards a common implementation goal. An organizational transformation approach is necessary where all the managers and stakeholders are involved and made aware of the transformation and its benefits to successfully implement PLM systems [10]. PLM adoption in many companies is usually limited to the product development phase of a product and not a product's entire life cycle nor the entire organization [3], thereby never realizing the true potential of PLM. Many users of PLM systems instead use them solely as an extension of PDM systems focusing on the designing of products [11][12][13]. Some companies have broadened their use to include virtual manufacturing and visualization, but very few use PLM systems to encompass the entirety of a products' life cycle. Collaboration is the underlying theme of PLM, which if not followed correctly, can slow down the processes instead of improving them [3]. Frequently top executives and managers do not take the PLM initiatives as an organizational transition approach. These efforts may remain limited among the few managers involved in the product designing or process planning. Whereas true PLM requires transforming an organization [10]. This company wide adoption is made more difficult when the primary goal for improving PLM is often attributed to one major business driver rather than to improve the complete product life cycle [14]. Considering the traditional and concurrent approaches, which dominate other ICTs, which companies have become accustomed to, it is unsurprising that companies struggle to implement PLM systems correctly.

There are other barriers than poor collaboration and company wide engagement that can hinder the wide spread implementation of PLM systems. A case study into the aerospace industry revealed that *High investment in PLM system, Complex licensing policies, Lack of training and technical knowledge in PLM systems* are the main barriers for PLM institutionalization [3]. The seven barriers investigated by the case study included *Lack of advanced IT infrastructure, Lack of Interoperability and Integration, Lack of training on PLM systems and awareness, Lack of technical knowledge, Effort duplication, Resistance to change, and Complex licensing policy* [10]. The investigation was conducted through a general online survey that captured insights from 207 respondents [10]. Lack of integration of ERP and PLM [15] is also a significant barrier to the success of PLM [3]. It may be mentioned that re-entering the data/data transfers from one system to another and bringing them in a standard format is a significant barrier to PLM systems' implementation [3]. A list barriers for PLM institutionalization in large manufacturing organizations is mentioned in Figure 2.3 [3].

Barrier	Description
Lack of advanced IT Infrastructure	IT infrastructure is an essential requirement to implement PLM systems
Lack of interoperability among various systems	Absence of interoperability among different PLM solutions and other existing enterprise systems such as ERP, etc.
Lack of training on PLM systems	Lack of training/awareness to execute work on PLM systems software
Efforts duplication	Duplication of efforts on multiple systems separately for designing, manufacturing, and financial working
Resistance to change	Resistance to change the practices of using previous software such as CAD, CAM, PDM, etc.
High investment in PLM system	High cost involved in the installation of various modules of PLM systems
Complex licensing policies	Complex Licensing policies for software usages, a limited number of licenses to the users indirectly limits the PLM utilization
Non-collaboration on common platform	Lack of collaboration with other PLM systems hampers the information exchange with other stakeholders
Lack of technical knowledge of PLM systems	Lack of technical expertise in PLM software creates dependency on outside developers

Figure 2.3: List of barriers and their description for PLM institutionalization

These barriers need to be overcome to successfully implement PLM systems in an organisation. A case study [9] involved the identification of 17 success factors within 3 dimensions to successfully implement PLM systems. In the dimension of *Business Processes and Practices*, the success factors are, *Business Process Re-engineering, Information sharing or communication, Risk management, Clear Business goals and objectives, PLM System Evaluation and Selection* [9]. In the dimension of *People*, the success factors are, *Leadership and Commitment, Training and Education,*

Knowledge sharing from previous experiences and Organisational Culture [9].In the dimension of *Technology*, the success factors are, *Project team spirit and commitment, IT infrastructure, Interoperability among all systems and Data security- user authentication* [9]. Similar to these three dimensions, another study presents an adoption model for PLM based on 4 main factors, *Human Factors, Organisational Factors, Economical Factors and Technological Factors* [7]. All these factors need to be taken into account while implementing an PLM system to ensure its success. IT infrastructure is one of the essential prerequisites [16] for PLM implementation posing the following technical requirements *number of systems, lease lines, the data conversion limits, memory storage, data transfer standards, set up servers, manage networks, remote provision sites, maintain the software, database tuning, timely upgrading, system modifications, and other technical infrastructures.* It is clear that a successful implementation of a PLM system requires more than simply purchasing a new system.

Considering the adoption characteristics of an IT system in an industrial context, the three major contexts which form the basis for an *IT Innovation Decision Making* open system adoption model are *external environment, characteristics of technology innovation and organizational technology* [17]. An open system is a system which facilitates information exchange and provides a combination of interoperability, interconnectivity and compatibility [17]. There is evidence that market uncertainty, complex and rapidly changing environments have an influence on the adoption of new and open IT systems where there is a need of flexibility, interoperability, interconnectivity and compatibility [17]. For the companies facing keen competition, the rumple between existing IT infrastructure and existing methods of conducting business incites the adoption of new systems [17]. The characteristics of the technological innovation should be perceived positively and its benefits should be understood for it to positively influence the IT Innovation Decision Making model [17]. The characteristics of an IT system should also be perceived to be better than the technology currently used in the organisation to positively influence the adoption of new systems. The existing organizational technology can influence the adoption of a new IT system considerably. A complex IT environment, with the existence of multiple systems will positively influence the adoption of new systems which promote flexibility, interoperability, interconnectivity and compatibility [17]. Research in organizational behaviour suggests that complexity in tasks advocates the ability of an organization to innovate. The increase in organizational complexity and the use of multiple heterogeneous systems in an organisation creates a need to integrate multiple platforms to effectively manage organizational infrastructure which can provide impetus to the management to adopt new open systems which have the capability to integrate multiple platforms and this can positively influence the adoption of new systems. An open system presents the processes of standardization in both technical and administrative items. Organisations that have an existent policy on standardization and a formal system in place can be more positively inclined towards the adoption of a new open system as organisations with lower degree of formalisation in management need spend more resources to first establish standardization in the organisation [17].

2.4 Small to Medium sized Enterprises (SMEs)

Since most of the research performed on PLM systems has been focused on larger enterprises, it is interesting to gain a background to how SMEs work and their relationship with PLM systems. SMEs often have less formal processes relying heavily on personal interactions. Factors such as trust, fairness, intuition, and empathy play an essential role in SMEs' business processes [14]. This makes a SME a more dynamic and agile enterprise in comparison to larger enterprises. On the other hand, knowledge management is not formalized, and most SME organizations are not able to describe their current or future state without external help, because they lack internal resources with process analysis and design skills [18]. According to the norms of the European Commission, *Extract of Article 2 of the annex to Recommendation 2003/361/EC*, the category of SMEs is made up of enterprises which employ fewer than 250 employees, since this study investigates companies larger than 250 employees the discoveries in the literature review may not be directly applicable to all companies included in the scope.

Large companies have generally been the main adopters of PLM systems, whilst SMEs still have difficulties understanding the potential of PLM [10]. SMEs adoption of ICTs in general is slow and lags behind large companies, primarily because SMEs find the adoption of ICTs difficult [9]. Implementation of PLM solutions seem to scare SMEs due to the resource requirements of time, knowledge, and money [7] yet, the exact reasons for the limited successful implementation of PLM cannot be precisely predicted as these organizations are majorly in the planning phase of PLM implementation [3]. An exploratory investigation [1] examining the drivers and barriers to the adoption of cloud computing by SMEs in Ireland studied the performance related concerns, such as internet connectivity, cloud availability, and security concerns (i.e., trust on solution provider and identity management), and found those as some barriers to cloud adoption in SMEs [6]. The relative cost of a PLM implementation is higher for SMEs because the fixed part of the investment is divided over fewer people. Failure has a high relative impact on the financial health of the company [18]. Commercial PLM systems are developed for reference process models, derived from large enterprises. These reference models often do not fit SMEs, even implementation partners do not have clear answers on how to implement PLM for SMEs [19].

Despite there being a resistance within SMEs to adopt Cloud PLM systems there are significant upsides to it. An exploratory investigation [1] concluded that the low capital costs, accessibility on mobile devices, teleworking, lower IT maintenance, and better collaboration were the top five drivers for adopting cloud in SMEs. The facility of immediate access without any setup time and cost supersedes all the drawbacks and forces the firms to adopt cloud [6]. Migration to the cloud can maximize resource utilization for the firm. This may be through freeing up internal employee resources, with staff released from maintenance tasks and non-core activities to focus on core skills and competences [1].

2.5 Cloud PLM

To understand Cloud PLM, one must first understand what Cloud computing is. Cloud computing facilitates improved device independence, portability, interconnection, and collaboration opportunities. Employees can, unrestricted by their location, be more flexible [20], instantly and remotely access and share information in real time through a variety of devices thereby supporting the growing generation of tele-workers and project teams across geographical locations [21][22][1]. The major drivers for adopting cloud technologies are: *reduced capital costs, access to mobile devices, feasibility of teleworking, reduced IT maintenance, improved employee collaboration, reduced operation cost, feasibility of continuity/disaster recovery, improved supplier/customer collaboration, improved feasibility of testing new ideas/applications, and ease of varying capacity* [1].

Cloud computing does not come without its concerns. An empirical study presents *data security* and *trust on solution provider* as the most important and critical challenges for migration to Cloud PLM adoption [1]. Security concerns present the greatest barrier to cloud adoption [23][24][25], since organizations need to trust external Cloud Service Providers (CSPs) with their possibly sensitive data. Cloud computing requires certain quality and availability of internet connection and the cloud service itself [26]. This raises concerns regarding business continuity due to internet downtime, connection unreliability, or CSP outages [1]. When looking specifically at the barriers for SMEs to adopt cloud technologies they are: *internet connectivity concerns, security concerns, lack of trust in cloud service providers, identity management concerns, cloud availability concerns, vendor lock-in concerns, data protection concerns, compliance concerns, lack of standards and delay in data transfer* [1].

Before the introduction of cloud computing, companies adopted on-premise PLM systems and set up dedicated in-house IT infrastructure with servers and an IT-department. The introduction of cloud computing is now moving PLM systems to the cloud such as it has done with several applications before [1]. However, moving to the cloud can be done with multiple adoption variants. The cloud technology adoption variants can be see in Figure 2.5 [6]. The adoption methods for cloud technology are: *Public Cloud, Private Cloud, Hybrid Cloud and Community Cloud.* Public cloud offers a service which is shared by many people often offered by a CSP. Scalability, low cost, and flexibility are the features of public cloud, but it lacks the controllability. Private cloud restricts access to a limited group of people and is considered costly yet offers customization, authorization control, and security. Community cloud provides the required service to a pool of selected organizations which share related goals, this is useful when collaboration over organizational boundaries is required. Hybrid cloud refers to an extended private cloud onto a public cloud for particular requirements; this extension provides a scaleable benefit to private cloud. This model is often used as a transition from on-site to cloud services [1].

Depending on the application a cloud service can be offered through different service models. The service models for cloud can be classified as: *Infrastructure as a*

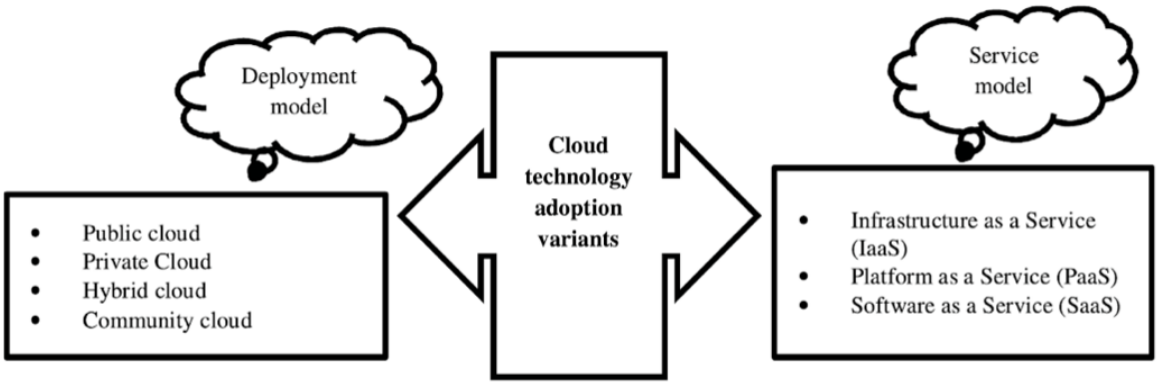

Figure 2.4: Cloud technology adoption variants

Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) [6]. IaaS provides infrastructure such as storage, computing power, servers, load balancers and other resources when requested by the customers without requiring any physical hardware on site [27]. PaaS provides resources which are mainly computing platforms such as operating system, web servers, databases and programming languages which has the ability to scale automatically to meet the demand of the application [27]. PaaS provides hosting capabilities to the customer without having the need to buy complex and costly hardware for application development [27]. SaaS forms the most basic form of offering where a common infrastructure, software and correlated data are hosted on the internet and the user can access the system through a web browser [27]. SaaS is usually based on a pay per use model which provides the capability to the customer to use the services anywhere with an access to the internet without having the need to install either the software or the hardware [27].

2.6 Sustainability

With all the talk about manufacturing companies, information systems and different types of technologies, one can wonder the role of sustainability in this particular context. With the unrelenting worldwide globalization, companies are compelled to think beyond just economic benefits and to contemplate on environmental and social aspects [28]. The world is currently running on limited and declining resources, manufacturing industries use considerable amount of resources to manufacture products and maintain industries. At the same time, manufacturing industries contribute to 36% of global emissions and is one of the sectors where there is an alarmingly high waste generation [28]. There is an undoubted need to reduce waste and increase sustainability. The use of PLM as a business strategy could serve as a means to achieve an increased sustainable way of working by managing the entire products' lifecycle from birth to death [28].

In the benefits section of PLM, it was revealed that using PLM systems result in numerous benefits where there is reduced quality costs, defects, faster time-to-

market, enhanced collaboration and overall reduced development costs. By using PLM systems and PLM as a business strategy by incorporating it in all the phases of a product's lifecycle, PLM can be a key component to create products by consuming less energy, less material, reducing unwanted outputs and by better utilizing existing material and information [28], PLM can not only reduce costs but increase sustainability by increasing the efficiency of resources and reducing the consumption of human, material, machine, energy and water resources [28]. PLM systems can help increase collaboration and plan the flow of information at all the stages of a product's lifecycle. This overview of a product's lifecycle can not only increase efficiency, but also control the consumption of resources to reduce environmental impact [29]. The factories of the future can optimize the work flow to create a more sustainable future at a product level by using PLM [29].

3
Methods

The following section describes how this study was performed. The study is structured as a funnel for the specificity of information collected in each stage. Commencing with a broad literature review, and concluding with the analysis of gathered data. The most fitting research approach to answer the research questions was determined to be an exploratory case study which has been adopted for the purpose of this research due to the lack of preliminary research data within the context of smaller manufacturing companies and Cloud PLM.

3.1 Exploratory Case Study as a Research Approach

Exploratory case studies are extensively used in social sciences to explore phenomenons and develop an understanding of these in a natural setting by using one or more data collection methods [30]. Case study research is mainly used to describe a phenomena, develop a theory and test the theory [30]. Multiple data collection methods can be used for a case study as a research approach, examples of data collection techniques include, interviews, questionnaires, observations, literature reviews, and document analyses [30]. An exploratory case study is used for our research approach where the primary data collection techniques are through literature reviews, interviews and surveys.

An exploratory case study best suits our research method as we are exploring an uncharted field requiring both qualitative and quantitative data. Our research describes the phenomena of the challenges faced by smaller manufacturing companies and tests the theory of Cloud PLM alleviating the challenges faced by smaller manufacturing companies. Our research aims to perform an exploratory case study by formulating research questions, performing a literature review, interviewing experts and smaller manufacturing companies, and conducting a survey. The literature study provides a foundation of theory to base the study on, the interviews provide qualitative data to supplement the theory, and the survey quantifies the result to gain numerical values to investigated aspects. The interviews with the experts were expected to provide a generalized level of knowledge which could be compared to the interviews with the companies that were expected to provide ground level experiences.

3.2 Literature Review

To gain an overview of existing knowledge of PLM systems, Cloud PLM, and smaller manufacturing companies a literature review was performed. Since the use of PLM systems traditionally have been restricted to larger companies, a surface level research of manufacturing SMEs was also performed. The cross section of traditional PLM usage and the understanding of manufacturing SMEs was deemed to provide an adequate foundation of understanding for the smaller manufacturing companies on which this thesis focuses. Below are the keywords and databases listed which where used for the literature review.

Keywords: PLM, Cloud PLM, Product Lifecycle Management, PLM AND implementation OR barriers OR challenges OR SMEs, Challenges for manufacturing SMEs, Manufacturing SMEs, Types of PLM, PLM adoption AND Criteria, PLM benefits.

Databases: Scopus, Web of Science, Chalmers Library.

3.3 Interviewing experts

To gain insights from experts who could provide an overview level knowledge of certain areas, interviews were performed. The interviews aimed to provide a deeper understanding of:

- The product related challenges smaller manufacturing companies are facing.
- The relationship between smaller manufacturing companies and PLM systems.
- SaaS Cloud PLM.

The areas selected were developed based on where the literature review provided insufficient information to answer the research questions. Based on these areas an interview template was developed, see Appendix A, which aimed to provide qualitative data for these areas which would help to answer the research questions. Due to the exploratory intent and the limitation to certain areas a semi-structured interview approach was selected. This ensured that all the areas of investigation where touched upon during the interviews and allowed follow-up questions to be asked for clarification or to investigate certain areas deeper. The information gathered regarding SMEs is deemed to be of some relevance to all the smaller manufacturing companies included in the scope of the thesis yet is less applicable for companies with more than 250 employees.

The selected experts where either employed by providers of PLM systems, professors and researchers, or people with industry experience. The experts either had a good understanding of all the areas of investigation or had knowledge regarding specific areas. Depending on the expert, the interview template was adjusted to accommodate their areas of expertise. Adjusting the interview template meaning that certain sections were omitted if the expert did not have knowledge within the field. 7 experts were interviewed providing insights based on their experiences and knowl-

edge within the domains of PLM, Cloud PLM smaller manufacturing companies, and cloud computing. The sample size for this section of interviews was justified when little new relevant information was obtained from subsequent interviews with experts.

3.3.1 Expert Interview Template

The expert interview template as seen in Appendix A is structured into four sections:*Introduction, Challenges for Manufacturing SMEs, SMEs and PLM, Cloud PLM*, all in relation to the research questions to gain generalized insights from experts.

The first section of the template is the *Introduction* section which describes the purpose of the interview and aimed to procure information about the interviewee. The second section of the interview is the *Challenges for Manufacturing SMEs* section. This section aimed to understand the product-related issues for manufacturing SMEs. The third section of the interview template is the *SMEs and PLM* section. This section aimed to understand the relationship between SMEs and PLM systems. The final section of the interview template is the *Cloud PLM* section. This section aimed to understand Cloud PLM and cloud computing.

The interviews were conducted in a semi structured format and if the interviewee provided any key information outside the context of the template, further probing questions where asked. When possible the interviewee was asked to provide examples of scenarios to gain insights through experiences of real scenarios providing richer data. The questions were formulated to gain generalized knowledge rather than industry niche information. Each interview was transcribed to ensure that the information collected reflects the interview in an as accurate way as possible. A summary of key points from each section was created per interview after transcribing the complete interview.

3.4 Interviewing Companies

To gain insights from companies which could provide on the ground experiences of certain areas interviews were performed. The interviews aimed to provide a deeper understanding of:

- The challenges small manufacturing companies face.
- The adoption willingness/criteria of small manufacturing companies.

The companies where selected based upon their size (number of employees) and the complexity of their manufacturing to provide a mix of companies interviewed. The complexity of manufacturing was estimated based upon the mechanical complexity of the products and the variation of their products. Variation includes amount of product variants as well as degree of customization. The employee that was preferred for the interviews was an employee with significant knowledge within the

companies product related tasks, depending on the company this could be a product manager, production manager, CEO, or other position. Due to the similar intent to the expert interviews, a semi-structured interview approach was selected. A total of 5 companies were interviewed, these companies covered the spectrum of size and complexity which this thesis aims to study. The small sample size was found sufficient since the purpose of these interviews was to gain an indication of the challenges smaller manufacturing companies face and what affects their adoption willingness.

3.4.1 Company Interview Template

The company interview template as seen in Appendix A is structured into four sections: *Introduction, General Questions, Challenges, and, Adoption Willingness*, all in relation to the research questions to gain specific insights from companies.

The first section of the template is the *Introduction* section which described the purpose of the interview. The second section of the interview is the *General Questions* section. This section provided a background to the coming section giving an insight into what type of company and employee is being interviewed. The third section of the interview template is the *Challenges* section. This section aimed to discover the product related challenges that the company is facing. The final section of the interview template is the *Adoption Willingness* section. This section aimed to gain examples of system or process implementation and the thoughts regarding what is important for the company to adopt new systems. The interviews were conducted and analyzed the same way as for the interviews with the experts, except for the questions being formulated to gain company specific insights rather than general insights.

3.5 Surveying Companies

After the interviews were compiled a survey was conducted to quantify certain aspects to answer the research questions. This was performed to gain insights as to how large or small these aspects where for smaller manufacturing companies. The companies were selected by going through the public database of allabolag.se which contains information regarding registered companies, filtering for manufacturing companies and then finding contact information to companies with 30-400 employees in the following manufacturing industries: Agricultural or forest machine, Automotive engine, Communication equipment, Electronics, Furniture, Home electronics, Machine, Machine tool, Marine, Metal, Motor and turbine, Plastics, Tool, Train and tram, other.

The contact information gathered for the companies was firstly emails to relevant employees such as product managers, production managers, Chief Executive Officers (CEOs), or other employees. If no email could be found to these employees, the info email was gathered. Firstly, an email was sent to the info emails asking for relevant contacts who could fill out the survey. Secondly, a notification email was sent to

all the personal email addresses notifying them about a survey being sent out and giving them the option to opt out from receiving the survey. Finally, the survey was sent providing the respondents with 1 week to answer the survey. A total of 195 respondents were sent the survey ending up with 77 responses.

3.5.1 Survey Template

The survey template was based on the literature review and the interviews to answer the research questions, refer Appendix B for the survey. It was structured into 5 sections: *General Information, Challenges, Benefits, Risks, and Adoption Factors*.

The *General Information* section was designed to provide an insight into what role the survey taker had and what type of company they represented. The size, industry, and production characteristics were asked for to provide a basis for possible segmentation when analyzing the data. These characteristics where developed based on the results from interviews with experts. The section contained 9 questions. The following 4 sections used a linear scale between 1-6 to gauge the response of the survey takers to each statement posed related to each section. The scale entailed the following degrees of agreement:

1. Completely Disagree
2. Strongly Disagree
3. Partly Disagree
4. Partly Agree
5. Strongly Agree
6. Completely Agree

The linear scale from 1-6 was used to avoid neutral answers making the survey takers lean towards either agreeing or disagreeing with the statement. An option to answer "Do not know/Not applicable" was provided to avoid guessing from the survey taker if they did not possess sufficient knowledge to react to the statement. The statements were attempted to be phrased in such a way that there was neither a right nor a wrong answer. The statements were formed to take into account the survey takers actions and thoughts rather than the viewpoint of the entire company, as the survey taker solely provides one opinion and cannot be assumed to reflect the collective opinion of their company. All of the challenges, benefits, risks, and adoption factors were not included in the survey but only those that would provide the most relevant information when answered to the research questions. This is mainly to reduce the length of the survey as a longer survey likely negatively affects the willingness of survey takers to complete the survey.

The *Challenges* section provided statements related to the challenges discovered in the literature review and the interviews. The section included 13 questions and were based on the challenges concerning administration, innovation, and external relations. The statements used "I can" or "I think" to encourage the survey taker to base their answers on their own experience rather than answering what might be

considered correct. The *Benefits* section provided statements regarding the possible benefits of PLM in general and SaaS Cloud PLM specifically. The section contained 11 statements with the first 6 pertaining to PLM benefits in general and the final 5 pertaining to if there was a preference towards SaaS Cloud PLM systems. The statements for benefits of PLM in general started with "I think my company is willing to spend resources to", to measure the willingness the companies have to pay for these benefits which they would have to do to implement a PLM system. The *Risks* section presented statements gauging the trust of software suppliers, the trust of cloud solutions, and the stability of cloud solutions. The section contained 4 statements. The final section *Adoption Factors* presented statements regarding adoption factors which where discovered during the literature review and the interviews. The section contained 9 statements relating to the survey takers and company's experience and knowledge of PLM systems, the human and technical viability of new systems, the survey takers satisfaction towards current systems and processes, and their belief in the benefit of IT-systems. To analyze the data from the survey the data was summarized in one overall average for each statement and split into three segmentations based upon the statements posed in the general information section being *Type of Manufacturer, Degree of customization/standardization,* and *Company size.* The segmentation *Type of Manufacturer* is divided into companies who are *Contract Manufacturer, manufacturers who own their own IP* and *Mix of both.* The segmentation *Degree of customization/standardization* is divided into manufacturing companies who produce products which are *Highly Customized, Mostly Customized, Highly Standardized, Mostly Standardized* and a *Mix of both.* The segment *Company size* is divided into companies with employees ranging from *30-60, 60-100, 100-250* and *Greater than 250.*

4
Results

The following sections present the results inferred from the exploratory case study.

4.1 Interviewing Experts

This section covers the results from the interviews performed with experts covering the three focal points of the interviews: *Product related challenges in manufacturing SMEs*, *The relationship between SMEs and PLM systems*, and *The need and function of SaaS Cloud PLM*. Additionally, other key insights from these interviews are summarized. All the answers from the experts were in accordance with each other, where most of the answers were either new developments or extensions of existing answers without any contradictions.

4.1.1 Product Related Challenges in Smaller Manufacturing Companies

Three main categories of challenges arose from the interviews: administrative challenges, innovative challenges, and external challenges. To see the original summary of the separate interviews refer Appendix C.

The administrative challenges relate to the handling of documents and systems related to products. Smaller manufacturing companies often have unstructured and decentralized storage of data making it difficult for employees to find the correct documents. This leads to both time wasting through inefficient searches for documents and less reuse of existing knowledge due to information not being easily available. The decentralized storage of documents further make it difficult to have the same version of documents throughout the company since different employees or departments may store and use the same document in different places. This invokes a risk of significant revisions of documents or products when these inconsistencies are noticed. The reasons for unstructured and decentralized documentation are attributed to two factors, the first being that the product life cycle processes currently are or recently have been quite simple and a large investment to improve this has not been viable. Secondly, the company may have unsynchronized systems that do not automatically update information leading to versions manually having to be updated.

The innovative challenges concern the companies' ability to innovate. Generally,

smaller manufacturing companies have a difficult time to efficiently innovate if they are to still remain profitable. The four main factors which limit the innovation of companies are: time, money, knowledge, and internal resistance. Employees are fully occupied with providing service to the customers or with other value adding processes and do not have time over to spend on innovation projects. The company does not have the funds to invest in new employees who could be staffed on innovation projects which results in complications to get the right talent with the correct skills needed to improve the organisation. These challenges of investing in research and development reduces their capability to understand new technologies that are available in the market that are needed to develop their organisation. The knowledge within the company could be limited both in pure technical knowledge but also be limited in the knowledge of new domains or processes. One interviewee was involved in a project where manufacturing SMEs where provided with funds to pursue an innovation project and most companies chose to spend this money on new knowledge. The internal resistance to innovation in a company often exists in mature industries where innovation has been stagnant and the need fro innovation has been of lesser importance.

The external challenges are mainly centered around the dependency of some smaller manufacturing companies on large customers such as Original Equipment Manufacturers (OEMs) yet include other challenges as well. The companies that have a single or few customers which constitute a large part of their sales can become greatly dependent on them. This leads the smaller companies to adjust their limited product development efforts to suit what larger companies want thereby becoming more integrated and dependent on the large companies. An interviewee mentioned that historically when large companies introduced new digitized administration systems they issued a demand to their suppliers that they needed the same type of system. The challenges of a lack of uniform documentation stretches towards the external partners as well where issues can arise due to customers or suppliers having incorrect versions of documents or file types being incompatible.

4.1.2 The Relationship Between Smaller Manufacturing Companies and PLM Systems

The relationship between smaller manufacturing companies and PLM systems is overall quite weak since very few companies actually work with PLM systems. There are three primary reasons for a lack of PLM systems in these companies: an unacceptable level of Return on Investment, internal resistance, and employees are used to the normal state. To see the original summary of the separate interviews see Appendix C.

The unacceptable level of Return on Investment is likely the largest contributor as to why PLM systems have a low adoption rate in smaller manufacturing companies. The reason for the low pay-off is that smaller companies tend to have less complex products and product development processes therefore the gains from optimizing these can be minimal. This lack of financial gain is for the traditional on-

premise PLM systems that require large investments to set the IT infrastructure and customize functionality. One interviewee doubted the need for PLM systems functionality overall for companies below 50 people. Another interviewee also claimed that smaller companies will start focusing on PLM systems when they see the benefit directly or visualise and understand that the smaller companies can have control over the information and data to be able to collaborate better.

The internal resistance towards PLM can emanate both from a lack of knowledge within PLM systems and from a fear of reduced importance. The ERP system is generally one of the first company wide systems companies employ and this contains all the necessary information for top management such as the CEO and Chief Financial Officer (CFO). Since the top management is comfortable with ERP systems and has little knowledge of PLM systems, the top management tends to avoid PLM systems. Employees who currently possess most of the knowledge regarding the company's products or processes may fear that implementation of PLM systems that aim to standardize these processes remove power from them and make them more replaceable.

The normal state for product life cycle processes in smaller manufacturing industries is that they are ad-hoc. One interviewee formulated that in the case of small companies, the PLM system is usually in someones head. It is commonplace to use large excels or similar files to document the processes. Even though this may not be the most efficient way, it is the way employees are used to working and therefore it currently continues.

4.1.3 The Need and Function of Saas Cloud PLM

The need to develop Cloud PLM seems to be based upon the customers needs as well as the needs of the software developer. There are several benefits tied to having a SaaS Cloud PLM, yet there are also drawbacks. To see the original summary of the separate interviews see Appendix C.

The benefits of SaaS Cloud PLM are closely linked to the needs of the customers as well as the software developer. SaaS Cloud PLM provides a far more flexible and cost efficient method for companies to attain PLM systems. Traditional PLM systems firstly require a large setup cost and may require an internal IT department to manage this system. With SaaS Cloud PLM no costly setup is needed and all IT support is provided by the developer. This provides "peace of mind" for both parties as an interviewee said. The customer can focus on their core business and does not need to worry about supporting a system and integrating it with other systems, whilst the software developer can use the same code for more licenses and does not need to tailor each system. Finally, SaaS Cloud PLM allows companies to try out the system and scale it accordingly where they can start with one or a few licenses and then be able to add what is necessary without any large initial investment. One interviewee stated that SaaS Cloud PLM solutions are better suited for smaller companies as most of them are in the beginning of their PLM journey

and they have more flexibility and adopting their processes rather than the tools. The interviewee also claimed that turn-key solutions also help smaller companies to focus on investing the right resources to develop products instead of maintaining IT systems and the way forward for smaller companies is 100% through the Cloud.

The risks of SaaS Cloud PLM are mainly placed on the customer and concerns safety, lack of control, and lack of customization. The actual safety or privacy of companies data could be questioned. This is mainly due to the fact that the information would reside with the software developers servers rather than in house, meaning that companies must trust the software developers. The risk of cyber attacks is also greater since SaaS Cloud PLM allows for more entry points. The location of the server depending on country could also pose a risk depending on local regulations. The lack of control of the system could be a risk since updates are not managed by your own IT-department leading to longer waiting times to fix bugs from new updates. An interviewee brought up an example when an update to a cloud system introduced a bug that rendered their usage of the system impossible. Since the software developer needed to fix this and ensure that no new bugs where introduced it took a week before they could resume work. The final drawback with SaaS Cloud PLM is the lack of customization since the system is designed to be standardized and offer best practices. However, if a company has unique products or usage then they will be limited to what they can adjust.

4.1.4 Other Key Insights

An insight that was highlighted by several experts is the difficulty in generalizing smaller manufacturing companies, and that it becomes more difficult to generalize, the smaller the company is. One possible generalization is however that companies which own the intellectual property and produce their own products have a different set of challenges compared to contract manufacturers. To see the original summary of the separate interviews see Appendix C.

For smaller manufacturing companies to adopt a PLM systems, the system likely has to be quite simple. This is due to the difficulty of implementing new processes and the low purchasing knowledge within smaller companies. The difficulty of implementing new processes often results in consultants being required for new process implementation and the cost of hiring these consultants are often outweighed by the expansions or upgrades of current production. As mentioned previously smaller companies tend to lack the necessary knowledge regarding PLM systems which complicates the purchasing of these systems. Having a simpler system would mitigate these factors. This aligns well with a trend software developers are noticing that companies are moving from fully customized solutions towards out of the box solutions.

One interviewee specifically mentioned 5 drivers for SMEs to adopt PLM systems. The first driver is receiving a single source of information, assuring that everyone in the company has the same centralized version of documents. The second driver

is traceability, being able to trace from where changes have originated and track development. The third driver is enabling the cloud push for access to future innovations. The fourth driver is sales visualization, allowing the sales department to show customers the products directly in the system with a 3D-view. The fifth driver is protecting IP, companies being able to store IP inside their systems instead of inside the mind of people.

One interviewee explained that the adoption of a new system needs to be promoted by creating a business case and an urgency for the customer to make the change as they are often affected by both global and local trends.

Smaller companies are also affected by the same challenges as large companies but the severity of the effect is greater due their lesser size. Smaller companies produce lesser volumes when compared to large companies, hence they have problems with being cost efficient and staying profitable. One of the solutions to this problem is by creating an early demand and ensuring that the products are brought in faster to the market which can be accomplished by effectively using a PLM system.

4.2 Interviewing Smaller Manufacturing Companies

This section covers the results from the interviews performed with manufacturing companies in Sweden having employees within the range of 30-400. The main focal points of the interviews: *Challenges faced by the companies*, and *Adoption factors to implement a new system*. Additionally, other key insights from these interviews are summarized.

4.2.1 Company Challenges

Four main categories of challenges arose from the interviews: administrative challenges, knowledge management challenges, external challenges, and system challenges. To see the original summary of the separate interviews see Appendix C.

The administrative challenges relate to the handling of documents and management of products. The growing product portfolio presents challenges in efficiently storing and retrieving documents. Having the right versions of drawings and managing them is also a challenge. An interviewee mentioned that it was always a confusion to to handle documents correctly and figure out the right drawing/document to use. It was mentioned by one interviewee that this is an ever present problem within manufacturing companies. The limited amount of production engineers are swamped even further by this increasing product portfolio and it is difficult to develop good instructions with images for manufacturing. The more customized the product or solution, the larger the challenge for the company. An interviewee also mentioned that miscommunication in using the right documents also leads to quality problems.

The knowledge management challenges arise both when old employees leave the company and when new employees enter the company. It is common that much of the knowledge regarding product development or manufacturing is stored in the minds of the employees that has been accrued from the years of experiences and tests. The lack of knowledge capturing from the employees usually leads to reoccurring of previously made mistakes and great effort needed to reverse engineer solutions to problems since the responsible engineer has left. The training of new employees to assure that they develop the knowledge needed can be time consuming. The effect of leaving employees and the time it takes to train new employees seemingly become larger the more complex the product and production is.

The external challenges spring from the difficulty to receive the correct materials, the competitive landscape, and customer service. Receiving materials with the correct quality, fit, and on time is an issue for most companies. The difficulties can arise from suppliers not delivering what was expected, materials/components not fitting the planned mold, and regulatory restrictions/quotas on certain materials. Some companies also face a challenge in understanding the exact needs of the customer. There is further always a risk that new competitors either domestically or internationally may threaten the companies. Due to the administrative challenges, it can be difficult to provide quick customer service if a certain component of a solution breaks down. This is due to the manufacturing company having the need to dig into old products/solutions and finding out exactly where and what article was able to provide assistance.

The system challenges revolve around the system structure at the company. A common challenge is that there are too many systems that cause information to become decentralized making it difficult to gain an overview of projects and creates an overload of channels of information. In some companies this extends past the project process and there is almost a separate system for each function which creates a great deal of confusion for the employees. Changing the system structure can be quite difficult as well, one interviewee mentioned that they estimated changing some of their systems would require 9-10 thousand hours of work.

4.2.2 Adoption Factors

The adoption of new systems is mainly due to external requirements or that an acceptable Return on Investment (ROI) can be calculated. All the interviewees were in accordance with the requirement of an acceptable ROI except for one interviewee who was mainly dependent on his gut feeling and the initial cost of the system. The largest factor that impacts if a new system is adopted in an organization is the support from the employees. To see the original summary of the separate interviews see Appendix C.

External requirements can originate from three main sources: it can be the owners of the company requiring them to implement a system, a large significant customer, governmental regulation, or a threat to the companies survival that requires a new

system. In all of these cases, the actual interest from the company has little effect. In the case of calculating the ROI, it often requires a tangible calculation such as energy savings, the more complex the calculation the less certain it becomes. If companies do not feel for certain that a system will provide them with a financial benefit they will generally avoid implementing a new system. As an interviewee mentioned that implementing a new system is like performing a heart surgery, you avoid it unless and until it is completely necessary.

When implementing new systems, it is critical to get both management and other employees on board. To get the management to prioritize the implementation of a new system is key. An interviewee did however mention that despite receiving the support from management to implement a new system, if the management was forced to prioritize tests for the new system or to full fill customer orders, it was the latter that was chosen. The employees that will be using the system are obviously important to get on board since they are the ones who will need to get adapted the system. It is important to introduce the new systems as early as possible in the implementation process to the employees that will be working with them and ensure that their voice is heard in the implementation process to make the transition into the new systems easier. The benefits and purpose of the new system has to be communicated to the employees to gain support otherwise there will likely be resistance to using a new system. This is since people are generally skeptical towards new things which they do not know. If an employee has a tried and tested method and a new method is suggested there has to be a will to change. An interviewee explained an example of how his company managed to get employees on board by clearly explaining the benefits of the system before implementation. If systems or processes that work well are changed, more resistance can be expected.

4.2.3 Other Key Insights

There was one other insight which was that a strong preference for standardized systems was expressed by an interviewee. Mainly because, as soon as any customization is performed to a system it becomes far more expensive to adjust in the future, and often the standardized system can work really well. To see the original summary of the separate interviews see Appendix C.

One interviewee also explained that employees fear change and it is important to convince them and make them understand the new system implementation clearly by involving them in the process.

4.3 Surveying Small Manufacturing Companies

This section contains the results from the survey sent out to manufacturing companies in Sweden. The response rate was 39.4 percent where a total of 77 responses were received from 195 industries to whom the survey was sent out. The graphical interpretation of the response for each statement presented in the survey can be seen in Appendix D.

The summary of survey statements and their abbreviations used in their respective sections can be seen in Figure 4.1.

The the average magnitude of acceptance for the statements in the challenges section, benefits section, risks section and adoption factors section for segmented manufacturing industries can be seen in Figure 4.2, Figure 4.3, Figure 4.4, and Figure 4.5 respectively.

Challenges	
C1	I can find documents/drawings that are needed by using the current systems in the company
C2	I can securely store product and process related information using the current systems in the company
C3	I can find the correct version of documents/drawings when I need them
C4	I think my company can efficiently create new products in our current systems
C5	I think my company can efficiently manage products in our current systems
C6	Suppliers are notified immediately when relevant documents are updated
C7	Customers are notified immediately when relevant documents are updated
C8	We have processes and documents to retain knowledge for when employees leave the company
C9	I think my company avoids repeating product related mistakes
C10	I think my company has the financial resources needed to innovate
C11	I think my company has the knowledge needed to innovate
C12	I think my colleagues and I have the time available to innovate
C13	I think we work efficiently on product related tasks

Benefits	
B1	I think my company is willing to spend resources to overview our product's life cycle within one system
B2	I think my company is willing to spend resources to increase efficiency of product related work processes
B3	I think my company is willing to spend resources to increase efficiency of collaboration between departments/branches
B4	I think my company is willing to spend resources to increase efficiency of collaboration with suppliers and customers
B5	I think my company is willing to spend resources to increase standardization of product related work processes
B6	I think my company is willing to spend the resources to increase the capturing of knowledge
B7	I think my company would prefer a standardized system for a lower cost compared to a customized system for a higher cost
B8	I think my company would want the ability to access systems remotely
B9	I think my company has the resources to maintain IT-systems by ourselves
B10	I think my company would prefer a software supplier to manage our systems rather than having our own IT department
B11	I think my company's customers want the ability to follow a project's process online

Risks	
R1	I think Cloud systems are secure enough for my company's information
R2	I think my company has a stable internet connection to use IT systems
R3	I trust Cloud system providers to keep adequate up-times
R4	I think the physical location of the cloud server is important

Adoption Factors	
AF1	I have experience of PLM systems (Product Lifecycle Management systems)
AF2	I have experience of SaaS Cloud PLM systems (Software as a Service Cloud Product Lifecycle Management systems)
AF3	I think that my company is considering implementing a PLM system (Product Lifecycle Management system)
AF4	I think the employees in my company are positive towards new IT-systems and work methods
AF5	I think it is possible to integrate new systems with our current systems
AF6	I am satisfied with our current IT-systems
AF7	I am satisfied with our product related processes
AF8	I think my company needs to become more digitized
AF9	I think that IT-systems support me to do the right things

Figure 4.1: Summary of Survey questions with abbreviation

Administrative Challenges
External Challenges
Innovative Challenges

Challenges																									
Overall		Type of Manufacturer						Degree of customization/standardization										Company size							
Overall Average		Contract manufacturer		Mix of both		Owns the IP		Highly customized		Mostly customized		Mix of both		Mostly standardized		Highly standardized		>250		100-250		60-100		30-60	
AVG	4.4	AVG	4.45	AVG	4.36	AVG	4.42	AVG	4.3	AVG	4.26	AVG	4.37	AVG	4.39	AVG	4.82	AVG	4.5	AVG	4.34	AVG	4.4	AVG	4.44
C12	3.84	C12	3.57	C12	3.63	C7	3.58	C6	3.38	C7	3.36	C12	3.84	C12	3.73	C6	3.89	C6	4	C12	3.66	C12	3.69	C7	3.75
C7	3.88	C6	4	C6	3.95	C6	3.85	C12	3.8	C12	3.77	C6	4	C7	3.83	C7	4.22	C12	4.18	C7	3.67	C6	3.73	C6	3.93
C6	3.89	C9	4.14	C13	4.04	C12	4	C7	3.89	C6	3.82	C7	4	C13	3.92	C12	4.22	C13	4.18	C6	3.93	C13	3.88	C12	4.05
C13	4.06	C13	4.14	C8	4.05	C13	4.07	C9	3.9	C13	3.92	C8	4	C8	4.09	C8	4.33	C8	4.22	C8	3.97	C7	4	C13	4.05
C8	4.12	C11	4.29	C7	4.32	C8	4.07	C13	3.9	C5	4.23	C13	4.03	C6	4.1	C9	4.67	C7	4.45	C13	4.13	C8	4.2	C9	4.2
C9	4.26	C7	4.33	C9	4.36	C9	4.22	C8	4.2	C9	4.23	C9	4.25	C9	4.33	C13	4.67	C5	4.55	C9	4.17	C9	4.31	C8	4.25
C5	4.58	C3	4.43	C10	4.36	C5	4.49	C10	4.22	C11	4.23	C5	4.38	C11	4.42	C11	4.78	C9	4.55	C2	4.55	C11	4.5	C4	4.55
C4	4.64	C1	4.71	C2	4.56	C4	4.64	C2	4.3	C8	4.33	C4	4.44	C2	4.64	C2	5.22	C2	4.64	C5	4.59	C5	4.63	C5	4.55
C11	4.66	C4	4.71	C11	4.6	C11	4.76	C3	4.6	C4	4.5	C3	4.56	C10	4.67	C4	5.22	C4	4.64	C4	4.66	C4	4.75	C3	4.7
C2	4.73	C8	4.71	C4	4.64	C2	4.79	C4	4.8	C2	4.69	C1	4.7	C5	4.73	C5	5.22	C11	4.64	C11	4.67	C2	4.81	C11	4.8
C3	4.75	C5	4.86	C5	4.67	C3	4.84	C5	4.9	C3	4.69	C2	4.77	C4	4.75	C3	5.33	C1	4.7	C3	4.73	C3	4.81	C10	4.95
C10	4.88	C2	5	C3	4.68	C1	5	C11	4.9	C1	4.77	C11	4.78	C1	4.9	C10	5.33	C3	4.82	C10	4.83	C10	4.88	C1	5
C1	4.92	C10	5	C1	4.83	C10	5.16	C1	5.1	C10	4.83	C10	5	C3	5	C1	5.56	C10	4.91	C1	4.86	C1	5.06	C2	5

Figure 4.2: Average magnitude of the statements in the challenges section for segmented manufacturing industries

Benefits of PLM
Benefits of Cloud PLM

Benefits																									
Overall		Type of Manufacturer						Degree of customization/standardization										Company size							
Overall Average		Contract manufacturer		Mix of both		Owns the IP		Highly customized		Mostly customized		Mix of both		Mostly standardized		Highly standardized		>250		100-250		60-100		30-60	
AVG	4.44	AVG	4.31	AVG	4.53	AVG	4.42	AVG	4.53	AVG	4.41	AVG	4.45	AVG	4.17	AVG	4.82	AVG	4.86	AVG	4.25	AVG	4.45	AVG	4.49
B4	4.62	B4	4.86	B2	4.68	B3	4.6	B5	4.9	B6	4.75	B4	4.71	B3	4.45	B4	5.22	B2	5.09	B5	4.55	B4	4.94	B3	4.79
B3	4.61	B2	4.57	B4	4.68	B5	4.56	B2	4.8	B2	4.54	B2	4.65	B5	4.36	B5	5	B3	5.09	B6	4.48	B2	4.81	B6	4.68
B2	4.59	B3	4.57	B6	4.64	B2	4.55	B3	4.7	B4	4.54	B3	4.63	B4	4.25	B3	4.89	B4	5	B2	4.34	B3	4.56	B4	4.6
B5	4.53	B6	4.57	B3	4.63	B4	4.55	B4	4.5	B5	4.54	B6	4.52	B2	4.17	B2	4.78	B6	4.82	B3	4.32	B5	4.44	B5	4.55
B6	4.49	B5	4.14	B5	4.58	B6	4.4	B6	4.4	B3	4.46	B5	4.34	B6	4.08	B6	4.78	B1	4.6	B4	4.31	B6	4.06	B2	4.5
B1	3.81	B1	3.17	B1	3.96	B1	3.83	B1	3.89	B1	3.64	B1	3.83	B1	3.7	B1	4.22	B5	4.55	B1	3.48	B1	3.87	B1	3.82
AVG	3.91	AVG	4.09	AVG	3.98	AVG	3.85	AVG	3.48	AVG	4.1	AVG	3.99	AVG	3.65	AVG	4.33	AVG	3.79	AVG	3.82	AVG	4.1	AVG	3.96
B8	5.03	B10	4.86	B8	5.32	B8	4.93	B8	4.9	B8	5.17	B8	5.07	B8	4.8	B8	5.33	B8	5.2	B8	4.82	B8	5.13	B8	5.16
B7	4.42	B8	4.71	B7	4.57	B7	4.48	B7	4	B11	4.27	B7	4.45	B7	4.55	B7	5.22	B7	4.64	B7	4.38	B7	4.4	B7	4.37
B10	3.58	B9	4	B11	3.58	B10	3.48	B9	3.1	B7	4.08	B10	3.66	B11	3.09	B10	4.63	B11	3.6	B11	3.38	B10	3.81	B10	3.95
B11	3.35	B7	3.57	B10	3.4	B11	3.21	B10	3.1	B10	3.77	B9	3.39	B10	3.08	B11	3.33	B10	3.1	B10	3.37	B9	3.69	B9	3.26
B9	3.19	B11	3.29	B9	3.04	B9	3.14	B11	2.3	B9	3.23	B11	3.38	B9	2.75	B9	3.12	B9	2.4	B9	3.13	B11	3.47	B11	3.06

Figure 4.3: Average magnitude of acceptance for the statements in benefits section for segmented manufacturing industries

Risks																									
Overall		Type of Manufacturer						Degree of customization/standardization										Company size							
Overall Average		Contract manufacturer		Mix of both		Owns the IP		Highly customized		Mostly customized		Mix of both		Mostly standardized		Highly standardized		>250		100-250		60-100		30-60	
AVG	4.18	AVG	4.14	AVG	4.13	AVG	4.22	AVG	3.77	AVG	4.28	AVG	4.19	AVG	4.06	AVG	4.72	AVG	4.53	AVG	3.98	AVG	4.46	AVG	4.06
R4	2.73	R4	3.25	R4	2.76	R4	2.65	R4	3	R4	3.33	R4	2.73	R4	2	R4	2.67	R4	2.67	R4	2.95	R4	3.2	R4	2.13
R1	4.24	R1	3.5	R1	4.2	R1	4.38	R1	3.38	R1	4.3	R1	4	R3	4.7	R1	5.13	R1	5	R1	3.89	R1	4.6	R1	4.07
R3	4.61	R3	4.5	R3	4.65	R3	4.61	R3	3.89	R3	4.4	R3	4.76	R1	4.73	R3	5.29	R3	5.18	R3	4.13	R3	4.92	R3	4.69
R2	5.14	R2	5.29	R2	4.92	R2	5.23	R2	4.8	R2	5.08	R2	5.26	R2	4.8	R2	5.78	R2	5.27	R2	4.93	R2	5.13	R2	5.35

Figure 4.4: Average magnitude of acceptance of statements in risks section for segmented manufacturing industries

PLM Knowledge
New system viability
Satisfaction with current processes/systems
Belief in IT-systems

Adoption Factors																									
Overall		Type of Manufacturer						Degree of customization/standardization										Company size							
Overall Average		Contract manufacturer		Mix of both		Owns the IP		Highly customized		Mostly customized		Mix of both		Mostly standardized		Highly standardized		>250		100-250		60-100		30-60	
AVG	**2.57**	**AVG**	**1.75**	**AVG**	**2.45**	**AVG**	**2.78**	**AVG**	**1.8**	**AVG**	**2.66**	**AVG**	**2.6**	**AVG**	**2.66**	**AVG**	**3.25**	**AVG**	**3.76**	**AVG**	**2.33**	**AVG**	**2.59**	**AVG**	**2.23**
AF1	2.97	AF1	2.29	AF1	2.78	AF1	3.19	AF1	2.56	AF1	3.08	AF1	3.06	AF1	2.67	AF1	3.5	AF1	4.36	AF1	2.57	AF1	2.94	AF1	2.78
AF2	1.74	AF2	1.14	AF2	1.74	AF2	1.85	AF2	1.33	AF2	1.91	AF2	1.7	AF2	1.55	AF2	2.5	AF2	2.64	AF2	1.48	AF2	1.5	AF2	1.78
AF3	3	AF3	1.83	AF3	2.82	AF3	3.31	AF3	1.5	AF3	3	AF3	3.04	AF3	3.75	AF3	3.75	AF3	4.29	AF3	2.95	AF3	3.33	AF3	2.14
AVG	**4.15**	**AVG**	**4.57**	**AVG**	**3.99**	**AVG**	**4.17**	**AVG**	**3.52**	**AVG**	**4.34**	**AVG**	**4.17**	**AVG**	**4.21**	**AVG**	**4.45**	**AVG**	**4.65**	**AVG**	**4.07**	**AVG**	**4.07**	**AVG**	**4.06**
AF4	4.21	AF4	4.14	AF4	4.38	AF4	4.13	AF4	3.78	AF4	4.23	AF4	4.25	AF4	4.42	AF4	4.33	AF4	4.73	AF4	4.17	AF4	4.13	AF4	4.05
AF5	4.08	AF5	5	AF5	3.6	AF5	4.21	AF5	3.25	AF5	4.45	AF5	4.08	AF5	4	AF5	4.56	AF5	4.56	AF5	3.96	AF5	4	AF5	4.06
AVG	**4.13**	**AVG**	**4.43**	**AVG**	**4.13**	**AVG**	**4.09**	**AVG**	**3.8**	**AVG**	**4.23**	**AVG**	**4.18**	**AVG**	**4.09**	**AVG**	**4.36**	**AVG**	**4.24**	**AVG**	**4**	**AVG**	**4.04**	**AVG**	**4.35**
AF6	4.09	AF6	4.57	AF6	4	AF6	4.07	AF6	3.6	AF6	4.15	AF6	4.22	AF6	4.08	AF6	4.33	AF6	4.18	AF6	3.9	AF6	3.94	AF6	4.45
AF7	4.17	AF7	4.29	AF7	4.25	AF7	4.11	AF7	4	AF7	4.31	AF7	4.13	AF7	4.09	AF7	4.38	AF7	4.3	AF7	4.1	AF7	4.13	AF7	4.25
AVG	**4.52**	**AVG**	**4.65**	**AVG**	**4.59**	**AVG**	**4.47**	**AVG**	**4.5**	**AVG**	**4.53**	**AVG**	**4.56**	**AVG**	**4.5**	**AVG**	**4.5**	**AVG**	**4.87**	**AVG**	**4.4**	**AVG**	**4.57**	**AVG**	**4.48**
AF8	4.53	AF8	4.29	AF8	4.61	AF8	4.53	AF8	4.6	AF8	4.38	AF8	4.57	AF8	4.58	AF8	4.56	AF8	5.09	AF8	4.5	AF8	4.47	AF8	4.32
AF9	4.51	AF9	5	AF9	4.56	AF9	4.4	AF9	4.4	AF9	4.67	AF9	4.55	AF9	4.42	AF9	4.44	AF9	4.64	AF9	4.3	AF9	4.67	AF9	4.63

Figure 4.5: Average magnitude of acceptance of statements in adoption factors section for segmented manufacturing industries

5
Discussion

The results from the interviews and the survey are deemed to be valid to use for the discussion. The interviews with experts and companies where included experts and companies with different backgrounds and where performed until most answers where repetition of previous answers. The survey had 77 answers providing a large sample size to analyze. Within these 77 answers 3 pairs of 2 where isolated belonging to the same company. These results were all included in the data analysis since the purpose of the survey was to collect the opinions of survey takers and these data points still added value. Looking at Figure D.2 in Appendix D, it can be seen that there are different employee types the have filled out the survey with production managers being more prominent than other positions. From the interviews it was stated that opinions will vary greatly in a company depending on the person and the position they have, even if no direct conclusions can be drawn from this distribution it is worth to keep this in mind.

The results from the survey as seen in Figure D.3 in Appendix D reveal that there is a good mix of industries who have taken part in the survey and an even mix of company sizes with 26% of the companies have employees in the range of 30-60, 20.8% of the companies have employees in the range of 60-100, 39% of the companies have employees in the range of 100-250 and 14.3% of the companies have employees in the range of 250-400. With a good percentage of companies covering the entire spectrum in which our thesis is focusing ensures that the results are valid for the entire range of smaller manufacturing companies and not only focusing on one particular segment of the manufacturing companies. The smallest segment analyzed is the one for contract manufacturers which can be seen in Figure D.7 in Appendix D being 9.1% of 77 or 7 answers. This is deemed to be a sufficiently large sample size to draw general conclusions, yet may definitely have an impact on the results. It is interesting to see in Figure D.5 in Appendix D that 66.2% of the companies that have participated in the survey have an ERP system in contrast to the 15.6% of the companies who have a PLM system. This is in accordance with the results from the interview which revealed that ERP systems are dominant in smaller manufacturing industries and PLM systems are still in the initial phases of implementation where there is not yet any large scale adoption.

All the statements presented in the survey are positively inclined statements whose magnitude of acceptance can be attributed directly to the presented sections in the survey except for the statements B9 and R4 whose magnitude needs to be inverted in order to corroborate with the formation of other statements in their respective

sections. This needs to be done in order to ensure that the statements when arranged in order of their magnitude reveal the most intriguing benefit or risk. The statement B9 specifies that the company has the resources to maintain IT-systems by themselves, which would render the benefit that can be reaped by Cloud PLM systems as unimportant, that is, if the company is in agreeance with the B9 statement, they are less likely to be intrigued by the benefit of Cloud PLM where they would not require to maintain their own IT-systems which is antagonistic to the other statements in this section to whom if agreed would mean that the company is intrigued by the benefit of Cloud PLM. Similarly, the statement R4 when agreed upon implies that the survey taker finds the physical location of the server important which would decrease the acceptance of Cloud PLM systems and increase its risk which is contrasting to the other statements posed in the Risk section. To ensure the validity of both these statements when arranged in order of their magnitude in their respective sections, the magnitude of the statements obtained from the survey results are inverted and presented in the Figure 4.3 and Figure 4.4 where their average magnitude of acceptance for segmented manufacturing industries are depicted.

5.1 RQ1: What product related challenges are smaller manufacturing companies facing?

To assess what product related challenges smaller manufacturing companies are facing, the results from the survey and results from the interviews with experts as well as companies will be analyzed. The survey posed statements related to the primary challenges identified in the literature review and interviews where 13 primary product related challenges faced by smaller manufacturing companies and their magnitude can be found in Figure 4.2. The lower score a challenge has received in the survey the larger this challenge is for the survey taker. To analyze the numbers in Figure 4.2 the following assumptions are made:

- A score between 1-2 indicates a critical challenge
- A score between 2-3 indicates a significant challenge
- A score between 3-4 indicates that there is significant room for improvement
- A score between 4-5 indicates that there is some room for improvement
- A score between 5-6 indicates that there is small room for improvements

It can be seen that for the overall average none of the statements pertaining to the challenges have a response between 1-3 or 5-6, which indicates that the challenges are relevant to the manufacturing companies yet they are likely not perceived as critical or significant challenges.

Looking at the results from the survey it can be seen that external challenges offer room for significant improvement for the overall average and almost for all segments. Even though the external challenges only focus on the updating of relevant documents to suppliers and customers (and not the entire collaboration with these) the survey result strengthens the findings from the interviews pertaining to compa-

nies' lack of collaboration with external parties. Following the external challenges, the innovative challenges appear to be the secondary concern for manufacturing companies with all challenges offering some room for improvement except for C12 which offers significant room . Finally, the administrative challenges appear to be of tertiary importance to smaller manufacturing companies yet all offering some room for improvement. The survey indicates that there is no clear trend in the segmented manufacturing companies expect for segmentation based on *Degree of customization/standardization* where it can be observed that companies with high-/mostly customised products rate the statements lower than companies with highly standardised products. It can be observed that the top three challenges overall for manufacturing companies C12, C7 and C6 have a similar magnitude of 3.84, 3.88 and 3.89 respectively. This indicates that these 3 challenges are of comparable concern to manufacturing companies. Below each challenge is explored in more depth in ascending order for the overall average.

C12 rated 3.84 is marginally the highest ranked challenge where the statement posed was: "*I think my colleagues and I have the time available to innovate*". This implies that there is significant room for improvement regarding the time that is allocated to innovate. The interviews determined that smaller manufacturing companies are limited in the ability to innovate due to 3 main constraining factors, namely, time, money, and knowledge, and one of the interviewees explained that the employees are mainly occupied with process related tasks do not have the time to innovate. C12's rating signifies time to be the most dominant constraining factor for innovation.

C7 comes next rated 3.88 where the statement posed was: "*Customers are notified immediately when relevant documents are updated*". This implies that there is significant room for improvement for notification of customers when smaller manufacturing companies update relevant documents. The interviews revealed that smaller manufacturing companies mainly have asynchronous systems that do not automatically update information and most of the updating work needs to be done manually leading to the updating of customer's documents lagging.

C6 is rated 3.89 and almost tying C7, comes next where the statement posed was: "*Suppliers are notified immediately when relevant documents are updated*". This entails that there is significant room for improvement for notification of suppliers when smaller manufacturing companies update relevant documents. This can lead to problems in procuring the right material from the suppliers at the right time. The interviews revealed that due to this challenge, the manufacturing companies face problems where the supplier does not deliver the required components or the material/components do not fit the molds accurately. C6 and C7 seem to strengthen the theory proposed in the results from interviews that smaller manufacturing companies struggle with their external collaborations.

C13 comes next rated 4.06 where the statement posed was: "*I think we work efficiently on product related tasks*". This implies that there is some room for improvement for smaller manufacturing companies product related tasks efficiency.

The interviews revealed that some smaller manufacturing companies have too many systems in place where the information is decentralised having separate systems for each task. The interviews further provided the insight that these companies often work more adhoc solving problems as they arise. The lack of standardisation in working methods and the decentralisation of information may be contributing to lower efficiency within product related tasks.

C8 comes next rated 4.12 where the statement posed was: "*We have processes and documents to retain knowledge for when employees leave the company*". This implies that there is some room for improvement for smaller manufacturing companies knowledge management processes. The interviews revealed that a great deal of knowledge is stored in the minds of employees due to their experience within the company. Due to the lack of processes in knowledge capturing within the company, the knowledge is often lost when these employees leave the company. This results in challenges where tasks take a longer time to perform since no employee has the previously collected knowledge. According to the interviews, the smaller the company, the greater is the impact when an employee leaves since they constitute a larger percentage of the entire workforce. Looking at C8's ratings across the segment of size, it appears that all segments rate their processes for retaining knowledge similarly yet the impact of poor processes is likely larger the smaller the company is.

C9 comes next rated 4.26 where the statement posed was: "*I think my company avoids repeating product related mistakes*". This implies that there is some room for improvement for smaller manufacturing companies to not repeat product related mistakes. The interviews revealed that the decentralised method of storing documents, which is prominent in most smaller manufacturing companies, results in problems of poor reusing of knowledge and information not being easily available.

C5 comes next as the first administrative challenge rated 4.58 where the statement posed was: "*I think my company can efficiently manage products in our current systems*". This implies that there is some room for improvement for smaller manufacturing companies to increase the efficiency in managing their products. The interviews revealed that a naturally increasing product portfolio presents a challenge for manufacturing companies where there is a need to handle large quantities of product related drawings and documents. Without a sufficient system to handle the ever growing database efficiently, it is easy for companies to become overwhelmed with documents and information.

C4 comes next rated 4.64 where the statement posed was: "*I think my company can efficiently create new products in our current systems*". This implies that there is some room for improvement for smaller manufacturing companies to increase the efficiency of creating new products. The interviews revealed that smaller manufacturing companies mostly have an unstructured product development and documentation process. This can hinder with the efficiency of creating new products due to the need of converting file formats, or finding the right version of documents, or create confusion in handling documents in general.

C11 comes next rated 4.66 where the statement posed was: "*I think my company has the knowledge needed to innovate*". This implies that there is some room for improvement for smaller manufacturing companies to increase the knowledge needed to innovate. The interviews revealed that smaller manufacturing companies mostly lack the capacity to invest in new knowledge domains required to innovate. It was mentioned in an interview that when these smaller manufacturing companies are provided with funding, they mainly invest in procuring knowledge in new domains or processes required to innovate. It is therefore noteworthy that a relatively high rating of 4.66 was achieved for this challenge.

C2 comes next rated 4.73 where the statement posed was: "*I can securely store product and process related information using the current systems in the company*". This implies that there is some room for improvement for smaller manufacturing companies to improve the process for storing information. The related statement C3 comes next rated 4.75 where the statement posed was: "*I can find the correct version of documents/drawings when I need them*". This implies that the manufacturing companies face a challenge in version management and finding the right version of the documents and drawing when needed. The interviews revealed that the decentralised storage method primarily used in smaller manufacturing companies make it difficult to have the same version of documents everywhere in the company as different employees may store and use the same documents in different places which can lead to inconsistency and errors in finding the latest version of the documents.

C10 comes next rated 4.88 where the statement posed was: "*I think my company has the financial resources needed to innovate*". This implies that there is some room for improvement for smaller manufacturing companies regarding their financial ability to innovate. The interviews revealed that smaller manufacturing companies usually do not have the funds to invest in new employees or staff innovation projects and when they have the funds, the company would rather spend them on new machinery or other resources. It is interesting that the results from the interviews and the survey differ where the interviews suggested that there was a clear lack of funds and the survey indicates an almost strong agreeance with there being enough funds. It may be since sufficient financial resources have not been defined in the study allowing for personal interpretation.

C1 is the final challenge rated 4.92 where the statement posed was: "*I can find documents/drawings that are needed by using the current systems in the company*". This implies that there is some room for improvement for smaller manufacturing companies regarding their ability to find documents/drawings in their current system. The results from the interviews again tended to portray this challenge as larger than it was assessed to be in the survey.

Overall the three challenges categories investigated seem to be relevant for smaller manufacturing companies based upon the results from the surveys and interviews. There are likely other product related challenges for smaller manufacturing compa-

nies considering the vast scope it entails. Yet, based upon the literature review and the interviews these three categories were seemingly most prominent when generalizing.

The most surprising result for the challenges is the difference in results between the survey and the interviews. The general impression from the interviews was that the listed challenges were far larger for companies than the survey results indicated. This could be attributed to 3 main factors. The first being that experts may tend to exaggerate the importance of issues that they have worked with due to a personal bias, there is no clear evidence for this from the results. The second being that the survey takers may have restricted knowledge regarding the other improved working methods and since their current methods work, they do not see to what extent they could improve and the lack of knowledge regarding improved working methods could be seen in the lack of experience from survey takers when it comes to PLM systems. The third factor is a lack of clarity in the formulation of statements in the survey, since the survey asked for the personal experiences of the survey takers rather than asking for specific work methods or providing measurable points on the scale and this combined with survey takers preference of existing work methods could cause the discrepancy between the results from the interviews and the results from the survey. It is therefore likely that the scores from the surveys would have been lower, indicating larger challenges, if the survey provided more information to the survey taker for each question. This would however drastically increase the time required to fill out the survey thus reducing the willingness from survey takers.

5.2 RQ2: How can Cloud PLM aid manufacturing companies in overcoming their challenges?

Within each of the three categories of challenges: *Administrative, External, and Innovative*, a Cloud PLM system offers help in overcoming or alleviating these challenges. To what extent a Cloud PLM system will aid smaller manufacturing companies will however greatly depend on how they manage to adopt it. The main benefit of Cloud PLM systems (especially when looking at a SaaS deployment) is the accessibility for smaller manufacturing companies that do not need expensive on-site solutions and therefore the following benefits for each challenge category actually become attainable for them. It provides an out of the box solution that reduces both the time needed to implement and the resources required to sustain a system. A Cloud PLM system with a SaaS deployment therefore provides a real solution to smaller manufacturing industries when compared to the previous enterprise PLM systems.

The first category administrative challenges was expressed as a key set of challenges in the interviews yet less important in the survey. However, moving from a 4.5 or a 4.9 score to a 6 in the survey answer still could save a company a great deal of time and would therefore provide significant benefits. Considering that only 29% of an engineers time is spent performing actual engineering work and that almost

50% of their time is spent on work that could fit in to the administrative challenges. Considering the importance that was placed on the administrative challenges during the interviews it is probable that aiding smaller manufacturing companies in solving their administrative challenges will provide greater value than they believe and can help solve their biggest challenges by saving time.

The administrative challenges are composed of time inefficiencies when performing administrative work such as storing/retrieving documents or creating new/managing existing products. The cause of the issues is often a decentralisation of information and lack of standardisation in administrative processes. With an implementation of a Cloud PLM system a company receives a centralized hub for information and accompanying standardised processes accessible at any time and any place. This provides the structure and standardisation that previously was lacking. The effectiveness of this centralisation of information will depend greatly on the adoption rate within the company. Since the benefits come from centralisation and standardisation, all concerned employees need to utilize the system, otherwise the same issues will arise. A Cloud PLM system will therefore greatly aid smaller manufacturing companies in overcoming their administrative challenges if it is adopted by all who contribute to the administrative challenges.

The external challenges smaller manufacturing companies face seem to be quite significant and center around the collaboration and communication between the company and the external party. A Cloud PLM system may indirectly improve the communication with external parties by increasing the structure of information within the company yet there are other systems that focus more on the communication with external parties. There could however be a significant improvement to the collaboration if both parties have the same Cloud PLM system. This would not only enable files to have a standardised format enabling easier sharing but promotes more combined work efforts. If both parties have the ability to work together in the same system, this would open up the possibility for companies to collaborate with suppliers or customers. These synergy effects that can be achieved by having the same system may even cause large customers to require their suppliers (which often are smaller manufacturing companies) to have a certain Cloud PLM system similar to what they have previously required for administrative systems. Implementing a Cloud PLM system solely in a smaller manufacturing company can aid them in a limited way, yet if their external partners implement the same system the possibilities to reduce these challenges drastically increases.

The final category of innovative challenges is where a Cloud PLM system has the largest possibility to provide drastic benefits. Looking at the largest overall challenge C12, it is the lack of time which restricts innovation. This would imply that freeing up time for innovation is the most critical aspect, which is something a Cloud PLM system can excel at. When discussing the administrative challenges it is clear that a Cloud PLM solution can free up a significant amount of time for a company yet is dependent on the adoption success. Considering the four aspects of PLM it is required that all of these aspects can harmonize with the a Cloud PLM system

to ensure an increase in time for innovation. Looking to the other two restrictions for innovation, namely knowledge and money, this is nothing a Cloud PLM system would aid directly.

The other innovative challenges regarding process efficiency and knowledge retention are challenges that a Cloud PLM system is well suited to aid in overcoming. A Cloud PLM system can provide best practice solutions in a standardised package which helps companies increase process efficiency. There might however be a risk for smaller manufacturing companies in adopting too standardised methods. As one of the strengths of these companies is that they are more agile in nature which allows them to adjust their work processes depending on market development. By becoming more standardised smaller manufacturing companies will reduce the impact of challenges regarding work efficiency yet may suffer a trade-off with their ability to be agile. The actual impact of this trade-off will vary depending on industry, company, and the Cloud PLM system. However, by having an out of the box solution, a company does not lock themselves into any customized solution that is difficult to further manipulate and will still be considerably more flexible than larger companies with completely customised solutions. The standardised processes and centralised information also ties more knowledge into the systems of the company. This reduces the knowledge loss effects when employees leave and can reduce the amount of work done more than once. All the knowledge will not be able to be captured in a Cloud PLM system yet will aid in reducing the effect of knowledge loss.

Cloud PLM with a SaaS deployment has a clear possibility to aid smaller manufacturing companies in overcoming their challenges. Firstly, it is realistic (depending on pricing from providers) for smaller manufacturing companies to afford this type of PLM system. Secondly, it addresses most of the challenges that smaller manufacturing companies face through standardising processes and centralising information flow. Finally, the actual impact of a Cloud PLM system will depend greatly on the adoption within the company. To actually reduce the effect of their challenges, the company would need to undergo an organisational change with all the employees on board and aware of the changes being made to maximize the benefits of a PLM system.

5.3 RQ3: What manufacturing companies are likely to adopt Cloud PLM?

To define the companies that are likely to adopt a Cloud PLM system is certainly difficult, especially considering the difficulty to generalize the nature of the smaller manufacturing companies that have been subjected to investigation. To structure the selection and answer RQ3 the headlines for the survey is used to discuss the results from the survey and interviews regarding that subject, ending with a summarizing discussion exploring the possible interrelations between the headlines.

Challenges

The more product related challenges a company has, the more purpose they have to address these, therefore the companies with a lower magnitude rating for the challenge statements in the survey will be more likely to adopt a Cloud PLM system. The benefits of implenting Cloud PLM have been discussed in RQ2 and have been determined to be able to aid the smaller manufacturing companies in solving these challenges.

Looking at the overall average from the survey in Figure 4.2, it can be seen that no overall average is below the 3.5 neutral point. This would indicate that in general the companies do not feel terribly troubled by the product related challenges which have been presented. This does conflict with the results from the interviews where several experts expressed that smaller manufacturing companies do have trouble with facing these challenges. The difference in results was discussed in RQ1 and is most likely due to a lack of knowledge regarding alternative work methods from the survey takers along with insufficient information being provided to the survey takers in the survey. Even though the survey takers do not feel that these challenges are critical, there still is significant room or some room for improvement within almost all challenges.

For the three segmentation's of the companies, namely, *Type of Manufacturer, Degree of customization/standardization,* and *Company size*, it is only within the degree of customization/standardization a possible trend can be isolated. The trend to be seen is the more customised a companies products are, the more challenges they have. The differences in averages, maximal, and minimal values for the segments of type of manufacturer and company size show no clear correlation. From the interviews it was indicated that SMEs, companies below 250 are more likely to face greater challenges, hence they would be more likely to adopt a Cloud PLM system yet the challenges in the survey do not enforce this.

There does not seem to be a clear ratio depending on the degree of customisation, yet companies with highly standardised products have a significantly higher average score than the other segments. The more and highly customised companies have significantly more challenges rated below 4.0. The rating for the administrative challenges for companies with highly standardised products is further an interesting point, observing that they all have an average above 5.0 which only a few other challenges in any segment have. This would indicate that these challenges is something that these companies are well aware of and often work with. One can also consider that the standardized companies manufacture products having less extensive variety and customizability, there is less information to handle and therefore less challenges associated with this information. The results from the interviews showed that company's with more complex products likely will have more to gain (more problems to solve) from implementing a Cloud PLM system. Making the assumption that a more customised product, in general, makes a more complex product and it can be ascertained that companies with a more customised product will have the measured challenges to a larger extent than companies with a standardised product.

The survey data indicates that none of the segments have critical or significant challenges from the presented challenges, even though the interviews portray the challenges to be more significant. There is however significant room for improvement amongst several challenges which could drive thr adoption of a Cloud PLM system. From the survey data it can be interpreted that the more customised or complex a company's products are, the larger impact the studied challenges have on the company. Therefore, the more customised a company's products are, the more likely they are to adopt a Cloud PLM system.

Benefits

The more willing a company is to receive benefits from Cloud PLM systems, the more likely they are to adopt a Cloud PLM system. When looking at the results from the survey a higher score indicates a larger willingness to pay for that specific benefit. The benefits in the survey where split between PLM benefits in general (B1-B6) and preference for a Cloud PLM system (B7-B11).

Looking firstly at the willingness to pay for PLM benefits in general, no clear trend can be discovered per segmentation. There are however two specific segments that stand out receiving an average rating slightly below 5.0, that being companies with a highly standardised product and companies with a size above 250 employees. Considering that companies with mostly standardised products and companies with 100-250 employees received the lowest rating for each of their segment, it cannot be stated that the more standardised the product is or the more employees the company has, the more willing the company is to pay for PLM benefits.

That the companies with highly standardised products are more willing to pay for PLM benefits is interesting since they face the lowest magnitude of challenges. However, if these companies are more willing to spend resources to gain the benefits it is unsurprising that they face less challenges correlated to these benefits. The reason for which companies between 250-400 employees are more willing to spend resources on PLM benefits could be attributed to a result from the interviews which mentions that the larger a company becomes, the more issues it faces with effective collaboration, for which these larger companies rated highly willing to pay for.

The overall averages from the survey indicate that there is an interest for the benefits provided by a PLM solution. The unique aspect of a PLM system where the companies gain an overview of the entire product life cycle, B1, is however rated the lowest of the benefits for the overall average and with all the segments except for companies between 250-400 employees where it is rated second to last. Comparing B1 to B3 and B4 which concern collaboration and which are the most important benefits, a question can be raised if PLM systems are that interesting for these companies. As the increase in collaboration can come from other systems or methods that do not have to be linked to a PLM system. However, looking at B2 and B5 which directly impact the efficiency of product related work tasks, these are rated similarly to B3 and B4. This would entail that companies are interested in improv-

ing the efficiency and collaboration of their product related work for which a PLM system is designed. This would mean that B1 being simply gaining an overview of the products' life cycles is either by itself not interesting to the companies or that they may not understand the implications of gaining this overview. Since gaining this overview is gaining control over its processes and thereby being able to increase the collaboration and efficiency of the product related processes.

Looking next at the benefits for Cloud PLM, (B7-B11) a possible trend can be seen in the type of manufacturer but no overarching trend for the other two segmentations. For the type of manufacturer, the survey data indicates that there is an increasing average for the part that contract manufacturing constitutes of a company's production, the more beneficial a Cloud PLM system specifically is. The difference between each segment is however relatively small so there is a risk that this trend does not continue when looking at larger sample sizes.

The two benefits above a neutral 3.5 are B7 and B8 which is in agreeance with the results from the interviews which are the most important benefits the companies can gain from implementing a Cloud version of PLM. B8 rated the highest at 5.03 on average, this shows that companies strongly prefer the ability to access their systems remotely which definitely is in line with the overall global trends. B7 rated 4.42 shows a clear preference from the surveyed companies towards a standardised system which costs less over a customised system that costs more. For this benefit, companies with highly standardised products stand out, rating B7 significantly higher than other segments at 5.22. There is a clear trend to be found within the segmentation degree of customisation/standardisation where the more standardised a company's product is, the more willing they are to have a standardised system. It reasonable that the less standardised a company's products gets, the less applicable standardised systems will get.

The three remaining benefits for Cloud PLM all rate around or below 3.5 which would indicate that there are certain aspects of Cloud PLM that the studied companies are restrictive towards. This can further be seen by the overall average ratings being lower than for PLM in general. However, these two sections of benefits cannot be directly compared which becomes clear when looking closer at B9, B10, and B11. B9, for which results for the overall table was inverted, measured the possibility of a company to maintain an IT-department by themselves, yet did not measure their preference, and therefore a rating of 3.19 on the lower end of the scale does not indicate that companies are adverse to Cloud systems. B10 did on the other hand measure the preference of the company regarding the ownership of the systems they used. For the overall average it was neutral rated 3.58 with greatly varying for type of manufacturer and degree of standardisation/customisation as well as a clear trend for company size. For contract manufacturers B10 was the most prominent Cloud benefit receiving the highest rating for B10 throughout all segments of 4.86. For degree of customisation/standardisation it is only the companies with highly standardised products which rate B10 above 4.0 with a rating of 4.63, indicating a strong preference for suppliers to handle their systems. Finally, it can be seen in

company size that the larger a company becomes, the less willing they are to have their IT-systems managed by suppliers. The final benefit B11 concerning the ability for customers to overview ongoing projects online received low rating across the board except for companies with mostly customised products. This is interesting to compare with B4 which was the highest rated benefit for PLM benefits in general concerning the increase of collaboration with suppliers and customers. Since an increase of collaboration is a broad benefit it is impossible to draw any direct conclusions when comparing B11 with B4, yet it is interesting to note the discrepancy.

Overall the benefits of a PLM system seems attractive to most companies with most companies preferring the B7 and B8 benefits of online access and lower cost standardised systems for Cloud PLM, yet depending on the segment being less inclined to have external suppliers own their systems. The most likely company segment to adopt a Cloud PLM system based upon the willingness to pay for its benefits is companies with highly standardised products. This is since they both have a high rating for PLM benefits in general and strongly preferred a standardised system at a lower cost that was handled by a supplier.

Sustainability

The topic of sustainability has not been the core focus of our research. As discussed in the theory section of this report, it is undoubtedly clear that by implementing PLM systems, there is an increase in sustainability also. There are direct and indirect consequences for implementing PLM which results in increasing sustainability. Smaller manufacturing industries are still in the early stages of adoption and are still figuring out the implications of standardization and using PLM systems. PLM systems increase collaboration among the various departments in an organisation, reduce wastage of resources, unwanted use of energy, time, raw materials, optimize technological improvements and thus increasing sustainability. Since this is not the core focus of the current research, topics of sustainability are excluded from the survey as it was determined to be out of the scope of this research. It would however be interesting to explore the sustainability implications of implementing PLM systems in smaller manufacturing companies.

Risks

The less worried a company is about the risks associated with Cloud PLM, the more likely they are to adopt it. When looking at the results from the survey a lower score indicates a larger perception of the associated risk.

The results from the survey showed R4 to be the largest risk for implementing Cloud PLM, rated 2.73 which is significantly lower than all other risks, which concerns the physical location of the server. The interviews revealed that the security concern of implementing Cloud PLM and the physical location of the server were two of the biggest risks for manufacturing industries agreeing with the R4 survey results. When looking at R1 which is concerned with handling the security of Cloud

systems, which is the second largest risk in the survey rated 4.24, there is a slight positive belief in the security of Cloud systems. The two segments placing the largest trust in the Cloud system providers are companies with highly standardised products and companies with a head count of 250-400, which also have the highest average ratings amongst the segments. A trend can also be isolated within the segmentation degree of customisation/standardisation where the more customised a company's products are, the less trust there is to Cloud systems. It can further be noted that the companies with highly customised products clearly have the lowest overall rating for risks indicating that they are the most concerned segment. R2 is the least impactfull risk rated 5.14 showing that most companies have a stable internet connection, yet again companies with highly standardised products stand out clearly having the best internet rating with a rating of 5.78.

Based upon the results from the survey, the server location and security of a Cloud solution are the two main risks for Cloud PLM which is in agreeance with the results from the interviews. The company segments that have rated the risks the highest, thereby being least affected by them and most likely to adopt a Cloud PLM system are companies with highly standardised products and companies with 250-400 employees.

Adoption Factors

The adoption factors for a Cloud PLM system can vary greatly as seen in the interviews. These adoption factors where split into 4 main categories for the survey being: *PLM Knowledge, New system viability, Satisfaction with current processes/systems,* and *Belief in IT-systems*. The discussion for adoption factors will follow the structure of these 4 main categories. For adoption factors, the higher the score is, the more positive the company is to adopting a new PLM system.

The more knowledge a company has within PLM systems, the more likely they are to understand what a PLM system can offer and may therefore be more likely to adopt a PLM system. The interviews revealed that the relationship between PLM systems and smaller manufacturing companies is quite weak and this was in accordance with the results of the survey which revealed that smaller manufacturing companies in general have a very low knowledge of PLM systems and SaaS Cloud PLM systems. The first three statements, AF1, AF2 and AF3 concern the knowledge of PLM systems. From AF1 and AF2, it can clearly be seen that the experience of PLM systems is low with the experience of Cloud SaaS PLM systems being even lower. The two segments that distinguish themselves with their more experienced survey takers are companies with highly standardised products and companies with 250-400 employees. On the opposite end it is companies with highly customised products and contract manufacturers that have the least experience with these PLM systems. AF3 considers the adoption of PLM systems and is closely related to the degree of experience which the companies have had with PLM systems. Interestingly around 15% of surveyed companies already have a PLM system showing that PLM systems

are not completely foreign to smaller manufacturing companies. However, the general lack of experience from PLM systems within smaller manufacturing companies is accentuated in both the results from the interviews and the survey.

The survey statements AF4 and AF5 concern new system viability and it can be observed that the survey takers in general partially agree with the statements where the employees are positively inclined towards new IT systems and that there is a possibility to integrate new systems with current systems. Looking at the survey results, it can be observed that the magnitude of new system viability and the acceptance of new IT systems is comparatively higher in companies where there is a high degree of standardization and with employees greater than 250. One can also recognise that the companies with high degree of customization has a relatively low magnitude of acceptance rating 3.52 in contrast with companies with a high degree of standardization. All companies, except for companies with highly customised products, have a clear positive inclination towards the system viability. It is however a hindrance for adoption of Cloud PLM systems that most ratings are around 4.0, indicating that there still can be significant resistance towards change from employees and hurdles to implement a new system.

AF6 and AF7 handled the satisfaction with current IT systems and product related processes. All the segments indicate a slightly positive attitude towards their current systems and processes with ratings slightly above 4.0. Similar to the previously discussed challenges, a 4.0 rating still indicates some room for improvement within the satisfaction. From the interviews it was clear that all companies found some part of their systems or processes underwhelming. The segment that stands out for these adoption factors is companies with highly customized products receiving an average rating of 3.8.

The results from the survey reveal that the smaller manufacturing companies in general have a belief in IT systems. Statements AF8 and AF9 concern the belief in IT systems where the statements investigate the company's need to be more digitised and if IT systems support them to do the right things. The overall averages show a positive belief in IT systems yet not a strong belief, with the average ratings around 4.5. A segment that distinguishes itself slightly is companies with 250-400 employees having an average rating of 4.87.

In general companies are positive to the viability to a new system, towards their current systems and processes, and within their belief of IT systems. There is however little strong belief within these areas and most support is slight. The positive inclination towards the viability of a new system and their belief in IT systems supports their likelihood of adopting Cloud PLM. The lack of dissatisfaction of current systems and processes is however more a hindrance. The largest differential within the adoption factors is the experience that survey takers have had within PLM systems. Here the segments within highly standardized products and companies with 250-400 stand out having more experience than the rest. The results from the interviews also reveal that a restricting factor for evaluating systems for purchasing in

smaller manufacturing companies is the lack of knowledge within the system they are looking at. Since, the two aforementioned segments have more experience and therefore likely more knowledge within PLM, they are more likely to adopt a Cloud PLM system.

Summarizing discussion

In general all companies that face challenges within the three presented categories, are willing to pay for PLM and Cloud PLM benefits, are not terrified of the risks associated with Cloud systems, believe new systems can be integrated in their current processes, and have a positive belief in IT systems. This would seem to set a foundation when smaller manufacturing companies in general will adopt Cloud PLM systems in the future. However, there are two main restricting factors at play. The first being that companies are not dissatisfied with their current systems and product related processes and that they do not have a strong positive rating of Cloud PLM benefits. From the interviews it was presented that some companies would only choose to implement a new system if they are facing a threat of survival. Considering that the benefits are not ranked overwhelmingly positive and that companies in general are not miserable with their current processes and systems, it is difficult to argue that a mass adoption of Cloud PLM is near. The second restricting factor is the knowledge of PLM systems which was clearly lacking for most companies. There is a correlation between the degree of PLM knowledge and the willingness to pay for the benefits of a Cloud PLM system and the severity of associated risks. When a company segment has more knowledge regarding PLM systems, they are more likely to want to pay for the PLM benefits and less likely to find the risks severe. Considering the findings of the study that a Cloud PLM systems defiantly can aid companies in overcoming their challenges, it is likely that the spread of knowledge regarding Cloud PLM systems will increase the adoption willingness for smaller manufacturing companies.

The segments of smaller manufacturing companies that are the most likely to adopt a Cloud PLM system are companies with highly standardised products and companies with 250-400 employees. With companies having highly standardised products being the most likely to adopt a Cloud PLM system. This is due to the relatively high PLM knowledge this segments possesses. This leads to a high willingness to pay for the benefits of PLM in general and Cloud PLM despite facing the smallest magnitude of challenges in the measured segments. This segment further has a low rating of the risks associated with Cloud systems, have a belief that it is viable to integrate new systems in their company, and have a positive belief in IT systems. The reason the segment of companies with 250-400 employees are slightly less likely to adopt Cloud PLM systems is that they have all aforementioned attributes yet have rated the benefits for Cloud PLM lower. It is reasonable that these two segments are the most likely to adopt a Cloud PLM system based upon the two main benefits of PLM being standardizing processes and increasing collaboration. It is easier for a company with highly standardized products to standardize their processes reducing the barrier to gain the benefits of standardization. When a com-

pany is smaller, it is simpler to have direct communication with responsible parties, yet when a company grows this communication becomes more distant and therefore larger companies have more to gain from systems that increase collaboration. The results are based upon the current situation for smaller manufacturing companies and would likely look differently if all companies had a similar level of knowledge regarding PLM systems.

5.4 Recommendation

The current study answers the research questions which were in the scope of the research. But the extent of its validity has not been analyzed due to the limited time frame of the study. On continuation of the current study, future work would need to entail in depth case studies in the segmented companies to further verify and validate the work. The current study establishes that knowledge of PLM places a major role in adopting PLM in manufacturing companies. Future work should encompass further development and clear understanding of this relationship and understand the weightage that this relationship actually carries. It would also be interesting to further understand and develop these key features which would influence the adoption characteristics of Cloud PLM systems and develop a scale to weigh these features.

The current survey which involves the quantification of data would need to be further developed to increase the complexity and depth in which each question is portrayed. It would be ideal to explain each question in depth for the survey takers to provide more accurate answers and for each question to have a further scalable measure to increase the accuracy of each response where the survey taker understands the consequence of each question to a greater detail.

6
Conclusion

The challenges that smaller manufacturing companies face can be divided into three categories and are ranked in the following order starting with the most relevant: External challenges, Innovative challenges, and Administrative challenges. The three most important challenges concern the lack of time needed to innovate and the lack of collaboration with suppliers and customers. The challenges measured in the survey indicated that companies rate the challenges they face less severely than the interviewed experts who saw several challenges as more critical for the smaller manufacturing companies. This may be explained by the knowledge gap between experts and survey takers along with a positive bias from the survey taker being used to their current state.

Cloud PLM systems has the opportunity to aid smaller manufacturing companies in overcoming most of their challenges. The improvement potential of Cloud PLM systems is therefore within the administrative, external, and innovative challenges of smaller manufacturing companies. Cloud PLM systems are further a far more suitable option for smaller manufacturing companies both due to the lower price tag and due to the standardized system which allows companies to be more agile compared to locking themselves into customized solutions. The actual degree of aid a Cloud PLM system can provide will however depend on the companies degree of adoption where the benefits to be gained from Cloud PLM systems are directly correlated to the percentage of successful adopters in a company.

The company segments that are most likely to adopt a Cloud PLM system are companies with highly standardized products and companies with 250-400 employees. This is due to their high willingness to pay for PLM benefits and their, relatively, high knowledge within PLM systems. In general most smaller manufacturing companies show a positive inclination towards Cloud PLM systems yet there are two hindrances for wide spread adoption. The first being that companies are not overwhelmingly dissatisfied with their current processes and systems neither are they overwhelmingly worried regarding the challenges they face. The second being the lack of knowledge within PLM systems. Since there is a clear correlation between increased knowledge and an increased willingness to pay for benefits and a decreased worry regarding the risks, PLM knowledge will be critical for Cloud PLM adoption.

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A

Appendix 1

A.1 Expert Interview Template

A.1.1 Introduction

Hello, we are Max Lundstrom and Rahul Gowda. We are from Chalmers University of Technology and we are currently working on our Master Thesis in the area of Product Lifecycle Management. We will be researching the product-related challenges faced by SMEs and the challenges faced in implementing PLM in SMEs. Until recently PLM was mainly focused in large scale industries and there is a lot of research done in that particular field. This is mainly due to two reasons: firstly PLM has been difficult for SMEs to implement correctly and secondly since the manufacturing SME market is quite fragmented rendering it difficult to draw general conclusions. We are trying to segment the manufacturing SME market to be able to draw general conclusions within these segments regarding the product-related challenges SMEs face. We will further investigate the impact Cloud-PLM in a SaaS format could have on these segments.

With that context in mind, we would like to explain the purpose of the interview and how it would be conducted. The main purpose of the interview is to gain a deeper understanding of PLM in the context of SMEs and the challenges SMEs face. The interview will be in a semi-structured format, meaning that we have an amount of set questions we will ask and can ask follow-up questions depending on your answer. We will focus on your experiences with PLM and dig deeper into the context of SMEs.

Your participation in the interview will be completely voluntary and you can choose to refrain from answering any question. We would like to record the interview with your permission and if you are not comfortable with recording it, we would like to take notes during the interview.

Do you have any questions before we begin with the interview?

Introductory Questions

- Tell us a bit about yourself and what you are researching?
- What previous experience do you have with IT systems within SMEs?
- What previous experiences do you have within PLM?

A.1.2 Challenges for manufacturing SMEs

- What product-related challenges are SMEs facing? This can be related to manufacturing, organization, aftermarket, communication, etc.
  - SMEs face challenges related to mainly technology, finance or knowledge limitation, would you agree with it or do you have any other particular challenges in mind?
- How do SMEs work with countering these challenges?
- How would you categorise or segment SMEs?
- What do you believe to be appropriate countermeasures to these challenges?

A.1.3 SMEs PLM

- What are SMEs' relationship to PLM systems?
  - Are they positively inclined or negatively?
- Are PLM systems often used in SMEs?
  - Why?
- What are the challenges of implementing PLM systems for SMEs?
- Does PLM systems aid in the aforementioned challenges?
  - Which and in what way?
- Are current PLM systems suited for SMEs?
  - How can they be better suited?

A.1.4 Cloud PLM

- How would you define cloud PLM?
- What was the need to develop cloud PLM?
- Do you believe that Cloud PLM is more favoured in SMEs?
- What are the advantages of using SaaS in SMEs?
- What are the disadvantages of using SaaS in SMEs?
- Do you feel that the advantages outweigh the disadvantages?
- Do you believe that the cloud PLM will prove to be a solution to the challenges faced in implementing PLM in SMEs?

A.2 Company Interview Template

A.2.1 Introduction

Hello, we are Max Lundstrom and Rahul Gowda. We are from Chalmers University of Technology and we are currently working on our Master Thesis in the area of Product Lifecycle Management. We will be researching the challenges faced by smaller companies and the introduction of PLM in the context of smaller industries. Until recently PLM was mainly focused in large scale industries and there is a lot of research done in that particular field. Due to the increase in competitiveness in manufacturing industries, SMEs are also in the process of implementing PLM systems to stay ahead of its competition.

With that context in mind, we would like to explain the purpose of the interview and how it would be conducted. The main purpose of our research is to gain a deeper understanding of the advantage of PLM in the context of smaller companies and the challenges these companies face. The interview will be in a semi-structured format, meaning that we have an amount of set questions we will ask and can ask follow-up with questions depending on your answer. We will focus on your experiences with your company, challenges faced by your company and the adoption characteristics for a IT system in your company.

Your participation in the interview will be completely voluntary and you can choose to refrain from answering any question. We would like to record the interview with your permission and if you are not comfortable with recording it, we would like to take notes during the interview.

Do you have any questions before we begin with the interview?

The first set of questions will concern general information about you and your company, the second set will concern your challenges, and the final will focus on the adoption process of new IT systems and work methods. For the first set in general we would prefer it if you gave more concise answers and in the last two sets providing more detailed answers.

A.2.2 General Questions

- Could you please tell us about yourself and your role in the company?
- Could you please explain a bit about your company and what you work with?
  - What is the size of the company?
  - What kind of products and how many variants do you work with?
    - Are you a contract manufacturer, do you develop your own products, or do you do both (to what extent)?
      - If you are a contract manufacturer, how do you manage your products and their variants?
      - If you are manufacturing your own products, how do you work with product development and variant management?
      - Do you use any system at all to manage your products in house?
    - Do you manufacture all the components inhouse?
    - Do you work with a lot of suppliers or do your products ship directly to customers?
    - How do you currently manage your network of suppliers?
      - Is there any particular management system you use?
    - How would you rate the complexity of you products from 1 to 5. Where 1 is simple products as screws and 5 is highly advanced products such as airplane engines?
- Could you please walk us through your process in manufacturing and would you describe it to be more or less complex?

  - Is there any system to manage the various processes in manufacturing? or is there a need?
  - How would a change in product design or manufacturing process be performed?

A.2.3 Challenges

Now that we have understood your processes within the company, we would like to dig a bit deeper into the challenges you face in these processes.

External Challenges

- What challenges do you face when working with external parties such as suppliers or customers?
  - Do you have a system to work with these challenges?
- How is the competitive landscape for your?
  - Who is the competition (local, global, etc)?
  - What do you compete on (price, quality, etc)?
- What are your challenges in general when working with external parties, is there anything else that you have not mentioned previously?

Internal Challenges

- What challenges do you face in internal product development and manufacturing?
  - What challenges do you face in designing a product and communicating the design within the company?
    - Is there any system within your company for this?
  - What challenges do you face in information handling and maintaining documentation?
    - Is there any system within your company for this?
- How do you work with knowledge management or making sure that knowledge is shared within your company? Are there any particular challenges within this?
  - Is there any system within your company for this?
- Do you face challenges or quality problems due to miscommunication or due to different people having different sources of information?
  - How do you handle this? Is there a system for this?

A.2.4 Adoption willingness

After understanding your challenges, we would like to discuss about the attitude or adoption willingness of your company for new software systems

- What do you feel are the main factors which can influence the adoption of a new IT system in your company?
- Can you give an example of the last time you implemented a new system and how was that experience?

We see that PLM touches upon 4 axis or factors which are important for the adoption of PLM in an organization. These factors are Human, Organizational, Technological, and Economic. We will ask some questions regarding each factor to gain your viewpoints on each area. Feel free to base your answers on examples you have experienced.

Human Factor

- How would the employees perceive a new IT system?
  - How did you employees react to the last IT system implementation, why? How do you think they would react in the future?
  - Who's opinion is most likely to be decisive if an IT system is to be implemented?
  - Can you give an example of your employees reaction when a new system was installed?

Organisational Factor

- Do you think that your company's size or age or the organisational structure has anything to do with the attitude of your employees towards a new IT system?
- Would there be resistance if the new system altered existing processes?

Technological Factor

- How digitized is your company compared to other companies in your industry?
- Do you have customized or standardized systems?

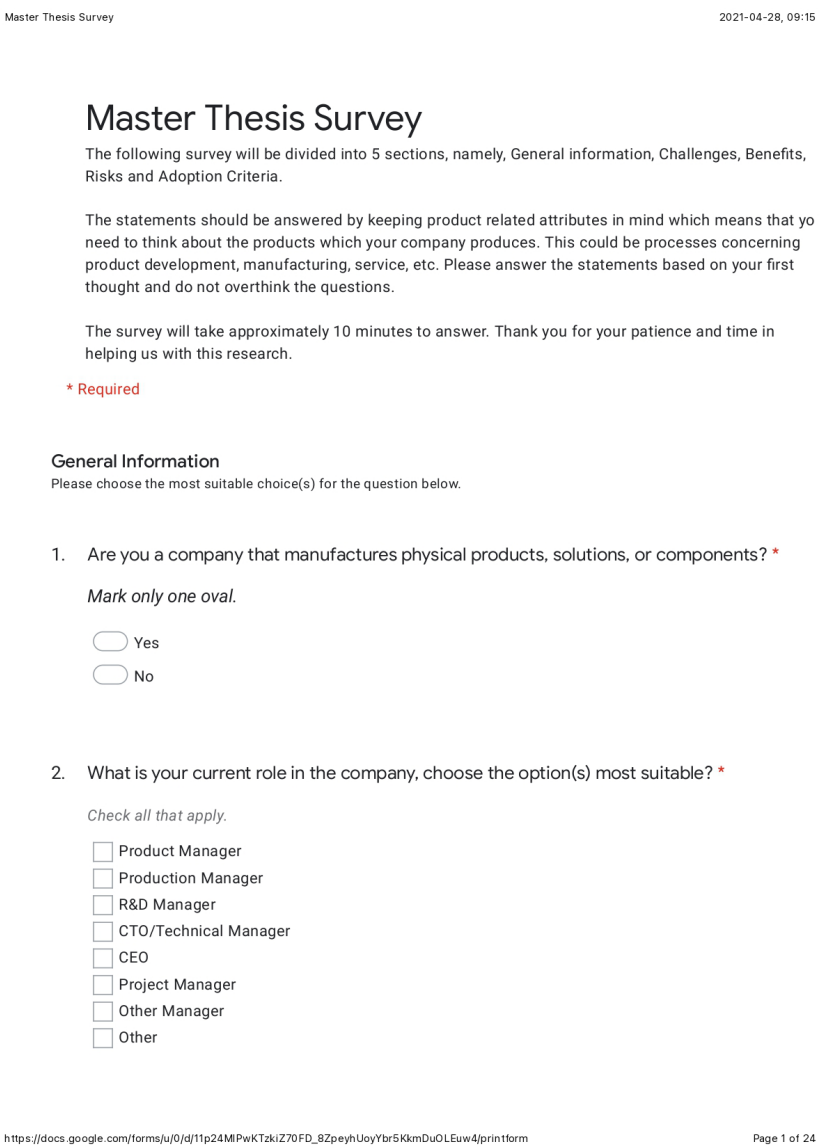
Economic Factor

- How do you calculate the profitability of investing in new systems?
- What is required for new systems to be prioritized in spending?

B

Appendix 2

B.1 Company survey



Master Thesis Survey 2021-04-28, 09:15

Master Thesis Survey

The following survey will be divided into 5 sections, namely, General information, Challenges, Benefits, Risks and Adoption Criteria.

The statements should be answered by keeping product related attributes in mind which means that yo need to think about the products which your company produces. This could be processes concerning product development, manufacturing, service, etc. Please answer the statements based on your first thought and do not overthink the questions.

The survey will take approximately 10 minutes to answer. Thank you for your patience and time in helping us with this research.

* Required

General Information

Please choose the most suitable choice(s) for the question below.

1. Are you a company that manufactures physical products, solutions, or components? *

Mark only one oval.

- Yes
- No

2. What is your current role in the company, choose the option(s) most suitable? *

Check all that apply.

- Product Manager
- Production Manager
- R&D Manager
- CTO/Technical Manager
- CEO
- Project Manager
- Other Manager
- Other

https://docs.google.com/forms/u/0/d/11p24MlPwKTzkiZ70FD_8ZpeyhUoyYbr5KkmDuOLEuw4/printform Page 1 of 24

Figure B.1: Page 1 - Survey

3. How many employees does your company have? *

Mark only one oval.

- Less than 30
- 30-60
- 60-100
- 100-250
- 250-400

4. How many employees are working within research and development or product innovation your company? *

Mark only one oval.

- 0-5
- 5-10
- 10-20
- 20-40
- 40-60
- more than 60

5. What is the name of your company (this will not be used in the study but is used to handle possible duplicate answers)? *

Figure B.2: Page 2 - Survey

6. What IT systems related to products do you use in your company? *

Check all that apply.

- [ ] CAD (Computer Aided Design) - Tool to design products on a computer
- [ ] ERP (Enterprise Resource Planning) - Tool to manage the flow of resources in the factory.
- [ ] MRP (Material Resource Planning) - Tool to manage production and manufacturing processes.
- [ ] MPS (Master Production Schedule) - Tool to schedule when and what products should be manufactured
- [ ] PDM (Product Data Management) - Tool used to manage product data
- [ ] PLM (Product Lifecycle Management) - Tool to manage the entire lifecycle of a product
- [ ] Other
- [ ] No systems

7. What best describes your company's products/solutions variation? *

Mark only one oval.

- ◯ High degree of standardization
- ◯ Mainly standardized
- ◯ Mix of standardized and customized
- ◯ Mostly customized
- ◯ Completely customized

8. Do you own the IP of your products/solutions or are you a contract manufacturer? *

Mark only one oval.

- ◯ We produce and own our products
- ◯ We have a mix of both
- ◯ We are solely a contract manufacturer

Figure B.3: Page 3 - Survey

9. Select the industry(ies) that is most suited to your company: *

Check all that apply.

- [ ] Agricultural or forest machine manufacturing
- [ ] Automotive engine manufacturing
- [ ] Communication equipment manufacturing
- [ ] Electronics manufacturing
- [ ] Furniture manufacturing
- [ ] Home electronics manufacturing
- [ ] Machine manufacturing
- [ ] Machine tool manufacturing
- [ ] Marine manufacturing
- [ ] Metal manufacturing
- [ ] Motor and turbine manufacturing
- [ ] Plastics manufacturing
- [ ] Tool manufacturing
- [ ] Train and tram manufacturing
- [ ] Other manufacturing

Challenges

Rate the following statements based upon how well you agree with them on a scale 1-6.
1 - Completely Disagree, 2 - Strongly Disagree, 3- Partly Disagree, 4 - Partly Agree, 5 - Strongly Agree, 6 - Completely Agree

10. I can find documents/drawings that are needed by using the current systems in the company. *

Mark only one oval.

- ◯ 1 - Completely Disagree
- ◯ 2 - Strongly Disagree
- ◯ 3 - Partly Disagree
- ◯ 4 - Partly Agree
- ◯ 5 - Strongly Agree
- ◯ 6 - Completely Agree
- ◯ Do not know/Not applicable

Figure B.4: Page 4 - Survey

11. I can securely store product and process related information using the current systems in the company. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

12. I can find the correct version of documents/drawings when I need them. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.5: Page 5 - Survey

13. I think my company can efficiently create new products in our current systems. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

14. I think my company can efficiently manage products in our current systems. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.6: Page 6 - Survey

15. Suppliers are notified immediately when relevant documents are updated. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

16. Customers are notified immediately when relevant documents are updated. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.7: Page 7 - Survey

17. We have processes and documents to retain knowledge for when employees leave the company. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

18. I think my company avoids repeating product related mistakes. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.8: Page 8 - Survey

19. I think my company has the financial resources needed to innovate. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

20. I think my company has the knowledge needed to innovate. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.9: Page 9 - Survey

21. I think my colleagues and I have the time available to innovate. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

22. I think we work efficiently on product related tasks. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Benefits

Rate the following statements based upon how well you agree with them on a scale 1-6.
1 - Completely Disagree, 2 - Strongly Disagree, 3- Partly Disagree, 4 - Partly Agree, 5 - Strongly Agree, 6 Completely Agree

Figure B.10: Page 10 - Survey

23. I think my company is willing to spend resources to overview our product's life cycle withi one system. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

24. I think my company is willing to spend resources to increase efficiency of product related work processes. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.11: Page 11 - Survey

25. I think my company is willing to spend resources to increase efficiency of collaboration between departments/branches. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

26. I think my company is willing to spend resources to increase efficiency of collaboration w suppliers and customers. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.12: Page 12 - Survey

27. I think my company is willing to spend resources to increase standardization of product related work processes. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

28. I think my company is willing to spend the resources to increase the capturing of knowledge. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.13: Page 13 - Survey

29. I think my company would prefer a standardized system for a lower cost compared to a customized system for a higher cost. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

30. I think my company would want the ability to access systems remotely. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.14: Page 14 - Survey

31. I think my company has the resources to maintain IT-systems by ourselves. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

32. I think my company would prefer a software supplier to manage our systems rather than having our own IT department. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.15: Page 15 - Survey

33. I think my company's customers want the ability to follow a project's process online. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Risks

Rate the following statements based upon how well you agree with them on a scale 1-6.
1 - Completely Disagree, 2 - Strongly Disagree, 3- Partly Disagree, 4 - Partly Agree, 5 - Strongly Agree, 6 - Completely Agree

34. I think Cloud systems are secure enough for my company's information. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.16: Page 16 - Survey

35. I think my company has a stable internet connection to use IT systems. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

36. I trust Cloud system providers to keep adequate up-times. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.17: Page 17 - Survey

37. I think the physical location of the cloud server is important. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Adoption Factors

Rate the following statements based upon how well you agree with them on a scale 1-6.
1 - Completely Disagree, 2 - Strongly Disagree, 3- Partly Disagree, 4 - Partly Agree, 5 - Strongly Agree, 6 - Completely Agree

38. I have experience of PLM systems (Product Lifecycle Management systems). *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.18: Page 18 - Survey

39. I have experience of SaaS Cloud PLM systems (Software as a Service Cloud Product Lifecycle Management systems). *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

40. I think that my company is considering implementing a PLM system (Product Lifecycle Management system). *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.19: Page 19 - Survey

41. I think the employees in my company are positive towards new IT-systems and work methods. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

42. I think it is possible to integrate new systems with our current systems. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.20: Page 20 - Survey

43. I am satisfied with our current IT-systems. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

44. I am satisfied with our product related processes. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Figure B.21: Page 21 - Survey

45. I think my company needs to become more digitized. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

46. I think that IT-systems support me to do the right things. *

Mark only one oval.

- 1 - Completely Disagree
- 2 - Strongly Disagree
- 3 - Partly Disagree
- 4 - Partly Agree
- 5 - Strongly Agree
- 6 - Completely Agree
- Do not know/Not applicable

Thank you

Your input is very valuable to our research, we thank you again for your patience

47. Please add your email below if you would like us to send a copy of your response.

Figure B.22: Page 22 - Survey

C

Appendix 3

C.1 Experts Interview Results

C.1.1 Interview 1 - Expert on PLM software

C.1.1.1 Increasing understanding of product related issues for smaller manufacturing companies

- There is a great deal of copying and pasting information and mismatching information between the company and partners.
- Tightly linked to the drivers for adoption in other key insights.

C.1.1.2 Increasing understanding of the relationship between smaller manufacturing companies and PLM systems

- CEO and CFO of companies have a hard time understanding their value and that they find most of the value in ERP systems.
- Most SMEs rather have PDM systems or other types of data storage than having real PLM systems.
- People at the company are the “PLM system” in the way that information is inside their heads.
- "PowerPoint sales" does not work at SMEs CEO and CFO need to be convinced of the true impact of their problems and the value of PLM systems needs to be thoroughly explained.

C.1.1.3 Increasing understanding of need and function of SaaS Cloud PLM

- Cloud PLM connects users and systems without fixed connections.
- IT tracks named users to see who has done what, when, and all access can be performed remotely with login.
- SaaS was created since it is easier for both sides to manage, avoiding the messy integration and updating of on-premise.
- It offers peace of mind but is less customizable.

C.1.1.4 Other key insights

- The the mid 90s early 20s what the customer wanted was fully customizable software solutions. This is not the case anymore looking at more out of the

box solutions since they are simpler. Simpler since there is a single point for update and no nestled systems.

- Drivers for SMEs to adopt PLM:
  - **Single source of information** - Many times happens in an SME company is that when that product is finished and it comes to the assembly line it doesn't really fit because what you did was you were communicating 2D drawings and PDFs via email. A PLM system allows for a single source of information assuring everyone works with the same version and has the same information. This makes both storage and retrieval of documents far easier.
  - **Traceability** - Today coming from the lifescience business it is all about traceability as well there are a lot of regulatory demands from outside pressure from outside a lot of regulatory demands from C-market teams you need to be ready for an audit. Who took that decision when and on what version of information so that's also this getting closer to the SME business. It has been the reality for medical device manufacturing companies for some while but it is getting closer and closer to the traditional manufacturing business.
  - **Cloud push** - Then we have the classic know there is a Cloud drive as well. SME companies are really trying to understand the easiness and the robustness of not having their own IT infrastructure so having someone be able to take care of all the IT infrastructure in terms of service and all the resources needed around those services and infrastructure just leaves it to the people who really know this.
  - **Sales visualization** - From a sales point of view it is easy to not only show the value of a machine but also show the value because you can show a simulation of the machine and you fly as you know if a customer says well your machine you say it can deliver 13000 something per minute and it looks very good on paper but how does it really work how do you accomplish it so if you can just be able to show a video or fly through in a VR environment showing how things are filled and visualizing that in a way you will be able to increase you hit ratio so suddenly the sales department at a SME company is interested in the solution because they will be able to visualize the value.
  - **Protecting IP** - If someone leaves or goes into pension you get quite much harder hit so its all about protecting the IP as well if someone leaves your company and that person was the only one who can handle manufacturing BOM that competence is just out of the door but if you had that IP in a Cloud PLM platform it does not matter if a new person comes in because the information is the system it is consistent in the system so that's another, protect your IP so it does not stay around in peoples head but rather in your system.

C.1.2 Interview 2 - Professor with experience of PLM software

C.1.2.1 Increasing understanding of product related issues for smaller manufacturing companies

- Smaller companies, in the professor's experience, are fairly one dimensional and need help with CAD files and some sort of a CAD vault for their storage issues.
- As the complexity of a product increases, then many issues across the product life cycle arise and also the need for PLM arises.
- Smaller companies have practical challenges, for example, with the need of engineering change and compliance related issues where they might need to change the product. PLM can be the solution to these challenges.

C.1.2.2 Increasing understanding of the relationship between smaller manufacturing companies and PLM systems

- PLM is mainly for mechanical related industries. Most SMEs use the PLM system as a CAD vault.
- Most SMEs do not have a requirement of a PLM system or engineering change processes as the cost of preparation to implement a PLM system does not usually pay off.
- If you can have a pre prepared package where everything is automatic, and you can just start working without any installation and hassle and the license fee is fairly low, then of course, that preparation cost is getting lower, and then it pays off to do more. So then maybe you could use the CAD vault, but you could also maybe introduce a couple of lifecycle processes, like for example, a compliance process and a release process. And, and something like this engineering change process will probably pay off.

C.1.2.3 Increasing understanding of need and function of SaaS Cloud PLM

- Cloud PLM has various versions. But the one to focus on for SMEs is SaaS, Software as a Service, "just pay a monthly fee and you log in using your email address or and provide your credit card". Not to overburden the user with too many functionalities.
- PLM system previously was very difficult and complicated to set up and only big companies could afford it.
- Cloud PLM systems are most suitable for SMEs unless there are really high security issues like in the case of the defense sector then you need a private cloud and not SaaS.
- Advantage of cloud: Time, cost and flexibility.
- Disadvantages: Security(which is really high for normal companies, more than on premise, but for defense, one would need higher than the average)

- Advantages outweigh disadvantages of cloud absolutely, especially since there is no need of administration for PLM inhouse.
- At the moment PLM systems are not widely being used in SMEs. It's a combination of that it takes too much time to set up and configure to have it work. And then if they are also quite agile, the way they worked yesterday may be different from the way that you only work tomorrow. So it doesn't pay off to build rigid systems.

C.1.2.4 Other key insights

- Difficult to find companies that are small and still work with PLM
- For segmenting SMEs: number of employees (especially engineering), greater employees, greater is the complexity. Product complexity (multi technology used to produce product) and increase in CAD files Sourcing technology (multiple suppliers) Market segment where there is a need for multi configuration and different certificates associated with different products.

C.1.3 Interview 3 - Professor with experience of PLM software

C.1.3.1 Increasing understanding of product related issues for smaller manufacturing companies

- Difficult to generalise the challenges because some companies have a product that they would have refined through many generations while others might be a startup with a new product idea.
- The common challenge that all SMEs face is to renew their product and finance required to drive product innovation.
- Main challenge is on meeting the needs of financing this development.
- They work with these challenges in a good way due to lack of hierarchy and usually the management team takes all the decisions which makes it simpler.

C.1.3.2 Increasing understanding of the relationship between smaller manufacturing companies and PLM systems

- SMEs who manufacture their own product need their own product management and service management related to the product. SMEs who are contract manufacturers are linked to the customer's data management system, then everything is sort of set up by the customer.
- Smaller SMEs manage their process with excel sheets and simple ways which they can afford. But bigger SMEs have the possibility of working with PLM.
- Installing PLM systems can be cumbersome to invest and implement. It can slow down their operations which the SMEs cannot afford.
- SMEs want to be more structured to help their customers but they have not come to that level yet.
- PLM system is not a key concern for SMEs with less than 50 employees from the professor's experience.

- PLM systems is sort of a key to digitalization
- PLM system is required when there are a lot of customers.
- SMEs need a simplified solution for PLM

C.1.3.3 Increasing understanding of need and function of SaaS Cloud PLM

- Not much experience.
- Cloud PLM can have a lot of trust issues about who owns data and aspects regarding data management.

C.1.3.4 Other key insights

- SMEs work close to the market and customers. Their innovation is completely dependent on customer demand.
- All departments within SMEs are integrated, the innovation process is sometimes integrated to the operations process and there is no distinct R&D department.
- SMEs greater than 50 employees work just like large companies, where there is a formalized organization for communication. SMEs smaller than 50 have very good communication and discuss ideas in many informal ways also which works well for them.
- Segmenting SMEs: Own product vs contract manufacturers
- SMEs are a very heterogeneous group which is very hard to generalise.

C.1.4 Interview 4 - Professor with experience of Cloud software

C.1.4.1 Increasing understanding of product related issues for smaller manufacturing companies

- Not much experience.

C.1.4.2 Increasing understanding of the relationship between smaller manufacturing companies and PLM systems

- Not much experience.

C.1.4.3 Increasing understanding of need and function of SaaS Cloud PLM

- Cloud computing is a computing infrastructure where a cluster of computing resources are bounded together
- SaaS is a functionality where the software or the code itself is provided as a service
- Advantages of cloud:
  - **Flexible**: Cloud computing serves different needs at different levels for example for a private user or for a company level

  - **Cost effective**
  - **Robustness**: redundant resource computing and computing power in the background, just in case it's one database, one server down, but you always have a backup, you'll have something else working for you to make sure you're all your business
- Disadvantages of cloud:
  - **Security concern**: Where is the data, who has access to it?
  - **Concern about location of servers**: Different countries may have different legal regulations
  - **Cyber attacks**: People with good knowledge about software science can breach the data, it is difficult but not impossible
- Need or advantage of SaaS:
  - Can run on any device as the main computing power is on a cloud server elsewhere, hence the software will have same functionality and performance on all devices
- Disadvantage of SaaS:
  - Communication between servers and the cloud can be breached even if the server itself is secure
  - Need a very stable network to operate SaaS, good internet connection
- Biggest advantage of cloud is for SMEs
  - Lower cost
  - Lower initial investment
  - Flexible
  - Can be setup in a lot less time

C.1.4.4 Other key insights

- SMEs are more flexible and more adaptive for new systems as their team is smaller and they need lesser effort to make changes.

C.1.5 Interview 5 - Expert with experience of PLM software

C.1.5.1 Increasing understanding of product related issues for smaller manufacturing companies

- Difficult to have the correct information at the correct place.
- Smaller companies have an issue synchronizing different systems due to variation in customization and cost of integrating.
- I guess one of the biggest problems, if we are talking about the smaller companies, it's to do the product preparation. The products and products can be a mess.

C.1.5.2 Increasing understanding of the relationship between smaller manufacturing companies and PLM systems

- Smaller companies work file based.
- They don't have PLM systems because it is too difficult for them.

- There is a close relation to the OEMs, their requirements and how they want the file format which can force companies to implement PLM systems.

C.1.5.3 Increasing understanding of need and function of SaaS Cloud PLM

- Costs and simplicity are key aspects with SaaS Cloud PLM that smaller companies would look for.
- There are central updates that go live and companies do not need to have week long updates which otherwise may be required for traditional PLM systems.
- However it is the suppliers of software that choose when to update which can cause unnecessary downtime which can not be controlled by the smaller company.
- The expert had an experience when and update to a cloud system created a bug that caused the usage of the system to be non-functional for a week.
- The collaboration with OEMs could be crucial being able to provide the correct form of information by using the same system.
- You can have the customer go in to your cloud solution with a special login so they can view and review data in a continuous manner. So you can get feedback more or less in real time today that it's very iterative.

C.1.5.4 Other key insights

- There may be a resistance from SMEs to actually change the way they work which would hinder new system implementations.

C.1.6 Interview 6 - Expert with experience of smaller manufacturing companies

C.1.6.1 Increasing understanding of product related issues for smaller manufacturing companies

- Large companies can have a real impact on the smaller companies through pressure. Previously when administrative systems were digitalized for the large companies it became an ultimatum for the smaller companies to either follow suit or lose business. In general most contracts favour larger companies and smaller companies will struggle with this.
- SMEs have 3 limitations when developing new products. Time, information, and money. When provided money they invest in information and knowledge. This was shown during a project the expert was involved with where grants for innovation was given to smaller companies.
- It is quite difficult to introduce a new advanced way of working and often consultants are hired to do the job. This has to be contrasted with the cost of purchasing new equipment which is often done instead.

C.1.6.2 Increasing understanding of the relationship between smaller manufacturing companies and PLM systems

- Not much experience.

C.1.6.3 Increasing understanding of need and function of SaaS Cloud PLM

- Not much experience.

C.1.6.4 Other key insights

- Many companies produce both Lego and own products to have a viable product mix.
- Smaller companies often have several ideas of what to do, to innovate, but are not able to realize it.
- Smaller companies have in general a low purchasing competence making it difficult for them to know what to purchase.
- Smaller companies tend to dislike sales persons.

C.1.7 Interview 7 - Expert on PLM Software

C.1.7.1 Increasing understanding of product related issues for smaller manufacturing companies

- Smaller companies do not have the right resources, they also have issues to get the right talent on board with the right skill needed to develop the organisation.
- Smaller companies have problems investing in research and development to understand the new technology to utilize in their organisation. This is also faced by large organisations but affects smaller organisations more due to their lesser capacity.

C.1.7.2 Increasing understanding of the relationship between smaller manufacturing companies and PLM systems

- Smaller companies will start focusing on PLM systems when they see the benefit or see that they can have control over the information and data to be able to collaborate better.

C.1.7.3 Increasing understanding of need and function of SaaS Cloud PLM

- Cloud PLM is a turn-key solution which can directly used from the internet.
- Turn-key solutions are better suited for smaller companies perhaps as they are primarily in the beginning of the PLM journey, and have more flexibility and adopting their processes rather than the tools. So then it's important to provide the capabilities needed for startups or smaller companies, so they get the turnkey solution. So it's easy to start up.

- Turn-key solutions also help smaller companies focus on investing the right resources to develop products instead of spending resources on maintaining systems.
- The need of Cloud PLM is to get easy access and value quickly.
- Advantages of Cloud PLM: Easy access, turn key solutions, easy to switch, increase/decrease capacity and increases agility of the companies
- Disadvantages: Security is the biggest concern, integrating with ERP and other legacy system.
- For SMEs the way forward is 100 percent through the Cloud.

C.1.7.4 Other key insights

- The adoption of a new system is promoted by creating a business case and an urgency for the customer to make the change as they are often affected by both global and local trends.
- They have internal industry teams that are focusing to understand what is really affecting that particular industry, like the global trends. This input is then positioned in the value based message towards the customers and encouraging them to act and make changes in the organisation.
- Smaller companies produce lesser volumes when compared to large companies, hence they have problems with being cost efficient and staying profitable.
- The challenge of creating high value products, but competing at lower costs with larger companies can be overcome by creating demand early in the market and bringing the product faster to the market.
- It's very important that it's easy to use a PLM system that is easy to adopt and get the benefits straight on.

C.2 Companies Interview Results

C.2.1 Interview 1 - Company A

C.2.1.1 General information

- Long and complex sales cycles.
- Highly customized solutions.
- Owned by global coorporation.
- Mainly uses ERP and PDM systems.
- Below 200 employees

C.2.1.2 Company challenges

- Difficult to manufacture all customized solutions correctly on the first try. 10 different views of the solution in A0 paper is printed and there is often some small detail that is difficult to understand correctly. It would be better with a rotational 3D-model.

- Finding exactly what part may have broken down for customers in after sales is an difficulty where a large amount of work is required to dig into old projects and understand exactly which piece is affected.
- Project information can be spread through several different platforms making it difficult to overview.
- Old highly customized projects where the responsible employee has left the company often requires a great deal of reverse engineering to replicate.

C.2.1.3 Adoption factors

- Management support from the areas which will be affected regarding new processes is essential.
- The interviewee had experience of receiving full support from management yet when management is forced to chose between prioritising tests of new processes versus fullfilling customer orders the customer order always takes priority.
- People are generally skeptical of new systems if they do not understand the benefits they and the company will get.
- There is also resistance to change since everyone knows that the current processes works and new systems/processes introduce uncertainty.
- Two reasons to implement a new system. Either a suitable ROI is found or there is a demand from our owners or the government.

C.2.1.4 Other key insights

- Interviewee shared their own experience and said that it seems that larger companies may have an easier time implementing new systems despite there being more people to activate. This since the large size of the company requires communication between people and departments. At a smaller company things usually stay with one person and all tasks that need that knowledge run through them. Each person at a smaller company will also feel closer to the issue.

C.2.2 Interview 2 - Company B

C.2.2.1 General information

- Around 100 employees.
- Produce one main product with few variants along with some accessories.
- Work mainly towards OEMs.
- Changing the design of a product is simple (automated) when a decision to change has been made.
- Mainly uses ERP system.

C.2.2.2 Company challenges

- Receiving the correct material is sometimes difficult.

- Has challenges with handling documents for multiple article numbers, which the interviewee mentioned was reality in all manufacturing companies the interviewee had worked in.
- The interviewee's previous company had faced a challenge with there being too many systems handling seperate tasks causing confusion.
- The company has had some issues with losing knowledge when employees leave in certain departments.
- A future challenge for them is to handle an increasing product portfolio.

C.2.2.3 Adoption factors

- New IT system will be implemented only if it is critically necessary, like "performing a heart transplant", implementing new systems will be avoided if it can be.
- Choose systems which are standard. "I would say don't do any adaptations. Look for a system which fulfills your needs, and don't change it. Because if you do adaptations, you're up shits Creek already from the start all these adaptations, they cost you a lot of money". " So don't change the system, use the standard as long as you ever can."
- Changing a current system which works well and is used by everyone will offer high resistance
- Finance and operation departments are most important when implementing new systems
- A new IT system will be implemented only if there is a dire need to do so and this would be to earn more money, or be more effective, or to preserve the business. "Threat of survival" is required or a demand from a parent company.

C.2.2.4 Other key insights

- No other insights.

C.2.3 Interview 3 - Company C

C.2.3.1 General information

- Employ just below 400 employees.
- All produced solutions are customer specific.
- Have an extremely large product portfolio.

C.2.3.2 Company challenges

- Issues arise from the large product portfolio. One article can look 10 different ways depending on the usage.
- Quotas for certain products in Europe resstrict the flow of materials.
- Due to the complex nature of the manufacturing it takes some time to train new employees.
- The production engineering department is too small to be able to develop good instructions with accompanying images for production.

- Currently changing systems which has been estimated to take 9-10 thousand man hours.
- Possible future competitors entering the market is something the company is aware of and could increase competitiveness.

C.2.3.3 Adoption factors

- It is important to get everyone on board.
- Limiting or controling the amount of information channels/notifications.
- Avoid trying to convince the biggest opponents initially.

C.2.3.4 Other key insights

- The larger the company has become the more sway they have had as an actor when working with suppliers and customers.

C.2.4 Interview 4 - Company D

C.2.4.1 General information

- Roughly 200 employees
- Bulk production
- A couple of standards with customer adjustment if required.
- Old mature industry.
- Uses specialized systems.

C.2.4.2 Company challenges

- There is a big risk that knowledge is lost form the company when people leave. This is since a great deal of development is performed based on experiences and learnings from engineers.
- Large variation in production methods makes it difficult to get an overview.

C.2.4.3 Adoption factors

- The people that are going to use it have to be behind it.
- The finances always govern if a new system is brought in unless it can be motivated with worker safety.
- There has to be something clear to calculate benefits from such as energy savings or similar.
- Interviewee had an experience when implementing a new system and expected resistance from employees. The employees surprised the interviewee and were positive to the new system. The interviewee thinks this is due to the good support from management and clear communication of the benefits for the system.

C.2.4.4 Other key insights

- No other insights.

C.2.5 Interview 5 - Company E

C.2.5.1 General information

- Company size: 130 employees (30 people working in the factory).
- The company manufactures Windows. They work with sales, manufacturing and installation of windows.
- Each window is customised in dimension, but they manufacture mainly one type/style of window.
- The company follows a Make To Order strategy.
- They mainly use an ERP system which is interlinked to the sales order.
- They communicate with suppliers mainly via email for orders.
- They have a safety stock level which some suppliers are notified automatically if there is less stock.

C.2.5.2 Company challenges

- Difficult to understand the exact need of the customer (the quality needed or details of the product).
- Difficulty in communicating exact needs to suppliers. Miscommunication with suppliers is also a problem where the orders are mismatched.
- High competition (both nationally and internationally) where the competition is in price and variety.
- They have problems with version management, where the drawings are not in order and it is always a confusion to handle documents correctly and understand which is the right document to use.
- They also face problems with knowledge management and problems with transferring knowledge between employees
- They also face quality problems due to miscommunication

C.2.5.3 Adoption factors

- People working with the system need to be introduced early into the implementation process and their voice needs to be heard in the implementation process.
- Age of employees also played a role in implementation of a new system. Historically when there were only old employees, it was much more difficult to make changes.
- Gut feeling and initial cost is used mainly in making decisions of implementing new systems

C.2.5.4 Other key insights

- They have too many systems which creates confusion. They have a different system for each function
- Employees are mainly afraid of changes.

D

Appendix 4

D.0.1 Results from the General Information section

Figure D.1 to Figure D.8 represent the survey response obtained from the *General Information* section.

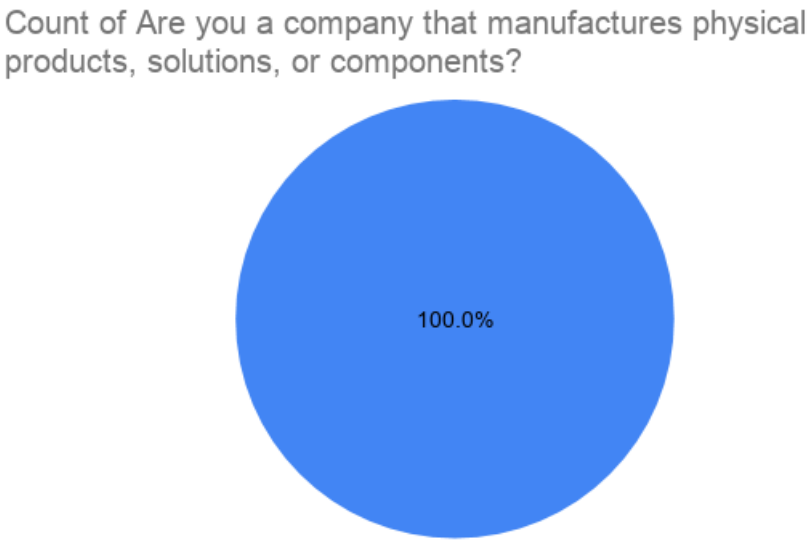


Figure D.1: Survey Question: Are you a company that manufactures physical products, solutions, or components?

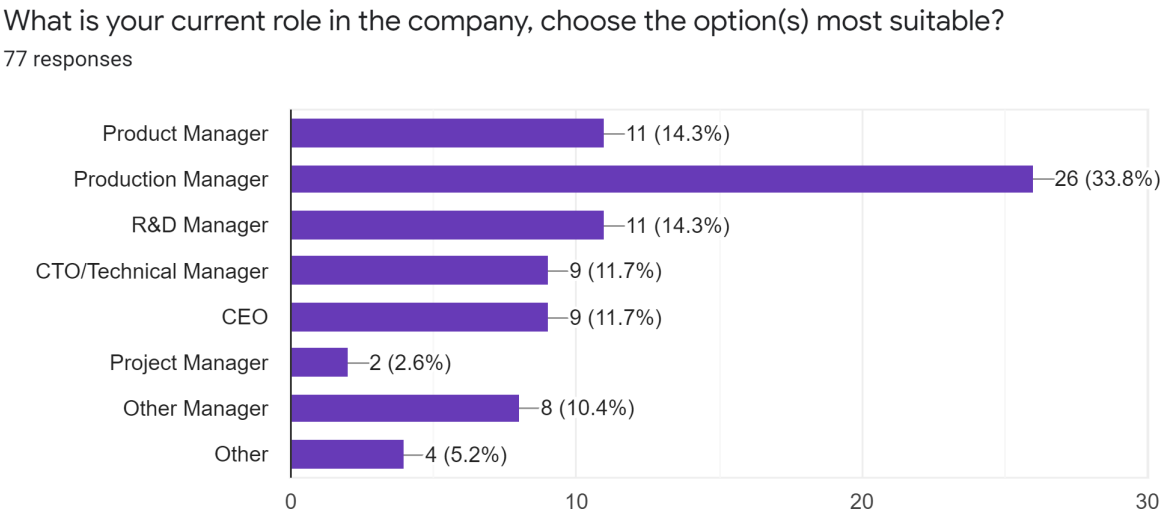


Figure D.2: Survey Question: Are you a company that manufactures physical products, solutions, or components?

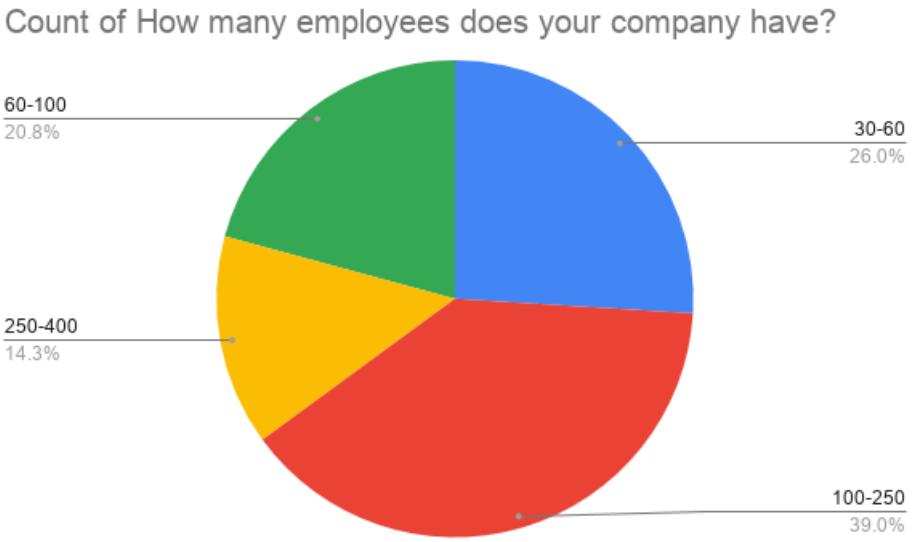


Figure D.3: Survey Question: How many employees does your company have?

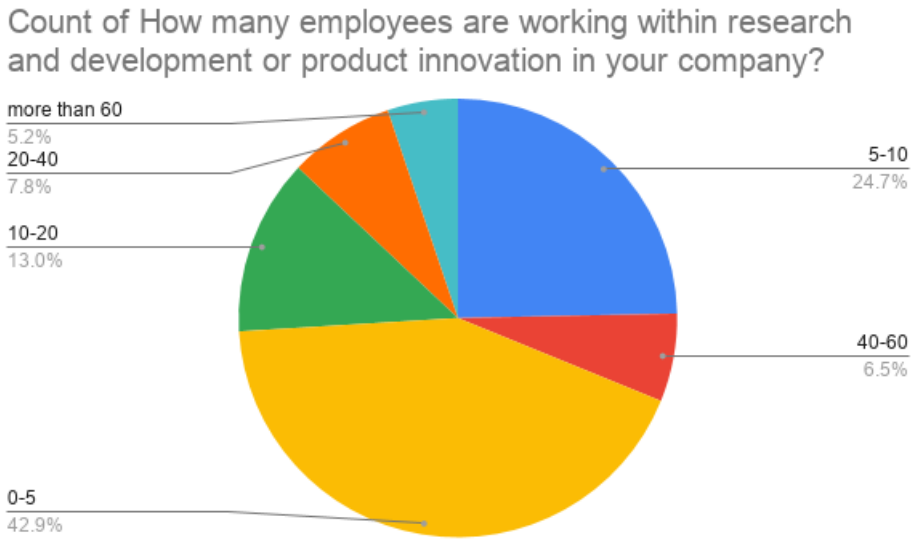


Figure D.4: Survey Question: How many employees are working within research and development or product innovation in your company?

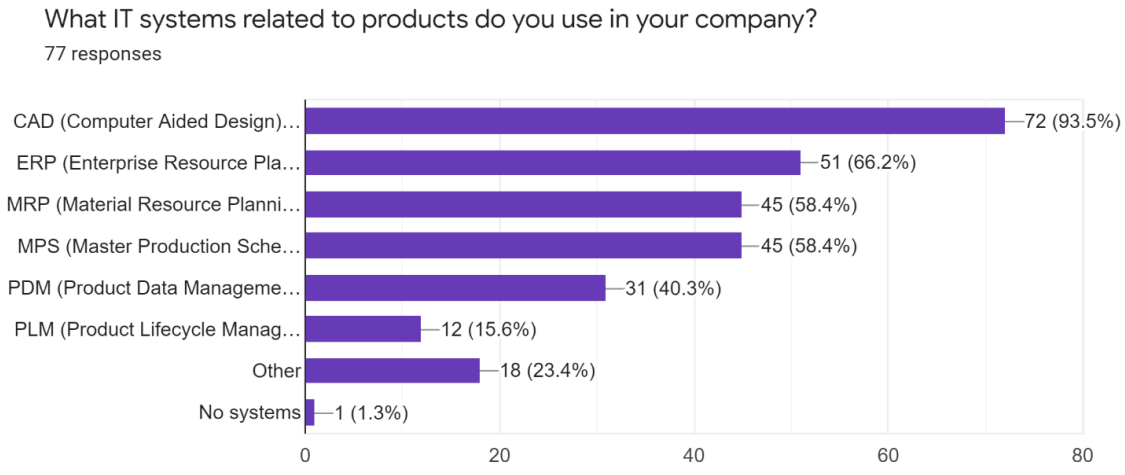


Figure D.5: Survey Question: What IT systems related to products do you use in your company?

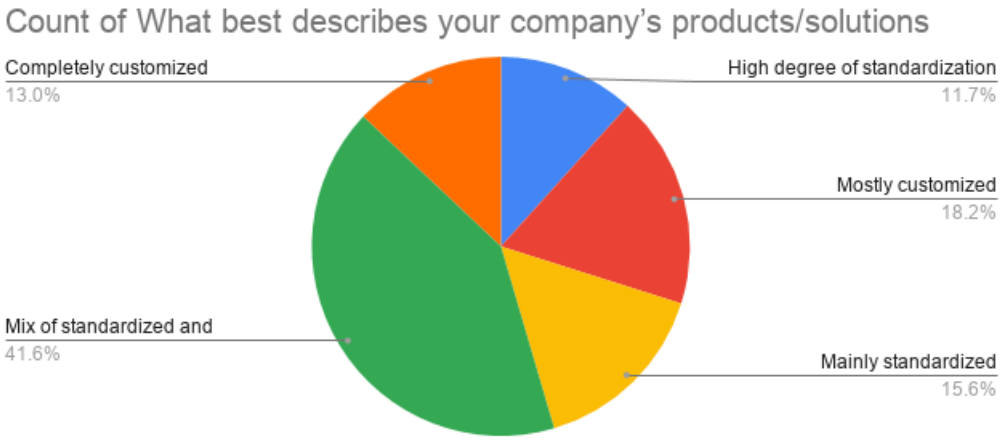


Figure D.6: Survey Question: What best describes your company's products/solutions variation?

Figure D.7: Survey Question: Do you own the IP of your products/solutions or are you a contract manufacturer?

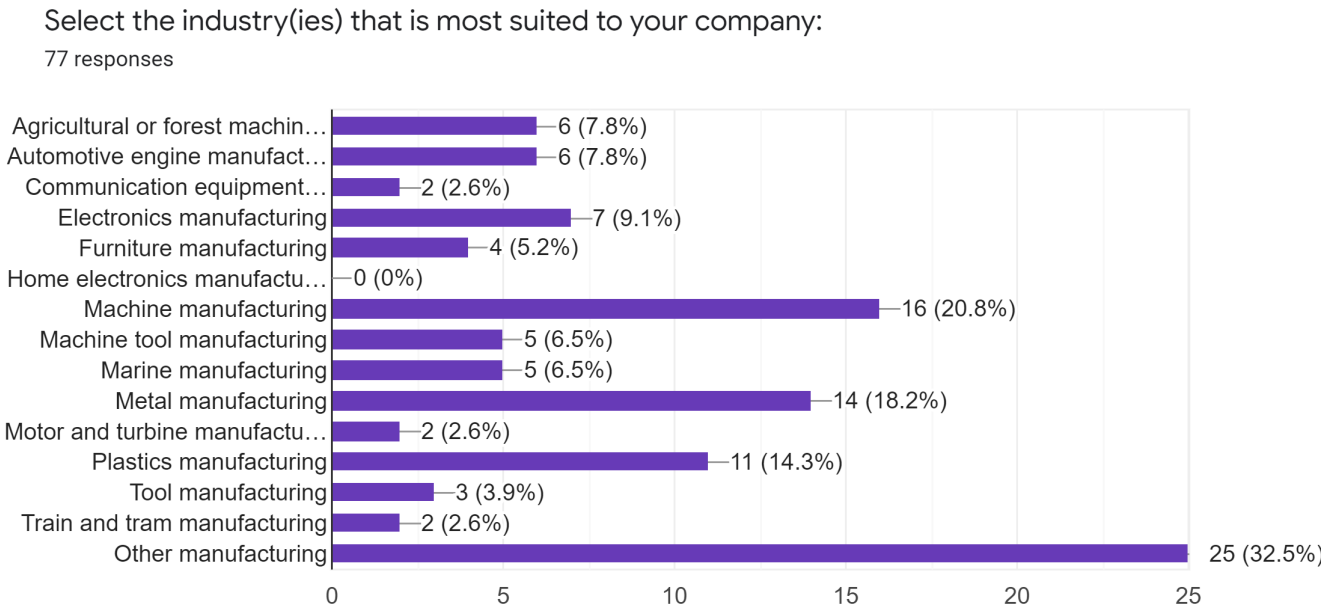


Figure D.8: Survey Question: Select the industry(ies) that is most suited to your company

D.0.2 Results from the Challenges section

Figure D.9 to Figure D.21 represent the survey response obtained from the *Challenges* section.

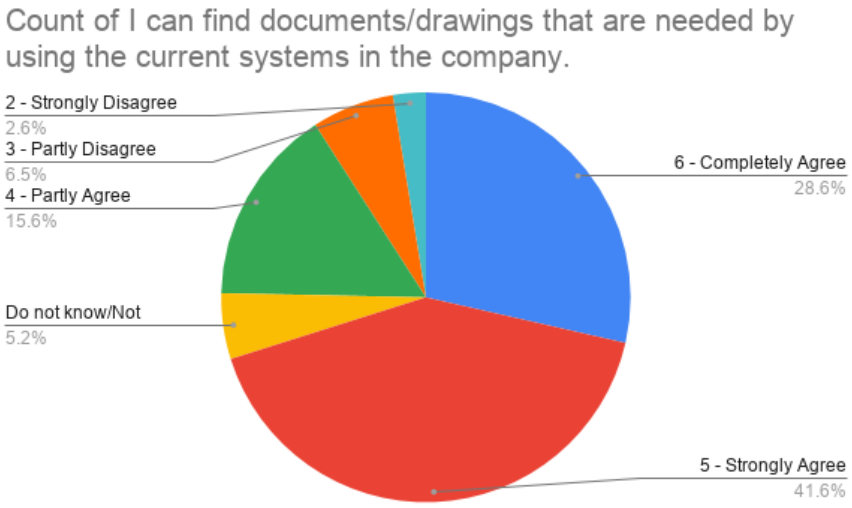


Figure D.9: Survey Statement C1: I can find documents/drawings that are needed by using the current systems in the company

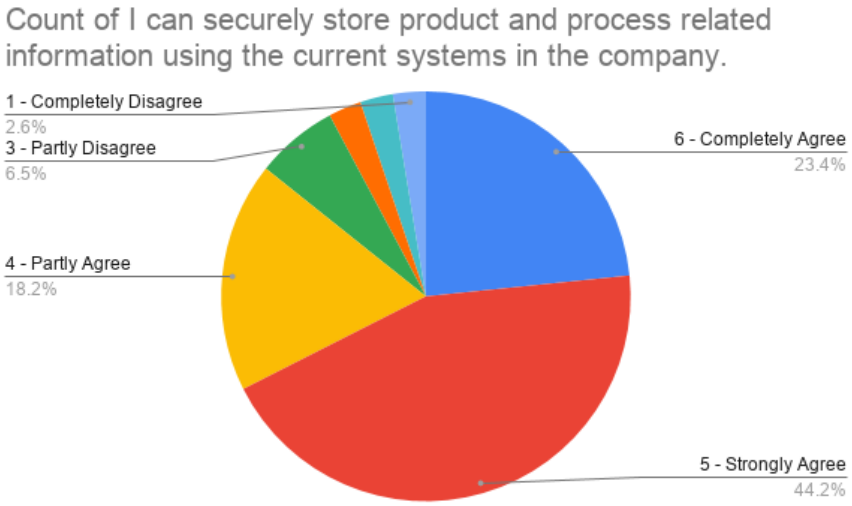


Figure D.10: Survey Statement C2: I can securely store product and process related information using the current systems in the company

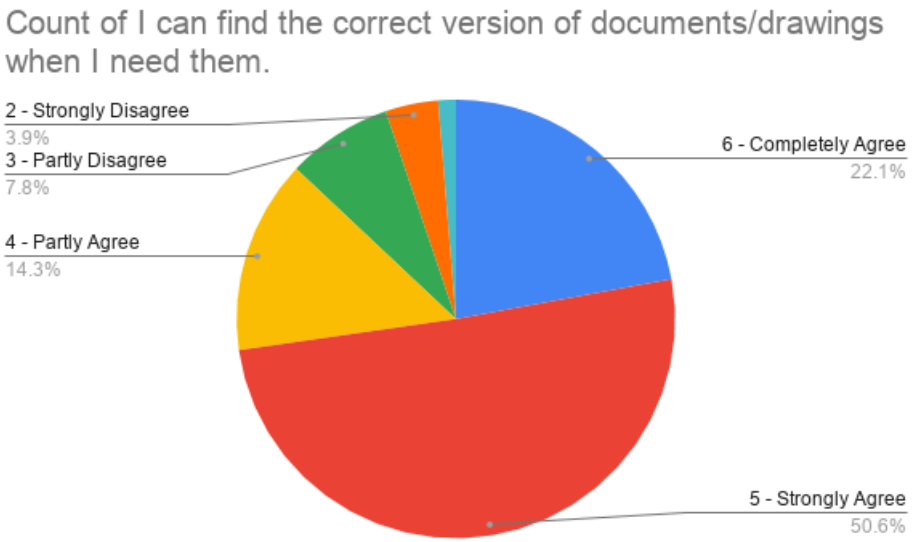


Figure D.11: Survey Statement C3: I can find the correct version of documents/-drawings when I need them

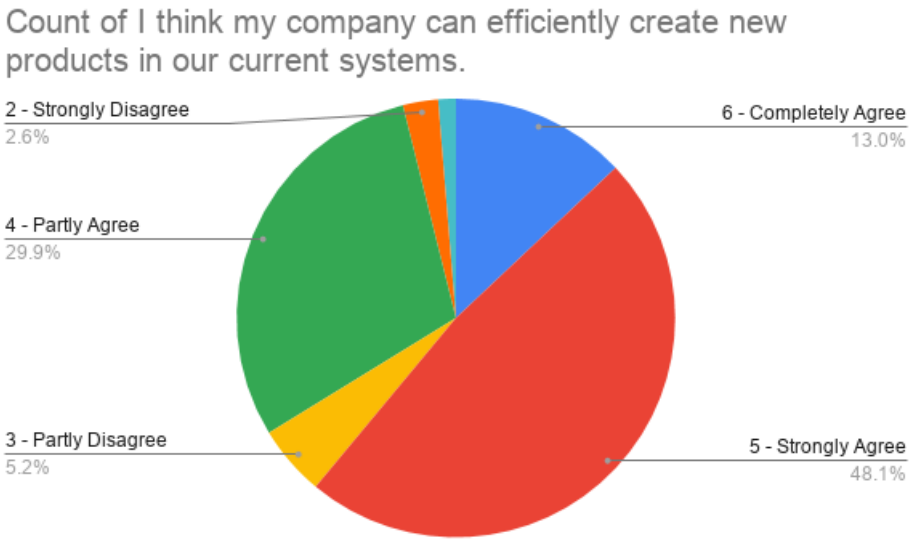


Figure D.12: Survey Statement C4: I think my company can efficiently create new products in our current systems

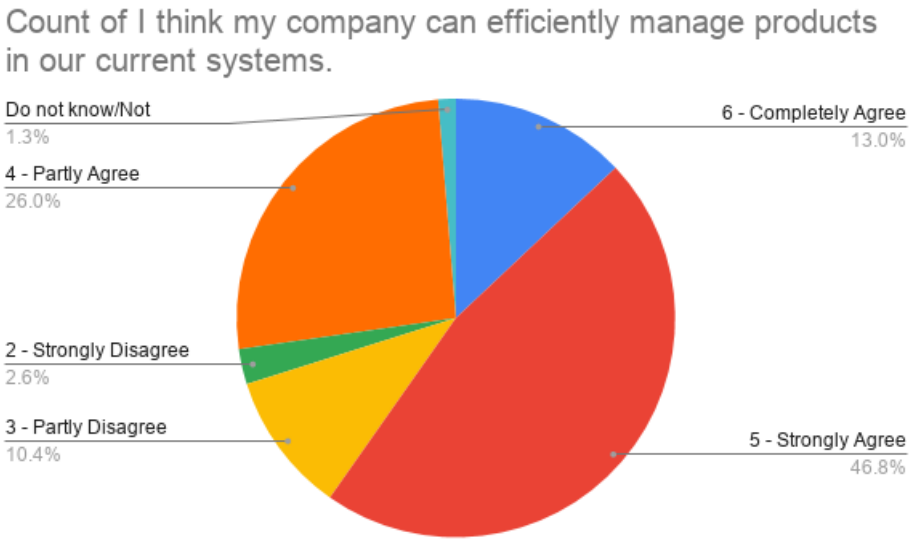


Figure D.13: Survey Statement C5: I think my company can efficiently manage products in our current systems

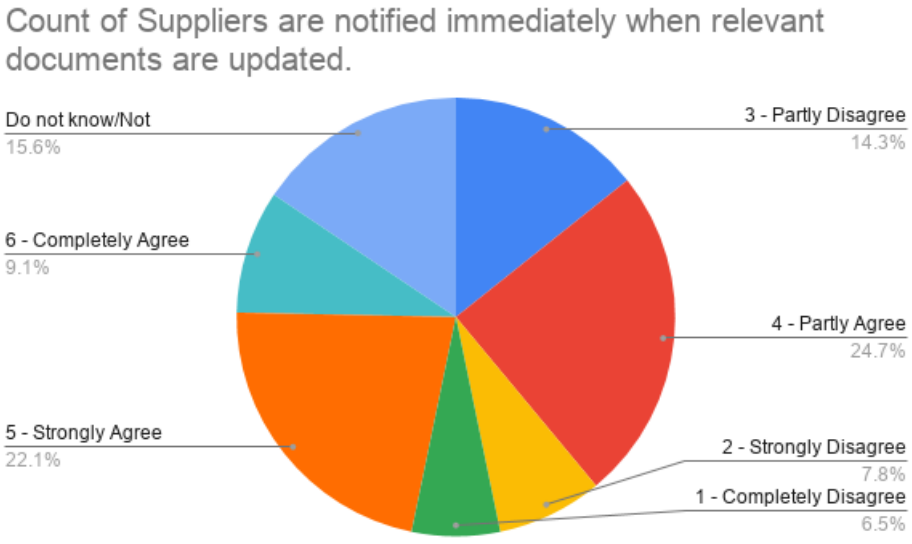


Figure D.14: Survey Statement C6: Suppliers are notified immediately when relevant documents are updated

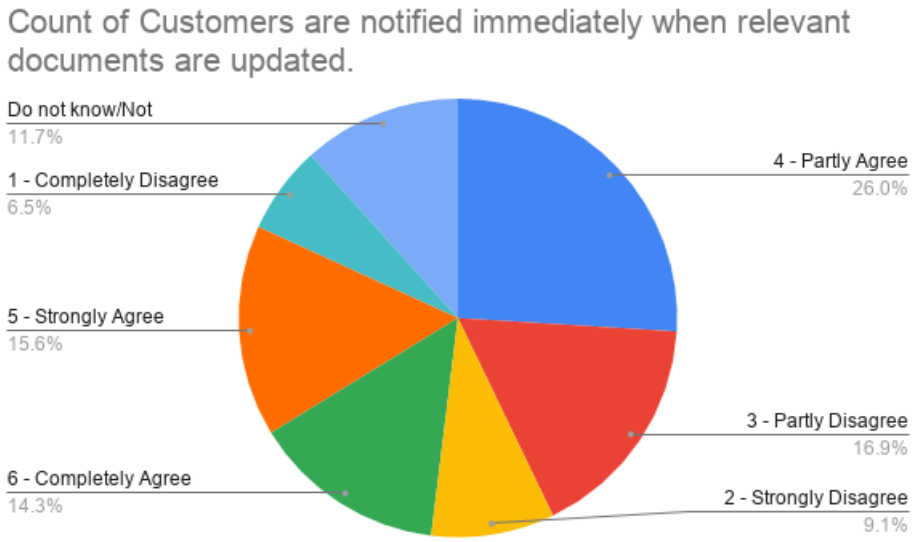


Figure D.15: Survey Statement C7: Customers are notified immediately when relevant documents are updated

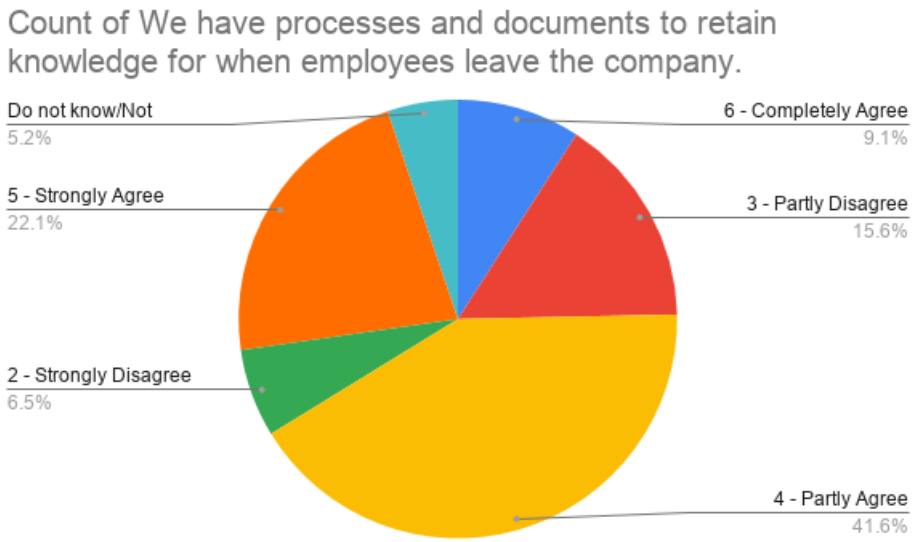


Figure D.16: Survey Statement C8: We have processes and documents to retain knowledge for when employees leave the company

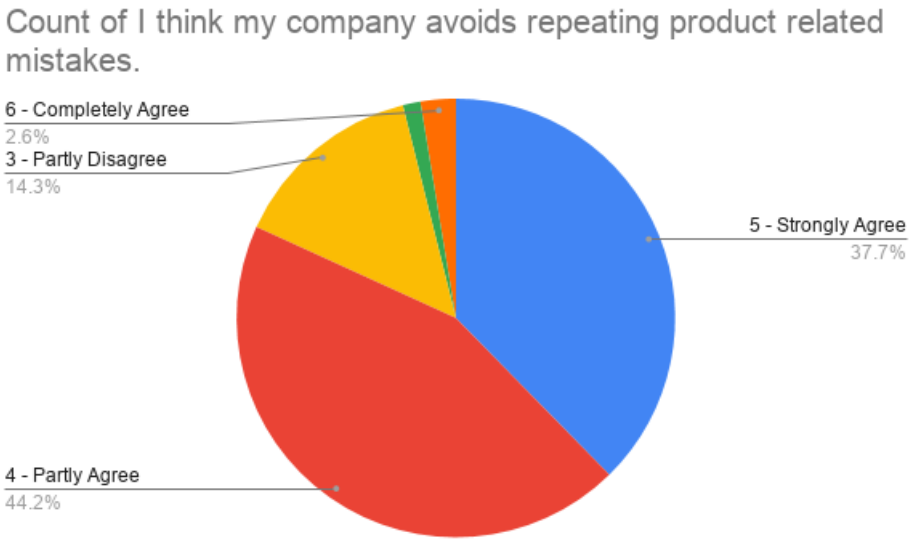


Figure D.17: Survey Statement C9: I think my company avoids repeating product related mistakes

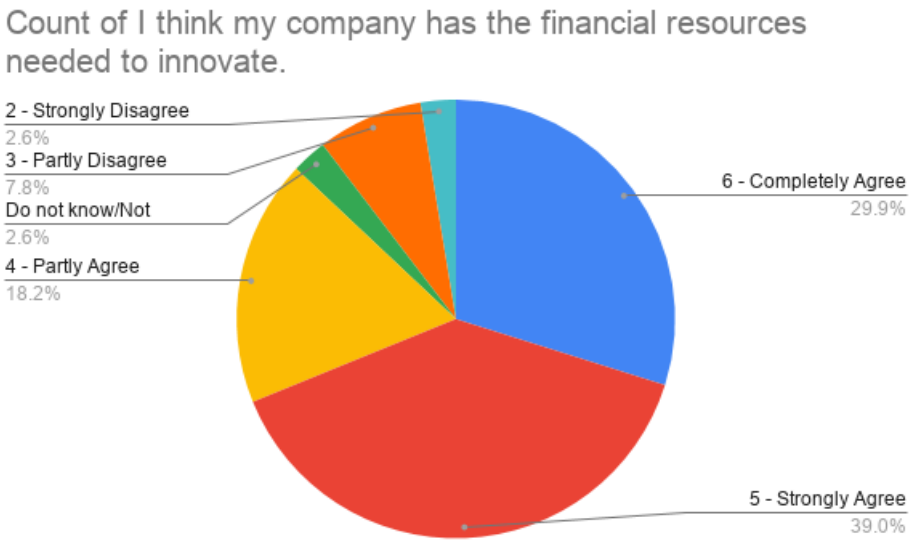


Figure D.18: Survey Statement C10: I think my company has the financial resources needed to innovate

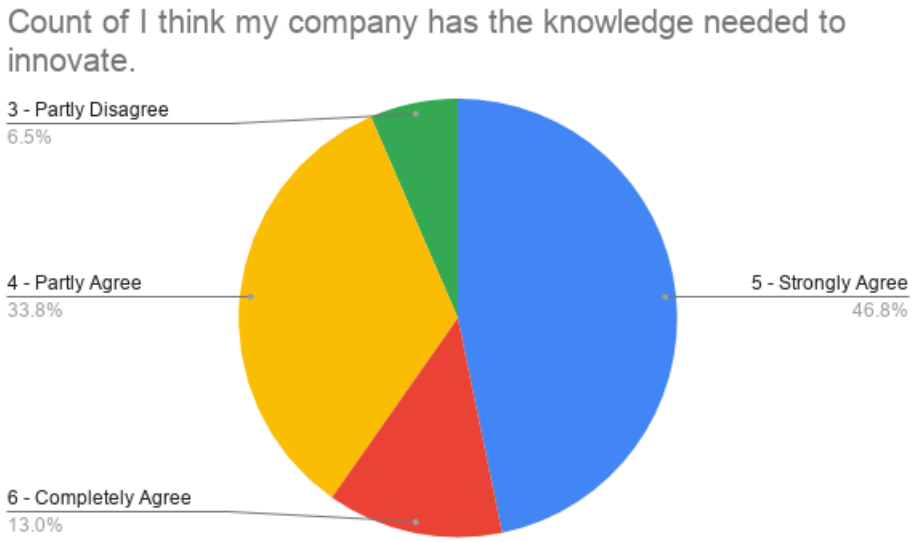


Figure D.19: Survey Statement C11: I think my company has the knowledge needed to innovate

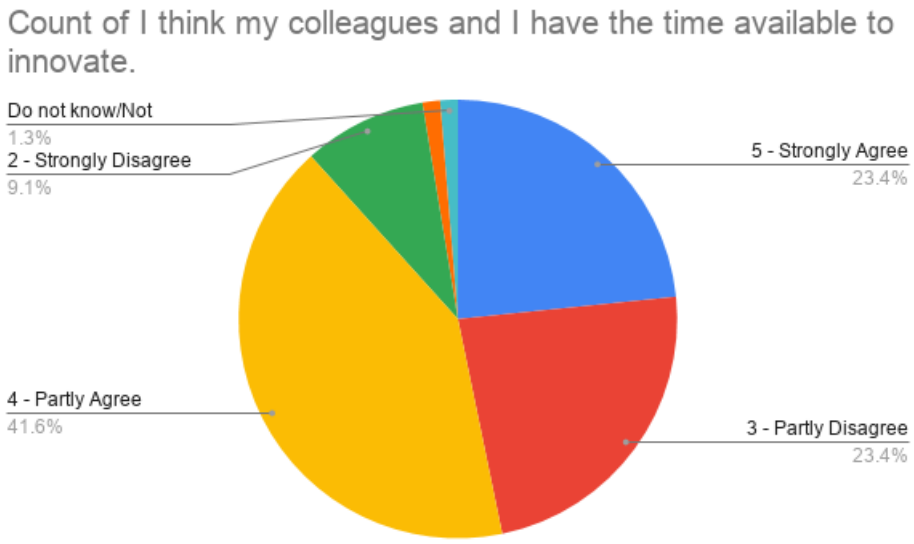


Figure D.20: Survey Statement C12: I think my colleagues and I have the time available to innovate

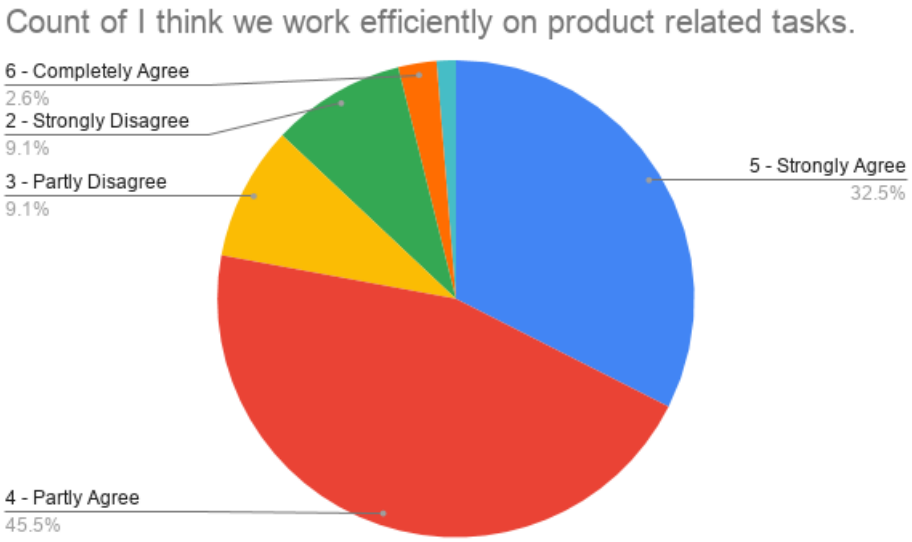


Figure D.21: Survey Statement C13: I think we work efficiently on product related tasks

D.0.3 Results from the Benefits section

Figure D.22 to Figure D.32 represent the survey response obtained from the *Benefits* section.

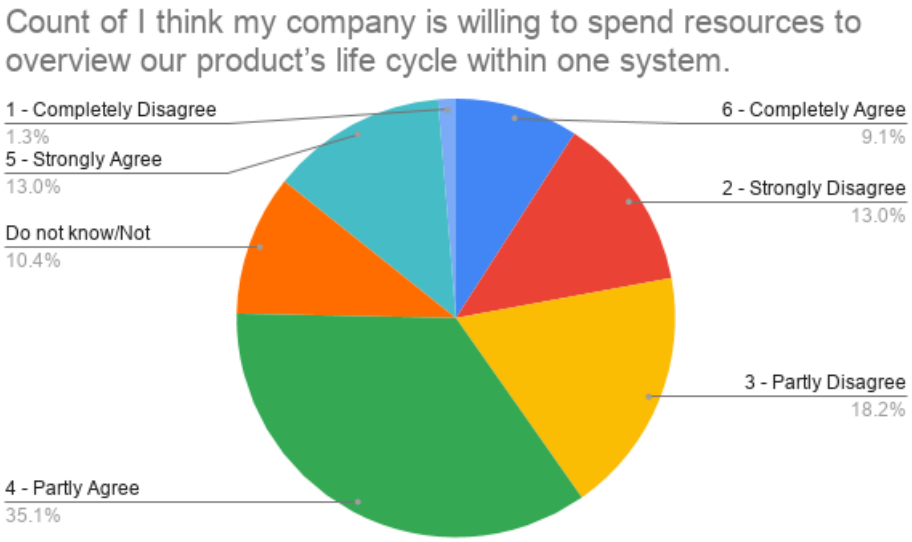


Figure D.22: Survey Statement B1: I think my company is willing to spend resources to overview our product's life cycle within one system

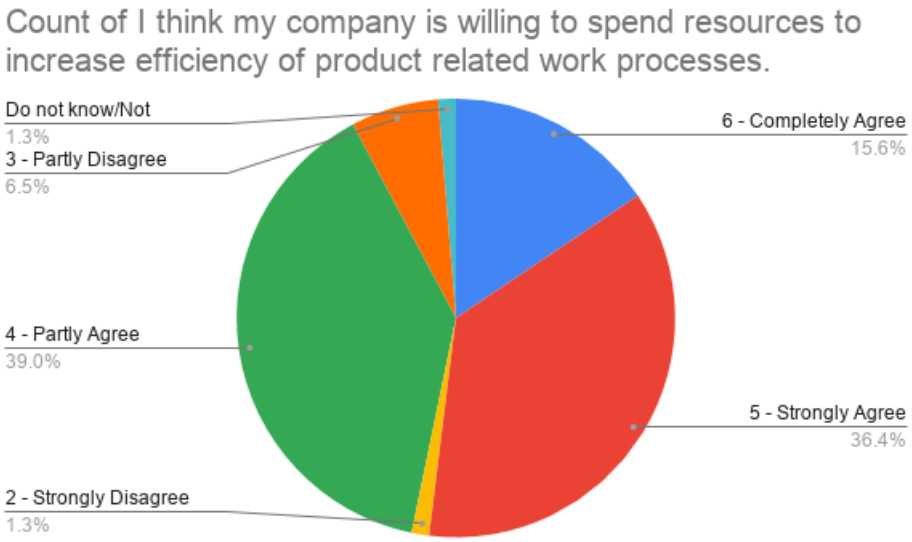


Figure D.23: Survey Statement B2: I think my company is willing to spend resources to increase efficiency of product related work processes

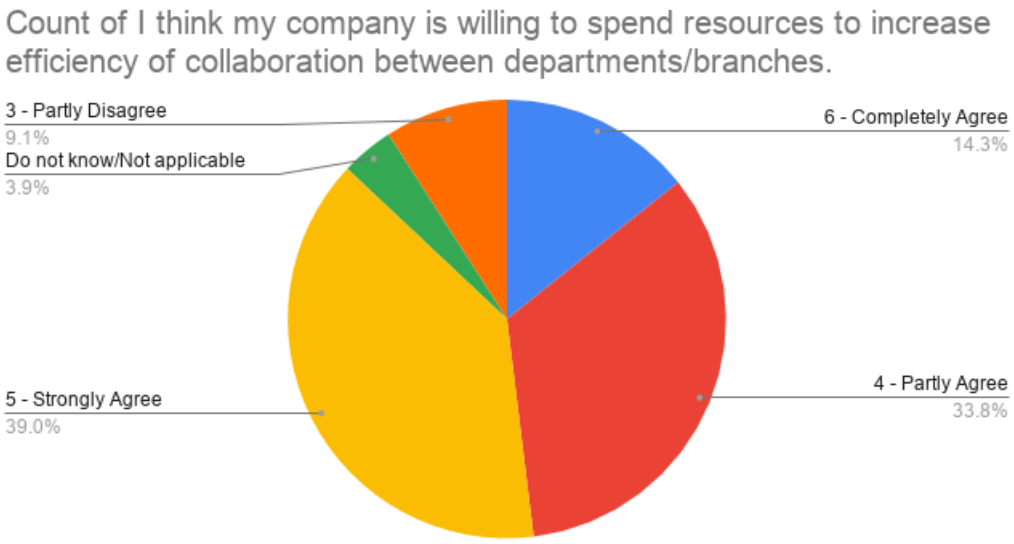


Figure D.24: Survey Statement B3: I think my company is willing to spend resources to increase efficiency of collaboration between departments/branches

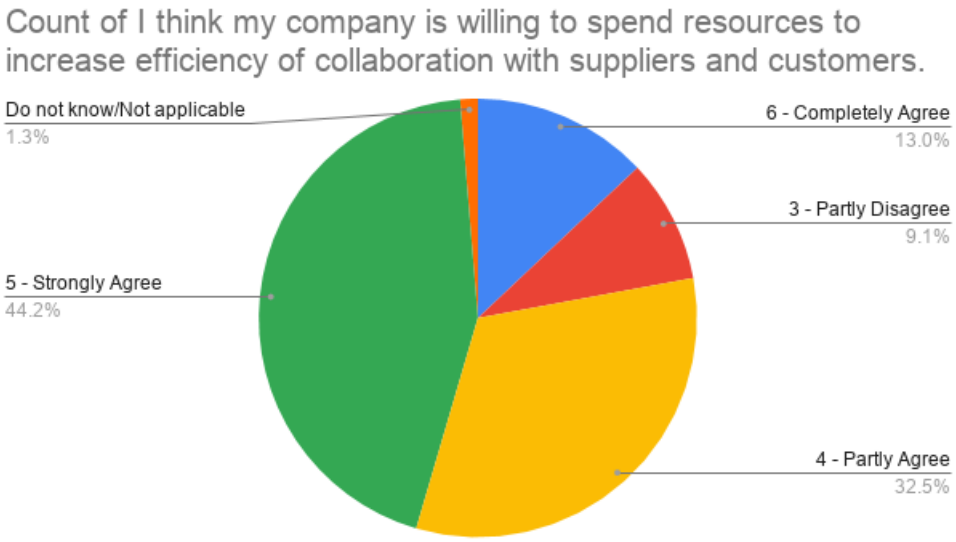


Figure D.25: Survey Statement B4: I think my company is willing to spend resources to increase efficiency of collaboration with suppliers and customers

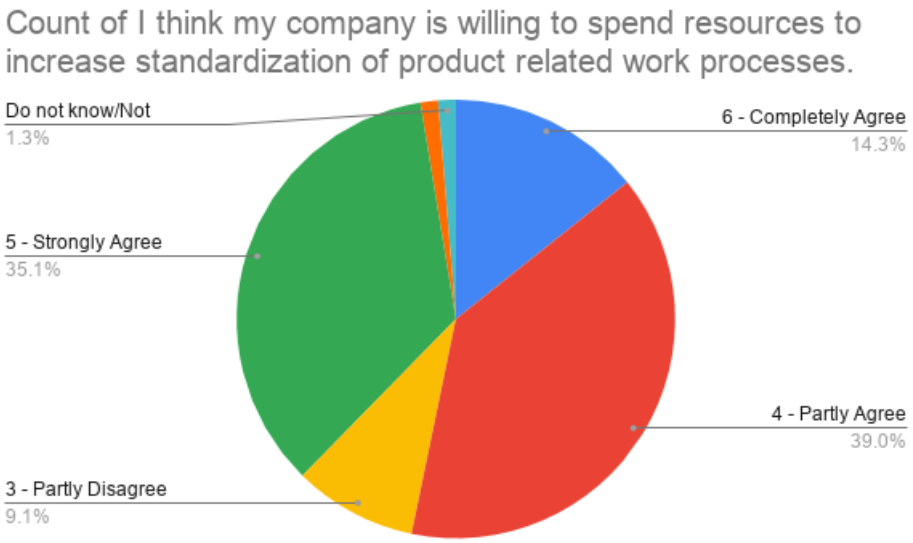


Figure D.26: Survey Statement B5: I think my company is willing to spend resources to increase standardization of product related work processes

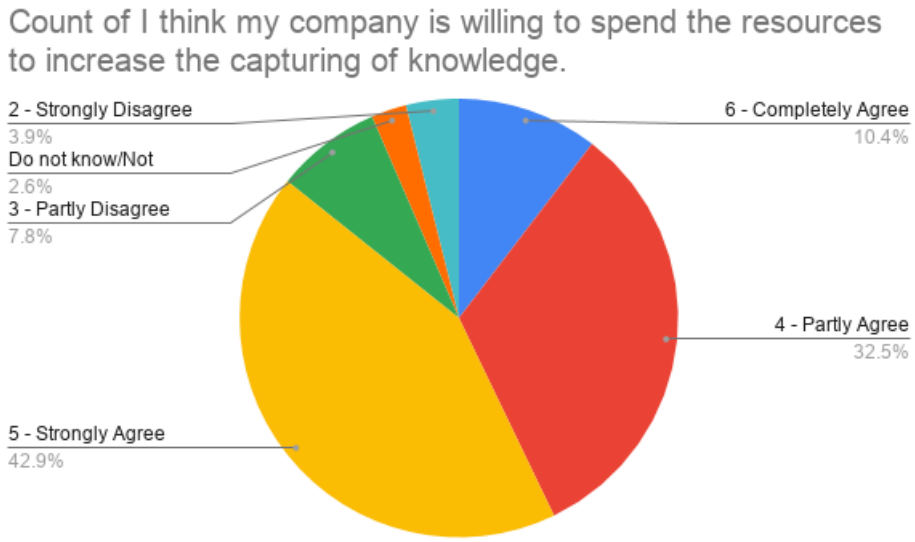


Figure D.27: Survey Statement B6: I think my company is willing to spend the resources to increase the capturing of knowledge

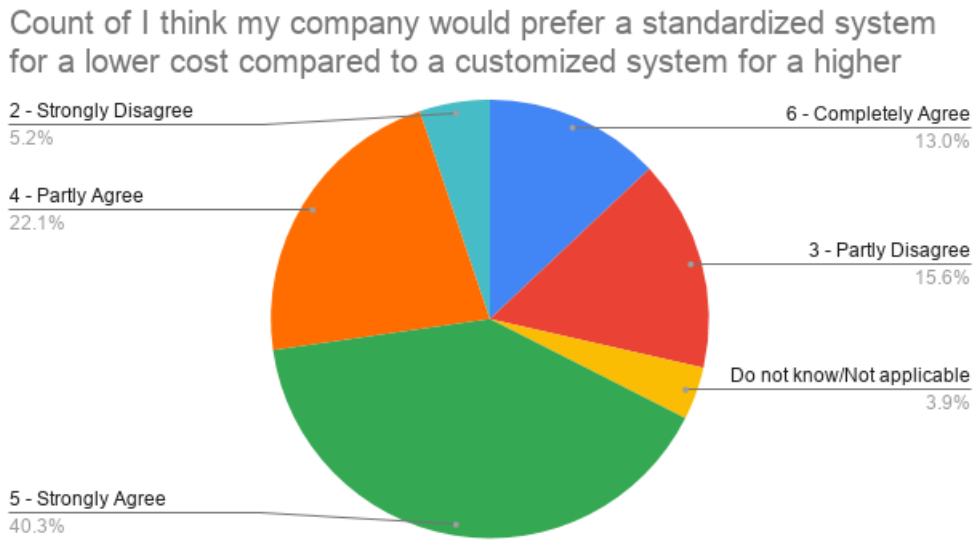


Figure D.28: Survey Statement B7: I think my company would prefer a standardized system for a lower cost compared to a customized system for a higher cost

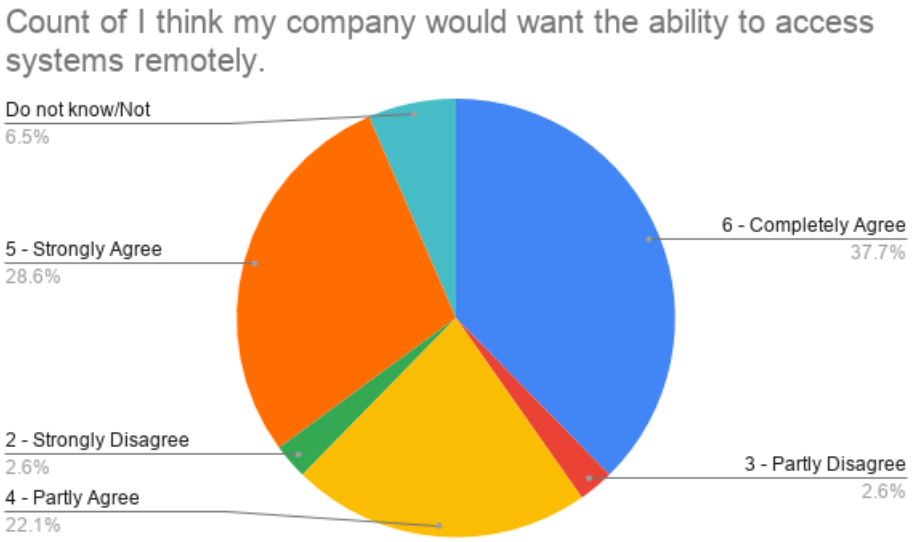


Figure D.29: Survey Statement B8: I think my company would want the ability to access systems remotely

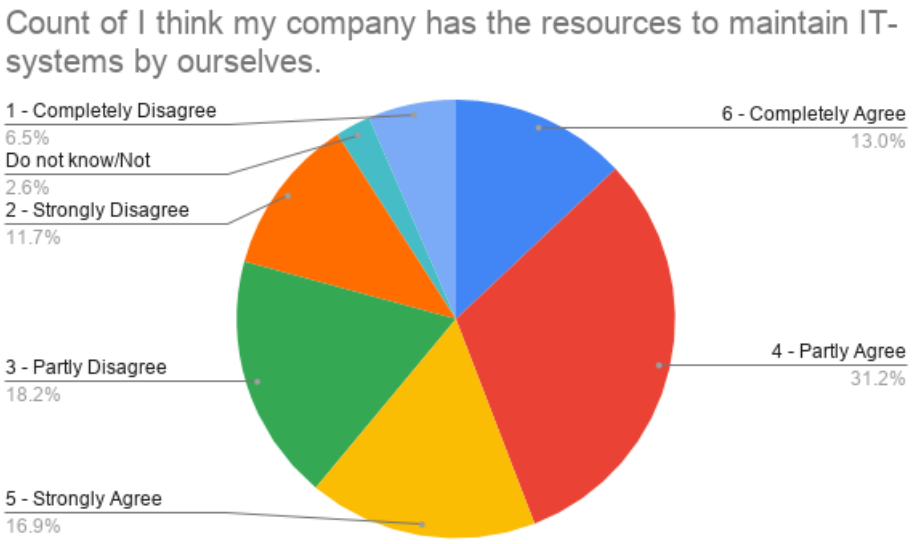


Figure D.30: Survey Statement B9: I think my company has the resources to maintain IT-systems by ourselves

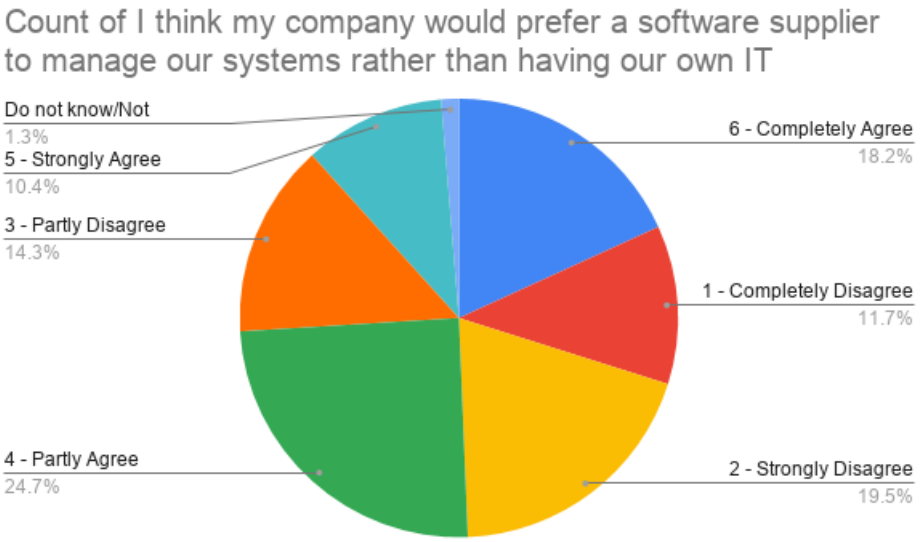


Figure D.31: Survey Statement B10: I think my company would prefer a software supplier to manage our systems rather than having our own IT department

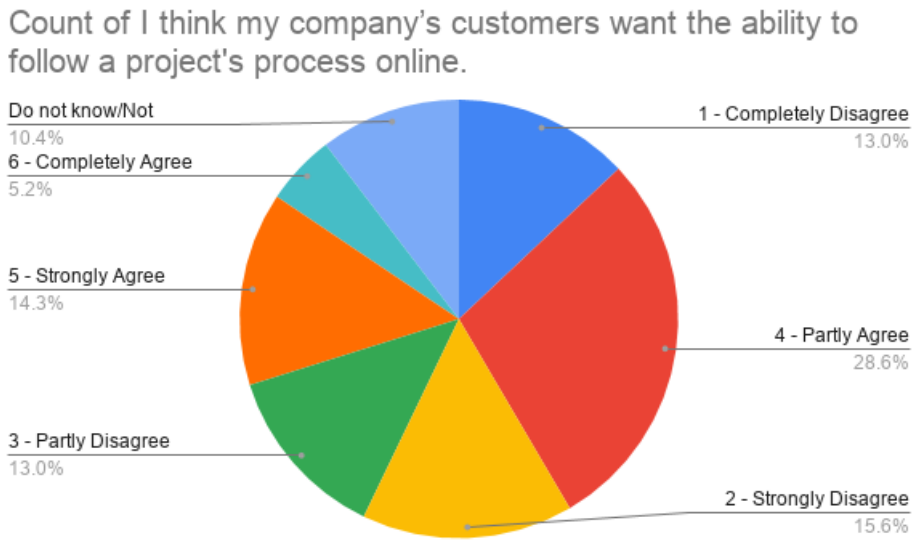


Figure D.32: Survey Statement B11: I think my company's customers want the ability to follow a project's process online

D.0.4 Results from the Risks section

Figure D.33 to Figure D.36 represent the survey response obtained from the *Risks* section.

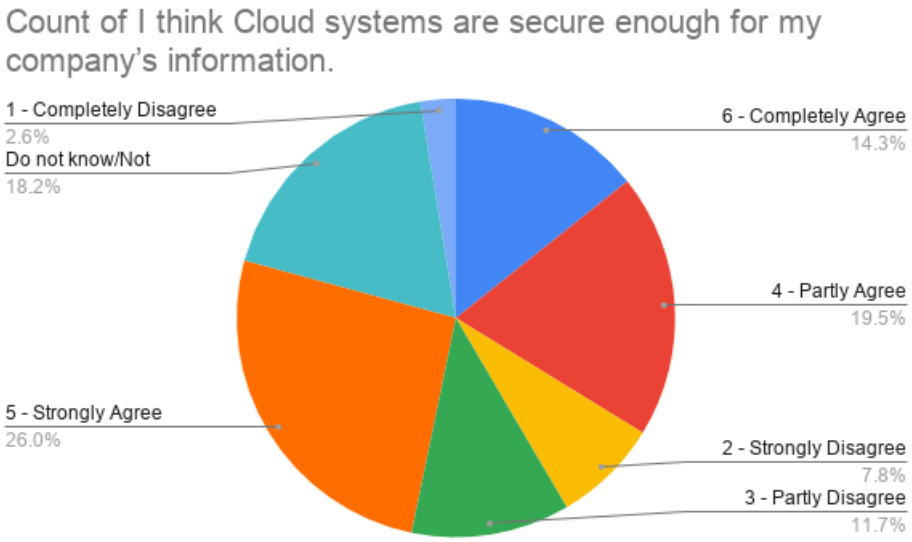


Figure D.33: Survey Statement R1: I think Cloud systems are secure enough for my company's information

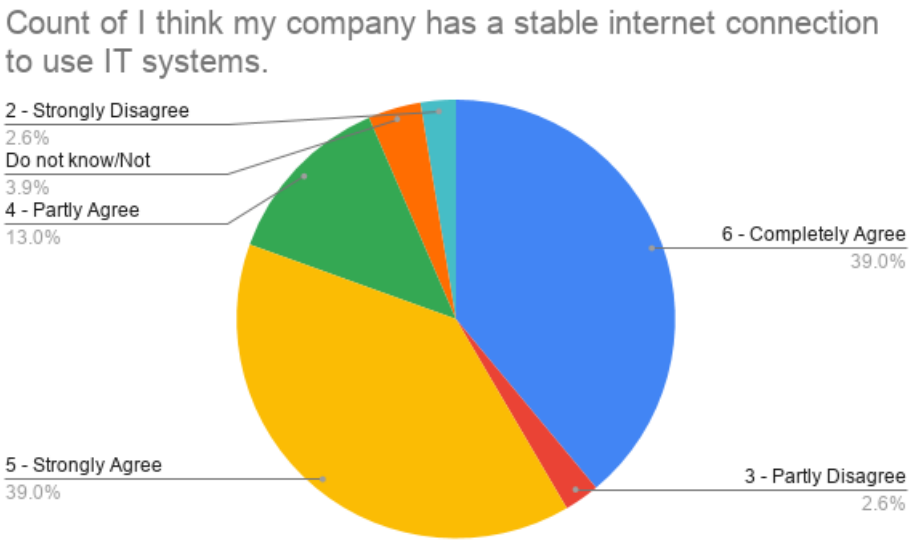


Figure D.34: Survey Statement R2: I think my company has a stable internet connection to use IT systems

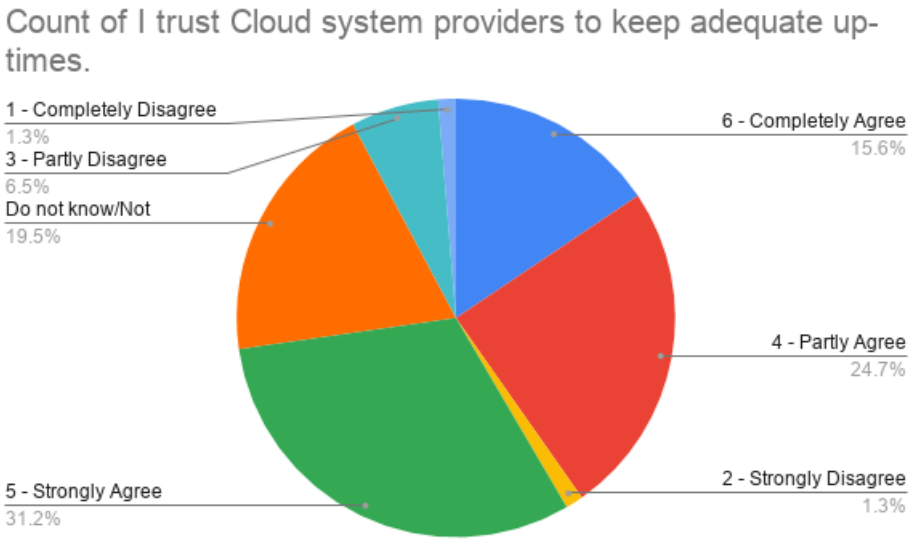


Figure D.35: Survey Statement R3: I trust Cloud system providers to keep adequate up-times

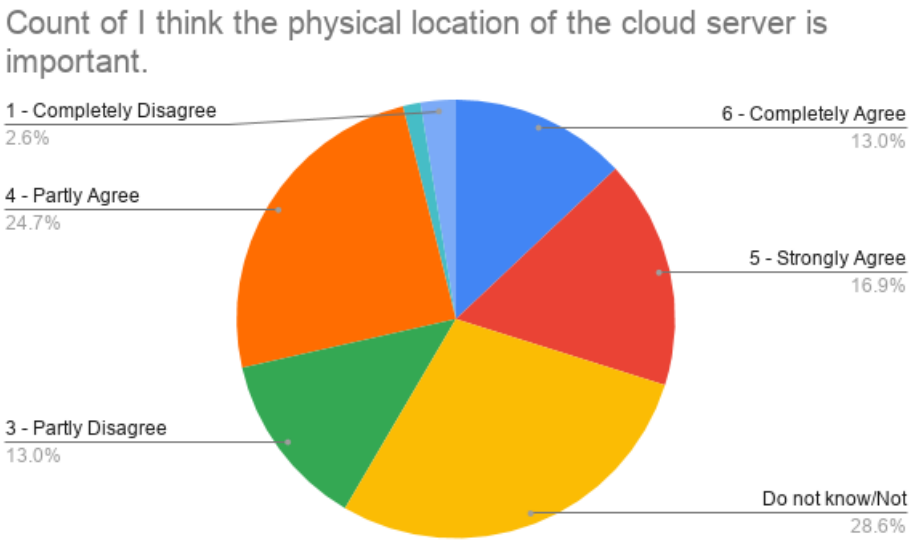


Figure D.36: Survey Statement R4: I think the physical location of the cloud server is important

D.0.5 Results from the Adoption Factors section

Figure D.37 to Figure D.45 represent the survey response obtained from the *Adoption Factors* section.

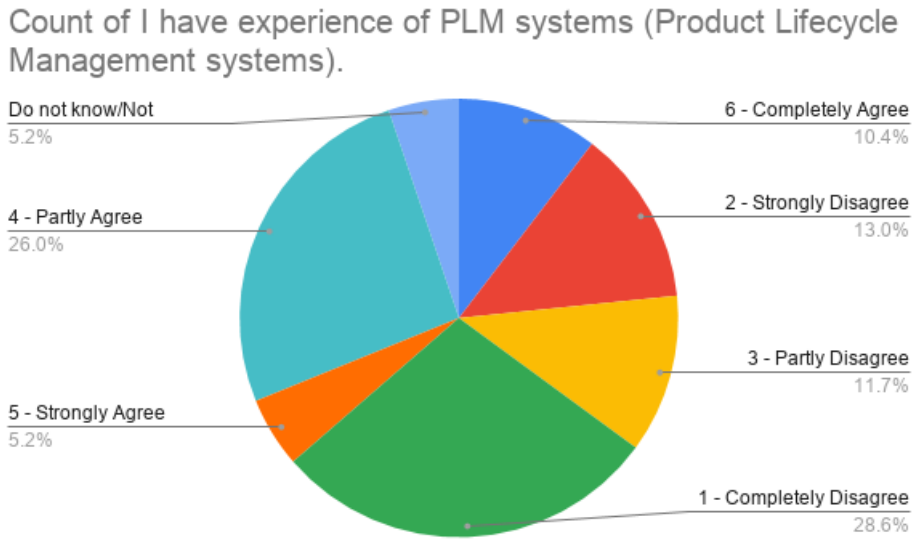


Figure D.37: Survey Statement AF1: I have experience of PLM systems (Product Lifecycle Management systems)

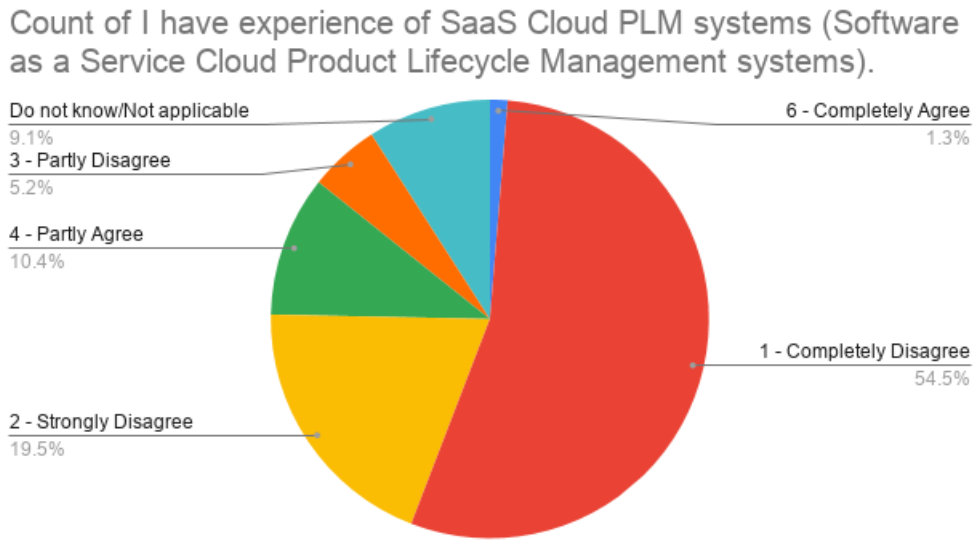


Figure D.38: Survey Statement AF2: I have experience of SaaS Cloud PLM systems (Software as a Service Cloud Product Lifecycle Management systems)

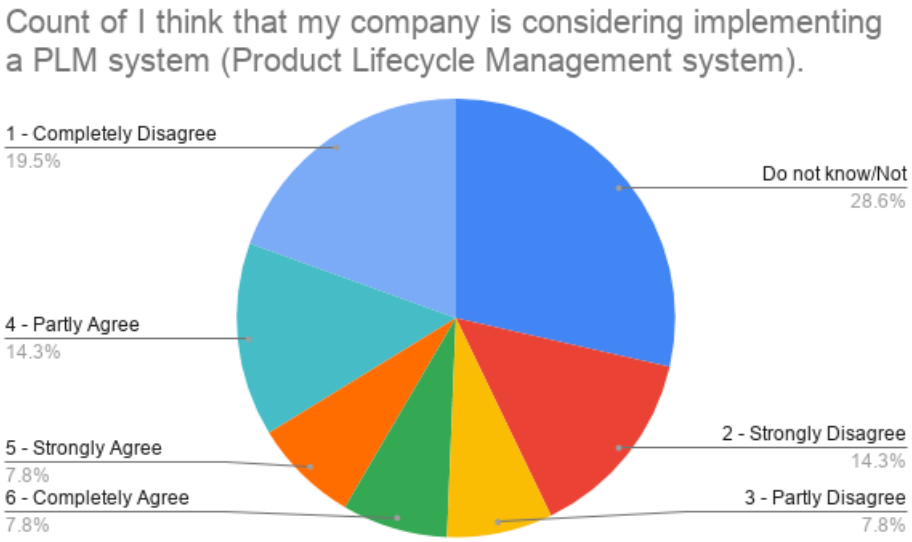


Figure D.39: Survey Statement AF3: I think that my company is considering implementing a PLM system (Product Lifecycle Management system)

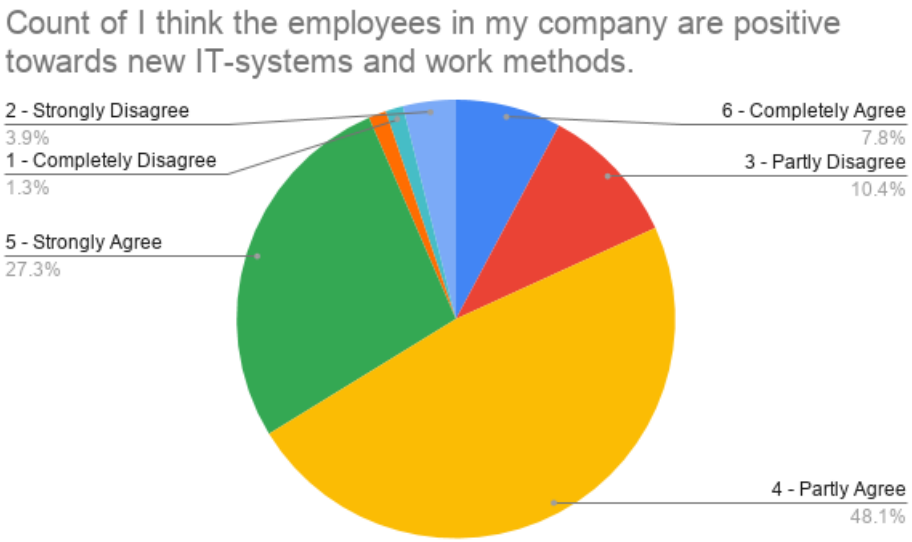


Figure D.40: Survey Statement AF4: I think the employees in my company are positive towards new IT-systems and work methods

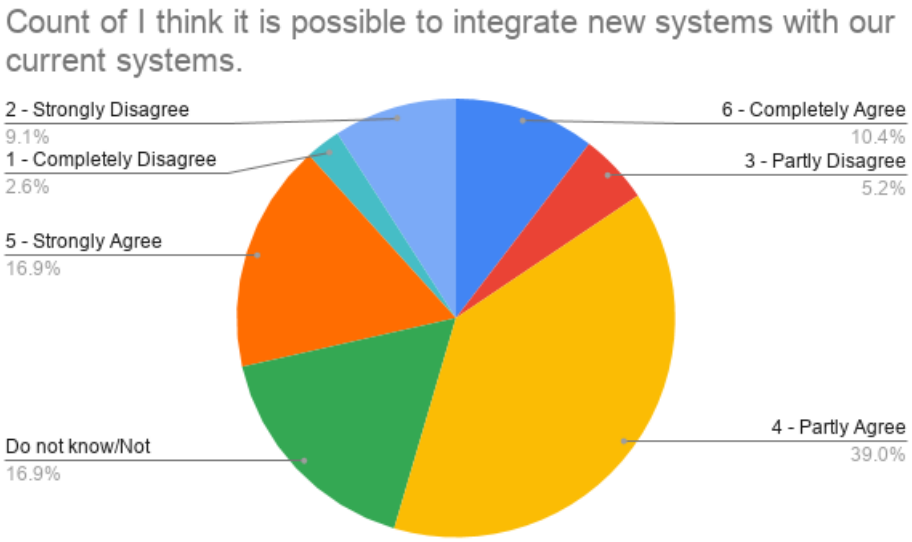


Figure D.41: Survey Statement AF5: I think it is possible to integrate new systems with our current systems

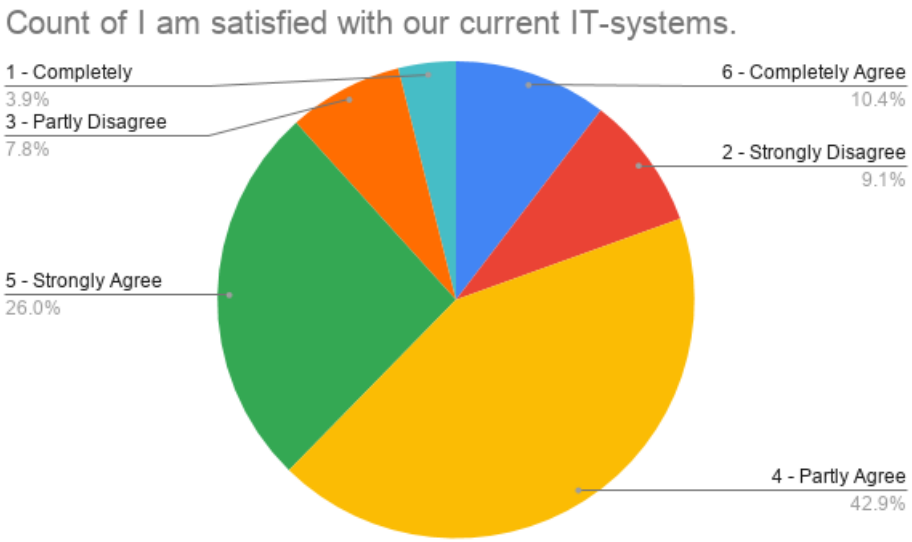


Figure D.42: Survey Statement AF6: I am satisfied with our current IT-systems

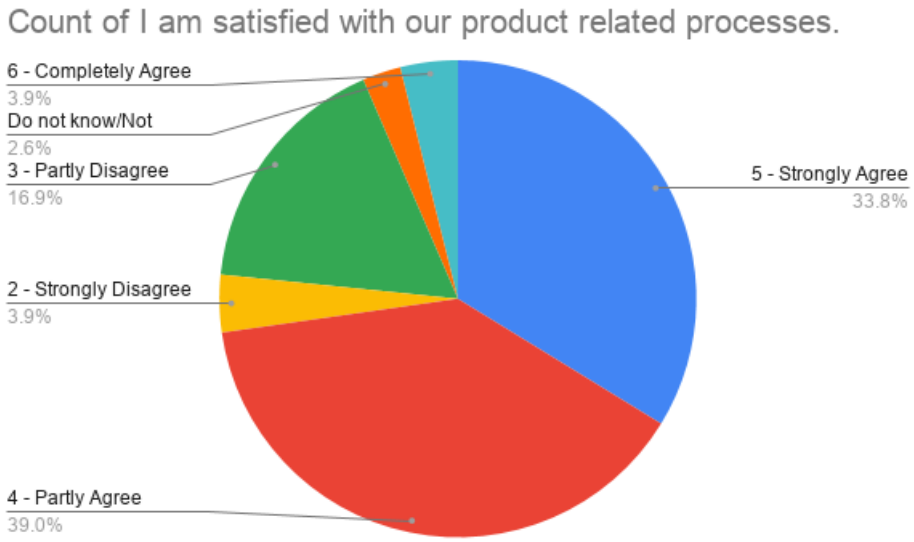


Figure D.43: Survey Statement AF7: I am satisfied with our product related processes

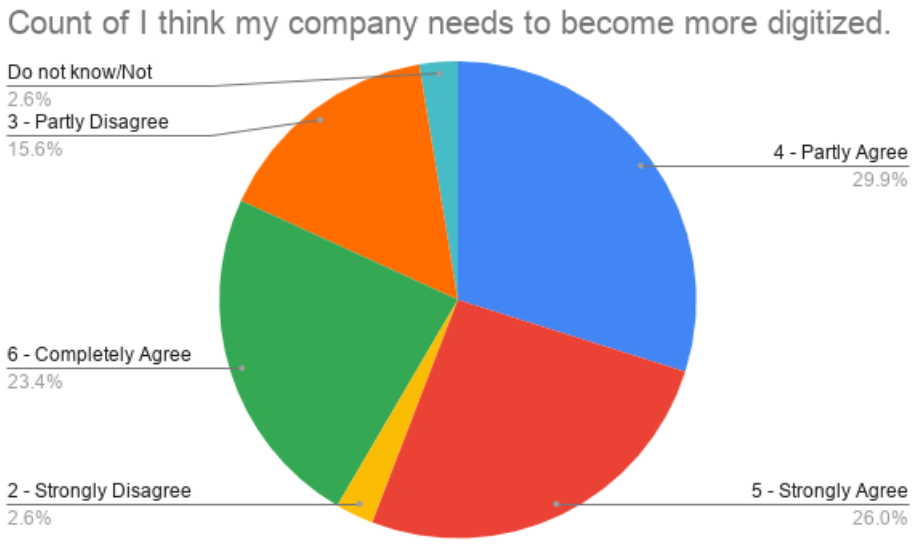


Figure D.44: Survey Statement AF8: I think my company needs to become more digitized

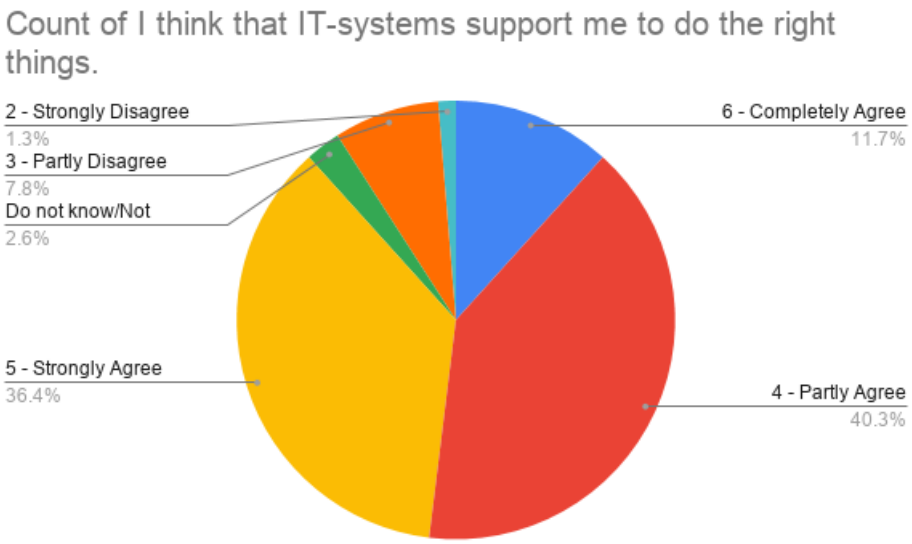


Figure D.45: Survey Statement AF9: I think that IT-systems support me to do the right things