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Adoption of Augmented Reality

Potential use-cases in an industry context

Master's Thesis in the Master's Programme
Management and Economics of Innovation

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ABSTRACT

Industries of today experience increased competition and cost pressure, further the trends Industry 4.0 and servitization have emerged. A technology that could facilitate for the necessary business transformation, further support the increased amount of digital content, is Augmented Reality.

This report aims to give a comprehensive understanding of what, positively or negatively, influences the adoption of AR amongst asset intensive manufacturers, from an external environment-, organizational-, and a technological perspective. Furthermore, different use-cases for AR have been evaluated in order to determine whether these are applicable today, or rather in the future.

The research was of qualitative nature and both primary- and secondary data sources have been used. The primary data were collected from interviews with industry experts, AR experts, and managers or employees involved in AR initiatives. The secondary data were mainly collected from consultancy reports, but also from panel discussions and seminars.

It was found that AR is a communication and visualization tool, that has great potential to deliver business value due to its ability to support a mixed reality, in other words the merge of the real- and the digital world. Furthermore, by the usage of a head-mounted-display (HMD) device, additional value propositions could be received, such as hands-free. Therefore, it is believed that AR by the usage of HMD brings the highest business potential, further that it will become the next computer platform. However, there are many technical limitations that must be solved in order for AR to achieve its full potential. Furthermore, it was found that the current AR-market is highly fragmented, and there are no standards regarding hardware, platforms, and how to describe information. Similarly, companies are uncertain regarding AR's capabilities, and the cost and benefits of an AR investment. Therefore, these concern must be solved in order for AR to take off.

Ten different use-cases were found valuable for asset intensive manufacturers, and a common theme amongst these were that AR facilitated for increased understanding and collaboration. The focus in a short time-horizon should be on applications that solves a critical problem, as well as providing high business value. Furthermore, the current focus should be on applications with low technical requirements, and where it is possible to reuse existing content. Therefore, the most valuable use-areas from a short time-horizon are: remote guidance, visualization of 3D models, and dashboarding. However, several of the other use-cases will become beneficial in a near future, further new applications will arise in the future.

Keywords: Augmented Reality, Mixed Reality, Servitization, Industry 4.0, adoption and diffusion of innovation, remote guidance, visualization tool, communication tool, disruptive innovation.

TABLE OF CONTENT

1. INTRODUCTION

The following chapter presents the background of the paper and the subject Augmented Reality in relation to an assent intensive manufacturing context. Furthermore, the purpose of the research and the following research questions are presented.

1.1 BACKGROUND

Derived from the growing global competition and the increasing digital world, low-cost countries outcompete western manufacturers and they are forced to find new ways to compete and do business (Oliva & Kallenberg 2003). These implications have spurred the adoption of new and innovating technologies and one of those technologies is Augmented Reality (AR). AR enhances the real world with digital information, and in its simplest form it could be compared with the popular game "Pokémon GO". However, in a more advanced form AR has the possibility to create new business opportunities (PwC, 2016a). At Facebook's F8 conference 2017, Mark Zuckerberg argued that AR technology will be the next big innovation, which will take over the existing smartphone market.

AR is not a new phenomenon and can be traced back to the 60's (Augment, 2016). However, the consultant firm PwC, who have conducted a technology forecast regarding AR, argue that with recent technological developments, companies have started to show interest for the technology and the potential business opportunities it can create (PwC, 2016a). On the one hand, PwC (2016b), believe that AR enables new ways to perform business activities in which *"people look at operations from a combined view of digital and physical operations and externalize the cognitive burden that is inherent in the task*". On the other hand, there are still some limitations and impediments related to AR as PwC (2016a) consider that *"AR is limited by a highly fragmented ecosystem of hardware platforms and operating systems, a lack of standards for sharing data and supporting interactions, and technical barriers in optics, 3-D capabilities, authoring tools, and interaction methods"* (p. 2). Despite these limitations, PwC (2016a) believe that a better performance of the AR-device and a decrease in price will spur the growth of AR, and they predict that the time horizon of enterprises adopting AR is between three to seven years. Additionally, AR is expected to generate revenue of $90 billions by 2020 (IDG, 2015).

Due to higher rivalry amongst manufacturing companies and the fact that also complex products are becoming commodities, it is harder for companies to differentiate themselves (The Manufacturer, 2017). Historically, companies have been able to compete with quality, but today they are being outcompeted by companies from the east who provide the same products with the same good quality but for a lower price (ibid). Consequently, western manufacturing companies are forced to find new ways to differentiate themselves rather than compete with price and quality. This also applies to asset intensive manufactures (AIM), which are companies that provide complex and expensive products. Due to these concerns a trend called servitization is emerging, where companies incorporate an increasing number of service components in their offerings (Desmet, 2003).

The servitization trend is a way for companies to strengthen their competitiveness (Vandermerwe & Rada, 1988). This is because services are inherently more difficult to imitate because they are intangible and dependent on the people delivering the service (Heskett et al., 1997). However, despite the servitization goal studies have shown that far from all projects succeed with it (Ulaga & Reinartz, 2011). According to Martinez et al. (2010) and Brax (2005) this failure depends on the different way of doing business and it incorporates a change in everything from sales, R&D, and service to management. In addition to the servitization transformation, companies have to stand in the forefront of the digital development and to adapt new and helpful technologies in order to survive in the high rivalry amongst manufacturing companies (Cambridge Service Alliance, 2015).

Historically, world leading companies have collapsed when new, unexpected and game changing technologies have attacked from underneath (Christensen, 1997). Such technologies have both created new markets and taken over existing ones, such as Nokia's fall when Apple came. Technology has developed rapidly over the past decade and the lines between the virtual and physical world have started to blur (Deloitte, 2015). From a manufacturing point of view this implies that factories and production systems need to become communicating and collaborating entities and by this smarter and more autonomous (ibid). This current trend is called Industry 4.0, and AR is one of the potential technologies that could support manufacturers in the Industry 4.0 context. Monostori (2014) states that the aim of Industry 4.0 is to obtain totally collaborating entities that exchange data regarding their ongoing processes, both from the digital and physical world. Furthermore, ISRA & Acatech (2013) argue that an Industry 4.0 initiative has "huge potential" to optimize decision making, increase resource productivity and efficiency, meet individual customer's requirements and create value opportunities through new services.

A combination of Industry 4.0 and Servitization can support western AIM companies to increase their competitiveness by smart production systems and better service offerings. Since AR is one of the possible technologies that could support such a system or activities, it is of great value to investigate AR's business potential. Therefore, this thesis aims to investigate and analyze, what affects the adoption of AR and how AR can be used in practice.

1.2 PURPOSE AND RESEARCH QUESTIONS

This thesis investigates Augmented Reality from a business perspective for asset intensive manufacturers, and that is companies who provide complex and expensive products, namely assets.

The purpose of the research is twofold. Firstly, it aims to give a comprehensive understanding of factors that positively or negatively influence the adoption of AR. Secondly, different application areas for AR, that could be applicable for asset intensive manufactures, are examined.

In order to perform this study the following research questions have been constructed:

- *What affect the willingness to adopt Augmented Reality, positively or negatively, from an external environmental-, technological-, and organizational perspective?*
- *What type of AR-applications could be useful in an asset intensive manufacturing context and are these applicable today or rather in the future?*

1.3 SCOPE AND DELIMITATIONS

Firstly, this thesis only considers Augmented Reality and do not focus on other substitutional technologies such as Virtual Reality (VR). The justifications to only focus on AR was time limitations, further the prediction that AR is the medium which will provide highest business value for enterprises in the future, compared to VR. Additionally, the precision is that AR and VR will converge in the future.

Secondly, this study is limited to only consider manufacturing companies of complex and expensive products, therefore the findings might not be applicable for other industry's areas. Additionally, as this thesis is carried out on the behalf of the company IFS, who are an enterprise vendor company, the possible application areas of AR are evaluated from IFS customers' point of view, and therefore might not be applicable for all asset intensive manufacturers.

1.4 DISPOSITION

Chapter 1 - The first chapter provides a background and introduction to the topic, followed by the purpose and the research questions of the thesis. After this, a declaration of the scope and delimitations are stated.

Chapter 2 - In the second chapter the theoretical framework that are essential for the further analysis of the research questions in chapter 7 and chapter 8.

Chapter 3 - This chapter provides the reader with understanding of the methodologies used for this thesis and needed in order to answer the research questions. The chapter will also dive deeper into the methods for data collection and the analysis model. Moreover, the quality and the reliability of the thesis will be discussed

Chapter 4 - In the fourth chapter a summary of the external environment is presented. The emergence of the digital and the virtual world, and the trend Industry 4.0 and Servitization is presented.

Chapter 5 - The fifth chapter provides an overview of the phenomena Augmented Reality.

Chapter 6 - This chapter presents the empirical findings but also present the use-cases found for asset intensive manufacturers.

Chapter 7 - The findings are analyzed based from an external environmental, an organizational and a technological perspective in order to answer the first research question.

Chapter 8 - Findings related to the use-cases are then analyzed in order to answer the second research question.

Chapter 9 - In the last chapter the thesis will come to a conclusion and thereby answer the research questions.

2. THEORETICAL FRAMEWORK

The following chapter provides theories relevant to answer the research questions and these theories are: disruptive innovation, technology life cycle, technology ecosystem, network scope, and adoption theories from both an organizational and individual perspective.

2.1 DISRUPTIVE INNOVATION

According to Christensen (1997) disruptive technologies are described as technologies that initially underperforming the dominant ones but at some point in time takes over the established market. He describes that well-established and successful companies were replaced by new ones that from the beginning were small actors who used disruptive technologies as their weapon. He considers that a disruptive technology often offers a different value proposition that existing technologies, and has features that are valuable to some of the customers in the mainstream market but at the same time the disruptive technology is often unattractive to current customer base since it underperforms. However, these disruptive technologies have generally other characteristics such as cheaper, simpler, smaller, or more convenient to use (Christensen et al., 2002). An example of a disruptive technology was the digital camera, which took over the market from the analogue camera (Christensen et al., 2015).

Incumbent firms are bounded by their current customer base, and they focus on satisfying their needs, which in turn prevent them from exploiting new opportunities (Bower and Christensen, 1995). Christensen (1997) makes a distinction between sustaining and disruptive technologies. He considers sustainable technologies to give increased performance of existing services or products. Further, he argues that the most common technology advancements in the industry are of sustainable nature. However, as incumbent actors continuously increase the performance of the technology, it will finally overshoot the required performance. At the same time, as seen in figure 2.1, the performance of the disruptive technology is also increasing and soon it will be "good enough" to compete with the existing technology, but then also with an additionally feature (Christensen, 1997). However, according to Tushman and Anderson (1986), incumbent firms benefit from technological change if it enhances their competence.

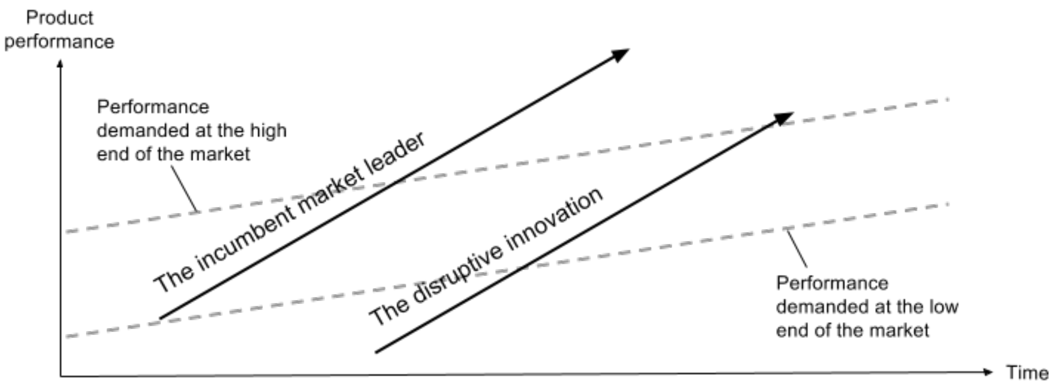


Figure 2.1. An illustration of the technology overshooting (Christensen, 1997).

2.2 TECHNOLOGY LIFE CYCLE

The technology life cycle, presented in figure 2.2, consists of three phases: the fluid phase, the transition phase, and the specific phase (Utterback, 1994). The model describes the rate of innovation in the different phases from two perspectives; product innovation and process innovation. Tornatzky and Fleischer (1990) argue that organizations that are in industries with a high grow rate also tend to innovate more rapidly, meanwhile in mature or declining industries innovation practices are "not clear-cut".

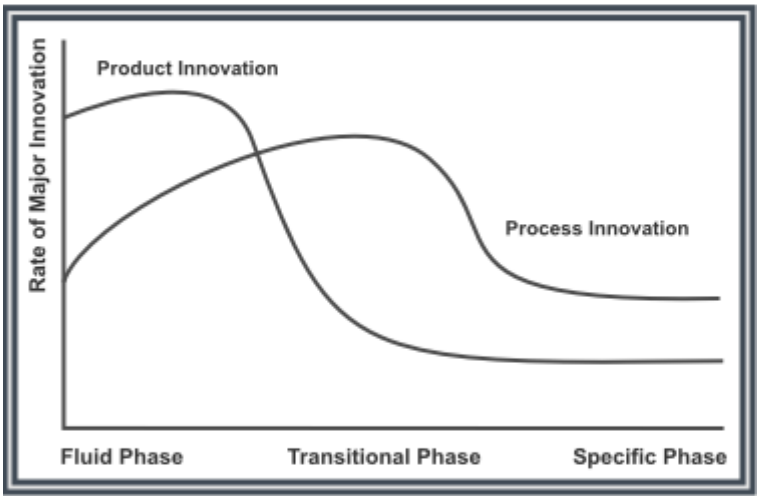


Figure 2.2 The figure visualizes the technological life cycle (Utterback ,1994).

The fluid phase is characterized by high rate of product innovation and low rate of process innovation (Utterback, 1994). Tushman and Anderson (1986) argue that this phase could be related to technology discontinuity, and it could either be competence enhancing or competence destroying. In this phase, there are many different proposed products, due to uncertainties among both users and manufacturers regarding the user's preferences (Klepper, 1996), further new technologies usually create uncertainty, experimentations and entry of new firms (Sandström, 2016). The length of this phase is related to both the amount of new knowledge associated with the innovation and if the existing technology has to be abandoned, since existing firms probably will defend the old technology (Anderson and Tushman, 1990). This further creates an uncertainty related to if the technology will become dominant or not.

The transitional phase is characterized by decreased rate of product innovation and increased rate of process innovation (Utterback, 1994). Klepper (1996) argues that in this phase an industry standard emerges, which means that a dominant design emerges and the number of producers and new entries decreases. However, Anderson and Tushman (1990) argues that the process of choosing a technology could be risky, since if the wrong technology is chosen, that did not become the dominant design, it will result in switching costs.

The specific phase, is characterized by stabilization of product and process innovation (Utterback, 1994). Utterback (1994) argues that instead of focusing on process and product innovation firms typically focus on cost, volume and capacity. However, there is still some product and process innovations but these are characterized by incremental improvement (Anderson and Tushman, 1990).

2.3 TECHNOLOGY ECOSYSTEM

The technology ecosystem consists of different components and technologies that are interdependent. Adomavicius et al. (2006) argue that a technology ecosystem could be very complex since it consists of technologies that have several different relationship and roles. They argue *"In practice, however, a manager is interested in the analysis of a specific set of technologies in a specific context"* (p. 3). Furthermore, Adner and Kapoor (2016) argue that the realized performance of the technology ecosystem and the perception of it can be hindered by the components in the ecosystem. Finally, Moore (1993) argues that competition within technology intensive industries are not taking place between firms, but rather between platforms and ecosystems.

According to Adomavicius et al. (2006) a technology could have three different roles in an ecosystem: component, product and application, or support and infrastructure. The authors describe the *component role* as when the technology is part of a larger system and the system is dependent on the component to function. An example is the processor which needs to be in place for the system to function and could further be a component in different types of systems, for instance in a computer, a phone or in an Augmented Reality device. The *product and application role* associates with a more specific application or use and Adomavicius et al. (2006) describe the role as a set of components, forming a technology, which function is to perform a specific task or satisfy a specific need. An example is a MP3-player which serve as a product, and it competes with other technologies such as CD players. The *support and infrastructure role* describes a technology that supports other technologies, but it is not needed in for the technologies to function. An example is a printer, which provides functionality, but it is not needed for the computer to function.

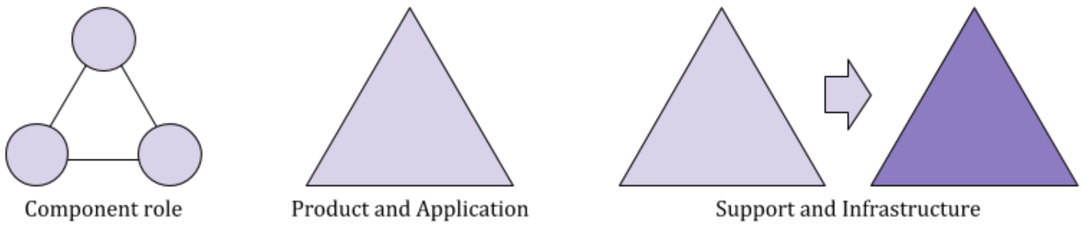


Figure 2.3. A technology's different roles in an ecosystem.

2.4 NETWORK SCOPE

Historically, a firm's scope has either been defined as market or hierarchy, where market involves low customer and partner integration, and hierarchy involves high customer and partner integration. However, industries of today are often organized as complex networks of firms whose integrated effort is necessary to bring customer value (Iansiti & Richards, 2006). Powell (1990) argues that this is neither market nor hierarchy but rather a network scope of organizations. In a network scope the customer and partner integration is neither high nor low, but rather in between, further it provides some flexibility, some scalability and some knowledge transfer. Companies and actors within a network scope are dependent upon each other, further these actors are interdependent.

A network scope has some benefits but it is also associated with challenges such as path dependency, interdependency, collective action problems (Powell, 1990; Adner, 2006), and integration risks (Adner, 2006). Path dependency refers to that decisions made in the past have a tendency to also shape decisions today and in the future. Interdependency refers to the fact that the outcome is beyond one's control since the actor is only a part in a larger system. Collective action problems refer to the fact that all individuals in the network would benefit from a certain action, but the associated cost of achieving the benefit makes it implausible for one individual to undertake it alone. Regarding integration risks Adner (2006) describes that it refers to the risk that not all concerned parties adopt the solution or the risk that the innovation does not reach the target group or customer in-time due to delays in the innovation ecosystem.

2.5 ADOPTION THEORY

There is a difference between theories related to adoption factors at an organizational level (Rogers, 1995; Tornatzky & Fleischer, 1990), and at an individual level (Davis, 1989; Venkatesh et al., 2003). When evaluating the AR technology, it is necessary to examine the adoption both in an organizational and in an individual level since it is the individuals in the organizations that are supposed to use the AR technology. Therefore, both levels, organizational and individual, are presented in the following section.

2.5.1 ORGANIZATIONAL LEVEL OF ADOPTION THEORY

The adoption of a new technology at an organizational level are often more complex compared to the adoption at an individual level since an organization has to consider several aspects (Furneaux & Wade, 2011). The adoption decision has to be made by a group or person in authority (ibid). An organization generates or adopts an innovation often with the objective to increase profit or to improve operational processes (Damanpour and Gopalakrishnan, 1998). Oliveira and Martins (2011) consider there to be two theories commonly deployed for technology adoption at an organizational level. These theories are; the Technology Organization Environment (TOE) framework, and the Innovation Diffusion Theory (IDT).

2.5.1.1 TECHNOLOGICAL-ORGANIZATION-ENVIRONMENTAL FRAMEWORK

The TOE framework explains the organizational adoption of a technology. As figure 2.4 visualizes, there are three elements in the TOE framework that explain the decision to adopt an innovation, namely technological, organizational and external task environment. Tornatzky and Fleischer (1990) state that these elements show "*both constraints and opportunities for technological innovation*" (p.154).

The **technological** perspective considers both internal and external technologies relevant to the firm, including current practices, equipment, and available technologies (Tornatzky & Fleischer, 1990). The authors argue that internal technology has similar or higher effect for facilitating adoption compared to external technologies. Moreover, the cost of adopting a new technology will be significantly reduced if the existing equipment and internal competence in the organization are aligned with the new technology (ibid). Furthermore, Tushman and Anderson (1986) argue that when evaluating a technology that will cause discontinuous change, it has to be considered whether it is competence enhancing or competence destroying. They state that a competence enhancing innovation makes it possible for firms to build on existing expertise, meanwhile competence destroying innovations result in an abandonment of existing technologies and obsolete of expertise.

The second perspective, **organizational**, concerns the internal resource and conditions in the organization that aim to support the adoption (Tornatzky & Fleischer, 1990). According to Chau and Tam (1997) the organization's characteristics normally consider size, formalization, centralization degree, the managerial hierarchical structure, and the skills of the human resources. Zhu et al. (2003) believe that since larger organizations often have sufficiently financial and human resources they have several advantages over smaller organizations. Another important factor is the skillset of the IT employees (Mijinyawa, 2008), since IT employees with sufficient competence and engagement could affect management by demonstrating the benefits of a new technology. Furthermore, management support plays a crucial role and if they do not support the adoption they will be an impediment for the realization of the innovation (Premkumar & Ramamurthy, 1995).

Finally, the **external task environment** perspective relates to the surrounding context the firm is present in, such as business, industry, trends and competition (Tornatzky & Fleischer, 1990). The external environment will influence the technology adoption, and according to Mansfield (1968) a competitive environment stimulates the adoption of innovation. Furthermore, Kamath and Liker (1994) believe that a dominant actor in the value chain could influence other actors in the value chain to adopt a certain technology.

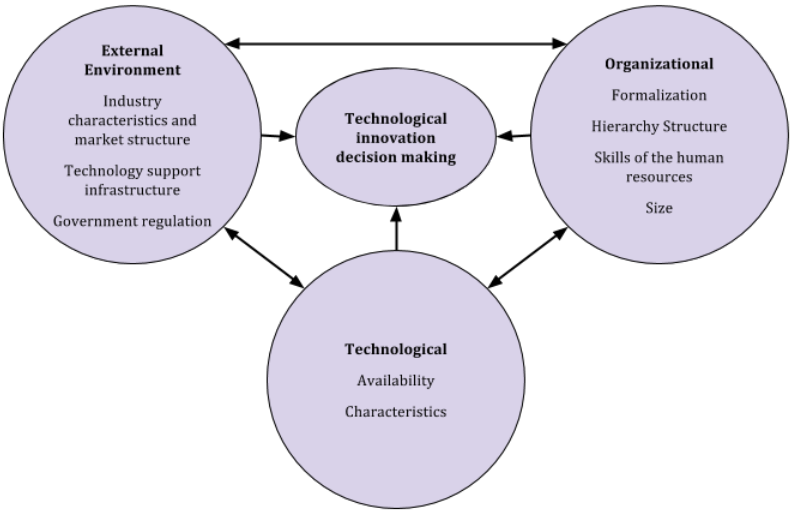


Figure 2.4. The figure visualizes the Technological-Organizational-Environment Framework, and the included factors for each of the perspective (Tornatzky & Fleischer, 1990).

2.5.1.2 INNOVATION DIFFUSION THEORY

The IDT model is the most commonly used theory for studies of IT adoption (Pervan et al., 2005). The model describes the factors related to the incentives to adopt an innovation, but in contrast to TAM model, presented in next section, it also explains the process around it. Rogers (2003) considers theories of diffusion and adoption of innovations to be vital, to understand how, why, and at what magnitude technologies are spread and adopted. He defines diffusion with four important elements; innovation, communication channel, time, and social system. He states, *"the process in which an innovation is communicated through certain channels over time among the members of a social system"* (p. 5).

The innovation decision process, as seen in figure 2.5, could help to foresee the innovation of diffusion over time. However, it is not always true that the adoption of an innovation follows this sequential process and it might be a circular process between the steps in the decision process. Rejection can happen in any stage process according to Rogers (ibid).

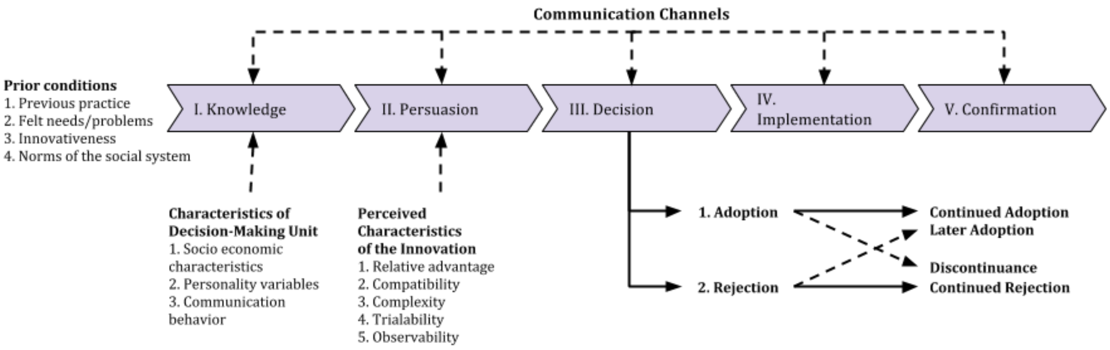


Figure 2.5. Rogers Innovation Decision Process.

Rogers (2003) defines the first element, **innovation**, as *"an idea, practice or object perceived as new by an individual or other unit of adoption"* (p. 12). Rogers (2003) considers that the existing degree of uncertainty about the innovation's functioning, and reinforcement from the social system, are affecting the attitude towards the technology. Further, he considers the adoption rate of an innovation to depend on the persuasion of five innovation attributes, namely relative advantage, compatibility, complexity, trialability and observability. These five attributes can be seen in table 2.1, and they are perceived as innovation characteristics and pertinent attributes to the AR technology. Altogether, Rogers (2003) argues that an innovation which offers relative advantage, compatibility, trialability, observability but less complexity are going to be adopted faster than other innovations. Therefore, he believes that those attributes are vital for the adoption and diffusion process.

Table 2.1 The attributes explaining the rate of adoption of an innovation (Rogers, 2003).

Attribute	**Explanation**
Relative Advantage	the degree to which an innovation is perceived as being better than the idea it supersedes.
Compatibility	the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters.
Complexity	the degree to which an innovation is perceived as relatively difficult to understand and use.
Trialability	the degree to which an innovation may be experimented with on a limited basis.
Observability	the degree to which the result of an innovation is visible to others.

The second element, **Communication channel**, refers to *"a process in which participants create and share information with one another in order to reach a mutual understanding"* (p. 5). The adoption rate of an innovation can increase depending on the effectiveness of the used communication channel (Rogers, 2003). There exist a lot of different communication channels, for example interpersonal communication, television, radio, magazines and channels through the Internet. The communication channels are important for most diffusion processes due to their ability to rapidly spread information to a wide audience. However, advice that comes from close colleagues, peers and friends often have higher credibility and are more convincing, compared to information revealed from outside experts or scientific researches (Rogers, 2003).

The third element, **time**, is involved in many aspect of the technology diffusion process. As an example, time is needed for an organization to decide whether to adopt or reject a technology or an innovation. Rogers (1995) registered that the innovation decision process was not an instant act, but it rather consists of many sequential actions, as seen in figure 2.5. The first step is the knowledge stage whereas the user becomes familiar with the technology and starts to gain understanding of the technology. This phase is associated with the questions *"what?"*, *"how?"* and *"why?"*, these in turn corresponds to three different types of knowledge: awareness-knowledge, how-to-knowledge, and principles-knowledge (Rogers, 2003, p. 21). The awareness-knowledge refers to the awareness of the innovation's existence, and the how-to-knowledge refers to the knowledge regarding how to use an innovation correctly (Rogers, 2003). The last type, principles-knowledge, refers to the knowledge of how and why an innovation works, but according to Rogers (2003) an innovation could be adopted without this knowledge, but it is not favorable for the innovation since it might be misused.

The second step is the adoption process is persuasion, where the user becomes more aware of the technology and takes a favorable or an unfavorable stand-point towards the innovation. The persuasion phase is more feeling centered and regards the individual's creation of a negative or positive attitude towards the technology, meanwhile the knowledge phase is rather cognitive centered. The third step in the adoption process regards the decision, which incorporates the decision of whether to adopt or reject a technology. The fourth step is the implementation and the start of using the innovation. Finally, the fifth step is confirmation, and this is where the user seeks reinforcement of a technology or an innovation decision that already has been made.

The fourth and last element, **Social system**, is where the members of a social system is engaged in joint problem-solving in order to achieve a common goal. Rogers (2003) considers the diffusion of an innovation to be influenced by the social structure of the social system. In other words, for a technology to spread, an adopter of the technology is needed. The adopter then act in, and affect, the social system. Rogers (ibid) argues that there are five categories of adopters, visualized in figure 2.6, and these are; innovators, early adopters, early majority, late majority and laggards. These categories of adopters have different characteristics, especially regarding product need and specific buying behaviors (Moore ,1991).

The innovators are associated with a high-risk tolerance that allows them to adopt innovations that might fail. Furthermore, they can handle unfinished products with high complexity, further provide knowledge regarding problems that have not yet reached the majority. The innovators are the gatekeeper to the early adopter, but they do not influence the rest of the social system to adopt an innovation (Moore, 1991).

The early adopters tend to take the leadership role in the social system and affect others to adapt through advising or by providing information about the technology to others. Moore (1991) argues that the early adopters play a crucial role for the adoption of a technology to begin spreading. To reach the early majority one has to "cross the chasm", which is the hardest part for in a technological diffusion. The early adopter is buying a revolutionary change, meanwhile the early majority is rather buying evolutionary productivity improvements. Further, the early adopters play a key role of funding the development of the technology. The early adopters are closer to the early majority, hence they are important actors in the social system in order to reach the early majority and by therefore important for the diffusion of the technology.

The early majority adopters are not risk takers, and therefore they focus on proven applications and prefer to go with the market leaders. Hence, they require vertical references, such as good references from trusted colleagues or a reference site, which already have the solution in production. Additionally, these early adopters expect a bug free product, an industry standard, and a low cost of ownership (Moore, 1991). As said before, to reach the early majority, hence crossing the chasm, is the hardest part in order for the technology to become mainstream (Rogers, 2003).

The late majority's key role is to extend the product life cycle, further these adopters account for a major part of the social system, as seen in figure 2.6. However, late majority have other needs and characteristics compared to the other actors in the social system, such as avoidance of competitive disadvantages, price sensitivity, and a need of completely pre-assembled solutions (Moore, 1991).

Finally, the laggards are not really a customer and their key role is rather to retard the development of high-tech markets. These actors often take a contrarian position and seeks to block purchases of new technology, since the does not believe on the productivity-improvement arguments (Moore, 1991).

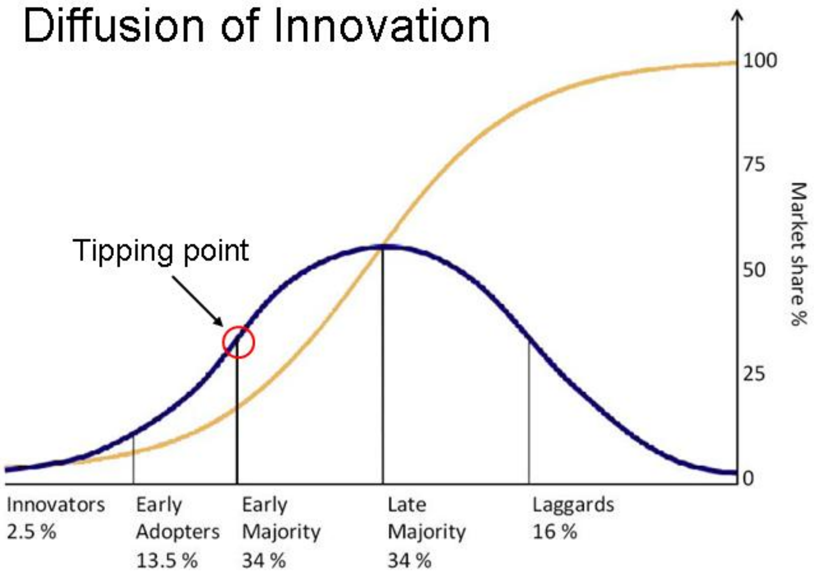


Figure 2.6. Visualization of the diffusion and the different categories of adopters (Rogers, 1995).

2.5.2 INDIVIDUAL LEVEL OF ADOPTION THEORY

One popular model for individual level of adoption is Technology Acceptance Model (TAM), visualized in figure 2.7. The framework explains and predicts the individual's intention and behavior concerning new technologies (Venkatesh et al., 2003; Wang et al., 2003). There are two key variables in the model, and these aims to explain why human accept or reject a technology, and these are; perceived usefulness (PU) and perceived ease of use (PEoU). The definition of PU is "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). Whilst the definition of PEoU is "the degree to which a person believes that using particular system would be free of effort" (ibid).

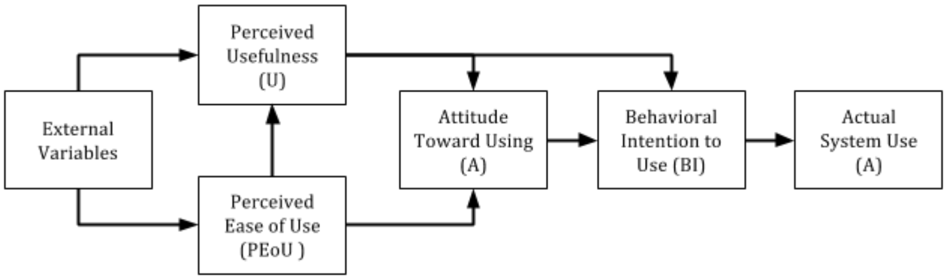


Figure 2.7. The Technology Acceptance Model (TAM)

3. METHOD

Following chapter describes how and why the research was conducted in the way it was. Firstly, the research process is described, which includes the determine of the topic, aim and research questions, the choice of research design, the data collection methods and the used analysis model. Secondly, the quality of the research is discussed.

3.1 THE RESEARCH PROCESS

The research process, visualized in figure 3.1, provides an overview of how the study was carried out. The process consisted of four main steps, and the writing activity was conducted in parallel throughout the whole thesis process. This research process was self-composed, with inspiration from both Easterby-Smith et al. (2015) and Creswell (2003). In the following section, all these steps are explained and justified in terms of how and why the thesis was performed the way it was.

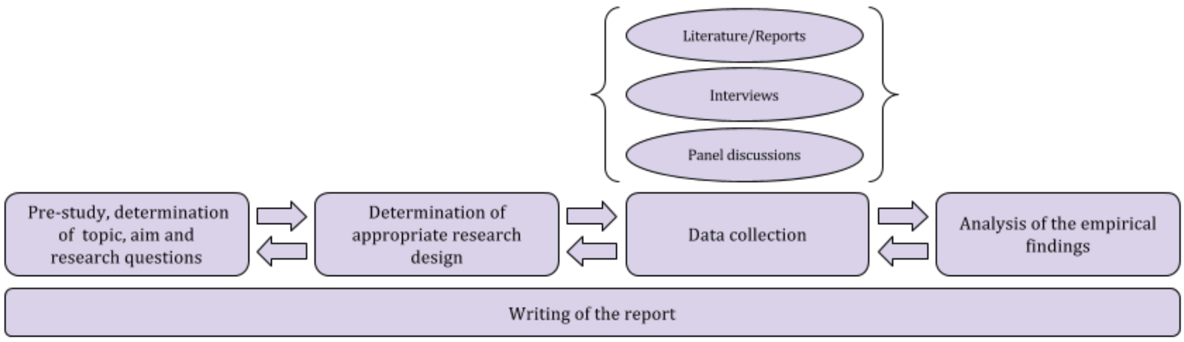


Figure 3.1. The research process used in this research and its included steps.

3.1.1 PRE-STUDY AND DETERMINATION OF THE TOPIC, AIM AND RESEARCH QUESTIONS

The company Industrial and Financial Systems (IFS) were the principal of this thesis. IFS develop and deliver enterprise software systems for customers around the world, and these customers manufacture and distribute goods, maintain assets, and manage service-focused operations. IFS offer many different enterprise software solutions and these are offered in a modular design, meaning that customers can pick and choose between different solutions to best fit their specific organization. The whole package is called IFS Applications business software and it provides Enterprise Resource Planning (ERP) functionality, including Customer Relationship Management (CRM), Supply Chain Management (SCM), Product Lifecycle Management (PLM), Enterprise Operation Intelligence (EOI), Enterprise Asset Management (EAM), and Maintenance Repair and Operation (MRO) capabilities. IFS strive to always stand in the forefront of offering their customers useful and relevant technology. For that reason, IFS were interested to examine the upcoming technology AR, which also became the topic of this master thesis.

First, a pre-study was conducted in order to get a brief understanding of AR from a business perspective. Where after, together with IFS, the initial aim with the research and the research questions were determined. As the knowledge base of the thesis author's increased during the thesis process, both the aim and the research questions have been revised several times. The hardest part was to set the scope of this thesis, since IFS have customers in many different fields, industries and regions. This, in combination with the opportunities found regarding the AR technology, made it difficult to decide where and how to focus. In addition, the time was limited for this thesis, and therefore it was a possible tradeoff between finding the best opportunities by working broad, or perform an in-depth study and find the most important details in a specific field. However, since the AR technology is new and not commonly used among enterprises, a relatively long explorative phase was considered suitable in this case.

3.1.2 DETERMINATION OF THE APPROPRIATE RESEARCH DESIGN

After determined research topic, aim and research questions, the research design was chosen. Easterby-Smith et al. (2015) consider it important to focus on the research design in order to conduct a high-quality research, and for the research objectives to be met. A research design could be helpful since it is a roadmap for how to answer the research questions (Saunders et al., 2012; Krishnaswamy & Satyaprasad, 2010). Additionally, Easterby-Smith et al. (2015) explain that the research design also incorporates explanations and justifications about what data to gather, how and where from. Furthermore, the research design explains how the data will be analyzed and how this will provide answers to the research questions. Therefore, a planning session were conducted in order to set an appropriate research design for this thesis.

Easterby-Smith et al., (2015) argue that during a constructionist research design, qualitative research is often used, since several truths may exist. Furthermore, Bryman & Bell (2015) consider that a qualitative research strategy use words in the data collection, and analyze the data in order to acquire a deeper understanding. This research did not aim to measure anything but rather to get a deeper understanding of AR and asset intensive manufacturers, further there were no predetermined results and many truths could exist. Therefore, the authors found it appropriate to use qualitative research strategies and methods. Furthermore, this thesis aimed to understand how and why asset intensive manufacturers could use AR. Therefore, the data have been collected from several different individuals with different fields of expertise. In accordance, Easterby-Smith et al. (2015) argues that the data collection for a constructionist research design should incorporate experiences and views from different individuals and observers.

Several different approaches and strategies for how to conduct a research exists. The most common distinction is between a qualitative and a quantitative approach (Bryman & Bell, 2015). The main difference between these approaches is that a quantitative approach uses quantification in the data gathering and analysis of data in order to find statistical correlations, meanwhile a qualitative approach does not quantify the data. In this thesis qualitative approaches have been used since the aim was to get a deeper understanding of the situation rather than finding statistical correlations. However, as Creswell (2003) argued, both qualitative and quantitative research strategies have weaknesses and strengths, and therefore a combination of both could have been used to neutralize biases. Furthermore, the combination of qualitative and quantitative research strategies is considered a mixed method strategy (Easterby-Smith et al., 2015). Therefore, the fact that this thesis only used a qualitative approach could affect the trustworthiness of the research. However, since the AR technology is relatively new, at least in a manufacturing context, there are still limited statistics and quantitative generation opportunities. Therefore, a mixed strategy was not seen as appropriate for this master thesis.

3.1.3 DATA COLLECTION

Both primary and secondary data have been used in this research. Primary data was collected by in-depth interviews and participations at fairs, and secondary data was collected by literature review from a numerous of sources, and by listening to panel discussions and podcasts.

The findings regarding AR and associated context, are presented in chapter four and chapter five, meanwhile the findings from the interviews and the panel discussions are presented in chapter six. In chapter six, section 6.2, the potential use-cases for augmented reality in a manufacturing context are presented, and in this section, we found it more intuitive to not distinguish primary and secondary data and instead provide a collective view of the use-cases. Therefore, this section includes, literature findings, and findings for the interviews and the panel discussions.

3.1.3.1 LITERATURE REVIEW

After the research design was chosen a comprehensive literature study was performed. Easterby-Smith et al. (2015) argue that in a literature review researchers describe, evaluate and clarify what is already known about the topic. In other words, literature review is a tool to learn about existing research. Hence, to extend the authors' knowledge-based regarding the subject area. The literature review was performed regarding the topic of AR and AR in a manufacturing context, further regarding manufacturers' current problems, Servitization and Industry 4.0. Findings from the literature review presents in chapter four and chapter five.

To compile the theoretical framework, a research was conducted in order to find suitable theoretical models and methods. The theoretical framework aims to provide suitable theories to use in the analysis and thereby being able to draw conclusions from the empirical findings and in order to fulfill the research's purpose. Theories used for the theoretical framework was: disruptive technology, technology life cycle, technology ecosystem, network scope, and adoption theories. Easterby-Smith et al. (2015) consider a literature review to be a continuous process, which was also true for this thesis work.

To find appropriate literature for the thesis, several databases and many different sources was used. This was important in order to expand both the viewpoint of the topic and to get variations regarding literature. The academic databases that were used were; Gartner, Google scholar, Chalmers University of Technology library's own search engine *Summon*, and so forth. Form these several academic papers were collected. Additionally, reports from different management consultant firms were used within this thesis. Moreover, other medias, such as podcasts and YouTube, were used in order to get a broader understanding of the topic, in order to gain a more realistic and visual understanding. The podcasts used were VR-podden and Voice of VR podcast - Designing for Virtual Reality.

3.1.3.2 INTERVIEWS

Primary data were collected in order to gain a greater knowledge of the asset intensive manufacturing industry, the potential adoption AR, and the usage of AR. This data was primarily collected by in-depth interviews, but also by interviews with experts at several fairs. Easterby-Smith et al. (2015) consider interviews to be the most commonly used method to carry out a qualitative research method. They argue that information such as ideas, thoughts, values, behavior and other valuable data can be collected through interviews. According to them interviews are the best way of gathering information, but it may also be more difficult and complex than first considered. Furthermore, in-depth studies are said to be optimal for collecting data such as individuals' perspectives, personal histories and experiences (Mack et al.,2005).

The interviews were semi-structured, which is a combination of a structured and an unstructured approach (Easterby-Smith et al., 2015). This means that the interviews had a pre-determined structure but allowed for flexibility, further the interviewees could answer the questions freely. Creswell (2003) points out that this way of working could generate more and deeper information from the interviewees. As mentioned previously, interviews had different focuses, this was since the interviews aimed to answer different research questions, whereas the interview for the second research were more specific and structured. All interviews were conducted continuously during the research process and the different interviewees are presented in table 3.1.

Table 3.1. Interviewees conducted for this thesis.

Name	**Company**	**Title**	**Other information**
Olle Alvemark	IFS	Industry director for Manufacturing in IFS Scandinavia	
Anthony Bourne	IFS	Global Industry director for High-tech and Manufacturing	
Colin Beaney	IFS	Global Industry Director for Energy and Utilities	
Mark Brewer	IFS	Global industry director for Service Provider	
Ulf Stern	IFS	Co-founder of IFS	
Dan Li	Chalmers University of Technology	PhD Student, div. of Production Systems, Product and Production Development.	
Marcus Enered	Volvo Group Truck Technology	Innovation Manager	Project regarding visualization of CAD-models in AR.
Tony Gustavsson	Volvo Group Construction Equipment	Manufacturing Engineering coordinator of Operations in Europe	Project regarding smart work instructions in AR.
Oliver Edsberger	HiQ	Business Unit Director Visualization (VR/AR)	Manage projects regarding VR/AR in asset intensive manufacturing companies
Torbjörn Gustafsson	XmReality	Co-founder of XmReality	AR remote guidance company
Bertil Thorvaldsson	ABB Robotics	Global Product Manager for Software Products	Projects regarding AR

3.1.3.3 PANEL DISCUSSIONS

Information from two panel discussions are incorporated in the thesis. The first of the panel debate was seen live at the Electron fair in Gothenburg, and the participants in this one are presented in table 3.2. The second panel discussion, Tech trends in Augmented/ Virtual Reality at the transforming manufacturing fair in San Francisco, was streamed over the Internet, and the participants are presented in table 3.3. Participants in both panel discussions were either manufacturing experts, researchers, AR-experts or similar, and therefore valuable information was provided from both discussions. In contrast to interviews, the authors consider that a panel discussion could bring additionally information, since experts in the field exchange knowledge with each other. The participants could possibly spur each other and highlight aspects that during an interview would not have been detected. A potential drawback, compared to interviews, could be that one cannot lead the discussion. However, in the end of the panel discussions there were time for questions from the audience.

Table 3.2. The participants from the Virtual Reality panel discussion

Virtual Reality panel discussion, Electronic fair, Svenska mässan, Gothenburg, 8th of mars 2017.		
Name	Company	Title
Viktor Peterson	CLVR Works	CEO
Tobias Fröberg	BoldArc	CEO
Elena Malakhatka	KTH	Ph.D. research
Carina Sundqvist	IBYR	Digital strategy
Oliver Edsberger	HiQ	Business Unit Director Visualization (VR/AR)
Jonathan Tiedtke	VR Vision	CEO
Steve Hogan	VR Safety	Director

Table 3.3. The participants from the Tech trends in Augmented/ Virtual Reality panel discussion

Tech trends in Augmented/ Virtual Reality, Transforming manufacturing, Galvanize, San Francisco, June 22nd 2016		
Name	Company	Title
Dr. Mohsen Rezayat	Siemens PLM	Chief Solutions Architect
Nathan Christensen	Orbital ATK	Senior manager
Matt Miesnieks	Super Ventures	Partner
Matt Kammerait	DAQRI	Vice President
Mike Pegler	PwC	Partner

3.1.4 ANALYSIS

The analysis model, presented in figure 3.2, aims to find consensus regarding the literature findings and the empirical findings. As seen in the figure, the analysis was carried out in two steps. The first step consisted of analyses of external environment, the AR technology, and organizational impediments and facilitators for an AR-adoption. This analysis aimed to answer the first research question *"What factors affect, positively or negatively, the willingness to adopt Augmented Reality?"*. Based upon the first analysis, the second analysis aimed to answer the second research question *"What type of AR-applications could be useful in an asset intensive manufacturing context and are these applicable today or rather in the future?"*. In the second analysis the findings from the first analyses were combined with the empirical data of use cases, presented in section 6.2. For each case, it was evaluated if the specific case was applicable today or rather in the future. Additionally, the specific facilitators or impediments for realization of the specific use-case, were also identified and analyzed.

The analysis model was based upon the adoption theories presented in chapter two and these are; Technological Organizational Environmental Framework (TOE) and Innovation Diffusion Theory (IDT). The TOE framework was used for the first analysis to provide insight from an external environment, technological and organizational perspective. Further, the IDT was used to provide a more comprehensive analysis for each of these perspectives. For the second analysis only the IDT model, and especially the stage persuasion, were used, in combination with the findings from the first analysis. In addition to the TOE and IDT, the other theories, presented in chapter two, were also taken into consideration for both of the analyses.

External factors include the industry trends; digitization, Industry 4.0, and Servitization. Furthermore, external factors account for the fact that the organization operates in a network that consists of different actors who are interdependent of each other.

Technology factors includes factors derived from AR. These regards the technological components and the technological ecosystem. Furthermore, factors related to the AR experience, for instance application, content etcetera.

Organizational factors include technical and non-technical factors that might affect adoption, positively or negatively, from both an organization's point of view and for an individual's point of view.

The use-cases was analyzed from the factors; relative advantage, compatibility, complexity, trialability and observability, and were based upon the thesis authors' collected understanding of the adoption of AR for a specific application in a specific context.

A limitation of this research is that a test of the specific areas/ use cases within an organization could not be conducted and thereby truthfully analyzed. Therefore, any further analysis of the decision of adoption, and analysis of an individual's attitude towards using the technology, could not be made for a real use case. However, alternative ways to investigate specific use areas have been used instead of testing in reality, and the information have been collected by the interviewees previous experiences and expectations.

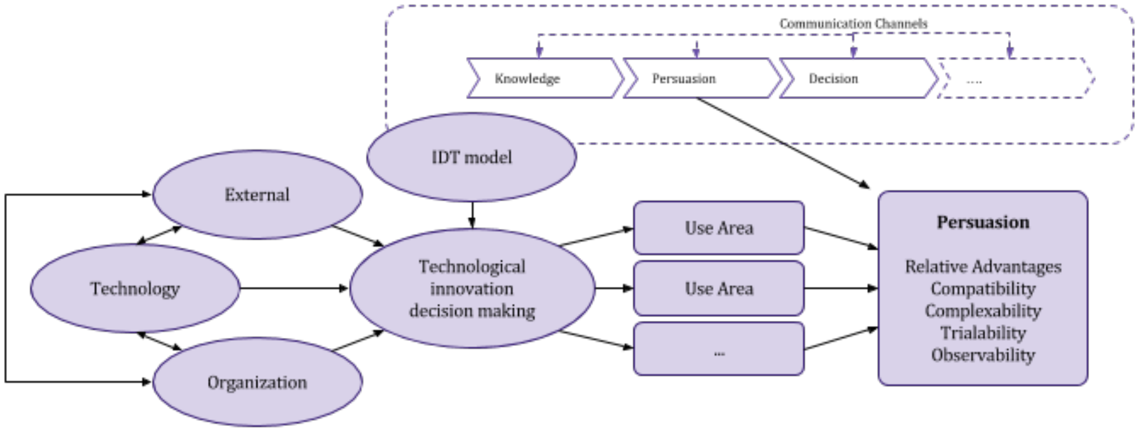


Figure 3.2. The analysis model used in the research, consisted of the TOE, IDT, and TAM framework.

3.2 QUALITY OF THE RESEARCH

In this section, the quality of this study has been evaluated.

3.2.1 VALIDITY AND RELIABILITY

It is not possible to completely validate a research, but it is possible to claim that the research has strong validity (Drost, 2011). Depending on the researcher's standpoint, positivist or constructivist, they are likely to use different criteria for judging the quality of the study. Furthermore, the researcher's viewpoint will affect both, how their own research is designed but also how they judge others' work. From a positivist viewpoint validity should consider the question "*Does the design make it possible to eliminate plausible alternative explanations?*" (Easterby-Smith et al., 2015, p.103). In contrast, for a constructivist viewpoint validity should consider the question *"Have a sufficient number of perspectives been included?"* (ibid). Further, while considering reliability the main questions is *"Will similar observations be reached by other observers?"* for a constructivist viewpoint and *"Do the measures used provide a good approximation to the underlying concept of interest?"* for a positivist viewpoint (p.103). As this thesis is conducted from a constructivist viewpoint the aspect of validity and reliability are discussed from that perspective.

To incorporate a sufficient number of different perspectives within this research, the authors have conducted a literature review and compared this with findings from panel discussions and interviews. It is impossible to be certain that research findings reflecting reality. However, by interweaving several different persons with different expertise and background, and collect material from many different sources it is easier to be more confident that a more realistic view has been found. The above reasoning supports that the thesis authors have tried their best to gain a deeper understanding of AR in an asset intensive manufacturers context. However, issues that arose during the literature review process was regarding the technology's rapidly development. The fact that the market continuously is changing makes it difficult to be up-to-date and use the latest information. Questions that were considered were for example: *Are articles out of date if they are over one year old? Will this thesis be less valid when it is finished compared to when the material was collected?* During this thesis, an information search has been made continuously, but the authors cannot be ensured that the material is up-to-date and valid, since the amount of information on the Internet is massive and the technological development is improving rapidly.

To strengthening the validity, and to avoid leading questions, the interview questions were revised several times before an interview was conducted. According to Mack et al. (2005), leading questions are formulated in a way that could influence participants' responses. Such questions risk to bias and imposing a perspective on participant's answer. Furthermore, in the beginning of an interview the respondent was asked if he or she wanted to be anonymous. Mack et al. (2005) consider that asking participants about confidentiality is important in order to earn their trust and thus eliciting good data. Contradictory, the interviews were recorded, and according to Mack et al. (2005) this could make the interviewees uncomfortable, and therefore not reveal the whole truth. However, by ensuring the participant that the recording only would be used for transcription purpose, further being deleted after the work is finished, mitigated this risk. Hopefully, the recording has not affected the validity of the research but this cannot be ensured. The recordings of the interviews were made in order to being enable to listen to the interviews again in a retrospective, and thereby conduct better and more trustworthy transcriptions. This made the empirical finding more reliable since the material could not be interpreted in such way as if it they only would be based on memories or unclear notes.

3.2.2 CREDIBILITY OF THE SOURCES

Today, there is an information overload and therefore the authors have had a critical standpoint when selecting and analyzing the collected information. Furthermore, the information gathered might be misinterpreted and thereby influenced by both the sender and/or the receiver (Carlsson, 1995). On the one hand, the information that has been selected was derived from mainly well-cited articles and literature released by reliable sources, this in order to make a trustworthy study. On the other hand, the reliability of a source is subjective and thus it depends on the judger of this thesis to consider if there are credible sources or not.

To get a better understanding of the manufacturing context, interviews have been conducted with Industry directors at IFS. This could bias the result of the research since the interviewees are employed by the company who supervise this research. However, IFS are successful when their customers are successful. Therefore, IFS must have a good understanding of what their customers' problems are, and it is these issues that have been taken into consideration in the report. However, the directors might have influenced the direction of the report and therefore there is a risk that the information about asset intensive manufacturers is biased and not reflects a realistic view of the reality. Amongst companies and AR experts, only early adopters and visionaries have been interviewed, due to the lack of knowledge and experience of the technology in a real context. Since these respondents might have a too enthusiastic or visionary viewpoint on the subject, this could increase the risk for bias in the research,

Interviewees that were experts in the field of AR were firstly found through research of the topic, and later on by further recommendations of those people. Additionally, an email was sent out amongst members in the visual arena network at Lindholmen Science Park, in Gothenburg, Sweden. Visual Arena is an open and neutral collaboration platform for the development and use of visualization in Gothenburg. From this email, the thesis authors came into contact with many different persons that had experience or knowledge about AR. In this case, the difficulty was rather to choose whom to talk to, since all could not be interviewed due to time limitations. The authors considered this method to have both pros and cons, since one risk is that the researcher miss a certain viewpoint, but at the same time these experts would probably not have been found without this method.

4. EXTERNAL TRENDS

The following chapter describes trends that affect asset intensive manufacturers. Firstly, the convergence of the physical and the virtual world is presented. Secondly, the servitization trend is described, but also the adoption of new technologies in a servitization context, and lastly, the Industry 4.0 trend is described.

4.1 CONVERGENCE OF THE PHYSICAL AND VIRTUAL WORLDS

Since the development of personal computers in the 1960s the modern society has evolved through a revolution in a digital context (PwC, 2016b). Nowadays it has become possible to store, create and retrieve information rapidly and in real-time. These abilities, combined with network interconnection and accessible computers, laptops, tablets and smartphones, have led to several inventions and innovations, which have increased the accessibility to information. According to PwC (2016b) recent researches show that businesses are experiencing an information overload and this has further generated a cognitive overload of worker's abilities to *"make decisions, process information and prioritizing tasks"*.

Nowadays, we take it for granted that people are available both in the physical world and the digital world, but it has not always been like this. PwC (2016b) argue that the movement between the physical and the digital world has increased in frequency. From the beginning workers were incorporated in the digital world through computers at the workspace, this was followed by the introduction of the personal computer, hence the digital world was brought home in the everyday life. Smartphones and tablets have increased the frequency of movement even further and today's generation is constantly moving between the physical and the digital world. However, we have been doing things differently in the physical and the digital world, for instance interaction have been made through keyboards and mousses in the digital world and in the physical world by gesture and voice. Therefore, we have been forced to learn how to handle both of these worlds simultaneously but in different ways (PwC, 2016b; Deloitte, 2016; Goldman Sachs, 2016). PwC (2016b) believe that the diverging of these two worlds and the increasing volume of information are the reasons to the cognitive overload. However, PwC (2016b) argue that a tool that has the ability to merge the physical and virtual world will reduce the cognitive burden, since there is no need to change focus between the both worlds.

4.2 INDUSTRY 4.0

Industry 4.0, also called the 4th Industrial revolution, refers to the digitalization, and integration, of all physical assets in the ecosystem and throughout the whole value-chain (PwC, 2016g). This includes *"integration and digitalization of horizontal and vertical value chain"*, *"digitalization of products and services"*, and *"the formation of digital business model and customer relationship"* (p. 6). Monostori (2014) argues that companies try to obtain totally collaborating entities that exchange data regarding their ongoing processes. Further, this data comes from both the digital and physical world and the collaboration is facilitated by the use of data-accessing and data processing services provided on the Internet. The idea is that it could result in smart-networks, -cities, -production systems, -communication and -products (ibid).

Industry 4.0 is based on cyber-physical production systems (CPPS), which merge the real and virtual world (Deloitte, 2015). CPPS enable smart communication by linking IT with mechanical and electronic components, these can thereby communicate with each other (ibid). Monostori (2014) argues that CPPS could enable and support the interaction and communication between machines, humans and products alike and the fundamental concern regards "*explore the relations of autonomy, cooperation, optimization and responsiveness"* (p. 10).

The characteristics of Industry 4.0 are interoperability, information transparency, decentralization, real-time capability, service orientation and modularity (Gilchrist, 2016). ISRA & Acatech (2013) argue that an Industry 4.0 initiative has huge potential in several areas such as; individual customer requirements, flexibility, optimized decision-making, resource productivity and efficiency, and finally creating value opportunities through new services.

However, to obtain the aim of Industry 4.0, and to receive the potential benefits of it, several different technologies and components have to be successfully implemented, and one of these technologies is Augmented Reality. Additionally, technologies that are important for Industry 4.0 are presented in table 4.1. In addition to technologies, the work organization and design, but also the training, have to be changed, due to new skills and new work-tasks' requirements (ISRA & Acatech, 2013).

Table 4.1. Technologies identified as important for the enabling of servitization

Technology	**Description**
System Integration	Several independent systems are interlinked with each other in order to work together.
Simulation	The ability to simulate or visualize data and systems.
Big Data	The large amount of data that is collected and stored today and the difficulties of using traditional database tools to process this large amount of data.
Internet of Things	Connectivity between everything, from machines and tools to home appliances. It is based on the integration of sensors and processors within these things. By this the things could communicate with each other by the use of the Internet or by being physically interlinked.
Cloud Service and Cyber Security	The ability to store and process data by the Internet on a distance service, called cloud, instead of on a local server or computer. This raises questions regarding Cyber Security, for instance examination of access permission and the safety of cloud storage and processing.

4.3 SERVITIZATION

Servitization is a widespread phenomenon which means that the industry shift their business models to add or incorporate service in their offerings (Cambridge service alliance, 2015). Vandermerwe and Rada (1988) explain servitization as *"increasingly offering fuller market packages or "bundles" of customer-focused combinations of goods, services, support, self-service and knowledge*" (p.314). The process of offer services instead of products can be a game changer (Baines & Lightfoot, 2013), since there is a huge difference between products and services. Jagstedt (2016) explains that a product is tangible, and made or manufactured meanwhile a service is intangible and "everything else". Further, she explains that a service is heterogeneous (high variety of services), perishable (it cannot be saved or stored), and it characterizes by the simultaneous production and consumption. However, servitization as a concept is nothing new and Schmenner (2009) argues that servitization goes 150 years back in time even if the concept of "servitization" was coined in 1988 (Vandermerwe & Rada, 1988).

According to Jagstedt (2016) there is two ways for a company to move into a solution provider. The first is to add service upon the product. In this case, the focus should be on adding services that could be linked, but not integrated, with the product. Examples are services as repair, training, maintenance or finance. The other way, or the next step, is to integrate product, service and knowledge in the offering. The focus should in the latter case be on the customer's processes, results or usages. Additionally, the integration of product, service and knowledge could create value surplus. Examples of such character could be to optimize the customer's flow, facilitate the customer's processes, or manage the customer's activities. In a research by Baines & Lightfoot (2013), regarding companies who are in the process of changing their business models towards service focus, they found that suppliers often offer a product as a basis and as a service they incorporate the overall responsibility for the solution. This means that the supplier maintains, optimizes and provides functionality for their customers.

The revenue is based on the outcome or value for the customers, and the supplier is compensated accordingly, meaning the customer's value of using the offering. Baines & Lightfoot (2013) argue that this way of doing business opens up for longer contracts with long-term relationships. Furthermore, it could create a lock-in effect, which in turn could generate stable revenues (ibid). As seen above, there are different forms of services offerings. However, Jagstedt (2016) believes that optimally the combination of product and service should depend on the customer's overall needs and that is all about selling a solution. Jagstedt (2016), based on Baines & Lightfoot (2013) work, gave an example of Rolls-Royce, who transformed from a product to a service provider. They changed from providing Aero engines as a product to flying hours as a service, and for Rolls-Royce this meant that the new offer incorporated maintenance, logistic management, repair and overhaul of the engines instead of only engines as before.

Baines & Lightfoot (2013) argue that the servitization transformation is a challenge and many companies fail to gain the benefits that service solutions could offer. According to Martinez et al. (2010) and Brax (2005) this is due to the different way of doing business, which incorporates everything from management to sales, R&D, and service. Jagstedt (2016) argues that manufacturers have major difficulties in the transformation towards servitization due to the change in business model. However, in comparison to pure service providers they have a competitive advantage. The reason is that service providers have to integrate a product in their offering, meanwhile manufacturers have to integrate a service, but they already own the product basis and the associated knowledge.

Cambridge Service Alliance (2015) concluded that technology plays an increasingly important role for the enabling of services and servitization. They argue that if firms can identify and utilize technologies that support servitization these firms can stay in the forefront of the market. Further, they argue that the emergence of new capabilities and technologies enable more complete and advanced service options. To allow full employment of technology they believe that, organizational change, the culture and internal mindset, and the organizational infrastructure must be aligned. In the research, several technologies were identified as important for the enabling of servitization and some of those technologies are presented in table 4.2.

Table 4.2. Technologies identified as important for the enabling of servitization.

Technology	Description
Predictive analytics	To predict the future state of a product, such as predict specific failure mode of equipment or machines.
Remote communication	Related to the technology's ability to "receive, store and transmit data remotely and would enable someone to remotely adjust, fix or send software updates to machines/ products" (p.9).
Pushing information and mobile platform	Technologies to facilitate communicating with customers and access data for ERP activities.
Analysis of existing datasets	Relates to findings of causality and patterns of failure in contrast to an ordinary trend tracking technology.
Dash boarding	Make services more tangible and visible by highlight issues, provide possible strategies to address problems, and support human-decision making in a service systems.
Positional tracking	Concerns tracking of machines, products, people or components via GPS or Geo-spatial technologies.
RFID and 3D barcodes	Enables storing of information associated with the product when used throughout the whole supply chain.
Sensor network integration	Integration of sensors in assets and components

4.3.1 ORGANIZATION'S ADOPTION OF TECHNOLOGIES IN A SERVITIZATION CONTEXT

Cambridge Service alliance (2015) investigated the drivers for adoption of technologies with the aim to give insight regarding the main trends that drive technology adoption by Capital Equipment Manufacturers (CEMs). The top five drivers were; generate new revenue source; improved maintenance efficiency and effectiveness; demand for increased data gathering including smart sensors with network capabilities, GPS and mobile phones; improving product performance; and increased/ improved access to information.

According to Cambridge Service Alliance (2015), CEMs lag in their adoption of technologies and thereby also in the adoption of integrated product-service technologies. The authors argue that this is due to both struggles to identify relevant future technologies and slow internal adoption of technologies. Furthermore, they argue that the focus amongst CEMs is mostly often technologies that improve the product performance and the authors believes that there is a lack in focus on revenues from the aftermarket business.

5. AUGMENTED REALITY

Firstly, the following chapter provides a description of the real and virtual environment, the differences and similarities between AR and other similar technologies, and further how AR is defined. This follows by a description of the elements included in an AR experience, and the current limitations and concerns related to these elements. Thereafter, the industry landscape of AR, and organizations' current adoption of AR, are described.

5.1 THE REAL AND VIRTUAL ENVIRONMENT

The environment of today could be described as real, mixed or virtual, as visualized in figure 5.1. The real environment is our physical world and the virtual environment could be explained as our digital world, or with other words, Virtual Reality (VR). The mixed environment or Mixed Reality (MR) is a combination of the real and virtual environment.

Milgram (2016), the founder of the "virtuality continuum", describes MR to be a spectrum that involves the whole range of realness between fully real and fully virtual environment, he states that MR is a superset of Augmented Reality (AR) and Augmented Virtuality (AV). Further, he argues that the mixture of reality and virtuality classifies whether it is AR or AV. However, the definition of AR, AV and MR is not generic and several contradictory descriptions could be found. Some argue that AR, AV and MR are interchangeably and the term used is rather based on the current trend, meanwhile other argue that there is a distinction between AR/AV and MR (Foundry, 2016). Those who argue for a distinction state that the content from the real world and the content from virtual-world are not able to interact and respond to each other in AR/AV, meanwhile this is possible in MR (ibid). However, in this research the terms AR/AV and MR are interchangeably but the term used is AR, since it current is the most commonly used term.

Figure 5.1 The spectrum from real to virtual environment

AR is described as a not fully immersive media, where the real world is enhanced with virtual elements in real-time. This means that AR enables a direct or indirect view of a physical, real-world environment combined with augmented elements, for instance the user is presence at the physical location of the AR-experience as stated in table 5.1.

VR is also, as AR, an upcoming and hyped technology, but there are important differences between these technologies. VR is described as a fully immersive media, where the real world is replaced with a simulated one. This means that the user interacts with information in an unreal and simulated world. Craig (2013) explains that even if the VR technology can track the user's location, to generate an appropriate vision on the screen, it is not always true it will display the user's specific location, in contrast to AR. General differences and similarities between AR and VR are presented in table 5.1.

Table 5.1 Distinctions between AR and VR. Source: (PwC, 2016a).

Feature	**Augmented Reality**	**Virtual Reality**
Presence: The user is at the location of experience	Yes	No
Real time: The user is interacting in real time with the environment	Yes	Yes and No
See-through capabilities	Yes	No
Movement: The user can physically move in the environment	Yes	No

5.2 DEFINITION OF AUGMENTED REALITY

In AR, information is provided in registration to the physical location, and, as seen in table 5.1, the user "remains" in the real world, but the real world is augmented or enhanced by a virtual objects or information. The idea of AR is that the user could use his or her senses, such as being able to see and hear, in the same way as in the real world (Craig, 2013). In its simplest form, the game "Pokémon GO" could be used as an example of AR. In this game, a Pokémon appears on the user's smartphone-screen based upon his or her location and the Pokémon is further displayed on a view of the physical world.

Craig (2013) defines AR as "a medium in which digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world and that is interactive in real time" (p.36). From another point of view, Oxford's dictionary (2016) defines AR as "a technology that combines computer-generated images on a screen with the real object or scene that you are looking at".

In summary AR could be characterized by following characteristics (Ma et.al, 2011; Craig, 2013):

Relation to context: The physical world is augmented by digital information superimposed on real objects in a view of the physical world. Hence, it is dependent on the registration or the location of the real world, further the user's specific perspective of the physical world.

Real-time capability: The information is displayed in registration with the physical world in real-time.

Interactivity: The AR experience is interactive. The information or objects are displayed in an intuitive way and the user could sense it and make changes to the information provided. The level of interaction could be simple, such as changed user perspective, and more advance, such as manipulation and creation of new information.

5.3 ORGANIZATIONS' ADOPTION OF AR

As have been described, AR merge the real and digital information and the user could thereby interact with the information in the same ways as in the real world and it lets the users to interact with both worlds simultaneously (Craig, 2013). In other words, AR will merge the physical and digital world with a seamless integration (PwC, 2016b; Kipper, 2012; Deloitte, 2016). Furthermore, AR will give rise to new and novel ways to filter and contextualize the information given to the user (PwC, 2016b; Deloitte, 2016), and PwC (2016b) point out that one way to handle the cognitive overload is to use AR and thereby reduce the cognitive burden by filtering and contextualize the information presented to the user. Finally, AR opens up for a new lens on business activities (ibid). PwC (2016b) argues *"people look at operations from a combined view of digital and physical operations and externalize the cognitive burden that is inherent in the task"*. Additionally, Goldman Sachs (2016) argue that AR could create a change in current business models and further change the ways in which we transact.

PwC (2016h) argue that AR/VR are heading towards mainstream adoption, further they believe that US manufacturers probably will experience a need to adopt AR in order to compete in the future, due to the improvements the technology demonstrate within several areas, for instance productivity and product development. However, currently manufacturers are using AR *"pretty much any way they can"* (PwC, 2016h, p. 4). Furthermore, there are still some concerns that have to be addressed in order to spur the adoption and Goldman Sachs (2016) argue "*We view the user experience, technology constrains, the development of content and application, and price as key hurdles to adoption*" (p. 4).

According to Goldman Sachs (2016) consumer, enterprises and public sector will drive the adoption of AR. This could be compared to PC and smartphones, where companies were the drivers of PC and consumers the drivers of smartphones. They further believe that when the AR technology matures stronger enterprise use cases will emerge. As seen in diagram 5.1, most US manufactures in 2015 planned to adopt AR, and one out of ten were at that time adopting AR (PwC 2016h). However, in comparison with diagram 5.3, it could also be seen that almost three of four respondents thought that less than 25% of the US manufacturers will adopt AR before year 2025.

In PwC's research, it could be seen that one of five respondents not adopting AR experience a lack of practical use of AR-applications, further one of three did not considered AR ready for its "prime time", as seen in diagram 5.2. However, Goldman Sachs (2016) believe there is a chicken-and-egg issue, related to the development of application and content, and enterprises investment in installed based. Enterprises are hesitant to invest in AR-hardware without AR applications, and developers are hesitant to create apps and content without AR-hardware. However, VR Sverige (2016) argue that the technologies of VR and AR is getting closer, and since VR is more mature and several use-cases are already developed, it will also become easier to identified use-cases for AR when AR and VR converge.

Goldman Sachs (2016) believe that AR have the potential and qualities to become as ubiquitous as the smartphone. They argue that one of the main reasons for the mass appeal of smartphones is the easy-of-use interface derived by its touch-screen and they believe that AR will experience the same, further drive the intuition to the next level by its interaction methods and 3D interface. PwC (2016h), regarding HMDs, argues that "*AR not only gets things done faster and better—but more efficiently. Hands-free, workers who might previously need to consult another device or manual* *or hand-held scanner, for example, now access data with the tilt of the head, a spoken command or a simple touch--all shaving seconds or even minutes off tasks frequently carried out*" (p.4). Furthermore, VR Sverige (2016) believe that the current state of hardware and software will spur the demand for AR.

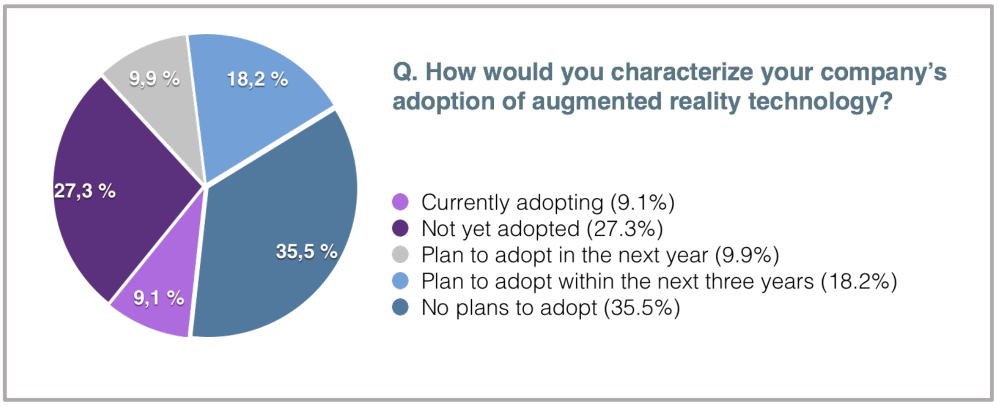


Diagram 5.1. US Manufacturers characteristics of AR adoption. Number of respondents: 21. Source: PwC and Zpryme survey and analysis, "2015 Disruptive Manufacturing Innovations Survey," conducted in November 2015.

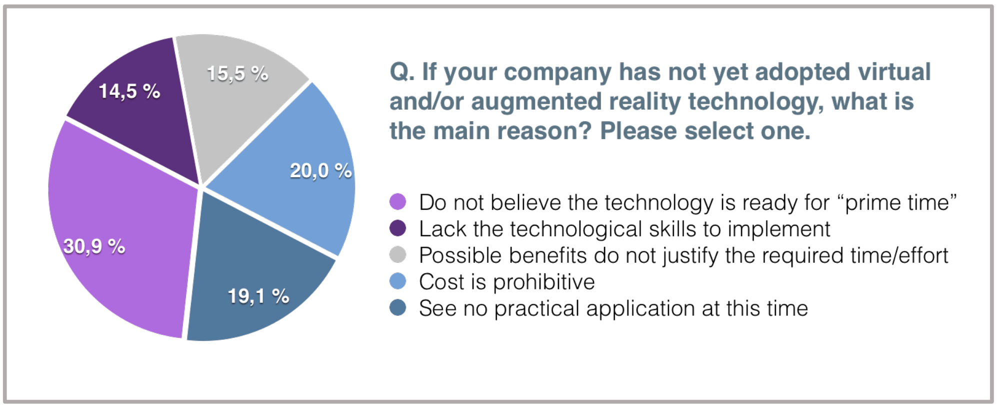


Diagram 5.2. US Manufacturers characteristics of AR adoption. Number of respondents: 21. Source: PwC and Zpryme survey and analysis, "2015 Disruptive Manufacturing Innovations Survey," conducted in November 2015.

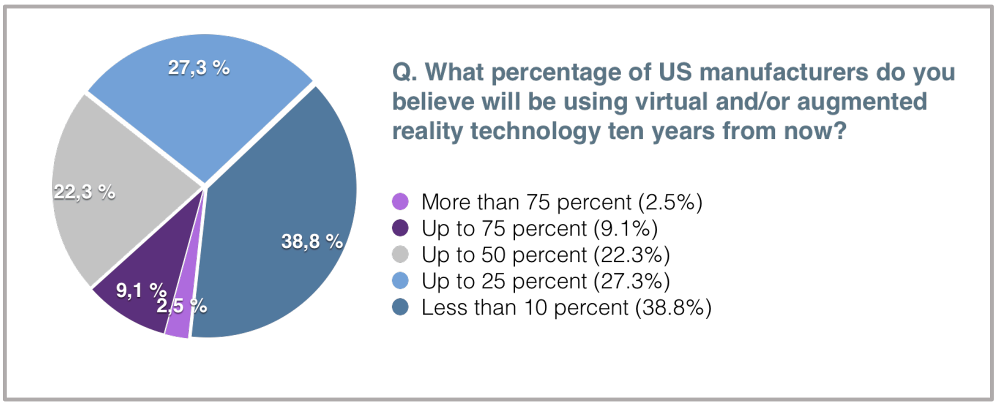


Diagram 5.3. US Manufacturers characteristics of AR adoption. Number of respondents: 21. Source: PwC and Zpryme survey and analysis, "2015 Disruptive Manufacturing Innovations Survey," conducted in November 2015.

5.4 THE AR LANDSCAPE

PwC (2016a) argue that industry landscape is highly fragmented and today there is no dominant design presented on the market. They state that there are no standards when it comes to hardware platforms, operating systems, and data formats. However, PwC (2016a) believe that *"Over time, platforms should emerge that can operate across the diversity of devices and connect to the existing back ends that most enterprises have. Today, no such platform is dominant. Emergence of a dominant platform would likely signal the inflection point where adoption accelerates" (p.5).* However, according to Goldman Sachs (2016) AR have the potential to create new markets and disrupt existing market and they believe that AR could be compared with the entranced of PC and smartphones.

The sales of VR/AR were not as high as expected in 2016, but people who had a realistic understanding of the technology knew that the expectations were too high (VR Sverige, 2016). However, several large companies, such as HTC, Microsoft, Facebook, and Samsung, expanded their investments in the technology, which is an indicator that these companies still believe in the technology. For example, Facebook bought oculus for billions of dollars, and currently 750 engineers and developers are working fulltime with VR and AR development.

VR scout (2017) has mapped the augmented reality landscape for the fourth quarter of 2016. The landscape visualizes the biggest actors that are either developing the infrastructure, the tools or platforms, or applications. Some companies are involved in many of these areas, for example Microsoft are actors in all different fields. Actors that develop the infrastructure was divided into Head mounted display (MR/AR) and component. Components was further divided into display, 3D cameras, input or computer vision. When VR Scout's research were conducted there were in total 17 hardware producers of HMD, which for example, were Microsoft's Hololenses, magic leap, DAQRI, and ODG.

Actors that develop tools or platforms was divided into distribution, standard development kit (SDK), 3D Tools (engines/audio) and 3D Reality Capture. Some actors, presented in the industry landscape, are also more recognized within the field of AR. For instance, Vuforia, who was placed in the SDK slot, and Unity, who was placed in the 3D-tool slot. Additionally, Facebook was one of actors in the distribution area. Marc Zuckerberg, CEO at Facebook, said at their F8 conference 2017 that their mission is to make it possible for all people to share experience, and that AR is a big part of their long-term plan.

Lastly, there were the developers of applications, which were further divided into games, consumer, enterprise, healthcare and education. For example, IKEA has developed an app where it is possible to view and place IKEA furniture in a real home through the use of a smartphone or tablet. IKEA has therefore extended the ordinary catalogue in order for the customer to "test" the furniture at its intended location.

5.5 AR EXPERIENCE

To experience an augmented reality the following six elements have to be in place; technology, AR application, content, interaction, the physical world and a participant (Craig, 2013). Together these elements create the AR experience and the performance and success of each element will affect the perceived user experiences. However, if there are several persons in an AR-experience they could perceive the experiences and environment differently, since their different versions might consist of different information overlays (Tech Policy Lab, 2015).

There are mainly three different categories of AR-systems, as seen in figure 5.2, that could be used for an AR-experience (PwC, 2016f). In a *geospatial system,* the virtual content is mainly driven by GPS data, and the provided data is based upon location and orientation tracking. This is the simplest form of system and it has evolved with the diffusion of smartphones and the availability of GPS (ibid). In a *2D augmented reality system* the virtual content provided is based upon detection of a certain object in the real world, and the virtual content usually reacts in a predefined manner. An example is a poster where a virtual-3D-model is presented when AR is used. This system relies on a marker, or some kind of image recognition tool, to identify the object. In a *3D augmented reality system,* the virtual content is based upon scanning of the physical environment, and interactive virtual content is provided in relation to the physical environment. For instance, live and real-time directions could be given to a maintenance worker meanwhile he or she is disassembling or servicing an engine. This is the most advanced form of AR, and according to PwC (2016f) it could enable new groundbreaking applications for industries.

For geospatial AR and 2D AR simpler devices, such as smartphone or tablets could be need. However, since 3D AR systems requires scanning of the physical environment, and provision of content in relation to that environment, 3D AR could only be performed by more advanced devices. Currently it is mainly the HMD that has these abilities. However, there are upcoming smartphones devices that also have some of the more advanced abilities.

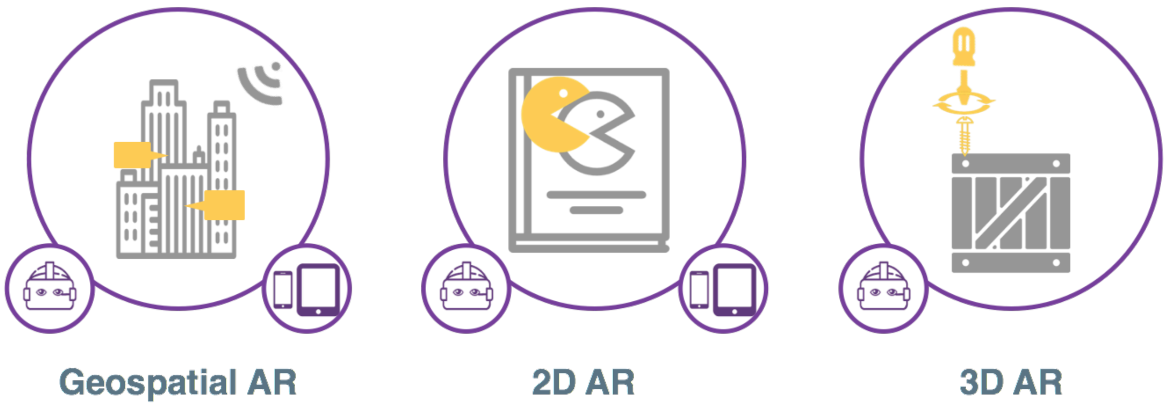


Figure 5.2. The three categories of AR-systems.

5.5.1 THE TECHNOLOGY ECOSYSTEM OF AR

The included technologies in AR are input device, sensors, computer and display. These components form the AR technology ecosystem and the level of requirements dependence on the specific AR experiences it aims to support, further the performance of the technology ecosystem depends on the performance of these components (Craig, 2013).

5.5.1.1 TECHNOLOGICAL COMPONENTS INCLUDED IN AR

Input device Input device is a sensor for gathering of user input, such as keyboard and buttons. There are several different devices that could be used as an input device, for instance computers, laptop computers, tablets, smartphones and head mounted displays (HMD), such as smart-glasses.

Sensor Sensors determine the position and state of the real world and there are several different sensors that have to be in place in order to respond correctly to the physical world. For instance, sensors used for tracking, which determines the position and orientation, and sensors for gathering of environmental information. These sensors have to collect information about the real world in real-time.

Computer Every AR system requires of a computer. The computer coordinates and analyzes sensor inputs, stores and retrieves data, further it handles the tasks of the AR application and send the right signals to the display. The computer could be physically integrated in the AR-device, connected to the device by an external device, or accessible through servers located somewhere else. However, it is important that the computer is powerful enough to handle its tasks with minimum lag in real-time.

Display Displays are used in order to display information to the user, it creates the illusion of coexistence between the real and virtual world and it gives the participant appropriated signals in order for he or her to experience an augmented reality. The signals given to the participant could be visual signals (see), audio signals (hear), olfactory signals (smell), gustation (taste) or haptic (touch). However, the most common are visual signals and audio signals, further these two are in focus for this research.

5.5.1.2 THE CURRENT STATE OF THE TECHNOLOGY ECOSYSTEM

An AR experience takes place in the physical world, therefore the AR experience also has to be experience in three dimensions, in real-time, and it is the 3D capabilities that make this possible. In order to make the experience seamless, without any delays, the physical and virtual world must match precisely, further change according to the user's movement. This requires that sensing, tracking, orientation, interaction, modeling and displaying all must happen in three dimensions and in real-time (PwC, 2016a). Additionally, all of these 3D capabilities must be proceeded for the AR-equipment, such as controls, for the AR device, and in relation to the surrounding environment (ibid). As seen in table 5.2, there are different kinds of 3D-capabilities that have to be in place in order to make the experience seamless. However, as will be seen, the specific usage and applications will have different requirements of these capabilities.

According to PwC (2016a) and Goldman Sachs (2016) 3-D capabilities have to progress within several areas included tracking, processing and displaying. PwC (2016a) argue that one of the key challenges is to identify the location and orientation, further to provide the right content at the right place, and the progress of these are strongly related with the progress of 3D-capabilities.

Table 5.2. Different kinds of 3D-capabilities that could be used in AR.

Capability	Description
3D perception	To sense depth and capture 3D information about objects or environment
3D modeling	To collect 3D-information and create a model in real-time or ahead of time based upon this 3D-information
3D mapping	To localize the orientation and location of the user, the device, the equipment and other information in the 3D environment.
3D displaying	To display content in relation to the physical environment, in other words, the right content at the right place in the user's field of view.

PwC (2016a) argue that improving performance is needed in areas such as optics in order for AR to take off. They argue *"The weight, size, and power requirements of optical components can be expected to continue to improve."*. However, PwC (2016f) argue that the technology used for gathering visual and audio information is sophisticated, mature and capable of providing high quality. Additionally, that 3D displays are very good and are expected to get even better. PwC (2016f) further argue that the experience *"depends on a few key optical characteristics: eye box (relates to head freedom), field of view, and image quality. Ideally, each should be as large as possible. However, increasing any of them leads to bigger optical components, greater size, more weight, discomfort, and higher cost".*

The availability and performance of input devices have increased the ability to store, manipulate, and retrieve information quickly (Craig, 2013). However, there are also challenges and limitations related to the AR device's performance and these are; device interoperability, authoring limitations connected to the specific platform, and device constraints such as the limited size of the display (Craig, 2013). Today's smartphones include the necessary sensors for geospatial AR and 2D-AR, therefore one of the key benefits with mobile AR is that many people already own an input device (Craig, 2013). However, Craig (2013) also argues that many mobile devices experience limitations concerning memory, computational- and graphical capacities, and he further explains that memory limitations is highly related to the amount of content possible to process and store at a given moment. Furthermore, the adoption of mobile AR is currently limited by the battery life and its mobility (Goldman Sachs, 2016). Regarding 3D-AR there are some components that are unique, for instance 3D lenses and position tracking systems, which is not incorporated in a smart-phone today (ibid). According to Goldman Sachs (2016) these components drive the prices up for 3D-AR devices, but they believe the prices of these will experience similar cost reduction curve as smartphones and PCs, hence a price reduction by 5 to10 percentages annually.

AR can sense information from the real world (input) and project information onto the real world (output). Cambridge Service Alliance (2015) argue that this type of abilities will have major influences on information access in the future since it could provide *"real-time efficient data access and, increasingly, context-aware answers"* (p. 14). However, these abilities also provide concerns, including privacy, distraction and discrimination (Roster et al., 2014; Tech Policy Lab, 2015). The input issues mainly concern privacy in public, but also infringements of intellectual property and the right to record in public. The output issues concern distraction of the user and provision of incorrect information or information that could be used unlawful or unethically in the decision-making. These concerns, both input and output, depends on the where and how AR is used but irrespective of AR's design (ibid).

In addition to the above mentioned, there are also limitations concerning the environment where the device is supposed to operate in (Craig, 2013). The environment could affect devices, sensors, computer, and displays in such a way they are not working correctly. For instance, this could be caused by the temperature, humidity, pressure or magnetic fields. Furthermore, there might be restrictions regarding the type of devices allowed to carry and use, and limitations that affect the performance, such as network accessibility, bandwidth and latency.

5.5.2 APPLICATIONS, CONTENT, AND CONTENT AUTHORING

Content is the key element within AR, it is all elements of the virtual- and the augmented physical world, and includes aspects such as ideas, objects, stories, sensory stimuli, and "laws of nature" for the AR experience (Craig, 2013). Content authoring is the software or environment for content development. Furthermore, the AR application is the computer program, which interacts with the different technology components. Craig (2013) argues that the AR technology is not yet fully developed and therefore future applications might be able to do things that are not possible today. However, if an application is created for being used in AR, it is important to evaluate if AR is the right medium to use and if the application make use of the unique affordance of AR (Craig, 2013).

Regarding authoring methods for geospatial AR systems and 2D AR systems it is largely a matter of content development (PwC, 2016f). However, authoring methods and tools used for 3D AR are complex, require expertise, and in order to create high-quality and accurate content, high production effort is needed (PwC, 2016f; Craig, 2013). In addition, 3-D content is very data intensive which increases the requirements of 3D-displaying, as described in table 5.2. PwC (2016f) states "*authoring methods today are complex, fragmented across media types, and not well integrated… For AR to take off, the ability to rapidly create, manage, edit, and deploy 3-D content is one of the problems that should be addressed*". Furthermore, they argue that "*AR lack standards to describe information, share data, support interactions, integrate systems, and swap components or algorithms*". However, PwC (2016f) further states "*As AR authoring tools evolve, the nature of content that is best suited for AR will evolve as well and will lead to a future that merges the physical and digital realities*". Another interesting aspect is that Goldman Sachs (2016) see that VR/AR technology will disrupt the Computer-aided manufacturing (CAM) and the Computer-aided design (CAD) market.

Section 6.2, provides examples of specific use cases of AR that could be used within the industry.

5.5.3 INTERACTION IN AR

Interaction is the way the users interact within an AR experience and by definition, an AR experience includes interaction with the physical world and the virtual world. PwC (2016d) argue that since AR overlays the reality with digital content the interfaces and interaction methods have to become optimized for humans rather than computers, further being probabilistic, which means that the systems could use probability to predict what the user's next intent will be. However, since AR combines real- and virtual worlds it supports multiple types of interactions and interaction that goes beyond the possibilities in the real world (Craig, 2013; Tech Policy Lab, 2015).

As described in section 5.5.1.1, display of information could be of different kinds such as visual or audio, in the same way interaction could be done in multiple ways. Examples are interaction through gesture and speech, but other methods could also be used such as eye tracking and motion tracking, furthermore these methods could be combined. However, in general, the interaction possibilities in AR could be categorized into manipulation, navigation or communication (Craig, 2013). Manipulation refers to the user's possibility to manipulate the virtual world in the same manner as the real world, or using a physical device such as a tablet, or a virtual device such as virtual keyboards. Navigation refers to traveling and way finding. Traveling is done by the same way as it is in the real world, i.e. the user is moving, and way finding describes where you are and what to do next. Communication refers to the interaction among the participants from both the real- and virtual-world using real-world communication methods, but also communication that is mediated through the AR application, hence not possible in the real world. For instance, this could be live, real-time translation of the participant's used language (ibid).

The methods used for interaction experience challenges in different environment (Craig. 2013). Workplaces could be noise, dirty, bright or dark, hence the methods used must overcome these challenges. Gesture might not be optimal in a bright environment or where the user needs to have his or her hands free and audio or voice commands might not be optimal in a noisy workplace (ibid). PwC (2016a) further argue that improving performance of the interaction area is needed in order for AR to take off.

6. EMPIRICAL FINDINGS

The following chapter provides the empirical findings related to the external environment, organizations, AR, and AR use-cases. Firstly, the information collected from the interviews and the panel debates is presented. Secondly, information collected from both primary and secondary data sources, but related to specific use-cases, are presented.

6.1 FINDINGS FROM INTERVIEWS AND PANEL DISCUSSIONS

This section provides information gathered from the interviews and the panel discussion. The section presents findings regarding the external environment, the current state of AR, the future state of AR, companies' awareness and knowledge of AR, organizational adoption of AR, user's requirements of AR, current and future AR usage and its value, technological limitations and concerns with AR, and finally existing 3D-models and limitations.

6.1.1 EXTERNA ENVIRONMENT

Manufacturing companies nowadays have technology integrated in operations and processes to a greater extent than before, and in order to survive companies have to go through this digitalization transformation. It was revealed that digital transformation is one of many challenges companies experiences today, especially elderly companies, which have not had digital content integrated from the very beginning. Furthermore, trends as servitization and industry 4.0 appear to affect companies' future plans and strategies. In addition, it was revealed that manufacturing companies currently experience generational changes.

Cost pressure forces companies to find new and smart ways to do business and reduce cost. Several companies are nowadays investigating the possibilities of removing the workforce from the workplace in favor for an automated workplace, in purpose of decreasing costs. Furthermore, this might also explain why the industries, who experience cost-pressure, often are the industries standing in the forefront of adopting new technologies. However, many manufacturing companies are a bit behind, or at least not leading in the adoption of new technology. Although, this is not true for all industries and all companies, for example the automotive industry is ahead of the curve probably due to the technology involved within their products. In addition, it appears that younger organizations, in general, more easily adopt new technologies, further are more flexible. However, several of the respondents believe that AR will be an interesting technology in order to manage cost better.

Nowadays there are less possibilities for companies to differentiate themselves by product since even more complex products are becoming commodities. This seems to be one of the reasons for the emergence of the industry trend servitization. By changing the focus from selling a product to instead focus on the outcome it becomes harder for customers to compare different offerings, for instance by only evaluating a product based on lowest-price. Therefore, many companies currently are trying to figure out what problems the customer want to solve with their products and thereby provide a solution to the problem, instead of providing just a product. However, some of the respondents believe it will be more difficult to sell a service since more knowledge about the customer's problem is needed.

Furthermore, servitization seems to entail major changes in the company's business model. It was explained that servitization results in new challenges for businesses mainly as the responsibility is changed. For example, the service providers will have the responsibility for the outcome, hence also the responsibility for the maintenance and service of the asset, which they might not have had before. This does also incorporate system changes and many companies, that are trying to transform to service providers, does not have IT-systems that support this transformation and they do not know how to handle this new complexity. However, as for several other companies, ABB's greatest revenues comes from services. Therefore, it could be a great opportunity to extend the service offerings. However, as stated above, this also depends on current business model since service and maintenance could be performed by the supplier of the product, by the user or customer itself, or by an independent service provider. In summary, many of the respondents considered that servitization will have big impact on several industries.

Another challenge revealed was the high expectations from customers. Nowadays customers do not want to know everything about the product, they just want it to work properly. However, one consequence of selling services will be higher incitement to produce high-quality products since companies will strive to reduce the service and maintenance of the product. In other words, service providers want to provide services in the most efficient and economical way. Therefore, a synergy effect from servitization could be sustainability opportunities which in the end might lead to a more sustainable society.

Revealed from the interviews were also the trend of Industry 4.0. However, some of the respondents considered that Industry 4.0 is a hype, and it appears that many companies currently are trying "to-just-do-something" in order to not lag behind. However, it still appears that Industry 4.0 will be important for companies in order to stay competitive, but it is a long way to go for many companies.

Regarding the generational changes, also expressed as aging workforce issue, several of the respondents argued that it will occur in many western industries and companies. This implies that a big part of the workers in ancient manufacturing companies will retire the upcoming years, and they are carrying a lot of know-how and knowledge that cannot easily be transferred. Due to the complexity of the processes it can take decades to learn and understand, therefore the knowledge of these retiring workers is very valuable for the company. In addition, this new generation have been born into a more digital world and commonly they have higher expectations on the technologies at their workplaces. Therefore, several of the respondents consider that manufacturing companies must search for technologies that could serve this specific problem, that is derived from the generational change and the knowledge transfer.

6.1.2 THE CURRENT STATE OF AR

The current interest of AR amongst companies appears to be high. Further, the interest seems to be derived from a diversity of companies, which ranges from car manufacturers to asset intensive manufacturers, but also financial companies. For instance, ABB are very interested in the AR technology and currently they are trying to incorporate AR into their business, in order to provide better offerings to their customer. It seems that the increased interest of AR partly could be explained by the increased interest of VR. Furthermore, since several technological components are similar in AR and VR, the technology improvements of VR have also increased the performance of the AR technology, hence also increased the interest of AR.

The developments and improvements of AR have been moving more rapidly in the last years. An example that arose was that a solution costed 1.5 million dollars twenty years ago, respective 300 000 dollars for the same solution today. The current AR development focus appeared to be on both consumers and businesses, but these two stakeholders experience different needs and demands. For instance, cost is not as critical for companies as for individuals. Furthermore, enterprises require solutions that serves a specific issue, meanwhile consumers rather require application alternatives. In addition, it was revealed the robustness and the reliability of the system is more critical for enterprises.

The ecosystem of AR is fragmented and there are players needed within several key-areas. For instance, companies are in some cases forced to develop their own immersive technologies, since they need customized solutions. However, usually this is not these companies' main business and therefore they should not be the developer of this technology, but rather the end-users. Christensen stated, "*People do not want to develop things by themselves, yes they could, but they have other things to do, it is more important for companies what comes to their bottom line.*". However, these customized AR solutions result in higher investment costs for enterprises.

Another concern revealed by several of the respondents were the social acceptance of wearing AR-glasses. For instance, some years ago when Google Glass came, they were not socially acceptable for the mainstream consumer and therefore not used to the extent predicted by google. In accordance, current AR hardware, for instance Microsoft HoloLens, appears as something picked from science fiction. However, the social acceptance of wearable devices appeared to be higher in the industry compare to the consumer market. Anyhow, the respondents believed that the devices will become smaller and less outstanding, therefore probably also socially acceptable in both market in the future.

6.1.3 THE FUTURE STATE OF AR

Some people believe that from a business point of view AR could be considered as a hype, but one remaining question, revealed from the interviews, concerned whether the AR-market will grow further or not. There have been previous examples where a hype was nothing else than just a hype, for instance the VR-hype in the nineties when the technology was not ready yet. However, nowadays the AR technology seems to be ready and even if improvements are needed the technology is good enough to work with. Several of the respondents believe that AR is not only a hype and that it will spur and continuously improve in the upcoming years. Edsberger argued that AR will become ubiquitous, therefore used everywhere.

The prediction of when AR will become mainstream, if it will, ranged between everything from 5 to 20 years, but in general it was difficult amongst the respondents to predict the future of AR and how AR will develop. Although, some of the respondents agreed that AR will become the next ubiquitous technology, but not by incorporating the technology in a smartphone, but rather by the development of HMD. For instance, this was revealed by Thorvaldsson. Further, the respondents believed that this will happen when the HMD becomes smaller, when the performance become better, and when the device become affordable for consumers. In the future this could result in HMDs that look like ordinary glasses. However, a comparison between the smartphone development and AR development was done by several of the respondents and they believed that AR will experience the same improvements, hence become cheaper, smaller and the form factor will change. Edsberger gave the example of the huge technological- and performance differences between IPhone 1 and IPhone 7, but is not even a decade between the two releases. In addition, the partner from Super Ventures stated that the AR technology must come to the state where it is possible to plug-and-play. An example was given from a convent where the company Vuforia could build up their content within three minutes, and it is this kind of tools that currently are needed.

Regarding the AR ecosystem, the respondents considered it difficult to predict how it will evolve. For instance, the partner at Super Ventures compared the VR/AR ecosystem and said that if AR/VR is going to be like the console market there is not enough devices out there yet, and therefore an app-developer must develop for several platforms to be a profitable development. This is not the case regarding smartphones, where it is enough users at each platform, namely Android or iOS. However, the vice president at DAQRI argued that companies within the AR ecosystem must collaborate to be successful. Therefore, he does not believe that it will be one big player in the future that owns everything, but rather a dozen of actors in every layer, and a landscape of different devices and application. Therefore, he believes that it still will be fragmented for a long time, but this will probably be changed within five years, according to him.

6.1.4 COMPANIES' AWARENESS AND KNOWLEDGE OF AR

It was found that the technology emergence of AR experiences a fundamental change compared to previous technology emergence. The chief solutions architect at Siemens said that fifteen years ago, when he developed smartphone-applications, he went to the customer and said, *"this is going to improve your efficiency*" and the customer responded, "*what is a smart-phone?*". Nowadays, with AR/VR it is different and their customers are ahead of them, and it is the customers who are pushing them, according to him.

From this research it has appeared that most companies nowadays are aware of the AR concept. For instance, the vice president at DAQRI has experience that they do not have to explain what AR is in the first meeting anymore. However, the knowledge of AR differs among companies. Some companies already have some sort of program, department or single role around VR/AR, meanwhile others have ideas and use-cases, and they know what they want to do, but they cannot build it since they lack in-house competence or experience. Finally, some companies do not know their purpose of incorporating AR in their business, but they are urgent to do something with AR. One of the interviewees stated, "*companies do not know what they want, they just want to be a part of the AR evolution*", and another described that their customer's want to "*do something cool*".

Several of the interviewees declared that a lot of video-clips, found on the Internet, does not reveal the reality or truth of AR's current capabilities. As one of the respondent expressed *"those videos could rather be classified as science fiction"*. For instance, Microsoft HoloLens does not have all the capabilities and features presented in its promotion video. Another example is a video-clip by ThyssenKrupp, where maintenance of elevators is improved by using Microsoft HoloLens, but the technology does not work as presented in the video and it is all made up. However, it still makes some companies to think *"wow that is awesome, we need that technology",* but it might not be possible, or it could be too complex or costly to develop the needed content and the application for it.

In accordance, several of the interviewees have experienced that their customers sometimes have to high expectations of AR's capabilities, which could be a challenge since it sometimes results in disappointments from the customer's point of view. For instance, it was explained that some people think that everything will be in 3D when using the device and they believe that the AR-device by itself creates the content and does not realize that a lot of the content have to be created in advance. Similarly, one of the respondents explained that features often have to be cut off, due to budget limitations based upon a lack of knowledge regarding the pre-work and content that have to be made in advance.

There is a need of bridging the knowledge-gap of the AR technology among incumbent firms, hence a need of AR-expertise among companies. Companies, who often have specific domain expertise but poor knowledge of AR, could be supported by niche integrators.

6.1.5 ORGANIZATIONAL ADOPTION OF AR

The relative advantages of AR have to be proved and confirmed by the top management in order to be adopted, and one of the respondents stated that *"AR must be managed carefully in the bottom line"*. It seems important that AR solves a crucial problem, otherwise the project will be down prioritized when other pains are of more concern to the organization. However, it is always important that people in organizations understand why things change and the board have to understand how to make value of the technology. For instance, the value of being hands-free with the use of AR-glasses.

For an organization to acquire or initiate an AR-project it was argued that it is important to find the "entrepreneur" (a person with strong interest of AR) in the organization. However, some of the respondents argued that if the AR-solution proofs its benefits it will not be any problem for the managers to confirm the AR-investment. The challenge is rather how to overcome resistance within the organization. For instance, due to employees fear of becoming unemployed, since if a technology makes workers more efficient some people will naturally become unemployed. However, change management is always a huge concern for process changes, but as Edsberger stated *"historically it has never been efficient to hinder a technological development since it has only led to delays in technology adoption".*

Furthermore, it was described that, if an employee is aware of that he or she will not be educated anymore within the organization, but instead guided by another worker, it might affect his or her willingness to stay in the company. Additionally, there are concerns regarding losing know-how and competence in the organization, since the workers do not have to think themselves whilst performing a task. For instance, by usage of smart-work instructions where the worker is guided throughout the task. Furthermore, it was revealed that decreased autonomous might result in lost involvement, stimulation and engagement from the employees. One of the respondent feared that the pride of being good at something might be lost, when the competence loses its value. However, in contrast, the chief solutions architect at Siemens PLM argued that he has experienced that workers usually want to learn new technologies. He gave an example from when the computer emerged at the workplace, and stated that the workers wanted to know how to use a computer since they saw that it would help them in performing their tasks.

However, there is also a concern regarding if the supplier or the customer should be the investor of an investment if both parties gain from it. It could become a concern, for instance if Atlas Copco, who supply machines and products to Boliden, or Boliden should take the investment of AR, since both parties will gain from it, since it could optimize the service and maintenance of the asset. In this case Boliden's downtime is extremely expensive and for Atlas Copco there will be a huge cost to offer AR, for example remote guidance, as described in section 6.2, to all of their customers, but they would have a better offering that might differ from their competitors.

6.1.6 USER'S REQUIREMENTS OF AR

Currently, most HMDs are heavy and uncomfortable, which were brought up as a limitation from several of the respondents. Due to this, existing wearables could not be used during the whole workday. However, the device could still be used for specific tasks performed that are performed in a limited time. Anyhow, the weight, comfortability and easy-of-use aspects of the hardware, was considered as very important for attracting users.

One solution revealed was to integrate the device into a helmet that a worker already is using for safety reasons. Thereby, the AR-glasses could easily be flipped up-and-down in front of the user's view, and the AR-features could then easily be turned on and off if the task does not require AR all the time. It was argued that when these type of solutions or features are incorporated, AR will become truly useful.

The respondents agreed that the interaction methods in AR are often very intuitive and natural for humans, and easy to learn. It was argued that even a good device is worthless if it is not possible to interact with it in a convenient way. For instance, with Microsoft HoloLens, typing is hard and takes a long time. Furthermore, the ergonomic aspects of interaction by gesture was questioned. It was stated that the use of gestures a whole workday are not ergonomic and it would probably cause both back and neck injuries in the long run. Another concern revealed was the difficulties of using voice recognition in a noisy environment. Additionally, that not everyone is comfortable with using, for instance, voice recognition in public.

Finally, the fact that it is possible to record or see what the user sees could be useful for an organization, but from an individual perspective this might infringe his or her privacy. It was argued that employees in an organization might not be comfortable if others know and see what they are doing all days. Furthermore, a research conducted by a PhD student at Chalmers University of Technology showed that the user experienced more stress when guided by AR compared to other instruction methods, but on the other hand the user was more efficient.

6.1.7 CURRENT AND FUTURE AR USAGE AND ITS VALUE

The founder of XmReality, stated "AR aims to provide an extending and new ability to see and understand, and thus be able to take more accurate and faster decisions", therefore the technology could become truly interesting from a business perspective. The largest potential with AR also depends on the time horizon since some things are possible to develop today meanwhile others are not. However, according to the vice president at DAQRI currently almost everyone focuses on revenue generating opportunities rather than cost-saving opportunities in AR initiatives since every penny already is squeezed for many manufacturing companies. However, the partner at Super Ventures disagreed and stated that they have seen many startup-pitches regarding cost saving and increase productivity applications in AR initiatives. The partner at PwC also believes that AR provides great opportunities for cost- and cycle-time reduction and the chief solutions architect at Siemens PLM further explained that AR-intuitiveness in general should end up in reduced cost, or improved quality, or both. However, the partner at Super Ventures described that the pitches he sees mainly focuses on enterprise manufacturing, which he also believes will be one of the most interesting industry areas for AR. He described that these ideas often focus on either hands-free solutions on the factory floor, or simulation and training. Furthermore, most solutions are finished pilots that are ready to go into production rollout (note that he refers to both AR and VR).

It has appeared that AR have great potential to bring business value and to deliver additional features to companies' product offerings. However, a lot of companies struggles to understand what the compelling use-cases are, and therefore they are waiting to see what others are doing. However, one of the respondents stated, *"It will not come a specific killer-case, but AR/VR will be useful for all actors who are killers*". The spectrum of potential usage of AR is broad, hence it can be used for many different situations. However, currently AR is not used to a great extent, few real and implemented AR cases actual exists in a manufacturing context, further there are very poor use cases today. Currently, companies are in general mainly using AR to impress and show the technology on fairs etcetera. However, in those cases where AR is used today, it is often for small and very specific problems, for instance visualization of components for one single person.

One of the current main concerns regards the time and cost of development of AR, versus the received benefits. One of the interviewees stated, *"The pre-work of using AR should not exceed the benefits"*. However, for the moment the received value is commonly too low compared to the development cost due to time consuming preparatory work. Furthermore, the specific value with AR depends on where and how it is used. A lot of companies want to do something cool, but it was argued that it is important to find use-cases with high relative advantage, and not only use-cases that seems cool but are too complex or expensive to apply. However, most AR applications are technically possible today but too expensive or time consuming to develop. The senior manager at Orbital ATK stated, *"You have to have a story that make you profitable in the end. Otherwise the technology is only cool stuffs".*

According to the Vice president at DAQRI there is a silver bullet hunting at the moment where companies want to take advantages from others works and pilots. However, ultimately the companies who have the most pains in the organization are the ones who will get the most advantages from an AR-investment. It was described that it is possible to replicate others' use-case, but it does not facilitate for the required organizational change. In contrast to the above reasoning, the partner at Super Ventures do not believes there is a specific silver-bullet case. He argues that he has been working in the smartphone industry in many years and he explained that he often got the question: *What is the use-case for smart-phone or what is the killer app for smartphone?* According to him there was not one killer application, but rather the Internet could be considered as a killer feature, and it took a while to understand that the Internet was the largest potential. However, current market provides limited solutions that only solves pains, but when, for example Apple, releases those particular smart-glasses *"which everyone want to buy"*, then those particular apps, use-cases and ideas, that no one even could imagined of, will come to life, according to him. Similarly, several of the interviewees argued that it will be AR-applications in the future that we could not even imagine of today. From the past it could be seen that several functions and applications have been developed that no one thought about, even if they worked within the specific area. For instance, it was stated that "*When the cell-phone came, there were no* *one who thought that it could be used as a camera*", further "*no one thought about Uber before the application released*". However, currently no one knows and the remaining question is "*what the Uber of smart-glasses is going to be?*".

The vice president at DAQRI considered that there are mainly two key areas regarding the most promising near-term applications for AR. Firstly, were cost of error is very high but the task is not repeated very often. He said, "*Where someone have to handle 1000 different procedures or different pieces of equipment and it is still a burden for someone who has been doing it for decades*". Secondly, in areas where it is possible to make use of existing content and get things into practical application quickly. Furthermore, he said that all companies nowadays have 100 of things they could do but there is a question of prioritization, and he considered there to be a lot of opportunities. In addition, the partner at PwC mentioned developing applications that ranged from design, training, service and maintenance, to improved operation safety.

6.1.8 TECHNOLOGICAL LIMITATIONS AND CONCERNS WITH AR

As described in section 5.5 there are mainly three different types of AR-systems, namely Geospatial AR, 2D AR and 3D AR. From the interviews, it was found that several of the respondents only considered 3D AR and especially HMDs to have real business potential. Some of the respondents even considered that Geospatial AR and 2D AR should not been called AR. For instance, XmReality's founder referred to these as flat screens, and not AR, when he described the functionalities with 2D AR. Similarly, the global product manager of software at ABB Robotics described that they do not consider the use of AR by flat screens to be an interesting area, since much of the value comes from having the hands free, hence use AR by HMD. Several of the other respondents questioned if AR is the right medium for visualization in 2D. This was due to the above arguing, but also since other technologies might be more efficient to use in some cases. In general, it was argued that AR is a suitable technology when there is a need of visualizing in 3D, but in other cases other technologies or solutions might be more suitable. For instance, AR might outcompete the computer within many aspects, an example is communication, but for writing it will still probably be a better medium to use the computer.

Several limitations regarding the AR-hardware has been found and it was argued that these must be solved in order for AR to be adoptable by the mainstream market. The chief solutions architect at Siemens PLM gave an example from Microsoft HoloLens, and stated that 32-bit operating system, 2GB of RAM, and 33 degrees of field of views, are all huge limitations in order for Siemens to meet their customers demanded needs. However, even if the hardware has some way to go, and the form factor must improve, several of the respondents are certain that the device will become better in the future. It was stated that the perfect device does not exist yet.

Current devices experience several limitations. Limitations revealed from the interviews were; limited field of view, battery and computer capacity, synchronizations of devices, and concerns related to the fact that current devices are single-use-devices. The limited field of view was described as a huge limitation for a lot of tasks. For example, this limitation occurs when the size of the hologram is big and nearby, since the user then has to tilt his or her head in order to see the whole hologram. Therefore, the hologram must be centralized in the user's field of view and cannot be viewed in the periphery due to the small size of the screen or display. Although, it was argued that users seem to get used to it quite quickly, but first it appears as odd. Furthermore, the computer capacity was described as huge limitation. This is partly related to the limited battery capacity and the limitations in size and lifetime of the battery. It was described that with the current battery capacity, a worker might need to recharge the battery several times a day, hence carrying extra battery. Similarly, smart phones also have too poor battery capacity to process the large amount of data needed in AR. Regarding the synchronization of devices it was revealed that it could be problematic, since the different user might have different views. Finally, it was revealed that most of the current HMD devices are single-use-devices, which means that they have been developed to serve specific tasks. This partly depends on that the device is specified for the specific task and the specific environment it aims to function in.

One of the biggest challenges for AR regards the input. For instance, one of the interviewees has experience that when the devices are used in an environment where there are a lot of moving objects, for instance people, the holograms tend to move around. In addition, it was revealed that a computer is smart, but it does not think as humans, which sometimes results in limitations concerning the input. For instance, there is current problems caused by different lightning conditions, where it is easy for a human to understand shadows caused by lightning conditions but a computer might misinterpret a shadow for a dark object.

In accordance with above arguing, one of the respondents described that a computer might not know in what levels a visualized object should be separated. For instance, if the computer is going to visualize the components in a vehicle, it could be done by separating the bigger parts such as engine and wheels, or it could be done in a very detailed manner by separating everything in the vehicle including screws and nuts. Therefore, this must be built into the application, which can acquire a lot of time and effort.

Internet connection is required for a lot of AR-applications. It was described that it is possible to access Internet almost everywhere by the usage of satellite-phones. Although, the connection from satellite-phone might be too poor for some AR-applications. Furthermore, the Internet connection might also be too poor for AR in certain regions and areas, even if it is accessible by other methods than satellite-phones. However, Internet connectivity underground and below the water surface will always critical, and for usage of AR in such environment, either implementation of internet-connectivity, or place a transmitter on a buoy, are needed. Regarding the 4G-network it has also some limitations concerning latency and bandwidth, but with the entrance of 5G these limitations would probably be less of concerns.

In addition, there might be security or privacy concerns in relation to AR. For industrial use privacy should not be a problem within internal development if the data goes through private servers, but if the organization store information in the cloud, with other words on external servers, then privacy might be threatened.

6.1.9 EXISTING 3D-MODELS AND LIMITATIONS

Many organizations have existing 3D content, such as CAD-files. The senior manager at Orbital ATK said that, even if companies commonly have 3D content libraries, the question and problem is how to quickly and easily get them into AR. He considered it extremely important to solve these limitations, otherwise it is too much work to visualize the existing 3D models in AR/VR. Current 3D-files are often too large or complex for efficient usage in AR and the files usually have to be adjusted. In addition, existing CAD-models have often been made for another purpose than usage in AR. Therefore, these are in the wrong format and very detailed, which make them either incompatible with AR, or the processing them to slow in AR.

Currently, the files must process one by one and it is not possible to display several files at the same time. One solution could be to compress the files into smaller ones, but it was revealed that there is a lot of problems associated with converting these files into AR compatible formats. However, in the future there will probably be a standard where, for instance, all suppliers offer 3D-models that are AR compatible. Therefore, the data format is a key issue.

From one interview, it was revealed that a developer tool, that easily can get CAD-models into use, is Vuforia, which is a platform for development of AR content. A video was shown where a CAD model of a coffee machine were converted to an AR-friendly format in less than one minute, and then visualized via flat-AR. From this case, it was revealed that all components in the coffee machine are separate CAD models and therefore a video-clip can easily be recorded in order to demonstrate, for example, how to assemble the machine. A key issue for companies of today is that they spend billions of dollars on printing instructions in different language, but with a video companies are not dependent upon languages.

6.2 USE-CASES

This section describes appropriate and potential AR use-cases and applications that could be used by asset intensive manufacturers. This findings in this section are based upon literature reviews, but also upon findings from the interviews and panel discussions.

In a research, conducted by PwC in 2015, it was shown that the most popular VR/AR applications among manufacturers where, product design and development, and safety and manufacturing skills training, as visualized in diagram 6.1 (PwC, 2016h).

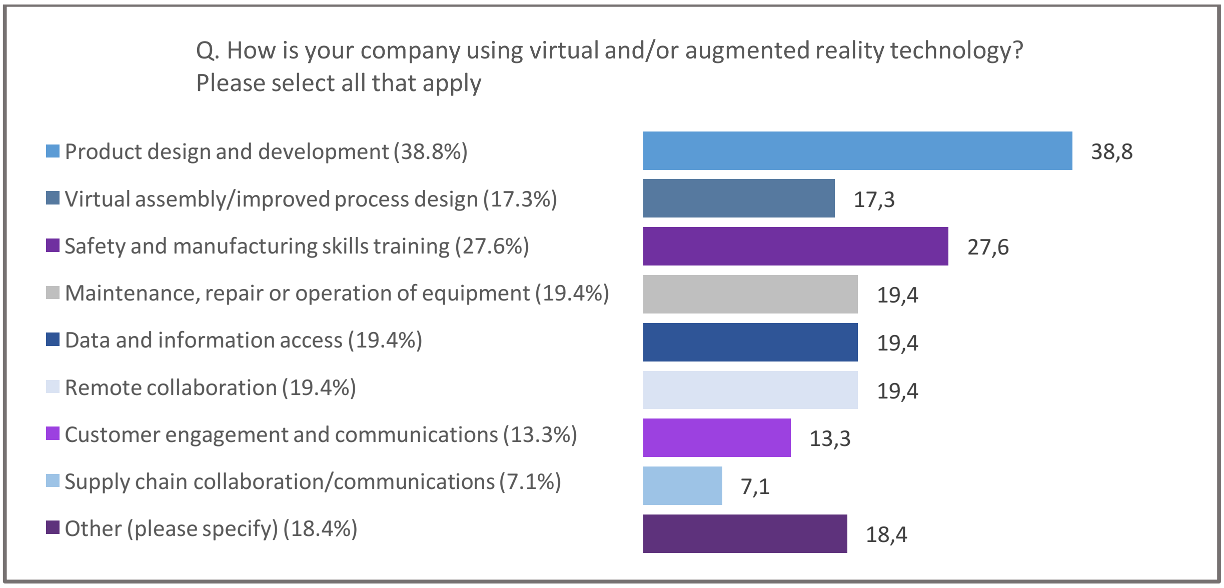


Diagram 6.1. VR/AR applications used by US Manufacturers. Number of respondents: 21. Source: PwC and Zpryme survey and analysis, "2015 Disruptive Manufacturing Innovations Survey," conducted in November 2015.

6.2.1 REMOTE GUIDANCE

Remote guidance solution is like a Skype call but with an additional augmented layer which can facilitate guidance at distance, often by the use of HMD. The user, for example the field technician, projects a live view of the requested issue to a remote colleague. The remote colleague could then help and supply the field technician by sending relevant data, instructions or images that function as a virtual or augmented repair manual.

In many industries, for example service on ships on the ocean, a person will be sent out to the ship. Many times this person does not have all the knowledge and/or information needed to service the asset, in fact this is a usual situation, and the person have to call back to the office and ask for advice. Another, problematic and extremely costly situation is downtime for many heavy industries. Similarly, in this case it could be that employees lack knowledge for the maintenance of the broken machine and to get an expert to the facility quickly is critical for the business. For such situations AR could be useful, and therefore remote guidance has started to get attention.

In general, remote guidance devices have shown to be valuable for uncommon but expensive problems, further it was found that remote guidance could be an interesting technology in the servitization area. Additionally, PwC (2016h) stated that some of the participants in the research used AR for remote maintenance, which they named remote collaboration (19,4%), see diagram 6.1. Additionally, almost all interviewees and respondent mentioned remote guidance as an application with huge potential. Remote guidance helps to reduce the distance between the expert and the location where the problem has occurred. Additionally, remote guidance supports the knowledge transfer. Service organizations can gain from such solutions since workers could be out in the field meanwhile experts could guide from distance instead of traveling to all places where support is needed. This enabling the possibility of having lower skilled persons out in the field since experts could guide them. This in turn would mean that the needed number of employees and skilled employees would decrease. Although, a research carried out from Chalmers University of Technology has shown that workers perform a little bit faster but experienced more stress, when using remote guidance by AR, compared to other instruction alternatives.

There are, different solutions of remote guidance that exist on the market, and the Swedish startup XmReality is one of the pioneers in the field. For instance, in XmReality's tool, the remote colleague can be digitally present and help to guide the person in need both with hands and voice, which is the augmented layer of digital content in their solution. Volvo has used their solution when they were setting up a factory in China, and they experienced that the solution reduced travel costs, accommodation costs, and minimized the risks of the specialist not being available for questions while traveling. XmReality has found that the most obvious value with remote guidance for their customers is cost savings in terms of travel costs. Additionally, XmReality has found that some of their customers use their solution in order to incorporate AR in their service offerings, and thereby use the solution as a way to charge for service. Customers to their customers expected that they could call and get help anytime, but with remote guidance it is instead possible to sell remote guidance hour. This was an unexpected use area for XmReality's product.

XmReality have experienced that companies experience a pressure to digitalize and adopt new technology, and that remote guidance is a way for these companies to do so. Therefore, it is important that the tool is simple, easy to use, and not requires advanced training or integration with other technology. Furthermore, the remote guidance solution is and will be used rarely by their customers, only when something goes wrong and cannot easily be solved. Therefore, the above stated is even more important.

ABB Robotics have started to investigate if they are going to use remote guidance in their organization. Around the globe, ABB have service departments, where it is possible for service technicians and customers to call for support and help. ABB Robotics' global product manager for software products considered that it could be powerful to use AR for such purpose, and in a near time-horizon. ABB does not consider the technology to be the most difficult part, but rather the organizational change, and the creation and extension of all the service centers that are needed in order to support the service it entails. Employees must be present in the right time-zone, speak the right language, and have knowledge about the product. However, this is also the case today, despite the use of remote guidance, but the same quick response is not expected. Additionally, many devices are needed for such an organizational change, and that is an expensive investment, but not as expensive compared to production downtime.

6.2.2 DASHBOARDING

Dashboarding refers to visualization of graphs and specific machine features in connection to the machine. Deloitte (2016) gave the example of *"deploying augmented interfaces that pair with connected devices, sensing objects, and relational data can deliver task-specific information to workers in the field in context and on demand. Augmented solutions can overlay a jet engine's service hours, component temperature, and service panel details into an aircraft mechanic's field of vision".*

In many organizations, visualization of data is available in a control room and the only way to access it is to be present in this room. Additionally, some information could be available in binders, but these might not be updated, further not easily brought. In some situations, it could be useful to have real-time metrics at a certain location.

Dashboarding, or rather visualization of dashboards, appeared to be requested by many companies and customer to the respondents. Furthermore, it could be a quite simple application area. However, some of the respondents also argued that this type of use area does not always make use of AR capabilities. Furthermore, the global product manager for software products at ABB Robotics argued that if the worker would have his or her hands free it could bring value, but if the dashboarding is provided by a flat device he does not believe that AR will be the right technology for this kind of visualization. However, this is a possible usage area for flat AR.

Additionally, it was found that visualization of sensor data, and seeing information at a certain location, is of interest. One example is to combine AR with IoT, which was something that PTC demonstrated with a bicycle that was equipped with sensors. The device used for this demonstration was a tablet and when it was held up towards a barcode on the bicycle, real time statistics popped up. For instance, if this is applied while operating heavy machinery out in the field, it is possible to get a real-time overview of which components that are in need of replacement. Another interesting use area of dashboards is maintenance, repair or equipment operations, which accounted for 19,4% in PwC's research, as seen in diagram 6.1.

6.2.3 VISUALIZATION OF 3D MODELS

Visualization of 3D-models refers to an interactive and realistic manner. In the future, it could further be done in combination to the physical environment.

6.2.3.1 DESIGN PHASE

A concern that appeared from several of the respondents were that the design of an asset often is very complex and that it is not easy to collaborate in a big group with different skills and expertise. The design group often consist of people with several different background and experience, for instance electrician experts, aerodynamic experts, marketing employees and other types of experts, and those people rarely have the same understanding and perception of 3D data. One example revealed from the interviews concerned the development of aerospace. In these cases, it is very valuable if modifications of parts can be reduced, since modifications might cost the company millions of extra SEK each time. Furthermore, it is very common today that a redesign might be forced just because of a simplistic misunderstanding. Therefore, with the help from AR such misunderstandings hopefully can be reduced.

From the interviews and panel discussions it was revealed that the biggest near time benefit of AR could be found in the design phase, in terms of visualization and product design. For instance, the Innovation Manager at Volvo Group Truck Technology has been involved in a project regarding visualization of CAD models by the usage of AR glasses. He believes that AR has huge potential to bring business value for Volvo in the truck's design phase. Moreover, in the research conducted by PwC in 2015 it was shown that the most popular VR/AR applications among manufacturers, visualized in diagram 6.1, where product design and development (PwC, 2016h).

During the interviews it was found that the product development often is more effective whilst the discussion is around a 3D object compared to viewing sketches, or models on a flat screen. The chief solutions architect at Siemens PLM meant that their customers already are convinced that displaying virtual 3D, by the usage of AR, increases the understanding of the object, compared to displaying it on a 2D screen. Additionally, PwC (2016h) found that some manufacturers were using VR/AR to create virtual prototypes, for example an engine, which designers and engineers could walk around and experience in 3D. They believe that this rises possibilities to cutting the considerable time and expense required by developing physical models.

6.2.3.2 SALES PHASE

Visualization of 3D prototypes has a huge potential, also in the sales process. A problem in the sales phase is that the customer is not always able to capture and understand all details of the acquired object, but after implementation it is too late or costly for system changes. The delivering of something that not functions as the customer anticipated, could result in risks such as customer disappointments.

The global product manager for software products at ABB Robotics believes that the greatest benefit of AR-visualization is in the sales phase. This is due to the customers' better understanding of the system, and as a consequence ABB is able to deliver better solutions. In accordance, PwC (2016h) argue that virtualization of a virtual products (before a physical prototype is created), enables sharing products with customers in the testing phase. Hence, creating closer relationship and better collaboration with customers.

In a short time perspective companies can make use of existing digital content. For instance, this is the case for ABB robotics who already have the digital content of their robots, and for them it is not a big step, or a large investment to visualize the robot in AR or VR. For example, ABB's product "RobotStudio" is used in the sales process in order to show the customer a virtual model of the robot that has not yet been produced. ABB already do this today, but by projecting it on a flat screen on the wall. The next step could be to project the robot on the conference table, as a hologram by the use of AR. They mean that this would enhance the discussion between them and their customer regarding how the robot should function for optimal use, hence also increase the customer satisfaction. However, ABB Robotics has not developed this application yet, but it is an upcoming project.

6.2.4 SPATIAL DESIGN

Visualization of 3D prototypes could be valuable for different purposes, and several use-cases related to visualization of real-size objects was revealed. For example, the real-estate industry is currently adopting VR mainly to visualize new constructions such as apartments for customers, which has showed to be of great value. Similar use-case could be possible by AR, and this is also upcoming. For instance, AR could be used for visualization of virtual buildings or big machines in its intended location, and in real-size. Currently, this is mainly applied as consumer applications via smartphones and tablets. For example, IKEA provide an application where it is possible to furniture the house.

Bold Arc has experienced that companies find it valuable to visualize the factory floor, and how it would look like and function in the future. Additionally, AREA (2017) describe that AR can be used to predict and analyze the optimal spatial layout. They consider the benefits to give a more realistic visualization, minimize the risk of poorly optimized use of space and quicker response to the intended change. Both AR and VR could be used as a planning tool for factories, but by AR it could be done in relation to the physical environment, meanwhile by VR it could be done in an environment that does not exist in the reality.

6.2.5 VISUALIZATION OF VIRTUAL DATA

AR has the ability to show things in the real world that former have not been possible to see. This is referred to as virtual data, and an example could be motion paths of a machine. Currently, some information is only presented in a digital environment and not reflected in the reality.

Sometimes it could be of value to see this information and AR could be used to visualize this information. For instance, ABB explained that the motion path of a robot could be visualized in relation to the physical robot. In the case of ABB, this information already exists in their RobotStudio program, but currently it could only be seen in a computer. However, it was explained that by the extension to AR, holograms can be synchronized with the reality and thereby merge the digital content (holograms) with the real world (the physical object).

However, there is a long way to go before this could be applicable. It was argued that the information must be digitized in an AR friendly format, the digital content must be able to synchronize very precisely with the physical object, and the content must be able to attach to a moving object. Furthermore, since the purpose with the hologram is to interact with a real object, and the real object has a set size, the hologram must be in real-size.

6.2.6 LOCALIZATION

One use-area is localization and guidance in factories, to find specific objects or places. In big factories, it has appeared to be problematic to find the right machine, especially for someone who has not been in the factory before. Therefore, AR could be a great tool for guidance and location tracking of equipment. This could be performed by showing arrows towards the right direction, or for instance, by coloring the search object in order to distinguish it from other products.

Similarly, AR could be used for localization of or guidance towards "hidden objects", for instance, pipes in the walls. This requires that the underlying data/sketches reflects the reality, but during the interviews it appeared that this is barely the case. It was described that a plumber might not report the changes made and therefore the sketches do not always reflect the reality. Similarly, changes or modifications could have been done after the construction were finished, and not reported in advanced. Additionally, the original sketches might exist on papers and then it is a lot of work to digitalize such data and for old building etcetera there might not exist sketches at all.

6.2.7 WAREHOUSE PICKING

Warehouse picking refers to guidance with quality check of the picked objects.

In warehouses today, the work is often performed by the use of papers to view what to pick, and sometimes hand-scanners for quality control. In the former case, it could occur quality issues in the picking. For the latter case, quality is higher but at the expense of efficiency.

PwC (2016h) stated that a logistic company in the research used AR for Warehouse picking. They equipped the warehouse workers with smart glasses, which read barcodes on the packages and gave detailed content and destination/origin information. For the logistic company this resulted in a productivity increase by 25%, and therefore PwC find that this application area has huge potential. However, from the interviews it was revealed that it is a complex and big investment for a company and it will take a lot of time to develop the system. Furthermore, it is even more complex as it also involves process change in the organization.

6.2.8 SMART WORK INSTRUCTIONS

PwC (2016h) describe smart work instructions as "smart glasses that help track and guide complicated assembly processes to ensure that all parts are assembled in the right sequence without the downtime of consulting a clipboard, manual or even tablet".

For many companies today the work instructions are placed in binders, which the workers do not check regularly, and therefore workers develop their own work-instructions or "best practice", which could result in quality problems and incorrect assembling. Furthermore, these instructions are not always up-to-date and employees have different versions.

The purpose of using smart work instructions is to increase the overall quality by minimizes the defects and the restructuring of the asset. Similarly, AREA (2017) considers one of the benefits with smart work instructions to be reduced risk for delay and error in the assembling. Another benefit of using AR for instructions could be the opportunity to always have the correct and latest updated work instructions. Moreover, smart work instructions also enable the possibilities to perform a task which the worker has not been trained for.

Volvo Group Construction Equipment is currently in the upstart phase of a project that focus on smart work instructions, and this is one of the projects in their Industry 4.0 initiative. Although, they have found impediments with this way of working. Firstly, the respondent considered the form factor of the device to be problematic and he was skeptical if the AR devices could be used eight hours a day. Secondly the respondent speculated in possible problems regarding the know-how and motivation amongst the employees, which might decrease with the use of smart work instructions.

6.2.9 AUGMENTED TRAINING

Augmented training refers to training and/or education with augmented objects in the physical environment.

To practice or perform training on the machines employees have to travel to the supplier's training facility. The current alternative would be to acquire an extra machine for training or to stop the production and do the training on existing machines. However, both of those alternatives are very costly due to very expensive machines and downtimes, and the best solution nowadays is therefore to travel to the suppliers training facility. Another example on situations where training is needed is for handling dangerous goods or perform critical tasks.

It has appeared that virtual training has huge potential and could be realized by the use of either VR or AR. Further, it seems to be one of the most promising applications. Although, VR is currently more commonly used for virtual training. In PwC's research, as seen in diagram 6.1, safety and manufacturing skills training (27,6%) was the second most popular usage of AR/VR amongst American manufacturing companies. Deloitte (2016) consider that AR and VR will play an important role in retooling high-cost training and simulation of environments.

The PHD researcher at KTH argued that the learning is more efficiently in VR and AR. Researches show that VR/AR training increases the learning rate, since the highest learning rate comes from visual-interactive experiences and VR/AR has all three: visual, interactive and experience. Therefore, with the use of virtual training it is possible to learn faster, understand more, and the quality of the information delivered will be higher. The researcher explained that she has experienced that people from other research areas can learn faster and understand more if she visualizes what she is doing instead of sending them a lot of text pages. Similarly, AREA (2017) consider that with AR training the learning is more likely to be retained by the trainee and self-corrected during work task performance.

Another example of training, provided by Orbital ATK, was handling of rocket fuel, which is a very dangerous task where training is needed. Currently this is performed by the use of empty containers. However, they do not consider this process to be optimal and it does not reflect the reality. Therefore, they are currently investigating the possibility of performing the training in VR.

However, this training could also be performed in AR. In contrast to training with empty containers, different scenarios could be visualized, but compared to VR it could be performed in the actual environment. However, by the use of an immersive medium, either AR or VR, it is possible to teach workers how to handle the fuels safely and efficiently within an environment, which allows for mistakes. Additionally, workers can understand dangerous situations better as it is possible to simulate these situations.

6.2.10 INTUITIVE INTERFACES

An intuitive interface is where changes or programming are performed in the same way as it would be performed in the real world.

Nowadays a lot of machines require specific competence to use and serve. Companies might lack the in-house experience, and it could be expensive to acquire the specific competence. Especially this regards small companies.

AR opens up for possibilities to create new type of interfaces. ABB believe that new interfaces can be useful for the robotic market and even create new market. Currently, robots are starting to become interesting even for smaller companies, but as described, smaller companies often lack the in-house competence to work with robots, and it is often expensive acquire the expertise. to do so. For such companies the threshold has to be lowered and they need a simpler way to work with robots. AR could function as an intuitive user interface for managing robots, therefore facilitate the robot usage. For instance, it was believed that for ABB Robotics this could be a massive opportunity in terms of AR usage. For ABB this could result in an increased robotic market, and for the customer that previously could not use a robot it would mean that they now could afford one. However, this application area requires a lot of technological improvements.

7. ANALYSIS; ADOPTION OF AR

The following chapter provides insights regarding factors affecting a company's adoption decision of the AR technology. This was analyzed by the use of three different perspectives: external environment, technological, and organizational. These three perspectives provide different knowledge and understanding of an adoption decision, but the three perspectives are also interrelated with each other. Therefore, the combination of these perspectives brings additional insights and values. Finally, this section aims to provide knowledge to answer the first research question:

- *What affect the willingness to adopt Augmented Reality, positively or negatively, from an external environmental-, technological-, and organizational perspective?*

7.1. EXTERNAL ENVIRONMENT PERSPECTIVE

The external environment is one of three aspects that affects the technological innovation decision making (Mansfield, 1968). As described in the theory, the external task environment element relates to the surrounding context the firm is present in, such as business, industry, trends and competition (Tornatzky & Fleischer, 1990). Therefore, these elements have to be considered in the investigation of willingness to adopt AR. However, the focus will be on the merge of the real and virtual world, and the trends Servitization and Industry 4.0.

As described in chapter 4, further found from the interviews in section 6.1.1, western manufacturers experience increased competition. Furthermore, companies are nowadays forced to find new and smart ways to reduce cost or increase revenue. It also appeared that companies, who experience most competition, will be the companies who stand in the forefront of the technology adoption. This also goes in line with Mansfield (1968) arguing that a competitive environment stimulates adoption of innovation. However, from the interviews it was found that many manufacturing companies lag in their adoption of new technology and this was also confirmed by Cambridge Service Alliance (2015) research. This new type of competition, that manufacturing companies currently are facing, might force them to adopt new technology, otherwise they will not survive in the high rivalry that exists amongst asset intensive manufacturers.

7.1.1. CONVERGENCE OF THE PHYSICAL AND VIRTUAL WORLDS

As described in section 4.1, the physical- and virtual worlds have previously been diverging, but in recent years they have start to converge (PwC, 2016b). Therefore, a need for technologies that support this new mixed reality has emerged, and a technology that has this ability to merge the physical and digital world with a seamless integration is AR (PwC, 2016b; Kipper, 2012; Deloitte, 2016). Additionally, a need for a technology that could support workers' ability to contextualize the large amount of information that is gathered from both the physical- and virtual world have emerged, and both PwC (2016b) and Deloitte (2016) argue that AR have this ability.

These two abilities, to provide a seamless experience of the mixed reality and to contextualize information, have not really been requested in the same extent before since it has not been needed, further not possible before. These new needs create new market opportunities, as will be discussed in section 8.1. From an adoption point of view the convergence of the virtual- and the physical world could affect the adoption of AR, since AR is defined as *"Augmented reality is a medium in which digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world and that is interactive in real time"* (Craig, 2013, p.36).

7.1.2 INDUSTRY 4.0

One emerging trend, presented in section 4.2, is Industry 4.0. As stated by PwC (2016g) Industry 4.0 refers to the digitalization, and integration, of all physical assets in the ecosystem and throughout the whole value-chain. From the interviews it was found that manufacturing companies nowadays have technology integrated in operations and processes to a greater extent than before. This integration of technology highly correlates with Industry 4.0, and could be seen as the first step of achieve the aim of Industry 4.0.

As stated in section 4.2, Industry 4.0 aims to obtain totally collaborating entities that exchange data regarding their ongoing processes, further this data comes from both the digital and physical world and the collaboration is facilitated by the use of data-accessing and data processing services provided on the Internet (Monostori, 2014). This capabilities and features could be facilitated by several different technologies, and among those is AR. Industry 4.0 is based upon the convergence of the real and virtual world (Deloitte, 2015), and AR is a tool for visualizing this, therefore AR could have great potential to bring value. For instance, the use of AR in Industry 4.0 could facilitate the communication and visualization of this mixed reality since it enables visualization of real and digital content simultaneously. This in turn could enrich the understanding of the company's systems and processes, further facilitates the communication among associated parties. Hence, this implies that AR could provide great value in Industry 4.0 by increasing the understanding of the systems and processes.

However, as stated before, AR is not the only technology associated with Industry 4.0. For instance, the merging of the real and digital world is based upon linking IT with mechanical and electronic components (Deloitte, 2015). In other words, the underlying infrastructure for Industry 4.0 is based upon IoT, and without having this properly integrated in the business the value of visualize the mixed reality decreases, hence also the value of AR. Furthermore, system integration, Big data, and Cloud and cyber security are all technologies or features that have to be considered in relation with AR. As described in the section 4.2, Industry 4.0 is dependent upon several technologies in order to achieve the full potential of it. Therefore, in order to obtain Industry 4.0 characteristics, namely interoperability, information transparency, decentralization, real-time capability, service orientation and modularity (Gilchrist, 2016), not only AR but several other technologies have to be in place.

As seen Industry 4.0 spur the adoption of new technologies, and among those AR. There is a great value of adopting AR in order to facilitate the communication, visualization and understanding. However, the technology is dependent on adoption of other technologies and it might not be able to gain the full potential of AR before these other technologies are in place within the organization but also in the horizontal and vertical value chain.

7.1.3 SERVITIZATION

As described in section 4.3, one of the emerging trends is Servitization, and it appeared that servitization will have big impact on many industries. This implies that the transition towards servitization will happen and that is rather a matter of time and the question is how AR could facilitate this process?

In the transition towards Servitization it is important to understand what problem the customer want to solve with the products, and instead provide a solution to that problem. From the findings it was revealed that a lot of manufacturers currently are trying to incorporate services in their offerings and Jagstedt (2016) described that this could be done by either add service upon the product or by integrate product, service and knowledge in the offering. In the first way, to add service upon the product, Jagstedt (2016) gave examples of services as repair, maintenance and training. These functions could all be supported by the usage of AR, for instance by remote guidance as described in section 6.2.1. Additionally, it could be seen that remote collaboration was amongst the third most popular application area among manufacturers in US, see diagram 6.1 in section 6.2. Further, AR could support training, as described in section 6.2.10, and this application area was the second most popular among US manufacturers, see diagram 6.1 in section 6.2.

Regarding the other way, integrate product, service and knowledge, Jagstedt (2016) stated that the focus should be on the customer's processes, result or usages. Even in this case AR could be used as a facilitator, but the connection might not be as clear, as in the first case. However, in order to direct the focus on the customer's needs it is important with a clear understanding and communication between the parties, which could be facilitated by the usage of AR. For instance, AR could be used to visualize the processes and products in 3D, as described in section 6.2.3 and 6.2.4, hence facilitate the understanding and decrease the amount of misinterpretations among the parties. This type of application area was also in the top among manufacturers in US, see diagram 6.1 in section 6.2.

Furthermore, as a consequence of using AR, information and data could be continuously collected from the real-world meanwhile an actual user is performing an actual task, due to AR's input abilities. This information could thereby bring insight and knowledge of the customer's processes and usages, hence increase the value of the service offering. Cambridge Service Alliance (2015) further argued that this type of abilities will have major influences on information access in the future since it could provide "*real-time efficient data access and, increasingly, context-aware answers*" (p. 14). However, as argued in section 5.5.1.2, this type of data collection might arise concerns regarding privacy and legislation in the future, but as described, this technology has to improve before it would be possible.

On the one hand, Baines & Lightfoot (2013) stated that servitization opens up for longer contracts with long-term relationships, but on the other hand it was found that a service would be more difficult to sell. However, both arguments are based upon the importance of having a comprehensive understanding and knowledge of the customer's business and, as described above, this could be facilitated by the use of AR. Further, it was argued that for ABB the greatest revenues come from services, which further enrich the incitement of provide great service offerings based upon great customer knowledge.

However, one remaining question is whether AR is the most important technology in a servitization context or if there are other technologies that are more important, or have to be integrated before the company could make use of AR. For instance, several of the respondents revealed applications ideas where AR could be used for visualization of data but the support infrastructure for this kind of application is IoT, which means that IoT have to be in place in order for the application to function. Furthermore, it was argued that many of the companies, that are trying to transform to solution providers, do not know how to handle the complexity. This is one major concern, and organizations have to find technologies to support the complexity of integrating these new ways of doing business. In this case AR could not be considered as the most critical technology, and in general it is important that companies understand what AR could do and what AR cannot do.

As described in chapter 4.3.1, there are several drivers for adoption of new technologies in a servitization context. As argued above AR could facilitate several of those drivers. For instance, AR could generate new revenue source, improve maintenance efficiency and effectiveness and improve product performance, for instance by applications such as remote guidance and 3D visualization. Furthermore, and as argued before, AR could in the future also increase data gathering, which was one of the drivers, but this requires technology improvements of AR.

However, CEMs struggles to identify relevant technologies and experience slow internal adoption of technologies (Cambridge Service Alliance, 2015). From the interviews it was revealed that many companies were investigating a lot of different technologies, but few had projects that were up and running which included the AR technology. Furthermore, it was found that there exist a lot of different technologies that a company could invest in, and once again the question is if AR is the right technology to invest in. Cambridge Service Alliance (2015) argued that the focus amongst CEM is often on technologies that improve the product performance rather than increase revenues from the aftermarket business. When investigating the technologies listed as important by Cambridge Service Alliance (2015), presented in table 4.2, it could be seen that AR could support several of those technologies, or rather the purpose that are considered to be performed by the listed technologies. For instance, AR could support the technologies such as remote communication and dashboarding.

It could be concluded that AR could facilitate servitization since it provides functionalities that could support "increasingly offering fuller market packages or "bundles" of customer-focused combinations of goods, services, support, self-service and knowledge" (Rada, 1988, p.314). However, it could further be seen that servitization probably spur the diffusion of AR, as for other technologies, since companies seem urgent to adopt new technologies. Therefore, AR could support servitization but it is not critical in a servitization context, at least not for now.

7.2 ORGANIZATIONAL PERSPECTIVE

The organization itself affect the technological innovation decision making (Tornatzky & Fleischer, 1990). First of all, an organization's decision of adopting an innovation is affected by the social system. Secondly, the section discusses how the organization's knowledge affect the adoption of AR. Thirdly, an analysis of the persuasion of the AR experience is presented. Lastly, an analysis of how the internal resource and conditions affect the organization's willingness to adopt AR is presented.

7.2.1 THE MANUFACTURERS' SOCIAL SYSTEM

Rogers (2003) considers the diffusion of an innovation to be influenced by the social structure of the social system. Therefore, actors in the manufacturing context affect each other in the adoption of AR. The social system consists of five different types of adopters; innovators, early adopters, early majority, late majority and laggards (Rogers, 2003).

From a manufacturer's point of view, AR will not be the core business, but rather a support function in current operations or similar. This implies that, in general, manufacturing companies will probably not be the innovators. Although, if a manufacturing company has a lot of problems internally in the factory, and if AR is proven to facilitate in the operations, then these organization possibly could be the innovators of AR, even if this adopting level involves an unfinished product and high risk. Furthermore, as described in section 6.1.2, there are manufacturers that develop their own solutions due to the need of customized AR-solutions. However, as stated, this is not their core business, but in such cases the actors are the innovators.

The manufacturing companies that are taking a leading position in the adoption of AR and further communicate and influence others to adopt the technology, are, in accordance to Rogers (2003), defined as early adopters. Rogers (2003) argues that early adopters are important actors in the social system in order for a technology to spread and will therefore be important for the adoption of AR. An example of an early adopter of AR could be ABB, since they have been participating in fairs where they demonstrated their future VR and AR plans, and thereby influenced others. Further, these actors are important from a communication channel perspective, which is one of the important elements for diffusion of an innovation (Rogers, 2003).

However, derived from PwC's (2016h) research it could be found that a majority of US manufacturers in 2015 planned to adopt AR, but only about 10% were adopting AR when the research was conducted, as visualized in diagram 5.1. Rogers (2003) considers that early adopters tend to take the leadership role in the social system and affect others to adapt through advising or by providing information about the technology to others. Therefore, the manufacturers who were adopting AR and further have the early adopters' characteristics could potentially lead the way of AR within a manufacturing context. Additionally, and as described by Moore (1991), these actors are further important since their key role is to fund the development of the early market. This implicates that the current challenges and limitations with the technology will be addressed by these actors, further these limitations must be solved before the early majority could be reached due to other needs compared to early adopters, such as a proven technology without any bugs (Moore, 1991).

From the empirical findings, it was found that many organizations wanted to adopt AR, but they did not know how to use it. Further, it was revealed that many companies struggle to understand what the compelling use-cases are and therefore they are waiting to see what others are doing. Similarly, PwC's (2016h) research amongst US Manufacturers shows that one fifth of the companies did not see any practical applications at the time, as visualized in diagram 5.2. In accordance, the early majority have characteristics such as a focus on proven applications and they like to go with the market leaders (Moore, 1991), and therefore these manufacturers could most likely be classified as early majority.

The early majority expect a bug free product, a dominant design, low cost of ownership and they are not risk takers, further wants vertical references (Moore, 1991). Therefore, before the early majority even would consider adopting AR, the technology limitations have to be solved, a standard must be set and the cost of ownership most decrease, but as predicted, these limitations will become of less concerns, as will be analyzed further in section 7.3. Furthermore, there are challenges associated with how to reach the early majority. These challenges are that they insist on good references from trusted colleagues, and they want to have a reference site which have the solution in production. (Moore, 1991). However, in order to provide those references some companies have to be adopters of AR, and one of the biggest challenges is how to get those first early majority adopters, in other words, how to cross the chasm that occurs between early adopters and early majority. In accordance with the above arguing, and companies' lack of knowledge of how to get value out of AR, the implication is that the early majority has not been reached yet in a manufacturing context.

However, as described in section 5.5.1.2, the technology is improving. Furthermore, as described in section 6.1, references are starting to accrue and several companies have started to provide compelling use cases within different industries. Therefore, the implication is that the AR could be on its way to reach the early majority, and when this happens the diffusion process will kick-in. In accordance, PwC (2016h) believe that US manufacturers probably will experience a need to adopt AR in order to compete in the future due to the improvements the technology demonstrate within several areas, for instance productivity and product development.

The next step will be, how to attract the late majority, whose key role rather is to extend the product's life cycle (Moore, 1991). These adopters also have other preferences and characteristics, such as avoidance of competitive disadvantages, price sensitivity, and a need of completely pre-assembled solutions. However, this group of adopters are a large part of the total market, therefore important to attract later on. In PwC's (2016h) research amongst American manufacturers there were 36% that did not plan to adopt AR, as visualized in diagram 5.1, and those actors could be seen as late majority, and if late majority will adopt AR the technology has to prove its benefits and become cheaper. However, as will be described in section 7.3.2, the prices will drop when there is economy of scale. Furthermore, better solution and more advantages will hopefully be proven when use-cases emerge. Therefore, the late majority adopters should be reached as well.

The last group in the social structure, namely laggards, are not described as customers, but they rather retard the development of high-tech markets (Moore, 1991). Furthermore, it is described that these actors do not believe on the productivity improvement arguments (ibid). Therefore, they will try to prevent the adoption of AR.

7.2.2 ORGANIZATION'S AWARENESS AND KNOWLEDGE

In order to even consider adopting an innovation, knowledge of the innovation is crucial. Rogers (2003) argues that an innovation decision consists of sequential actions, whereas the first action is the knowledge stage. The knowledge phase is where the user becomes familiar with the technology and starts to gain understanding of it. Therefore, the question is: how good knowledge and understanding does organizations have regarding AR?

From the interviews it is found that the respondents have experienced an increased knowledge among manufacturing companies in recent years. For instance, the vice president at DAQRI stated they do not have to explain what AR is in the first meeting anymore. The implication is that even if AR is an old phenomenon, as it could be traced back to the 60's, it is first in recent years the awareness has increased. This could be due to that the AR technology where too undeveloped before, and had even more constraints and limitations compared to the technology nowadays.

Furthermore, as seen in section 5.2 and 5.1, the definition of AR, and the distinctions between AR and MR, still varies (Foundry, 2016). Additionally, since there is no consensus regarding the term used it might result in misunderstanding and miscommunications among different parties since they are referring to different things. However, the fact that the term used, either AR or MR, depends on current trends of immersive technologies (Foundry, 2016), indicates an increased awareness in general. Further, it could be seen that in recent years AR has reached a broader audience by its entrance in the consumer market, for instance by the release of the game Pokémon GO in 2016. This have created an additional communication channel that spur the awareness of AR, and according Rogers (2013), communication channels are vital in the whole adoption process. Furthermore, it could also lead to more efficient communication since people have something simple and well-known to refer to while explaining what AR is. The implication from the above reasoning is that companies, in general, have reach what Rogers (2003) defines as awareness-knowledge.

Compared to previous technology development the respondents have experienced an increased awareness of AR among their customers. For instance, the chief solutions architect at Siemens argued that fifteen years ago, when he developed smartphone-applications, he went to the customer and said, *"this is going to improve your efficiency*" and the customer responded, "*what is a smart-phone?",* but this is not the case regarding AR, according to him. He stated that customers actually are ahead of them and that it is the customers who are pushing them. Furthermore, it is revealed that a lot of companies are trying to do something related to AR in order to be part of the AR evolution. Consequently, this implies that most companies possess awareness-knowledge as described by Rogers (2003).

Furthermore, on the one hand, it was revealed that companies do not always know what they want to do, but they want to do something with AR. One the other hand, it was found that some companies know what they want to do, they just cannot build it. These two argues are contradictory, but it could also be a result of different possessed knowledge of AR. The first statement implies that the customer know what AR is but not what AR could do, hence awareness-knowledge (Rogers, 2003), and the second statement implies that the customer know what AR is and what AR could do, hence these customers have reached the how-to-knowledge (Rogers, 2003). However, in both cases the companies lack in-house experience or competence of AR development, therefore a lack of principles-knowledge, in other words how and why an innovation work. However, Rogers (2003) argues that an innovation could be adopted without principles-knowledge, but it is not favorable for the innovation since it might be misused.

However, even if the knowledge regarding AR has increased the next question is if the knowledge corresponds to the reality, in other words if the companies have the right how-to-knowledge. From the interviews it was found that people sometimes have too high expectations of AR's capabilities. Those expectations are often derived from video-clips of AR found on the Internet, which does not always reveal realistic AR applications today. For instance, this is the case for

Microsoft HoloLens' promotion video Unfortunately, many times it results in that people receive false, or science fiction, picture of what AR could do and what it cannot do, further its leads to misinterpretations of AR's actual features. For instance, it was revealed that some people does not realize that the content have to be created in advance, they thought that it was the AR-device per se that created the content, hence they possess the wrong how-to-knowledge (Rogers, 2003). In summary, these video-clips could spread the knowledge regarding the phenomena AR (awareness-knowledge) but it could also result in disappointments of the technology (how-to-knowledge), which further can affect the adoption of AR negatively.

People who had a realistic understanding of the technology knew that the expectations were too high for sales in 2016 (VR Sverige, 2016). This further implies that there is knowledge of the phenomena AR but the expectations of the technology are somehow not realistic. Further, an incorrect knowledge of the technology also results in an incorrect estimation regarding time, cost and scope of an AR-project. For instance, it was explained that features often have to be cut off due to budget limitations based upon a lack of knowledge regarding the pre-work and content that have to be made. Hence, it could result in further disappointments regarding AR. Contradictory, almost one fifth of the US manufacturers, as visualized in diagram 5.2, considered cost, time and effort to be prohibitive for an AR adoption, which implies that their how-to-knowledge could be realistic.

7.2.3 THE PERSUASION OF AN AR EXPERIENCE

AR has great potential to bring business value by deliver additional features to a company's product offering, which indirectly could mean revenue generating opportunities. Moreover, there have also been found that cost-savings, productivity increases, and quality improvements, could be possible outcomes of an AR investment. In accordance, Damanpour and Gopalakrishnan (1998) consider that organizations mainly adopt an innovation with the objective to increase profit or to improve operational processes. Therefore, in a technology adoption process it is important that the evaluated AR application in somehow proofs its relative advantage, otherwise it will not be considered or adopted.

In the persuasion phase the decision makers in an organization shapes the attitude towards the innovation (Rogers, 2003). How an individual is persuaded about the attributes; relative advantage, compatibility, complexity, trialability and observability, determines the potential decision of a technology adoption. The persuasion derives from the incorporate knowledge by the individuals, as seen in section 7.2.2, and the social system, see seen in section 7.2.1. However, currently there are few implemented AR-cases and therefore there is an uncertainty regarding the observability and trialability. Additionally, the relative advantages have not yet been proven for all industries and for all AR-cases. Finally, the perceived complexity depends on several different factors, however in general it could be considered high, as will be seen in section 7.3, and therefore the uncertainty is high.

However, the uncertainty regarding the technology could be reduced by advices from trusted and close colleagues, peers and friends, who often are seen as more reliable and trusted sources compared to outside experts and scientific evaluations (Rogers, 2003). Therefore, in order for AR to take off, word of mouth is important, as will be discussed in section 7.3.2. As seen, the persuasion and beliefs about AR affect the adoption of AR. However, it is first in the next phase the decision will be made (Rogers, 2003).

7.2.4 THE INTERNAL RESOURCES AND CONDITIONS

Tornatzky and Fleischer's (1990) argued that the organization's internal resource and conditions are vital for the adoption process. It has been found that the organization's internal resources affect an AR decision. These internal resources and conditions could be the financials, the existing technologies and assets, the know-how in the organization, and the culture.

7.2.4.1 FINANCIAL IMPLICATIONS

The budget for an AR investment is critical since it might compete against other technologies or other types of investments that are critical and important for the organization. Zhu et al. (2003) believe that larger organizations often have sufficiently financial and human resources and therefore they have several advantages over smaller organizations regarding investments of new technologies. Furthermore, it is important the investment solves a crucial problem, otherwise the project will be down prioritized by the management when other pains are of more concerns to the organization. For instance, if a company's problem is expressed by declining margins or if someone's career is at stake, then the solution for it will be prioritized. In accordance, Premkumar and Ramamurthy (1995) argue that management support is crucial in an innovation adoption. As seen from the above reasoning, the adoption of AR in an organization depends on the budget aimed for it, which further depends on how critical the problem is for the organization. Therefore, the adoption of AR to a high degree depends on if AR is the appropriate technology for to solve the critical problem.

Another financial aspect that has to be considered regards the investor of a specific investment. One example that arose during the interviews regarded if the supplier or the customer should be the investor of an investment when both parties gain from it. For example, if Atlas Copco, who supply assets to Boliden, or Boliden should take the investment of AR, when both parties actual will gain from optimized service and maintenance of this asset. In accordance with Powell (1990), this could be seen as a collective action problems as all individuals in the network, in this case Atlas Copco and Boliden, would benefit from a certain action, but the associated cost of achieving the benefit makes it implausible for one individual to undertake the whole investment. Therefore, an integrated effort, from several actors, might be required in order to adopt AR, and as seen this could be an impediment for the AR adoption.

7.2.4.2 EXISTING TECHNOLOGY AND ASSETS IMPLICATIONS

If the use of AR is compatible with existing technology and assets, or even better, if it increases the value of those, AR will more easily be adopted. In accordance, Tornatzky and Fleischer (1990) argue that the cost of adopting the new technology will be significantly reduced if the existing equipment in the organization is aligned with the new technology. AR could provide functionalities to existing technologies, hence increase the performance of these technologies. Therefore, in such cases, AR will more easily be adopted. Similarly, the value of AR could hypothetically increase if AR is combined with other components and technologies, as analysed in section 7.1.2 and section 7.1.3. For instance, the incorporation of IoT increases the amount of digital information available, and therefore it increases the possible usage of AR, hence also the value of AR.

Manufacturing companies are lagging, or at least not leading in the adoption of new technology (Cambridge Service Alliance, 2015). Therefore, this implies that they also lag in the adoption of AR, which further appeared from the interviews. However, these companies might not experience an urgent need for such a technology if they also lag in their adoption of technologies that could be supported by AR.

7.2.4.3 KNOW-HOW IMPLICATIONS

The know-how in an organization is an important intangible internal resource (Mijinyawa, 2008). AR could be both competence enhance or competence destroying depending on the specific usage, but in most usage, it could be considered as competence enhancing due to its ability to increase the understanding of a system or process. Furthermore, since AR not always requires specific systems changes the organization could continue doing things in the same ways as before, but with an enhancement of AR.

As seen described in section 6.2, AR could be used for work instructions and training. For smart work instructions, it appeared concerns regarding employees' motivation when they do not have to think themselves meanwhile guided by an AR tool. In such case, the know-how would be digitalized. Thereby, the competence might be lost amongst the individuals and rather incorporated in the technology. However, the know-how would still be in the organization, further it will probably be compatible with existing knowledge since it just is another way to visualize the work instructions that previously been placed in binders. Similarly, but regarding training, AR makes it possible to perform training differently and therefore it could be considered as competence enhancing. Furthermore, training in AR could be even more competence enhancing, compared to current training methods, since it is a visual-interactive experience. Additionally, if AR is used in the right way it could also enhance the competence by competence transfer, for instance by the use of remote guidance.

However, additionally know-how must be incorporated in the organization in order to use AR. An AR investment may require process changes and it revealed that change management is always a huge concern for process changes. However, since AR rather is competence enhancing, further supports the internal resources in many aspects, it could facilitate adoption of AR in general.

7.2.4.4 CULTURAL IMPLICATIONS

As described previously, many organizations are lagging in the adoption of new technology. In accordance, PwC (2016h) found that not even one out of ten US Manufacturers were adopting AR in 2015. However, this does not regard all companies. One reason could be that companies have different size, managerial hierarchical structure, formalization, and centralization degree. In accordance, Chau and Tam (1997) argue that these aspects affect the adoption of new technology. In addition, it was revealed that younger organizations, in general, more easily adopt new technologies, further small organization are usually more flexible. This could be explained by differences in formalization, mindsets, norms or values between larger and smaller companies but also in between industries in general.

Rogers (2003) argue that an innovation have to be compatible with current values and norms in an organization in order to be adopted. For instance, if it is socially unaccepted to wear HMDs, then it will affect the adoption of AR negatively. From the interviews the example of Google glasses arose, which never became socially acceptable and therefore not used to the extent predicted by google. However, from an industrial perspective, the interviewees believed that the social acceptance of wearable devices are high. Furthermore, in a manufacturing context workers are often forced to wear safety equipment and therefore a HMD, for instance Microsoft HoloLens, could be socially accepted, even if the device look alike a science fiction device. From this perspective the implication is that the social acceptance of AR will not prevent the adoption of it. Anyhow, the respondent believes that the devices will become smaller and less outstanding.

Moreover, it was revealed that it is important to find the "entrepreneur" in the organization in order for an organization to adopt a new technology. Similarly, Mijinyawa (2008) argues that IT employees with sufficient competence and engagement could affect management by demonstrating the benefits of a new technology. Furthermore, management support plays a crucial role and if they do not support the adoption they will be an impediment for the realization of the innovation (Premkumar & Ramamurthy, 1995). Therefore, the entrepreneur in the organization could function as an early adopter and take a leadership role and affect adoption through advising and providing information about the technology to the top management, but also to the organization. For instance, there could be a cultural resistance among employees due to fear of unemployment, which the entrepreneur could help to overcome. As seen, informal institutions are not permanent by nature, and could therefore be changed over time. In accordance, Rogers (2003) argues that time is one of the elements important to considering in an adoption process. For instance, when time goes by, an "entrepreneur" within an organization could change an unfavorable standpoint towards an innovation to a favorable standpoint. Therefore, the implication is that the entrepreneur will play a key role in the adoption of AR.

7.3 TECHNOLOGICAL PERSPECTIVE

As presented in diagram 5.2, one third of the US Manufacturers, who have not adopted AR, did not believed that the technology is ready for "prime-time" (PwC, 2016h). The implication is that from a technological perspective AR has to improve in order to be adoptable everywhere by everyone. In accordance with Tornatzky & Fleischer (1990) and Rogers (2003), the development of the AR-market, the AR-industry landscape, and the AR-technology development, intrinsically affect a technological innovation decision making. Therefore, this section provides an analysis of each of these factors and how they affect the development and the willingness to adopt AR.

7.3.1 DISRUPTIVE OR SUSTAINING TECHNOLOGY

Derived from both the literature- and empirical findings it seems to be a huge interest for AR and notably it seems to exist a lot of business potential for the immersive technology. It further appears that the consumer market could play a key role for the further development of AR, and from a consumer context the forecast seems promising as well.

Christensen (1997) describes that a disruptive technology is a technology that initially underperforms the dominant ones but at some point in time it takes over the established market. In accordance, AR, and especially, HMDs underperforms within several areas and there are many aspects that have to be in place for the realization. For instance, Goldman Sachs (2016) argue *"We view the user experience, technology constrains, the development of content and application, and price as key hurdles to adoption"* (p. 4). However, these technological limitations will be analyzed in section 7.3.3. Additionally, the ecosystem is currently fragmented, which will be analyzed in section 7.3.2. However, these limitations imply that HMDs could become a disruptive technology since it nowadays underperforms both the smartphone and PC.

AR as a system could be seen as both a disruptive technology with the potential to create new markets, and a sustainable technology due to its ability to give increased performance of existing services or products (Christensen, 1997). Further, as described in section 4.1, the physical- and virtual worlds have started to converge (PwC, 2016b). This have led to a need of a new value propositions, which is a technology that support this new mixed reality, further support workers' ability to contextualize the large amount of information that is gathered from both the physical- and virtual, and AR have this ability (PwC 2016b; Deloitte 2016). These value propositions could be provided from the AR system per see and it does not matter what type of device that perform the task.

However, from the findings it has been revealed that it is not only AR intrinsically that has the greatest potential, but rather the HMD. All findings predict that HMDs will become as ubiquitous as the smartphone and therefore be used in a person's everyday life. Hence, the issue concerns if HMDs will become the next computer platform, or if it will fall into oblivion. The HMD devices have several additional value propositions, they could handle the 3D AR systems, give the user a fully immersive experience, but also provides the possibilities of being hands-free. The hands-free characteristics makes it possible for the user to perform task and use the AR-device simultaneously. Especially from an industry perspective this is beneficial since a lot of task requires instructions or other information in order for a worker to perform his or her task. In accordance, Christensen et al. (2002) consider that a disruptive technology often offers a different value proposition then existing technologies. Furthermore, they argue that a disruptive technology has features that are valuable to some of the customers in the mainstream market but at the same time these disruptive technologies are often unattractive to current customer base since it underperforms. As described above, AR via HMDs seems to add several additional value propositions compared to AR via the smartphone, further it provides features that are valuable to some customers but not all. In accordance with Christensen et al (2002), this implies that HMDs could become a disruptive technology.

Currently, neither the smartphone nor the HMD is technologically good enough to run all types of applications and systems. Although, the smartphone is decades ahead in the technological development compared to HMD, but HMDs could take advantages from several of the components in the smartphone. Furthermore, the development of components for VR, which is another type of HMD, could spur the development of HMD, since AR and VR are going towards each other (VR Sverige, 2016). However, there are still several other concerns than technical that also have to be solved for HMD, for instance smartphone and tablet currently have a larger customer base and are cheaper. Since both the technological aspects and the ecosystem is not in place for HMDs, it is also more natural that AR firstly will be developed from the smartphone and tablet market.

However, when the HMD becomes good enough, and if it becomes mainstream to have such devices, then it would bring extra value to provide the application on a HMD platform instead. In accordance with Christensen et al. (2002), it could be that the smartphone will become the over performing technology in the future, as visualized in figure 7.1. The smartphone per se could be considered as a sustainable technology that becomes better and better, and in the future, it might overshoot. The disruptive innovation, HMD, are offering another value proposition and if, and when, it becomes good enough it will probably take over the existing market. In accordance, Goldman Sachs (2016) argue that AR have the potential to create new markets and disrupt existing once.

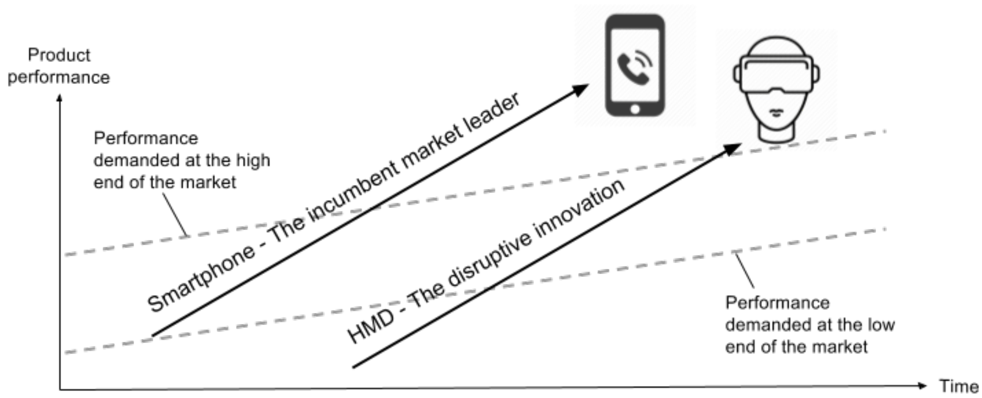


Figure 7.1 An illustration of the future scenario of when HMD disrupts the smartphone market.

7.3.2 THE AR NETWORK AND THE FUTURE DEVELOPMENT

As seen in section 5.4, the AR industry landscape, from a broad spectrum, consists of the infrastructure, platforms and tools, and applications and content. The players that are required for the ecosystem to function can be compared with the smartphone's ecosystem, since it has the platform structure. In accordance with Powell (1990) all actors in the AR-ecosystem are dependent and interdependent upon each other. Further, Iansiti and Richards (2006) argue that within industries it is the firm's integrated effort that is necessary in order to bring customer value. This means that the AR ecosystem will not be better than the weakest players performance. However, within the different landscape areas, for example HMD producers, these producers are competitors, and standard battles are ongoing within the different areas. Further, it was revealed that it is impossible to say how the ecosystem will look like in the future.

Despite the low sales-figures of VR and AR headsets in 2016 several companies, for example Facebook, expanded their investments in their development of both AR and VR. For example, Marc Zuckerberg said at their F8 conference in 2017 that AR is the essential part of their long-term plan. In general, there are currently mainly already established players, within for example smartphone, PC and social media, that are leading the way of the AR development, as described in section 5.4. This implies that these actors believe in the AR-technology, and in accordance with Kamath and Liker (1994), these dominant actors could influence other actors to adopt a technology, hence spur the adoption of AR.

Additionally, according to Goldman Sachs (2016) it was the industry that spurred the adoption of PC, meanwhile consumers spurred the adoption of the smartphone. However, for HMDs they argue that the demand comes from both the consumers, industry and even government. For example, this implies that even if it takes longer time to attract developers of content for business purpose, the consumer market still spur the development of the devices, consequently businesses usage of AR will gain from it. However, as described in the empirical findings these two markets experience different needs and demands. On the one hand, consumers are much more price sensitive than companies in general, but on the other hand companies require that technology is much more reliable and robust. Additionally, consumers want to have a lot of different applications and content, meanwhile business rather want to solve a specific key issue with AR. This implies that different types of devices, systems and use areas will be developed for the different interest groups.

As derived from the literature and empirical finding, the development of AR is going fast, much faster than for previous technological developments. It is revealed that there are a lot of product development and a lot of companies are involved. In accordance with Utterback's (1994) theory regarding the technology life cycle, it can be revealed that HMDs currently should be in the beginning of the fluid phase, as seen in figure 7.2. This phase is characterized by a high rate of product innovation and low rate of process innovation (Utterback, 1994), which seems to be the current state for the AR market. Furthermore, the numbers of AR-actors and different products are continuously increasing. Similarly, Sandström (2016) argues that new technologies usually create uncertainty, experimentations and entrance of new firms, and Klepper (1996) argues that it is characterized by many different proposed product. This goes in line with PwC's (2016a) reasoning regarding AR's technology ecosystem is highly fragmented and today there is no dominant design presented on the market. Further, PwC (2016a) consider that there are no standards when it comes to hardware platforms, operating systems, and data formats. Hence, before HMDs potentially will become mainstream a standard battle could be considered as necessary since standards it in the end reduces uncertainty (Klepper, 1996). Anderson and Tushman (1990) consider that the length of this phase is related to both the amount of new knowledge associated with the innovation, and if the existing technology has to be abandoned since existing firms probably will defend the old technology. As AR mainly is a supporting technology it is does not require a lot of new knowledge, further the old technology does not have to be defended. Therefore, the implication could be that the length of this phase will become relatively short. Consequently, from this viewpoint the transitional phase will be entered quicker.

The fluid phase is associated with uncertainty and experimentation (Klepper, 1996; Sandström, 2016). Related to the uncertainties the empirical findings revealed that it seems to be a waiting game amongst different actors. For example, Goldman Sachs (2016) believe that there is a chicken-and-egg issue related to the development of application and content, and enterprises investment in the hardware. Enterprises are hesitant to invest in AR-hardware without AR applications, and developers are hesitant to create apps and content without AR-hardware. This could further be related to the interdependency issues, which refers to the fact that the outcome is beyond one's control since the actor is only a part in a larger system (Powell, 1990; Adner, 2006). Contradictory, it has been found from the interviews that companies are urgent to do something with AR, which includes investments in the technology, but most of them do not know what they want to do. However, if drawing the parallel with the reasoning regarding the hug differences in performance between IPhone 1 and IPhone 7, it could be that customers and enterprises wait to invest in HMDs until the product increases in performance. This waiting game is critical for the AR's development, hence affecting the adoption negatively.

When and if standards for AR, regarding hardware, platforms, content and application, will start to crystallize the amount of product innovation will decrease and instead the amount of process innovation will start to increase, in accordance with Utterback's (1994) technology lifecycle theory, HMDs will then enter the transitional phase. Klepper (1996) argues that when an industry standard emerges, a dominant design emerges and the number of producers and new entries decreases.

Finally, the specific phase, which is the final phase in the technology lifecycle, is characterized by stabilization of product and process innovation (Utterback, 1994). Utterback (1994) argues that instead of focusing on process and product innovation firms typically focus on cost, volume and capacity. Therefore, will be firstly in this stage, with economy of scale, the price of the HMDs could be reduced significantly, further it is firstly then HMD could become mainstream.

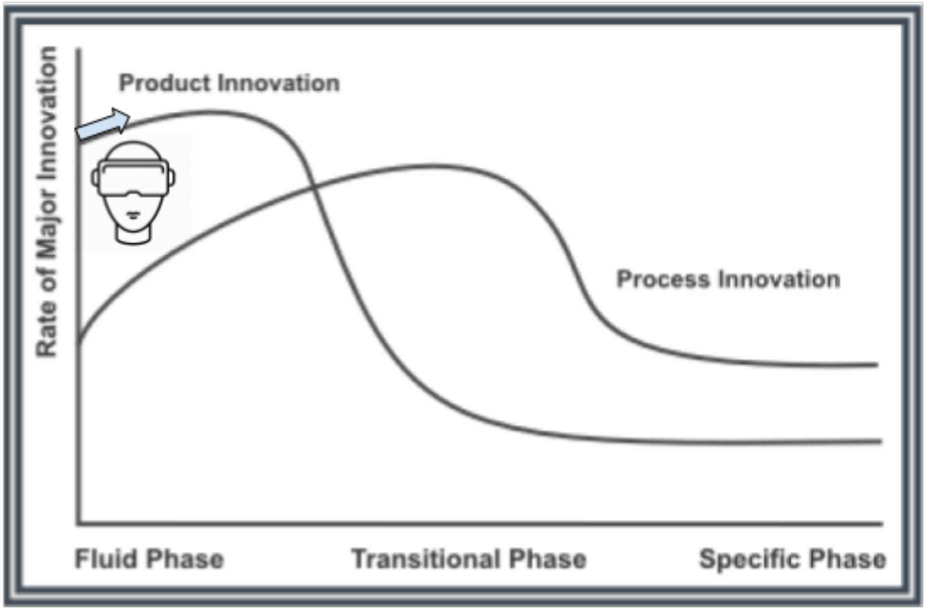


Figure 7.2. A visualization of the current state of HMDs in the technological lifecycle.

7.3.3 THE AR EXPERIENCE AND ASSOCIATED COMPONENTS

From the findings is has been revealed that an AR-experience currently possess several limitations that are derived from all included elements, that is; application, content, technology, interaction, the physical environment, and the participant. Further the AR-technology, which consists of input device, computer, display and sensors, experience several limitations. The performance and success of each of these elements will affect the AR adoption.

7.3.3.1 TECHNOLOGY ECOSYSTEM

As described in section 5.5, the technology ecosystem consists of different components and technologies that are interdependent of each other. In the case of AR, as for several other technologies, the technology ecosystem could be viewed from different perspectives, as visualized in figure 7.3. Firstly, AR consists of the technology ecosystem of sensors, computer, display, and an input device. Secondly, this system is part of a larger ecosystem consisting of the technology, content and application (but also interaction, participant and physical environment). Thirdly, the

AR experience is included in a larger system consisting of other technologies, for instance IoT and Big Data. As seen this is a quite complex system, where the technologies have different relationships and roles, which is also described by Adomavicius et al. (2006).

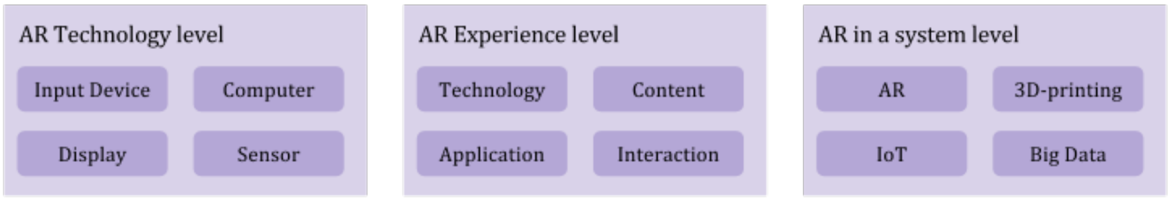


Figure 7.3. Three different viewpoint of the technology ecosystems

Adner and Kapoor (2016) argue that the realized performance of the technology ecosystem and the perception of it can be hindered by the components in the ecosystem. Therefore, all components are important for the system to function, and in accordance with the above reasoning it applies for all of the levels presented in figure 7.3. However, Adomavicius et al. (2006) argued *"In practice, however, a manager is interested in the analysis of a specific set of technologies in a specific context"* (p. 3). Therefore, an analysis of specific use-cases will be presented in chapter 8.

Similarly, with the above reasoning, AR could have different roles in a technology system; component role, product and application role, and support and infrastructure role. AR's component role could be described as when it is part of a larger system and the system is dependent on AR to function. For instance, this could be the case in Industry 4.0 in the future, depending on how AR is used. AR's product and application role could be described as it stand-alone-value, for instance by remote guidance as described in 6.2.1. Finally, AR's support and infrastructure role could be described as when it is used as a support tool, for instance by 3-D visualization of prototypes. The specific role and the specific context where it is supposed to be used affect the requirements, the interdependence, and the received value of AR. Therefore, it is difficult to evaluate the technology exclusively, further AR's role in a specific context will affect the willingness to adopt AR.

7.3.3.2 THE STATE OF CURRENT DEVICES

As described in section 5.5, there are several different devices that can be used as an input device, such as mobiles, tablets, and HMDs. However, as revealed from the interviews, further described in section 7.3.1, the most interesting AR-device is HMD due to its ability of handle 3D-AR, provide a more immersive experience, and being a hands-free tool.

However, HMD experiences constraints. Firstly, several of the respondents were concerned regarding the size, weight and uncomfortability of these devices. Secondly, most of the current HMD are single-use-devices, which means that they aim to serve a specific application or task. Thirdly, this type of device is quite novel, therefore it has not experience the same improvements, as for example the smartphone has. Further, this also means that some of the components that are unique for HMD, have not gone through the same development as the component in the more mainstream devices. Consequently, the HMD is also more expensive than other mobile devices and the technology is less developed. Goldman Sachs (2016) argue that it is these components that currently also drive the prices up for 3D-AR devices but, the prices of these will experience similar cost reduction curve as smartphones and PCs, hence a price reduction by 5-10% annually. However, even if the technology in smartphones and tablets is more mature, the relative advantages decrease due to the lack of additional value propositions.

Additionally, one concern revealed was the limited field of view, and this concern seems to mainly be related to HMD. However, it was considered that the user get used to it quite quickly. Anyhow, this concern has to be address in order to increase the perceived advantages with AR, but larger field of view also have some negative consequences. PwC (2016f) argued that the experience *"depends on a few key optical characteristics: eye box (relates to head freedom), field of view, and image quality. Ideally, each should be as large as possible. However, increasing any of them leads to bigger optical components, greater size, more weight, discomfort, and higher cost".* Therefore, it is a trade-off, and the implication is that a solution to one factor might affect the other factors negatively. However, all of those have to be considered in order for AR to be adoptable for everyone everywhere. Further, the limited field of view, is also a limitation with smartphone and tablet. This was not brought up equally often during the interviews, and one reason could be that people are used to the size of these displays, and therefore does not expect anything else, hence perceived as good enough.

It was revealed that several of the respondents did not considered the device good enough for all type of AR, and as seen in section 5.5.1.2, these kind of mobile AR, whether it is HMD, smartphone, or a tablet, still experiences limitations. For instance, limitations concerned computational- and graphical capacities, where the computational capacity is highly related to the amount of content possible to process and store at a given moment (Craig, 2013), further a higher computational capacity would require better battery capacity. Additionally, the battery affect the mobility (Goldman Sachs, 2016), as will be seen in chapter 8 mobility is very important for many of the AR use-cases. Currently, small-size batteries have to poor lifetime and if the life-time is extended the size become too large or too many recharges of the battery is needed. Additionally, Craig (2013) also brought up concerns regarding device interoperability, and this might be even more undeveloped for HMD since it is a more novel device.

As seen in section 2.5.1.2, a technology's rate of adoption affects by several different attributes. The relative advantages of HMD could be considered as higher compared to other devices due to its additional value propositions. However, since the HMD-device is novel and expensive compared to other devices it has some drawbacks. For instance, companies have to acquire the device which is not the case for smartphones and tablets, since most people already owns one. This means that the trialability is lower for a HMD compared to other devices. Furthermore, the complexity and compatibility with existing technology is also higher for other devices compared to HMD since it could be as simple as downloading an application. Since HMDs are single-used-devices, it makes the device less compatible with new use areas and new applications, and therefore higher barriers to acquire such a device. Additionally, the user has likely used a smartphone or tablet before, but most unlikely a HMD, which also affect the complexity. However, regarding compatibility of values, past experience and needs, there should not be any larger differences, and this is due to the similar functionalities of the devices and it is rather a new way to visualize things. Finally, the observability dependence on the actual use of it and in general the observability is rather affected by the specific use context, rather than the device per se.

However, several of the respondents argued that the device will become better in the future and similarly, this was revealed from Goldman Sachs (2016) and PwC (2016). It was stated that current devices have several limitations that is critical in order to meet customers' demands. Therefore, the hardware still has some way to go in order for AR to become adopted by manufacturing companies.

7.3.3.3 IN RELATION TO THE PHYSICAL WORLD - 3D-CAPABILITIES

An AR experience takes place in the physical world, therefore the AR experience also has to be experience in three dimensions in real-time and it is the 3D capabilities that makes this possible. However, one of the main concerns, revealed from the findings, regards the input, hence also the 3D-capabilities. The 3D-capabilities seems to be one of the main technical concerns.

The fact that an AR-experience takes place in real-time and in relation to our physical world provides new challenges that have not been experienced before. Consequently, prior technology has limitations and impediments for usage in AR. For instance, AR requires that sensing, tracking, orientation, interaction, modeling, and displaying, all must happen in three dimensions and in real-time (PwC, 2016a). If only one of those abilities are inferior it will affect the whole AR-experience, as argued by Adner and Kapoor (2016) the realized performance of the technology ecosystem can be hindered by the components in the ecosystem. Therefore, all of those abilities are equally important for the relative advantages, which affect the adoptability of an innovation, as described by Rogers (2003).

Some of the 3D-capabilities in AR are more mature than others. For instance, PwC (2016f) argue that the technology used for gathering of visual and audial information is sophisticated, mature and capable of providing high quality. The explanation for this could be these technologies prior application areas, such as filming, which are mature areas that have improved by decades of developments. Therefore, the associated components are also more mature. Furthermore, 3D displays are very good and are expected to become even better (PwC, 2016c), similarly with the above arguing, 3D displays are also included in other more mature technologies.

PwC (2016c) argued that one of the key challenges with 3D-capabilities are to identify the location and orientation, further to provide the right content at the right place, and the progress of these are strongly related with the progress of 3D-capabilities. This was further also found from the interviews. For instance, it was described that when the device is used in an environment where there are a lot of moving objects, for instance people, the holograms tend to move around. The implication is that improvements are needed regarding 3D perception, 3D mapping, and 3D displaying.

As described in section 5.5, it is important that the physical and virtual match precisely and change according to the user's movement to make the experience seamless. Therefore, it is also important that the 3D-files can be processed and handled in an efficient manner. In accordance, PwC (2016a) and Goldman Sachs (2016) argued that processing and displaying of 3D-content have to be improved. Since all of those limitations prevent adoption of the innovation AR, in accordance with Rogers (2003) arguing regarding innovation attributes, they have to be addressed in order for the adoption of AR to take off.

7.3.3.4 CONTENT, CONTENT AUTHORING, AND APPLICATION

As described in section 5.5.2, content is the key element within AR (Craig, 2013). As revealed in the empirical findings it is important that the technology comes to the state where it is possible to plug-and-play. However, AR has a way to go before this is possible, and currently some of the main concerns regards the content and the time-consuming process of creating content.

As stated in the empirical findings it is important that the relationship between cost and benefit have to be considered and *"The pre-work of using AR should not exceed the benefits"*. However, currently this is the case, and content authoring is one of the main concerns revealed by the respondents. Similarly, PwC (2016f) and Craig (2013) argue that authoring methods and tools used today are complex, require expertise, and in order to create high-quality and accurate content, high effort is needed. Consequently, the relative advantages of using AR becomes lower, similarly the AR-system is perceived as complex to use, and both factors affect the adoption of AR negatively. In accordance, PwC (2016f) stated, "*authoring methods today are complex, fragmented across media types, and not well integrated… For AR to take off, the ability to rapidly create, manage, edit, and deploy 3-D content is one of the problems that should be addressed*".

However, even if there are several concerns regarding content and content authoring it could be seen that there are several upcoming companies who are trying to solve this specific problem. One of those is Vuforia who provides a software where it is simple to convert files into AR-format, further their solution is perceived as easy to use. Another such development platforms are also Unity. However, the entering of these kind of solutions, whereas content authoring become easier, implies that the time spend on development of content will decrease. Therefore, the relative advantages, the trialability, hence also observability will increase and the perceived complexity decrease, which in accordance with Rogers (2003) theory will facilitate the adoption of AR.

However, content authoring is easier and simpler for geospatial AR systems and 2D AR systems. These does not require the same complexity both regarding the input and the output. PwC (2016f) argues that regarding authoring methods for geospatial AR systems and 2D AR systems it is largely a matter of content development and not the authoring per se. Therefore, these systems could provide higher relative advantages and lower complexability compared to 3D-AR systems currently. Hence, also increase the adoption rate of AR, whilst authoring methods for 3D systems are improved.

From the interviews it was revealed that current 3D-files are often too large or complex for efficient usage in AR and they usually have to be adjusted. Similarly, (PwC, 2016f) and (Craig, 2013) argued that 3D content is very data intensive. The respondents revealed several different solutions, for instance, to compress or convert the files or processing files one by one. However, these solutions affect the AR-experience negatively since it either affect the quality, or require a lot of extra effort from the user. For instance, there is a lot of problem of converting files and it is time consuming.

In addition, it was revealed that even if organization might have a large 3D-files library, these existing 3D-models have been made for other purpose than usage in AR. However, the implication is that the future 3D-files will be AR-friendly, since they have been created with AR in consideration, and PwC (2016f) further states "*As AR authoring tools evolve, the nature of content that is best suited for AR will evolve*". In accordance, it was revealed that in the future there will probably be a standard where all suppliers offer 3D-models that are AR compatible. However, the compatibility could be perceived as high since the companies might already have 3D-files, but as argued it is more complexed in reality, and the current compatibility with existing technology is quite low for content. Therefore, the trialability also decreases, since it requires a lot of effort to develop content, which in turn naturally affect the observability since few solutions are developed and observable.

Another concern is that companies often does not always understand the complexibility and time consuming of content development. For instance some people thought that everything will be in 3D when using the device and they believe that the AR-device per se creates the content and does not realize that a lot of content have to be created in advance. Further, a computer is smart, but tasks that might be simple for a human could be very complex for a computer, as described in section 6.1. This leads to that features often have to be cut off due to budget limitations based upon a lack of knowledge regarding the pre-work and content that have to be made. Consequently, the perceived value and the relative advantages decrease, hence also the willingness of adopting AR, in accordance with the TAM and IDT model.

The AR application is the computer program, which interacts with the different technology components (Craig, 2013). Therefore, the user experienced value of using AR comes from the specific application in combination with the hardware abilities. A specific application sets the requirements on the technological components in the device. However, since the technology for AR is limited today it further determine what type of applications that could be developed. Craig (2013) argues that the AR technology is not yet fully developed and therefore future applications might be able to do things that are not possible today. This is further analyzed in chapter 8.

7.3.3.5 INTERACTION

As described in section 5.5.3 interaction is the way the users interact with the physical world and the virtual world. The current methods used for interaction are mainly gesture and speech, but other methods could also be used such as eye-tracking and motion-tracking (Craig, 2013). These methods are naturally more undeveloped, compared to the usage of keyboards and mice, due to more novel character. Therefore, there are also currently several challenges related to current integration methods in AR.

One concern regards the efficiency of using specific interaction methods for different types of task, for instance writing is not optimal in AR, similarly gesture is not efficient if the user needs to have his or her hands free, as described in section 6.1. Furthermore, the methods could be limited by the environment since it could be noise, dirty, bright or dark, and for instance, gesture might not be optimal in a bright environment and audio or voice commands might not be optimal in a noisy workplace (Craig, 2013). Additionally, as revealed in the empirical findings, the challenges also concern the user's experience, for instance ergonomic concerns and the comfortability of using specific interaction methods, for instance voice recognition in public.

These limitations affect the user's perceived usefulness, and perceived easy of used, negatively, hence also the adoption of AR, as described in the TAM model. Additionally, the relative advantages of AR decrease and the complexibility of AR increases, which also affect the adoption of AR negatively, as described in the IDT model. As seen, these limitations currently affect the adoption negatively, therefore they have to be solved. Similarly, PwC (2016a) argue that improving performance of the interaction area is needed in order for AR to take off.

However, since AR overlays the reality with digital content the interfaces and interaction methods have to become optimized for humans rather than computers (PwC, 2016d). As seen, current methods are more intuitive and natural for humans compared to other methods such as usage of keyboards and mice, hence also easier to learn. Therefore, the implication is that when the current challenges and limitations are solved the factors mentioned above, relative advantages, complexibility, and perceived easy to use, will instead be positively affected by the interactions methods, hence spur the adoption. Additionally, since AR combines real- and virtual worlds it supports multiple types of interactions, and interaction that goes beyond the possibilities in the real world (Craig, 2013; Tech Policy Lab, 2015). Therefore, AR might have the ability to form new types of interaction methods, for instance real-time translation of the participant's used language (Craig, 2013). Further, PwC (2016d) argues that the interaction methods should be probabilistic. When these types of abilities occur the relative advantages of AR, and the perceived usefulness of AR, will increase even further. Hence, increase the adoption rate, in accordance with the IDT model and the TAM model.

7.3.3.6 INDIVIDUAL OR USER FACTORS

From the interviews it was found that current HMDs are heavy and uncomfortable, therefore it could not be used during the whole workday. Additionally, as described previously, the interaction methods might not be ergonomically correct, and socially acceptable. However, the weight, comfortability and easy-of-use of the hardware is very important in order to attract users since the AR-device will otherwise not be used by the employee. In accordance, the TAM model address a user's perceived usefulness and perceived ease of use which will affect the user's actual system use. In order for workers to use AR, the technology must be perceived as ease of use, therefore it has to be comfortable and light. However, this also depends on the specific use-areas, since these factors might be of less concerns if the device is used for specific tasks performed in limited time.

One solution could be to integrate HMDs into a helmet that workers already use for safety reasons. By this the AR-ability or AR-screen could easily be flipped up-and-down in front of the user's view. For instance, DAQRI currently is a hardware and software company that develop such AR-solutions. However, the development of AR points towards both lighter and more comfortable devices and from a long-term perspective several of the respondents believed AR will be integrated in ordinary glasses. As a conclusion, from the users point of view the device is today a limitation for adoption, but with the right technological development such problems could be erased.

7.3.3.7 THE PHYSICAL ENVIRONMENT AND NETWORK CONNECTIVITY

There are some technical impediments related to the specific environment where the technology is aimed to be used. As described in section 5.5.1.2, the environment might affect the technical components in a manner that they do not work correctly (Craig, 2013). These could be caused by humidity, dirty, noise, temperature etcetera, but also by other elements such as sunlight whereas avoidance of reflection of the sun must be addressed. These factors affect the possible usage of AR, hence also the perceived usefulness, as described in the TAM model, and its relative advantages, as described in the IDT model. In accordance, this might affect organizations' adoption decision, especially within industries which experience these environment limitations, such as noise and dirt. Further, the respondents were concerned that current devices are single-use-devices, and these environmental factors are one of the reasons for the single-use-devices. In other words, the devices are not good enough to operate everywhere, hence a limitation which affect the adoption of AR, but as concluded in many other aspects it depends on the use-case.

Since the AR-experience takes place in-real-time, in the real-world-environment, solid network connection is often needed, especially if the processor is available by the Internet. On the one hand, it was argued that network connection is too poor in certain regions and areas. One the other hand, is was argued that it is possible to access the Internet almost everywhere by the use of satellite-phones. However, even if the Internet is accessible it might be that the connection is too poor, but it depends on the specific use-area and its specific requirements. Therefore, this might be a limitation in some cases but not all, hence it is important to consider where the application is supposed to be used, further its requirement of Internet connection. Consequently, this could affect the relative advantages, but as argued it might depend on the specific use case. However, with the entrance of 5G the Internet capacity is expected to get better, therefore more data intensive application could be possible.

7.3.3.8 PRIVACY AND LEGAL FACTORS

These input and output ability, makes it possible to constantly collect data from the environment where the AR-experience takes place, further collect information regarding the performance of a specific task. For instance, when and how it was performed and by whom. This could be beneficial within regulated industries, for instance the drug industry. Similarly, Cambridge Service Alliance (2015) argued that this type of abilities will have major influences on information access in the future since it could provide *"real-time efficient data access and, increasingly, context-aware answers"* (p. 14). Therefore, the input- and output- ability could spur the adoption of AR.

However, these types of abilities also provide concerns. It was argued that one concern could be that employees in an organization do not want others to know and see what they are doing all days. Further, the question regarding the social accepted of tracking was revealed during the interviews. Therefore, this ability could be an impediment for adoption. Furthermore, it could affect the user's perceived usefulness as described in the TAM-model, due to the uncomfortability of being observed.

There are issues concerns privacy in public, but also infringements of intellectual property and the right to record in public (Tech Policy Lab, 2015). Furthermore, provision of incorrect information or information that could be used unlawful or unethically in the decision-making. In the future there might be restrictions or laws that prohibit the usage of AR at certain places or in public. Such a law could have major impact on possible usage of AR, hence prevent the adoption of AR. These concerns are related to governmental regulations, as described in the TOE framework.

7.4 SUMMARY OF THE EXTERNAL ENVIRONMENT-, ORGANIZATIONAL, AND TECHNOLOGICAL PERSPECTIVES

The trends Industry 4.0 and Servitization have shown to spur the adoption of AR amongst asset intensive manufacturers. In a servitization context AR could provide new or extended service offerings to customer, and in Industry 4.0 AR could facilitates for obtain the aim of totally collaborating entities. However, AR intrinsically is not critical for any of the trends. Further it could be seen that in a servitization context it could be easier to make value of AR as a stand-alone component compared to Industry 4.0, where AR is more dependent on the implementation of other technologies. Additionally, few incumbent firms have incorporated useful technologies for the business transformation. These firms, who lag in their technological adoption, will also experience a lower need for a technology that support a mixed reality context.

The social system affect the adoption of AR in a manufacturing context. Early adopters will play a key role as educators and lead the way for the adoption of AR. The early majority will first adopt when the technology is reliable and robust, and compelling use-cases can be seen.

It is shown that the awareness-knowledge regarding AR have been reached by most manufacturing companies. However, the know-how-knowledge differ between companies, further some have received a false know-how-knowledge which might lead to disappointments. Awareness of AR is important when considering an investment, and therefore this knowledge could facilitate for the adoption of AR. However, the disappointments of the technology could further spur the waiting game and thereby affect the adoption of AR negatively.

AR has shown to bring business values such as new revenue streams, cost savings opportunities, productivity increase and quality assurance, but this has to be demonstrated to the organization that evaluates the AR-application, and trusted references is of importance. It is in the persuasion phase that the decision maker gets a positive or negative attitude regarding the technology. The persuasion depends on the knowledge of the innovation, the social system and the degree of uncertainty that occurs regarding the innovation. Therefore, the proven relative advantage and the attitude towards AR will affect the adoption decision of the technology.

The internal resources in the organization; the budget aimed for the investment, if AR is compatible with existing technology and assets, if the know-how is enhanced or destroyed, and the organization's culture regarding adoption of new technology, affect the willingness to adopt AR. If the budget is large, the more advanced applications can be acquired. If AR is compatible with existing technology and assets, the value of both the AR investment and the existing technology and assets will increase, however, AR has also a standalone value. If the know-how is enhanced it is more likely that AR will be adopted and lastly, if the culture is open minded and accepts new technologies, then it is more likely that AR will be adopted.

AR, irrespectively device, has the ability to merge the real and physical world. However, HMD provides additional value propositions, namely a more immersive experience, the management of 3D-AR systems, and is hands-free ability. However, the HMD technology is less developed than the smartphone. However, since the smartphone has an established customer base this implies that AR first will be developed for the smartphone but when the HMD becomes good enough, it will probably take over the existing smartphone market. The implication is that AR, by the use of HMD, has the potential to become one of the next disruptive innovations.

The current market is fragmented, there is no standards neither regarding device, platform, nor to describe information. Additionally, new actors are continuously entering the AR industry landscape. This indicates that AR is in the early stage of the technology life cycle. Furthermore, all actors in the AR ecosystem are independent of each other and the spread of AR is therefore dependent on the contribution to the development for the whole ecosystem. Due to these current uncertainties, companies also experience uncertainties regarding an AR-investment.

There are several limitations related to an AR experience, which prevent the adoption of AR. Furthermore, the elements of an AR experience are interdependent and to increase the performance of the whole experience several improvements are needed. However, as described AR could have different roles, and depending on the specific usage and context different constraints and interdependencies are the most critical ones for the adoption of AR.

Currently, the most critical elements are the device, the 3D capabilities, interaction methods, and content and content authoring. There is also limited battery- and computer capacity, and currently, the technological concerns prevent the adoption to a large extent, but all of those are expected to improve in a nearby future.

Device constraints concern limited device interoperability, mobility, battery- and computational capacity, limited-field-of-view, and the single-use-devices issue. Additionally, there are environmental device limitations, and legal and privacy concerns regarding the input and output capabilities. There are also some constraints that concern the specific input-device used. Concerns related to HMD specifically are size, weight and uncomfortability, and in addition, HMDs are more expensive compared to smartphones or tablets.

However, when these limitations have been solved, some of those have effects on the adoption in a reversed manner. The 3D capabilities could open up for new business opportunities and the interaction methods are intuitive and easy-to-learn, hence these abilities will spur the adoption when they have improved. Additionally, if the device becomes smaller, more comfortable, and more mobile, it could be used for longer period of time and hence also spur the adoption of different use-cases, and thereby also AR in general.

8. ANALYSIS; POTENTIAL USE-CASES OF AR

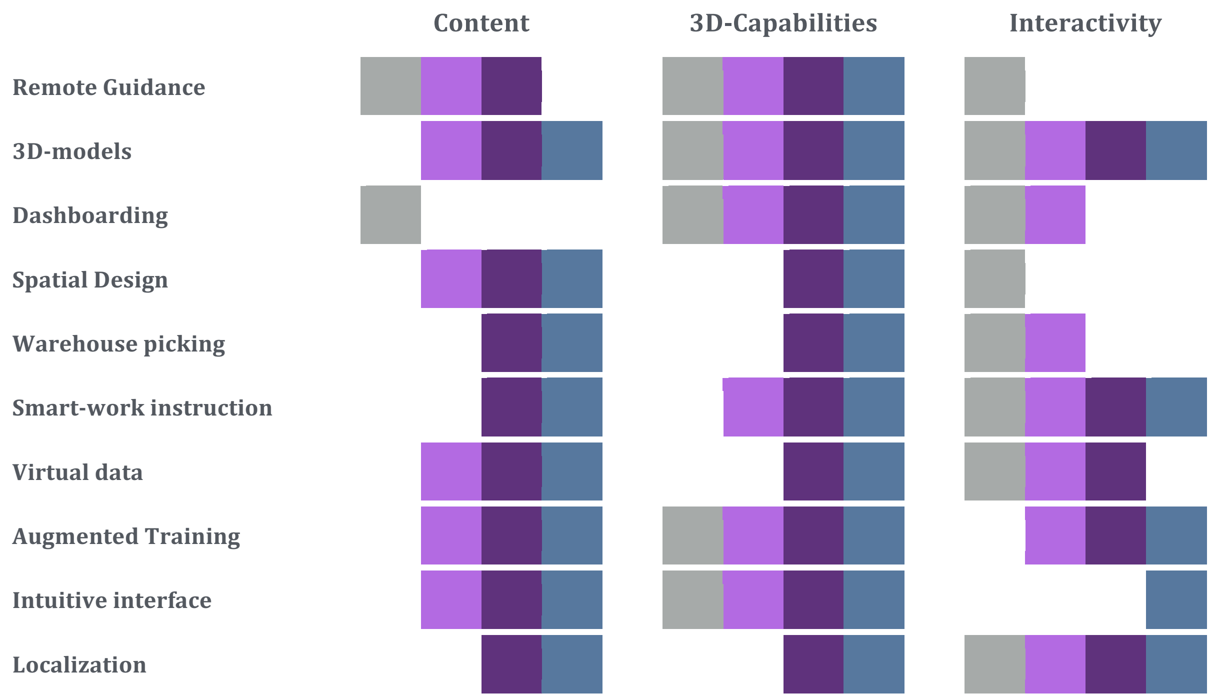
The following chapter provides insights regarding specific use-cases of AR, and the potential of a use-case depends on the context, the environment, the specific usage, and the time horizon. In accordance, this also affects the specific application and the relative advantages of it. This section aims to answer the second research question:

- *What type of AR-applications could be useful in an asset intensive manufacturing context and are these applicable today or rather in the future?*

8.1 REQUIREMENTS FOR THE SPECIFIC USE-CASES

The value and potential of a specific AR use-case varies. As described in section 6.2, most AR applications are actually possible to develop, but the pre-work would be too costly and time-consuming and therefore exceed the benefits of the usage. Furthermore, it might not be possible to provide a seamless experience due to poor computational capacity and poor developed 3D-capabilities. Furthermore, different context, environments, and usage have different requirements, hence the most critical concerns or limitations will differ.

In figure 8.1 the use-cases, described in section 6.2, have been categorized by how technical advanced they are estimated to be. The technical requirements depend mainly on the content, hence indirect on the content authoring, and the 3D-capabilities. However, some of the use-cases could be applied in easier or more advanced manner, as visualized in figure 8.1.



Content Requirements

Low	Visualization of information (not models)
Medium	Visualization of single models (specific part or product)
High	Visualization of several models (several parts or products)
Very High	Visualization of "everything" (many parts and products, e.g. in a factory)

3D-Capabilities Requirements

Low	Display 3D-models
Medium	Display 3D-models in relation to an object
High	Display 3D-models in relation to a physical environment
Very High	Display 3D-models in relation to moving objects

Interactivity Requirements

Low	Display static model in different size
Medium	Display action model (An action gives a predefined result)
High	Display layer model (More action possibilities in several levels)
Very High	Display modifiable model (Changes in model result in changes in real world)

Figure 8.1. This figure show for each application what the lowest requirements are for the three most critical technical areas for AR. The color to the left is the lowest requirement for the application to function in its simplest form that still provide value. All additional colors to the right indicates the additional value that can be of value when the technology advance for that specific application.

8.2 SPECIFIC USE-CASES OF AR

This section provides analysis of the ten different use-cases of AR. This is done by evaluating the use-cases from Rogers (2003) adoption factors, in combination with the analysis in the previous section. Furthermore, this section provides insight of necessary improvements of AR that has to be in place for such applications to function.

8.2.1 REMOTE GUIDANCE

Remote guidance is one of the near time applications, since the current AR-technology is good enough for this usage. The preferred device for remote guidance should be HMD, due to the value of being hands-free. The device should only be used in shorter periods of time, in critical situations, when service is requested. If the problem is critical enough the current single-use-device's features and benefits exceeds the costs and risks of investment, and thereby provide high relative advantage.

The device's weight and comfortability will not be a limitation for remote guidance, since it only will be used during a short period of time. Similarly, the limited field of view will not be and the limited battery capacity is good enough for shorter and specific usage in critical situation. Additionally, if the device is going to be used for a longer period of time, the carrying of extra batteries should not be a larger concern if the problem solved by remote guidance serves is critical enough.

There is no need to create content in advance, this means that the application does not have to be customized for the specific customer. Therefore, it could easily be used directly by companies.

Furthermore, all 3D capabilities of remote guidance depend on how the application technically is constructed in terms of both hardware and software, and the synchronization of those. However, remote guidance does not have to be technically advanced with abilities like synchronize content with reality and other critical limitations. Therefore, these capabilities are not critical limitation for usage in remote guidance. Although, this could become interesting in the future, but right now the application is good enough for its purpose.

However, the specific environment where the device will be used could be critical. Firstly, the device operational ability must not be affected by environmental factors, such as noise or dirt. Secondly, remote guidance requires Internet connectivity for communication with someone at another location. However, remote guidance does not require high data transferring. It has been revealed that at all locations over ground should not be a problem for this type of real-time streaming, but underground and below the water surface the connectivity is critical. However, in general for remote guidance, Internet connectivity should not critical.

The former analysis found that how compatible the organization's existing technology and assets are with the innovation, in this case remote guidance, will affect the adoption of the solution. For remote guidance, at least for now, the solution does not have to be integrated in other technology or assets and therefore it could more easily be adopted. However, in the future, when remote guidance will develop further, service work via remote guidance could be stored in some sort of database or ERP system, in order to provide a view of previous tasks, customer job or in education purpose. Therefore, when this is possible, remote guidance could create additional value by the combination of existing systems and AR.

From the servitization analysis, as presented in section 7.1.3, it could be seen that servitization spur the adoption of AR. Remote guidance is good enough to use today and it could facilitate for service and maintenance of an asset. In accordance, Jagstedt (2016) argue that a first step of becoming a service provider could be to add service upon the product, for example by offering services as repair, maintenance and training. As described, remote guidance could be used to offer service and maintenance and therefore, the servitization context spur the adoption and make use of remote guidance. Additionally, as seen in table 4.1, remote communication was one of the technologies requested by companies in a servitization context.

A remote guidance solution is and will be used rarely, only when something goes wrong, and cannot easily be solved without expertise. Remote guidance could be easy to use and understand, further it does not require any integration with other technologies. Therefore, the complexity of the solution is low, which implies that it is easy to adopt and incorporate the application in the organization. Furthermore, the trialability of a remote guidance is high, compared to other use-cases, since existing solutions are available, and it does not require any extensive installation in order to test the solution. Similarly, references of remote guidance are available, for instance XmReality's customers, who could provide customer reviews. Therefore, the observability could be considered as high. A summary of the innovation attributes, from a remote guidance perspective, could be found in table 8.1.

Table 8.1. A summary of the adoption attributes related to remote guidance.

Factor	Explanation
Relative advantage	• Hands-free • Facilitate for service and maintenance • Cost saving potential. E.g. reduce downtime and/or travel costs • Reduce distance • Knowledge transfer Supplier • A way to charge for service
Compatibility	• Does not have to be integrated in other technology Supplier • Could require organizational change and thereby not consistent with existing values and past experience. • experts on a service center • service technicians out in the field Customer • Consistent with current operations, just facilitate tasks that is already performed today and rather a collaboration and communication tool
Complexity	• Easy to understand and use
Trialability	• Easy to test, due to existing solutions and no need for integration
Observability	• Customer reviews are visible to others. There are existing use cases

8.2.1.2 HOW REMOTE GUIDANCE WILL BE USED AND BY WHOM

As seen in the analysis there are organizational factors that affect the adoption of an AR application and the relative advantage of the application. First of all, it depends on what type of organization that are going to use remote guidance. In general, it could be said that it could either be a company that are selling complex and asset intensive equipment that are searching for service options, or it could be an organization that aim to use remote guidance internally.

For the first type of user, the service providers, XmReality's founder argued that some customers invest in remote guidance solutions in order to charge for service, and thereby generate new revenue streams. Further, it was found that remote guidance can reduce travel costs for workers within service and maintenance. For service providers, the budget dedicated to the investment rather determines how many remote guidance tools that will be bought or subscribed. An AR-device is expensive devices today, even for companies, and many devices are needed for an organizational change, but not as expensive compared to customer's production downtime.

As described in the analysis in section 7.1.3, going toward being a service provider could be a business model issue, and therefore it is rather a strategic decision. The global product manager for software products at ABB Robotics considers that the technology is not the hardest part, but rather the organizational change and the creation and extension of all the service centers needed to support the service it entails. He considers it to be a challenge to have employees who are available for the right time zone, speaks the right language, and know all the products. Despite usage of remote guidance, the expertise is still needed, which means that the know-how of how to service and maintain the assets are still, or probably even more, important. However, for such huge organizational change, organizational resistance has to be taken into consideration, it could be a challenge if employees seem to be against the change since it is against the norms and values.

For the other type of user, companies who want to use remote guidance internally, remote guidance would rather be a supporting tool for communication and collaboration. For example, Volvo used it as a tool while they were setting up a factory in China. For Volvo, the solution reduced travel costs, accommodation costs and minimized the risks of unavailable specialist while traveling. Therefore, one advantage with remote guidance is reduced distance and knowledge transfer. This implies that remote guidance offer some advantages compared to existing communication tools, such as mobile phone or skype, since the guider could augment additional information and features to the user. Those are the technologies AR supersedes.

8.2.2 DASHBOARDING

Derived from the empirical findings, dashboarding refer to visualization of graphs and specific machine features in connection to the machine by the use of AR. It was found that this could be a quite simple application area which is possible to develop today, and requested by many companies. The value of dashboarding is the access to the right information at the right place and at the right time. For example, a service technician is maintaining a machine and can in real-time view the effect of maintenance by the metrics visualized in his field of view. As seen in table 4.1, dashboarding was also one of the technologies requested by companies in a servitization context.

Roger (2003) argues that an innovation's adoption rate depends on its relative advantage over the idea it supersedes, and thereby dashboarding could be compared with reaching the same information in other ways. For instance, the information could be visualized in the control room and the employee have to be present in the room to access the information. However, it is still valuable to have an overview of all measurements in one place, but the extra value with dashboarding is that the employees can get real-time metrics in relation to the machines or similar.

Visualization of information requires that there is underlying infrastructure in place, independently if the information is going to be visualized in the control room or by an AR device. Therefore, what could be visualized depends on what's been measured. In relation to Rogers (2003) this means that AR has to be compatible with existing technology in the organization, which can decrease the adoption rate of dashboarding via AR. In relation to Industry 4.0, dashboarding goes in line with totally integrated entities, since it is a way to visualize sensor data. Further, many companies already have sensor data, and therefore the underlying technology is already in place, it just has to be connected to the cloud to make value of it and to be visualized in an AR solution. IoT by itself is also a current trend, and therefore much of this work is already upcoming or in place, which indicates that the compatibility is not a critical aspect for the adoption of dashboarding via AR. In line with the reasoning in section 7.2.4.3, dashboarding is just a support tool for operation and thereby competence enhancing, and should therefore be compatible with existing norms and organizational culture.

However, some of the respondents argued that this type of use area does not always make use of AR's capabilities and therefore it is questioning if AR is the right medium for this type of application. Metrics could for instance instead be visualized via an application on a tablet, it does not necessarily have to be performed by AR. However, as argued before, much of AR's value is that is hands-free which also applies to dashboarding.

Dependent on the requested complexity of dashboarding there will be different requirements on the technology. For instance, if it only will visualize information, it is possible today on existing devices, such as smartphones and tablets, but a tracker or barcode is then required in order to know what information to visualize. Although, the value of being hands-free will not apply for smartphones or tablets. If a 3D-AR system instead is required, current smartphones cannot be used, and then it is rather the upcoming smartphones or HMDs that can be used. An example could be that AR is going to visualize what busses that need to change brake pads by color them red. This will only be possible with the more advanced type of AR-systems.

Moreover, dashboarding is a use area that can proceed in many directions, and therefore it could be of great value to test this type of application in an organization by the use of existing smartphone and tablets, since it then does not require a lot of investment. This with the argument of being prepared for upcoming values of what could be possible when better AR-devices enter the market. Dashboarding by smartphone will probably emerge in the upcoming years due to the IoT trend, the low technical advancement of this type of application, and due to curiosity to test AR in-house. A summary of the innovation attributes, from a dashboarding perspective, could be found in table 8.2.

Table 8.2. A summary of the adoption attributes related to dashboarding.

Factor	**Explanation**
Relative advantage	• Access the right information at the right place and at the right time • Hands-free
Compatibility	• Underlying technology to access data has to be in place • Has to be compatible with existing sensors/ IoT
Complexity	• Could be time-consuming to integrate with existing sensors/ IoT or other technology
Trialability	• Not easy to test before implementation in the specific organization
Observability	• Existing use-cases of this application today

8.2.3 VISUALIZATION OF 3D MODELS

AR could be used in order to visualize 3D models. Since this ability could be used for different purpose providing different business value, the analysis is divided into design phase, sales phase, but also visualization of real-size objects. A summary of the innovation attributes, from a visualization of 3D models perspective, could be found in table 8.3.

8.2.3.1 DESIGN PHASE

From the interviews and panel discussions it was revealed that one of the biggest near time benefits of AR for asset intensive manufacturers could be found in the design phase, in terms of visualization and product design. A concern that appeared was that the design of an asset often is very complex and collaboration is not easy in a large group of people with different skills and expertise, since they rarely have the same understanding and perception of 3D data. However, misunderstandings are costly, and cost-savings are one opportunity by using AR for visualization of 3D models. Furthermore, it was found that the product development is more effective whilst the discussion is around a 3D object compared to view sketches, or models on a flat screen, hence the understanding increases.

Visualization of 3D prototypes in AR is possible today, and many companies have existing 3D content, such as CAD-models or other types of visual data. It could be complicated to get the files into AR, but it is possible. However, there are several upcoming tools for easier conversion of files. In the design phase the use of AR via HMD could provide a more compelling understanding of an object, hence facilitate the communication around it. For some devices, it is possible for several users to share an AR experience. This makes it possible for everyone to view the same virtual object simultaneously, and in comparison with VR the participants are able to see each other's facial expression, which could be an important aspect. This means that the user can collaborate and communicate in a way that is unique for AR, and therefore have not been possible before. Although, the synchronization of devices could be problematic.

It could be time consuming and possibly complex to do the uploading in the device. Furthermore, object has to be uploaded one by one in AR and this means that the device only could process the file solely, and therefore objects cannot be compared beside each other. All of the above issues increase the complexity of an AR experience, which can prevent the adoption of such an AR application. However, if the technological development continues as today it will become more usable in the future. In the future it might be possible to quickly send models to each other in the development team and ask questions, and thereby even further prevent misunderstandings. Additionally, in the future, people from different places in the world could gather around an object, see each other as avatars that also have the same facial expressions as in the real world. Although, for such features in AR, many issues have to be solved.

8.2.3.2 SALES PHASE

If there exist digital content of the asset that will be sold, it was revealed that AR can be a useful tool in the sales phase. This could enhance the mutual understanding regarding how the asset should function for optimal use, which in turn could result in higher customer satisfaction. As in the case for ABB Robotics, the product is nowadays digitally presented, but on a 2D screen. With AR, the next step could be to project the product on the conference table as a hologram. However, the same limitations apply in the sales phase as in the design phase. In the sales phase, it could be argued that it is more critical that the device function appropriately since it could affect the customer's experience of the company and the sales meeting.

8.2.3.3 REAL-SIZE OBJECTS

Visualization of 3D prototypes could be especially valuable when models should be visualized in real size at their intended location. Many industries could get use of this feature, for example real estate could visualize their buildings at its intended location, or in a factory a new machine could be visualized where it is supposed to stand. However, currently this is mainly applied as consumer applications via smartphones and tablets. Today, this is done by using trackers, and therefore the 3D-capabilities are not critical for this usage. However, this usage will become even more widespread and valuable when the 3D-capabilities have improved, since the object then could match more precisely to the physical environment. Additionally, even if is currently is possible to visualize big objects, but the head must be tilted and it would be hard to understand the object better, therefore the field of view is currently a limitation. Moreover, currently HMDs are limited to in-house usage, which further limits the usages of visualization of 3D content. Therefore, visualization of real-size is not as beneficial today.

Table 8.3. A summary of the adoption attributes related to visualization of 3D models.

Factor	Explanation
Relative advantage	• Facilitate for collaboration and communication • Facilitate for a greater understanding • Can use existing digital content *Design Phase* • Visualize virtual prototypes and thereby cutting time and expenses required to develop physical models • Cost savings due to faster design cycles *Sales Phase* • Better customer relation by better customer understanding *Real size objects* • Real size visualization at the intended location
Compatibility	• Does not have to be integrated with existing technology • Compatible with existing development work and sales procedures • Reuse of existing 3D-files
Complexity	• Could be complex to convert the existing 3D files to AR files • Could be complex to upload the files • Could be complex with the synchronization of devices
Trialability	HMD • Could be tested at fairs or in sales meetings but a device is needed and the content must be converted to AR-friendly format Smartphone and tables • Same for these devices, but it is a more available device
Observability	HMD • There exists use-cases today Smartphone and tablets • By the use of smartphone and tablets there are many existing cases for visualization of a model or object in AR

8.2.4 SPATIAL DESIGN

From the empirical findings, it emerged that companies find it valuable to visualize the factory floor and how it would look like and function in the future, which both AR and VR can be used for. Therefore, AR can be used as a planning tool for factories. The relative advantage of using AR is that it could bring a more realistic visualization, minimize the risk of poorly optimized use of space and quicker response to the intended change.

This type of application require that the AR device are able to scan the physical environment and provide content in relation to this environment, for example a machine at its intended location. Therefore, the object has to be in real-size, this in order to provide better understanding. This use-case requires development of the 3D-capabilities, furthermore the same limitations regarding real-size object, as described in section 8.2.3.3, also applies for this use-case. Additionally, a lot of content is required. However, depending on the specific case, the accuracy requirements differs.

A summary of the innovation attributes, from a spatial design perspective, could be found in table 8.4.

Table 8.4 A summary of the adoption attributes related to spatial design.

Factor	Explanation
Relative advantage	• More realistic visualization • Minimize the risk of poorly optimized use of space • Quicker response to the intended change
Compatibility	• Do not have to be compatible with existing technology
Complexity	• This is technically advanced and it requires the ability to scan the physical environment and provide content in relation to that, therefore the 3D capabilities have to improve. • A lot of content is required
Trialability	• Cannot be tested without the specific content in the specific environment
Observability	• Currently a lack of existing use-cases

8.2.5 VISUALIZATION OF VIRTUAL DATA

AR has the ability to show things in the real world that currently only can be shown in the virtual world. From the interviews, there arose example such as virtual motion paths from a robot's movement. In such case, holograms could be synchronized with the reality and thereby merge the digital content (holograms) with the real world (the physical object). Therefore, the relative advantage is to visualize invisible things and this cannot be compared to anything else, since this is a new ability. However, the usage of such ability should be useful in the future.

From a technical point of view, there is a long way to go in order for this ability to be applicable. Firstly, the information must be digitized in an AR friendly format. Secondly, the digital content must be able to synchronize very precisely with the physical object. Thirdly, the content must be able to attach to a moving object. Currently, the technology is not accurate enough to place the hologram together with a moving physical object, and the 3D-capabilities but also many other technical aspects has to improve. A summary of the innovation attributes, from a visualization of virtual data perspective, could be found in table 8.5.

Table 8.5. A summary of the adoption attributes related to visualization of virtual data.

Factor	Explanation
Relative advantage	• Visualize things in the real world that previously only has been possible to visualize in the virtual world • Synchronization of the digital content with the reality
Compatibility	• Has to be compatible with the entity and the data that are going to be visualized
Complexity	• The digital content must be able to synchronize very precisely with the physical object, further the content must be able to attach to a moving object, which is not possible today
Trialability	• Cannot be tested before applications with this ability are developed
Observability	• No uses-cases exists today

8.2.6 LOCALIZATION

One use-case of AR would be guidance in factories, for example to find the right machine or to find objects that are hidden behind a wall. For the first example, the relative advantage of AR would be augmented guidance and it could be compared to a personal guidance. The extra value of augmented guidance is that the person guided is not dependent upon another person knowledge. Technically, this requires that the device knows where the searched object is localized and where the user is localized, and by this the application could provide information on how to get there. An ordinary GPS-system, such as Google Maps, does not yet have data or maps for indoor environment. In comparison, localization by AR could be provided by scanning the physical environment and in relation to that localize the direction towards the object. If there are existing data or maps these could be reused, but then it is important that the data is up-to-date, otherwise it is useless.

For guidance by scanning of the room, content is still needed but by scanning the room changes could be considered even if the content has not been updated. For the second usage, guidance by pre-created maps, it is a combination of a lot of content and 3D-capabilities in order to orientate and locate the object and the user. For this usage, the application requires less 3D-capability improvements but instead more content. For both, it is a combination of a lot of content and 3D-capabilities in order to orientate and locate the object and the user. Therefore, both of these areas have to improve. However, for usage based upon real-time scanning of the room even better 3D-capabilities are needed.

In addition to only guiding the user, the application could also "light-up" or mark the search object in the user's field of view. For instance, if there are a lot of similar machines or objects the searched one could be colored by AR in order to distinguish it from the rest. This application might not require predefined content, but still 3D-capabilities, especially distance or depth sensing, in combination with sensor data.

Furthermore, as stated above, the usage could also provide localization of hidden objects, for example visualizations of pipes in the walls in a factory. A more advanced form of this could be to provide a whole map of the hidden objects, for instance all pipes, electronics and cables, that are place behind the walls. From a maintenance perspective this could be of high value, since it could provide information of the exact position of an object in relation to other objects. However, from the interviews it emerged that this requires that the underlying data/sketches reflects the reality, but that is barely the case. Therefore, such application is only valuable if the underlying data is correct, and up-to-date, and it might not be beneficial to convert all original sketches to digital content since it currently would be very costly and time consuming. However, for new objects and buildings it could be valuable to provide this kind of data in an AR-friendly format. Furthermore, if the device could scan the environment and incorporate this data in a system, then this use-area could become truly valuable since the data would reflect the reality. Although, this sets high requirements on the development of the 3D-capabilities.

In general, all of those localization usages requires improvements of the technology. A summary of the innovation attributes, from a localization perspective, could be found in table 8.6.

Table 8.6. A summary of the adoption attributes related to localization.

Factor	Explanation
Relative advantage	• Localization and visualization of objects (unhidden and hidden) • Time-savings • Not dependent upon another person's knowledge or time
Compatibility	• Need underlying data, and could therefore have to be compatible with existing systems
Complexity	• The device has to be aware of the physical environment and provide guidance and content in relation to that • Digital content has to reflect the reality and constantly be updated
Trialability	• Cannot be tested without the specific content in the specific environment
Observability	• Lack of use-cases

8.2.7 WAREHOUSE PICKING

As described in the empirical findings, warehouse picking by the use of AR devices can result in productivity increase, and therefore it is seen to have a huge potential. Warehouse picking via AR, function as a quality check since it could scan the barcode and tell if it is the right products picked. Depending on how this type of application is developed it could for example visualize the order, how many packages that are going to be picked at each place, visualize the optimal route for picking and so forth. However, much of the stated features depends on other technology than AR, and therefore could require compatibility with existing or new technology.

The relative advantage, as described as the idea it supersedes by Rogers (2003), is that workers can have their hands free while performing the work, but also get the right information at the right time in their field of view. Currently, orders are often on papers, or a scanning device in the worker's hands is being used.

Currently, but depending on how the application is build, this is technically possible, since there is no need for advanced AR systems to perform such types of application. The limitations are rather that this will be a huge investment for a company and it will take time to develop such system. AR is just a device to visualize what the system generates. Further, it involves organizational and process changes, which is often critical. Therefore, the compatibility with the culture and norms is also critical, further the complexity could be considered as high. Those aspects indicate that the adoption of such application will be limited. However, companies that go through such change could achieve a competitive advantage over others due to higher efficiency and higher quality of the delivering.

Even if it is technically possible today, the form factor of HMDs limits the usability since it cannot be worn for eight hours a day. However, since there is no need for a technically advanced AR systems, lighter technologies like Google-glasses and similar might be good enough. However, when the form factor improves, this type of usage will probably be of great value for warehouse picking. A summary of the innovation attributes, from a warehouse picking perspective, could be found in table 8.7.

Table 8.7. A summary of the adoption attributes related to warehouse picking.

Factor	Explanation
Relative advantage	• Productivity increase • Improve quality of delivery due to quality check by the AR system • The right information at the right time in the worker's field of view • Hands-free value (HMD)
Compatibility	• Might not be compatible with the organizational culture since it requires organizational and process changes • Require integration with current or new technologies/ systems
Complexity	• Time consuming and costly to develop such systems • Complex to integrate with AR devices
Trialability	• Not easy to test before implementation in the specific organization
Observability	• Lack of existing use-cases

8.2.8 SMART WORK INSTRUCTIONS

PwC (2016h) describes smart work instruction as ”smart glasses that help track and guide complicated assembly processes to ensure that all parts are assembled in the right sequence without the downtime of consulting a clipboard, manual or even tablet”. Furthermore, smart work instructions can be used for less repetitive tasks, such as reappearance of a specific machine. For such tasks, it could be even more valuable with guided instructions especially if they are critical for operations to function, since they are not repeated very often and it is easy to forget how to perform them.

Roger (2003) considers that an innovation’s adoption rate depends on its relative advantage over the idea it supersedes, and therefore smart work instructions could be compared with the same work instructions that in many companies are placed in binders today. However, from the interviews it arose that workers do not usually use those binders, and instead they develop their own “best practice” instruction, which could result in quality problems and incorrect assembling. Furthermore, those binders might not be updated, which many times can be a critical problem, especially for new workers. If smart work instructions can solve such critical issues by guidance, then it will supersede the current idea. Other relative advantages are the possibilities for everyone to have the same updated work instructions, further improved overall quality by minimizing defects and reconstructing of an asset. Moreover, it opens up for possibilities to perform new tasks that the workers have not been trained for. An additional aspect is that smart work instructions could be a solution to ”the ageing workforce” issue. If it is possible to digitalize the know-how, the knowledge could stay in the organization instead of disappearing with retiring work force. Further it could be used for training of new employees.

Smart work instruction requires that the work instructions are digitalized and that the they are in AR-friendly format. This will probably be a costly and time-consuming work. The fact that there is no current AR-format standard, could make it risky to create content today, since it could become useless when a standard emerges. Furthermore, when changes in an operation are required the work instructions have to be updated digitally which will be even more important since employees constantly will have it in their field of view. Although, this also have to be done by current systems but with AR the instructions do not have to be updated manually. However, with smart work instructions in AR the person that normally is updating the instructions need to acquire AR knowledge, or the competence has to be bought in.

Depending on if the work instructions are going to be a simple checklist in the worker's field of view, or if it is going to be a guidance and quality check whilst the task is performed, different complexity of AR's capabilities is required. For the first case, the application is possible today, also from a technological perspective, however, it could be discussed if AR is the right system for this. In the latter case the application requires a more complex software, more content, and a more advanced hardware. For this more advanced application, the 3D capabilities are currently limiting the full potential for smart work instructions. Furthermore, as considered in the interviews, workers cannot wear the devices eight hours a day due to the form factor. Therefore, both to technology and the form factor are currently limiting the more advanced form of smart work instructions, and it will probably not be a good solution nowadays for asset intensive manufacturers. A summary of the innovation attributes, from a smart work instruction perspective, could be found in table 8.8.

From an organizational perspective, smart work instructions will probably not require organizational change, since AR rather provides support functionality for existing tasks, but with potential for increased overall quality. Even though, resistance to change does always have to be considered, since this application might not be compatible with existing norms in the organization. Further, this will most likely require integration with existing technology in the organization, at least systems where the work instructions will be stored. However, when the work instructions become digitalized the requirements of workers' specific knowledge of a tasks become less important. Therefore, it is important to consider how this will affect a worker's motivation. From an Industry 4.0 perspective smart work instruction could be seen as one step towards totally collaborating entities. As said before, Industry 4.0 refers to the digitalization, and integration, of all physical assets in the ecosystem and throughout the whole value-chain. Therefore, Industry 4.0 should also refer to integration of instructions and not just entities and technology. From a servitization perspective, while selling a machine, producers could incorporate content for AR in their offerings. For example, how to repair the machine.

Table 8.8. A summary of the adoption attributes related to smart work instructions.

Factor	**Explanation**
Relative advantage	• Improve overall quality by minimize defects and restructuring of the asset. • Workers could always have the correct and latest updated version • Possibilities to perform tasks that workers have not been trained for • Knowledge will stay in the organization and easily transferred
Compatibility	• Might not be compatible with the norms within the social system • Require integration in current technology or systems
Complexity	• Time-consuming and costly to create the content • Time-consuming to integrate with existing technology • Required to always have updated work-instructions, and competence for this
Trialability	• Not easy to test before implementation in the specific organization
Observability	• Lack of existing use-cases

8.2.9 AUGMENTED TRAINING

In many other sectors augmented training has already started to emerge, for example in medicine where it is possible to explore the human body. This is also possible to apply in manufacturing environment, as there is a huge need to perform augmented training in order to both reduce cost for training or make training more accessible. Furthermore, from the interviews it emerged that augmented training can be suitable for practice on dangerous tasks or situations. Those possibilities are relative advantages of training in AR since those opportunities is what supersedes traditional training. Furthermore, it is proven that training is more efficient in AR, since such training increases the learning rate. Researches have showed that the highest learning rate comes from visual-interactive experiences and training in AR has all three. Moreover, by perform training in augmented environments it is possible to make mistakes without real consequences and the simulations could be repeated many times.

Instead of travel to the suppliers training facility, the supplier could offer augmented training packages either in AR or VR, which further could make it possible to generate new revenue streams for the supplier. What medium that is most suitable depends on what type of training being requested. If drawing parallels to servitization, augmented training could become a new type of service offering. This goes in line with Jagstedt's (2016) arguing of adding training as a service, but it could also be taken a step further by offering augmented training as a service.

One example of training could be with interactive models, which could be model that has the ability to be separate into different layers, in order to understand for example the function of the engine or machine better. This is technically possible today, but as discussed in section 6.1.8, a computer is not intelligent enough and all layers must be pre-programmed and therefore it is a time-consuming application to develop. As for the other applications mentioned in this section, it is currently a risk to develop content since it later on can emerge other standards, and then the content developed will become useless. However, augmented training could be developed in many other ways, and therefore it is hard to consider what will be required and not from a technical point of view. It depends if existing content will be used, if it will be interactive models, if the environment will be mapped, and if situation-specific information will appear. Therefore, the complexity of training could vary from everything between high and low. However, since training is a simulated environment in some way, it will probably not have to be integrated in existing technology, and therefore it will not have to be compatible with existing technology. If looking at the future, manufacturing companies could have a virtual training library, that makes it easier, more accessible, and less costly to perform training and educate employees. As for smart work instructions, augmented training could be a way to keep know-how digitally in the organization, and therefore be one solution to the aging workforce. A summary of the innovation attributes, from an augmented training perspective, could be found in table 8.9.

Table 8.9. A summary of the adoption attributes related to augmented training.

Factor	Explanation
Relative advantage	• Reduce cost for training • Make training/ education more accessible • Possibilities to do practice in dangerous environments or perform dangerous tasks without real world consequences • The training could be repeated • Higher learning rate

Compatibility	• Since it is competence enhancing it should be compatible with the organizational culture and norms • Does not require integration of current technologies or systems
Complexity	• Time-consuming and costly to create the content
Trialability	• Not easy to test before the application for the specific organization is developed
Observability	• There exists use-cases of this application today

8.2.10 INTUITIVE INTERFACES

AR opens up for possibilities to create new type of interfaces that are more intuitive for the humans. From the interviews it was found that new interfaces could create new markets, for example in the robot area. New interfaces could lower an organization's required competence of owning a robot, and therefore robots could become available for smaller organizations as well.

However, technically this is currently not possible. First of all, underlying systems has to be in place and react on the action performed in AR. Secondly, the device must be able to scan movements and map that as input for the system. In the future, this will become possible and bring many new opportunities, currently it is complex and not compatible with existing systems. Further, this will change human habits, and therefore it could take longer time to become commonplace. A summary of the innovation attributes, from an intuitive interface perspective, could be found in table 8.10.

Table 8.10. A summary of the adoption attributes related to intuitive interfaces.

Factor	**Explanation**
Relative advantage	• Intuitive, and therefore easier to learn and use • Lower the required expertise
Compatibility	• This has to be compatible with current and new systems, but also with the entities that are being programmed
Complexity	• The underlying systems has to be in place and react on the action. • The device must be able to scan movements and map that as input for the system
Trialability	• Not easy to test before the application is developed for the specific organization
Observability	• No existing use-cases exist today

8.3 INSIGHTS OF CURRENT AND FUTURE POSSIBILITIES WITH AR

It has been found that there are several aspects that affect an adoption decision from an AR investment. Firstly, it depends on the competitive external environment and current trends within the industry, which is discussed in chapter section 7.1. Secondly, it depends on the organization's knowledge about the technology, the social system, the attitude towards the technology and how well the internal resources in an organization are aligned with AR, which is discussed in section 7.2. Thirdly, it depends on the technological aspects, which is discussed in section 7.3. Finally, it depends upon the specific use-case and how suitable it is for the issue it aims to solve or facilitate, which is discussed in section 8.2.

The converges of the physical and virtual world increases the communication possibilities and the amount of available information, and as argued AR has the possibilities to contextualize it. Deloitte (2016) predict that AR have the possibility to change how the business and the employees in the organization share information and take decisions. Furthermore, PwC (2016b) stated, *"people look at operations from a combined view of digital and physical operations"*. In general, it could also be seen that all discussed use-cases in section 8.2. regards either communication, visualization or both. Therefore, it could be concluded that AR is a communication and visualization tool, further AR's main value is to increased understanding and facilitate collaboration.

8.3.1 INSIGHTS FROM A SHORT-TERM PERSPECTIVE

The focus in short time-horizon should be on applications where AR's current limitations are not critical, and where the application solves a critical problem and provides high business value. Therefore, near time usage should focuses on the following:

Firstly, near time usage should focus on reuse of existing content. Many companies already have existing 3D content, such as CAD-models or other types of visual data, which with some modifications could be used. However, the problem is that the existing tools for compressing or modifying 3D content into AR-friendly 3D content are not sophisticated, further the files must be processed one-by-one. Therefore, this usage should still be for single occasions and models, and the perceived value of the visualization must exceed the pre-work of modifications. Furthermore, there is a risk of that the emerging standard of AR does not match the developed content and therefore it will become useless in the future. However, it is a possibility to make use of existing content and get things into practical application quickly, therefore it could be a great opportunity within several areas in order to increase understanding and facilitate for communication and collaboration.

Secondly, near time use-cases should focus on specific short-time usage applications. Currently, it is not possible to use the HMDs for a longer period of times since it is heavy and uncomfortable, further tablets and smartphones, do not offer the hands-free possibility. However, there could still be of value to visualize virtual content in short-term tasks, especially in critical situations where cost of error is very high, and where the task is not repeated very often.

Thirdly, near time usage of AR should focus on low requirements of the 3D-capabilities. Currently, most of the 3D-capabilities are immature regarding integration of virtual content in relation to real environment and objects. Therefore, usage should focus on applications where it is less important to provide virtual content in correlation with the real world in an accurate and seamlessly manner. In other words, where it is important that the right content is at the right place. This especially regards moving objects.

As visualized in figure 8.2, the business value and technological requirements in relation to the current state of these components have been considered in order to provide insight regarding short-term focus. Based upon this we consider the use-areas in the top left square to be the most promising near time applications, since they can be realized today and solves critical concerns. As seen in the figure these applications are: Remote guidance, visualization of 3D prototypes, and simpler forms of training and spatial design. Furthermore, dashboarding also provides business value, but it is lower compared to the previous. However, dashboarding could also be an interesting AR-initiative from a short-term perspective.

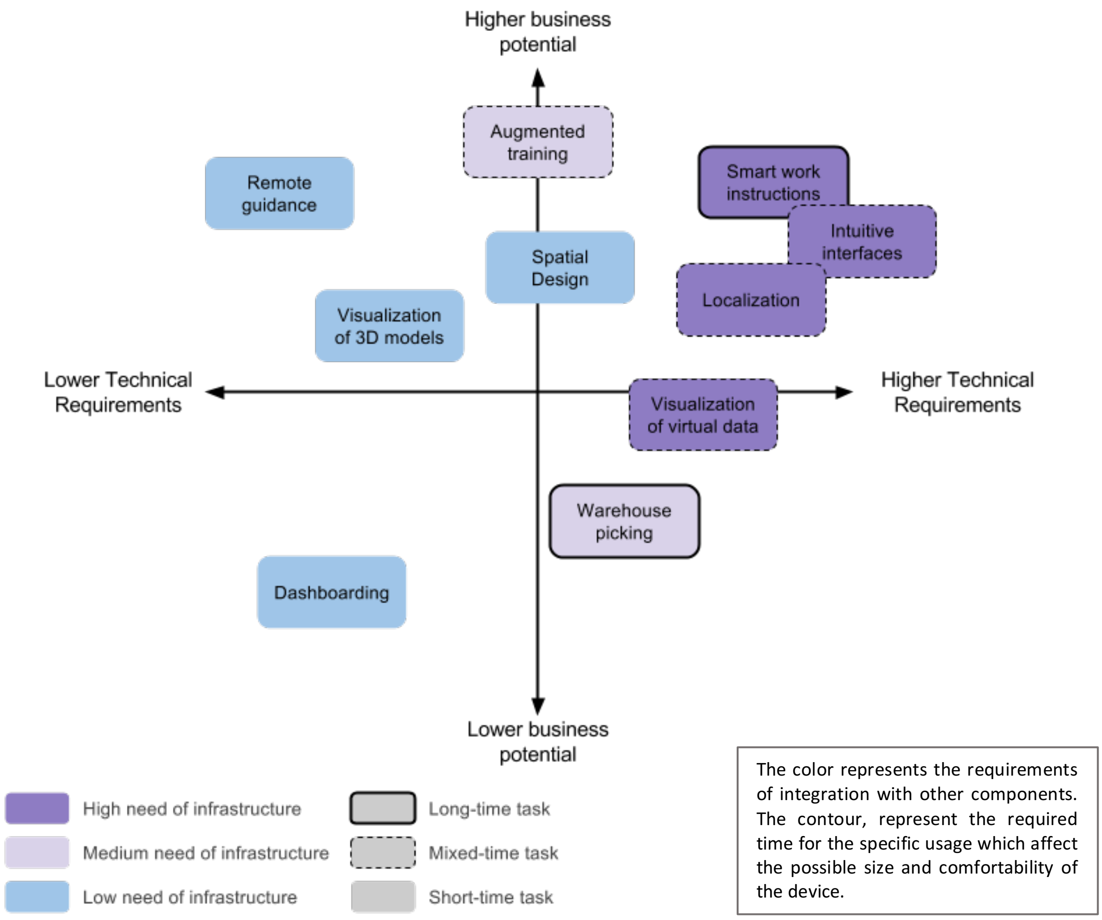


Figure 8.2. Visualization of the different use-cases in relation to business potential, technical requirements, the need of integration with other components (e.g. IoT), and the intended time the device will be used.

8.3.2 INSIGHT FROM A LONG-TERM PERSPECTIVE

The improvements of the device and the technical capabilities, described in figure 8.2, in combination with the business potentials could provide a roadmap for the future adoption of the different AR use-cases.

Firstly, we believe that the solutions which could provide a simple solution to a critical problem will be the first application adopted. The simpler an application is, the easier it will be to implement. Additionally, some use-areas requires a larger support infrastructure, such as IoT and sensors, and depending on the organization's availability of these support technology, the perceived simplicity and compatibility will differ. However, through the technology improvements, both regarding AR and other support technologies, the perceived simplicity will increase. Therefore, the implication is that in general it is the urgency to solve a critical problem that will affect the adoption decision of AR mostly.

Secondly, we believe that the first limitation solved will be the availability of AR content, due to the entrance of several actors facilitating for content authoring. Therefore, applications that require more content, but where the improvements of other limitations are not critical in order to function, will emerge. For instance, this will spur the opportunities for visualization of 3D object.

Thirdly, improvements of the device will become more usable, and thereby it will be possible to use the device for longer tasks, or even a whole work-day. These improvements regard both the form factor, the computer and battery capacity, the mobility, and the limited field of view. This will bring opportunities for development of use-cases such as spatial design, warehouse picking and smart work instructions.

Finally, we believe that the 3D-capabilities will become good enough to incorporate in these improved devices. The improved 3D capabilities will make it possible to experience a seamless mixture of the real- and virtual environment. Additionally, the 3D-capabilities is in general what defines AR, and therefore the greatest potential with AR could only be experienced when these capabilities, in combination with improvements of the other limitation, are in place. Thereby this will increase the possible usage even further and spur the adoption of the remaining applications; which are localization, virtual data, and intuitive interfaces.

Naturally, the adoption of the different use-cases depends on the improvements of the above stated concerns. Therefore, when the different use-cases will be adopted could be mapped in relation to these three aspects. Visualized in figure 8.3 is our evaluation of when, and in which order, the different use-cases will be adopted. Moreover, as seen in the figure, augmented training will become adopted more continuously, but in different forms and constellations, due to its high business potential but still low requirements regarding a seamless experience.

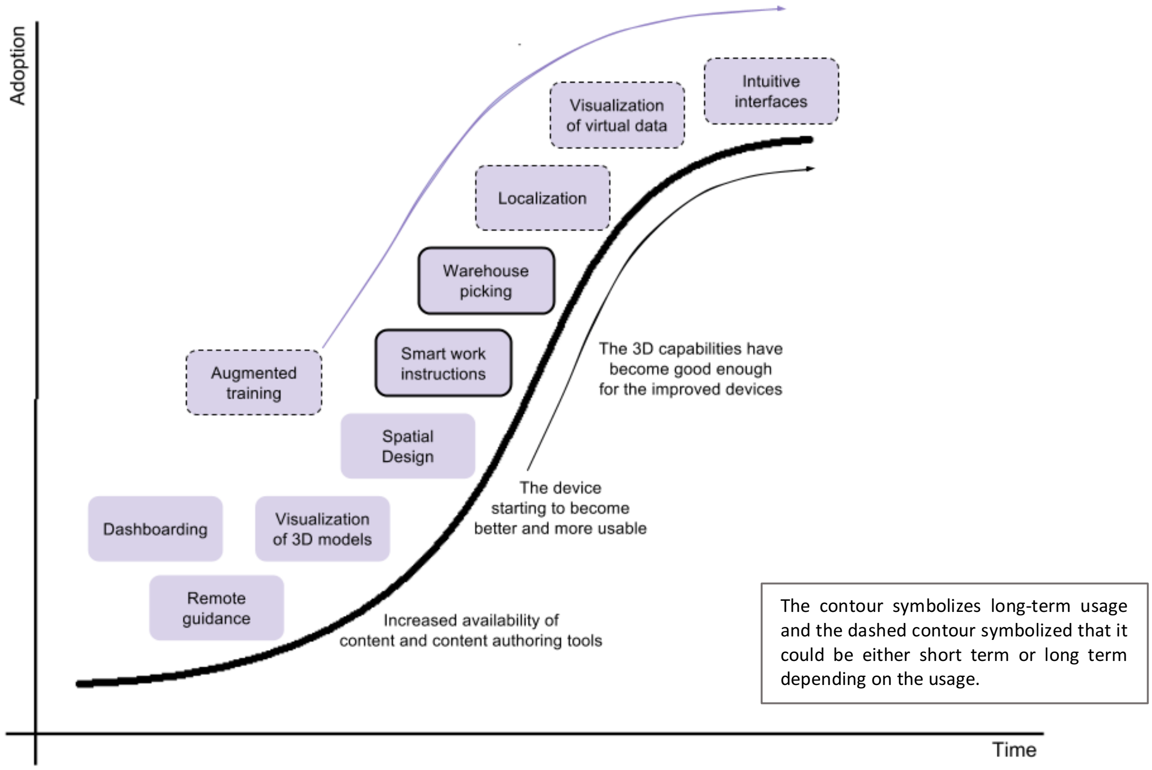


Figure 8.3. Visualization of our valuation of the different potential usage of AR in in terms of content and content authoring, 3D capabilities and short-term or long-term usage.

9. CONCLUSION

The following chapter aims to both answer research questions and to achieve the purpose of this thesis. The information presented below is a summary of the analysis.

The first research question was:

- *What affect the willingness to adopt Augmented Reality, positively or negatively, from an external environmental-, technological-, and organizational perspective?*

In summary, all perspectives affect the adoption of an AR investment respectively, but to what extent depends mainly upon the organization who is considering the technology. Firstly, from the external environmental perspective it was concluded that the competitive environment, the convergence of the virtual and real world, and the trends Servitization and Industry 4.0 spur the adoption of AR. It was found that some use-cases of AR could provide functionalities that support a servitization context. In an Industry 4.0 context, AR facilitate to achieve the aim of totally collaborating entities.

From the organizational perspective, it was concluded that organizations have different intentions with a technology investment. It is important that investments in AR proves to enhance the organization's competitive advantage and provides business value such as either new revenue streams, cost saving opportunities, productivity increases or quality improvements. The outcome of an AR investment further depends on the specific use-case of it, in combination with technological abilities and limitations, and the organization's internal resources. All these things together affect the adoption of AR.

Further, the early adopters in the manufacturing context will play a key role as educators and lead the way for the adoption of AR. The knowledge regarding AR is a key issue, since the expectations often are too high on the technology and its abilities, which currently affects the adoption of AR negatively.

From a technological perspective, AR has the ability to merge the real and physical world. It was concluded that AR firstly will be developed for the smartphone, but when the technology of HMDs improves it is AR, by the use of HMD, that potentially will become the next disruptive innovations, since it provides additional value propositions.

The current AR-market is fragmented, and there are no standards neither regarding device, platform, nor to describe information. This creates uncertainties regarding an AR-adoption. However, AR seems to be in the early stage of the technology life cycle, and the implication is that standards will emerge.

There are currently several limitations related to an AR experience that prevent the adoption of AR, but depending on the specific usage and context the constraints, interdependencies, and value of AR will differ. The most critical elements are: the device, the 3D capabilities, the interaction methods, and the content and content authoring. Additionally, there are legal and privacy concerns regarding the input and output capabilities. The technological limitations are expected to improve in a nearby future and when these limitations have been solved, some of those prior limitations will instead facilitate adoption.

The second research question was:

- *What type of AR-applications could be useful in an asset intensive manufacturing context and are these applicable today or rather in the future?*

Ten different use-cases were found valuable for asset intensive manufacturers. A common theme for all use-cases is that AR is a communication and/or visualization tool, and it enhance the understanding, and facilitate for collaboration.

The focus in a short time-horizon was concluded to be on applications where AR's current limitations are not critical and where it is possible reuse existing content, and also where the application solves a critical problem, as well as providing high business value. Such applications are remote guidance, visualization of 3D models, and dashboarding. Those are applicable today due to their low technical requirements, low need of content, and low requirements of the 3D-capabilities. Furthermore, augmented training is a near-time use-case due to its high potential of generating business value, but still relatively low requirements of providing a seamless experience.

The device constraints, in combination with increased availability of content, will be the next solved impediments. When the device's limitations, such as the form factor, the computer and battery capacity, the mobility, and the limited field of view, are solved the next upcoming use-cases will be spatial design, warehouse picking and smart work instructions. This is mainly due to their requirements of better field of view or ability to use the devices for long term tasks.

Finally, the implication is that the 3D-capabilities will be the technical limitation that will take the longest to solve, and it is this capability that makes it possible to experience a seamless mixture of the real and virtual environment. The use-cases that require this ability is mainly localization, virtual data and intuitive interfaces. Therefore, those applications will be the less near-time applications, but they are still predicted to deliver high business potential.

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