Adoption of Augmented reality solutions in field engineering and maintenance

-Drivers and barriers for organizations

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Abstract:

The aim of this study is to identify drivers and barriers of the adoption of AR solutions for organizations in field engineering and maintenance in Finland. The structure of the thesis is consistent of the literature review covering the theories and models of adoption and acceptance of technology, followed by a literature review of AR technologies. Methodology used is Expert interview and thematic analysis through The technology-organization-environment (TOE) framework. The research question to be answered is “What are the main drivers and barriers of a broader AR adoption in companies for field engineering and maintenance?” Results indicate that the most mentioned technological drivers look to be related to perceived benefits; possibilities of training and remote assistance and piloting being easy with existing devices. Perceived barriers again look to relate to profound limitations for demanding industrial use to, possible safety risks and occupational hazards of long-term use. In conclusion, it can be stated the drivers and barriers of a broader AR adoption in companies for field engineering and maintenance in Finland look to be aligned with findings from prior studies. any future benefits can be identified, but on the other hand, many fundamental obstacles related to usage in challenging industrial conditions are preventing a wider adoption also in Finland now.

Keywords:	AR in field engineering and maintenance, Drivers and barriers of AR adoption, Technology acceptance, Expert Interview
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Abbreviations

AI	Artificial Intelligence
AR	Augmented Reality
CAD	Computer Aided Design
DOI	Diffusion of Innovations
EHTrust	Enviromental Health Trust
IoT	Internet of Things
IS	Information Systems
IT	Information Technology
KIRA	Kiinteistö- ja Rakentamisala
NZSEA	New Zealand Spatial Excellence Awards
PoC	Proof of Concept
R&D	Research and Development
RF-EMF	radio-frequency (RF) electromagnetic field (EMF)
SME	Small and Medium-sized Enterprises
TAM	Technology Acceptance Model
TOE	The technology-organization-environment (TOE) framework
TPB	Theory of Planned Behaviour
UTAUT	Unified Theory of Acceptance and Use of Technology
VR	Virtual Reality
WHO	World Health Organization
XR	Cross Reality
3D	Three dimensional

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1 INTRODUCTION

It has been claimed that the rise of Artificial Intelligence (AI) and exploit of new technologies like machine learning and enhanced Virtual realities (VR) will change the future of business environments like never before, although the gap between ambition and the execution is still large for many companies and there is a disproportion between the potential and real life use cases of Augmented reality (AR) technologies (Hyacinth, 2017, p. 33).

According to Gartner Hype Cycle for Emerging Technologies 2019 -report, Augmented intelligence is stated as one of the key driving technologies, advancing but still in an emerging stage of Innovation Trigger with estimated 2-5 years to reach the Plateau of Productivity (Panetta, 2019), see figure 1s:

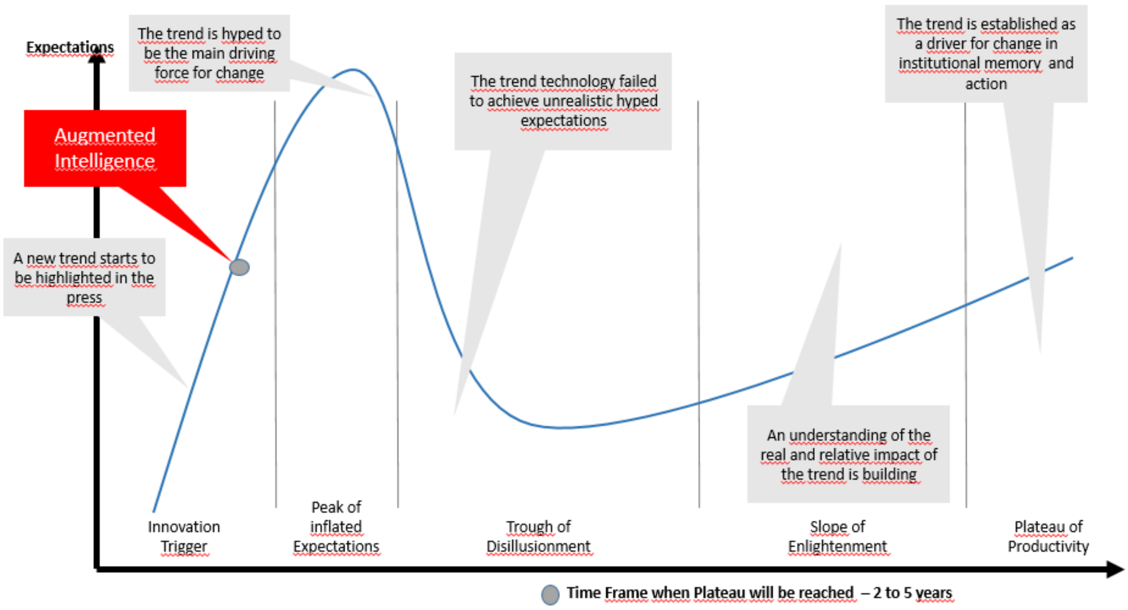

Figure 1: Gartner Hype Cycle of Emerging Technologies explained, modified from Gartner (source Burke, 2020)

Augmented intelligence is a form of a human-centered partnership model of people and AI working together to improve cognitive performance, focusing on AI's assistive role in advancing human capabilities. AI interacting with people and improving their skills reduces mistakes and routine work and can improve service in customer interactions, citizen services and patient care. The goal of augmented intelligence is to be more efficient with automation, while complementing it with a human touch and common sense to manage the risks of decision automation (Goasduff, 2019).

According to Gartner’s Top 10 Strategic Technology Trends for 2020 report (Cearley et al. 2019), by 2021 at least one-third of enterprises will have deployed a multi experience development platform to support mobile, web, conversational and augmented reality development. Towards 2028, the user experience will undergo a significant shift as conversational platforms are changing the way that users perceive the digital world and how they interact with it. This combined shift in both models enable the future multisensory and multi-touchpoint experience connecting people across edge devices, including traditional computing devices, wearables, automobiles, environmental sensors and consumer appliances (Cearley et al. 2019).

Augmented reality combines the physical and digital world by computer generated sensory input like sound, video, graphics, even smell. The consumer attitudes towards augmented reality technology appear positive already today, hence it can provide enriched consumer experience for instance in e-commerce (Kasey, 2018). Nevertheless, real life adoptions remain quite limited (Chandra et al. 2018). Company wise, those that are slow to adopt these new technologies, taking a settle "let’s wait and see approach”, may find themselves in a position of quickly falling behind of the development (Mainelli, 2018).

Finland is a small market area, but quite vivid as there are already over 100 VR/AR studios operating all over Finland with AR conceptualisations created for both business and consumer related solutions. A study by BusinessFinland (2017) with the Finnish Virtual Reality Association FIVR sees the consumer VR market slowly maturing towards lower entry price levels and the consumer AR applications especially designed for smartphones and tablets are ready to make larger impact in the near future. The popularity of face modification filters in Snapchat and Facebook, as well as the AR gaming phenomenon Pokémon Go have already shown a glimpse of the potential AR content possesses (Suominen, et al. 2017).

At the moment, most of the Finnish AR technology companies are mostly startups, quite small on average, with 68% having a headcount of less than 10. However, many companies operate in a joint Cross reality (XR) ecosystems, standing for the combination of Virtual, Augmented and Mixed realities. XR can be defined as a form of mixed reality environment that comes from the fusion or union of ubiquitous sensor and actuator networks and shared in online virtual worlds (Paradiso, 2009). XR can be called an Extended reality, as it includes virtual reality with augmented reality haptics, holograms and an expanding range of immersive tools that use and enhance human natural senses (Accenture 2019).

XR ecosystems are associated with a wide spectrum of activities and multiple industry sectors, also including more experienced and established companies, that have rather focused on R&D or development activities, instead of company growth. Companies have been quickly developing capabilities and funding for new business opportunities, which is essential for XR companies to get their business started and establish continuous client relations. For many companies, a great deal of finances is already coming from organic business such as genuine customer invoicing, although external and institutional funding is required as well. See figure 2 (Suominen, et al. 2017).

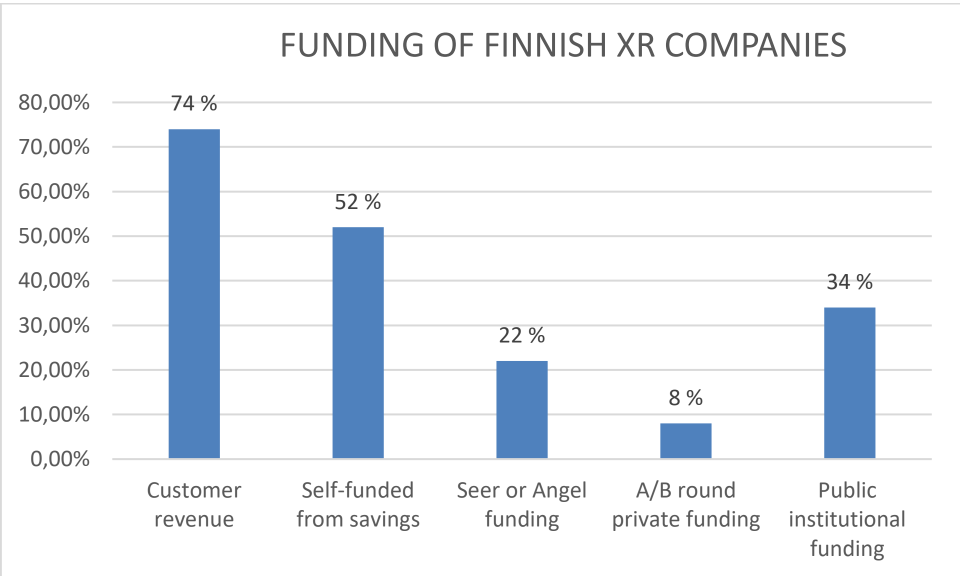

Figure 2: XR companies funding in Finland (source Business Finland, 2017)

1.1 Research aim and questions

The aim of this study is to identify drivers and barriers of the adoption of AR solutions for organizations in field engineering and maintenance in Finland. This master thesis will be based on expert interviews with participants with experience of AR solutions operating in the repair and maintenance industry, exploiting Augmented reality based maintenance, component replacement and remote support. The study will reflect on how the solutions around AR technologies have been adopted in a repair and maintenance industry; and if not, why? The originality of this master thesis is that it looks at the AR context in a repair and maintenance industry with an inductive reasoning based on learning from expert experience.

Studying the common key drivers and the value adding features to business and on the other hand identifying the bottlenecks and barriers of adoption are beneficial for business use cases as well. Business AR applications can be studied as successful examples of Augmented reality strategy implementations, which is essential for startups, but to existing technology companies as well (Porter & Heppelmaan, 2017). The aim of this study is also relevant, because scholars have only began the first studies of these recent trends from an academic point of view to understand why and how users react to wearable technologies (Kalantari et al. 2018). Based on these arguments the following research question is raised: What are the main drivers and barriers of a broader AR adoption in companies for field engineering and maintenance?

1.2 Structure of the thesis

The study takes a starting point in the literature regarding technology adoption and acceptance, thus the literature review will start with a description of theory and models of adoption and acceptance of technology, followed by a literature review of AR technologies. Next, the chosen methodology is described. Data collection method is covered and thematic data analysis is introduced, the results are represented and summarised. Lastly, the discussion section will consider the factors leading to conclusions, lessons learned, limitations and proposed further future research topics.

2 LITERATURE REVIEW

The core of a successful business use case lies in the successful adoption of technology, as the contribution of new technology to economic growth can only be realised when and if the new technology is extensively diffused and used. Diffusion itself is an outcome of series of various individual decisions to begin using the new technology. The decisions are often influenced by several factors and finally resulted by comparing the uncertain benefits of the new invention with the uncertain costs of adopting it. It is essential for both researchers, manufacturers of technology as well as all businesses to understand the factors behind the decisions (Hall et al. 2002). Therefore, the author will reflect upon the technology acceptance theories and the diffusion of innovations.

2.1 Adoption and acceptance of technology

Typical theories for understanding technology acceptance and adoption are Technology Acceptance Model (TAM) (Davis 1986, Davis 1989, Davis et al. 1989), Theory of Planned Behaviour (TPB) (Ajzen 1985, Ajzen 1991), Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003), Diffusion on Innovations DOI (Rogers 1995), and the Technology- Organization- Environment TOE framework (Tornatzky and Fleischer 1990).

The TAM, TPB and UTAUT models operate at technology acceptance in the individual (end user) level. DOI, and especially the TOE framework are the most suitable models to this particular study, as these apply at the organization and company level (Oliveira et al. 2011). Social science also introduces the institutional theories IT (Bill and Hardgrave 1981; Hodgson 1994; Scott 1995) that look to the deeper and more resilient aspects of social structure considering the processes by which schemas, rules, norms, and routines become established as authoritative guidelines for social behaviour. The influence of these structures can be examined as the component of the decision making process and the scope of applicants can range from micro interpersonal interactions to macro global frameworks (Scott, 2005).

2.1.1 Technology Acceptance

The Technology Acceptance Model (TAM) proposed by Davis in 1989 along with its further modifications clearly outline how the perceived usefulness and the ease of use are at the basis for the acceptance and adoption of any new technology. (Lamberti et al. 2014) Usefulness had a significantly greater correlation with usage behaviour than did ease of use suggesting that perceived ease of use may actually be a causal antecedent to perceived usefulness (Davis, 1989). From the point of technology acceptance model (TAM) by Davis (1989), the perceived usefulness and the ease of use play a large role in the process of how users come to accept and actually end up using a technology. See figure 3 for the first version of the TAM model.

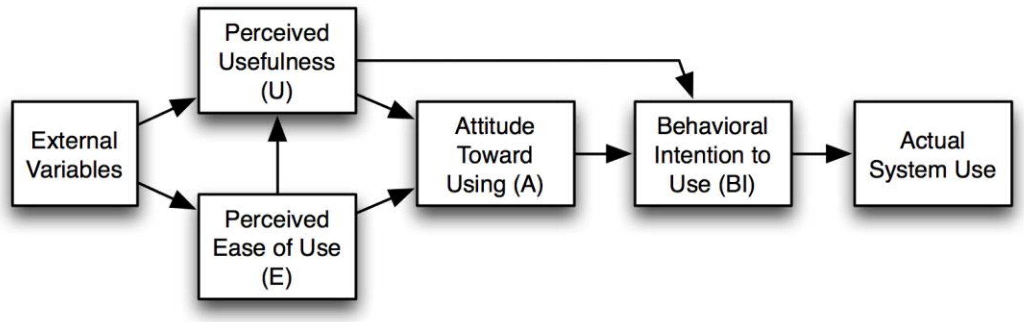

Figure 3: The Technology Acceptance Model, version 1. (Davis, et al. 1989)

Unified Theory of Acceptance and Use of Technology (UTAUT) was developed as a comprehensive synthesis of prior technology acceptance research, as earlier the theories to explain technology acceptance and use had primarily been developed from studies in psychology and sociology. UTAUT tries to explain the degree of end users' acceptance towards the use of information technology. UTAUT has four key constructs (Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions) that influence the individual's intention to use a technology. These four main concepts are independent variables which influence dependent variables: behavioral and usage. Gender, age, experience, and volunteers of system use have indirectly influenced the dependent variables through the four main concepts. Behavioral intention is seen as a critical predictor of technology use (Venkatesh et al. 2003).

The model has been used as a baseline model by many research institutions and applied to study a variety of technologies. UTAUT-based research has been adapted, specifically if applied with other theories or extended it to study a variety of technologies in both organizational and non-organizational settings, since the model covers a lot of influential factors and variables for predicting human (or organizations) intentions and behaviour. To study acceptance and use of technology in a consumer context through a systematic investigation and theorizing of the salient factors that would apply to a consumer technology use context, UTAUT2 model incorporates three constructs into UTAUT: hedonic motivation, price value, and habit (Venkatesh et al. 2012).

2.1.2 Diffusion of Innovations

The study of diffusion of innovations took off in the subfield of rural sociology in the Midwestern USA already in the 1920s, when researchers started to examine how farmers were adopting new products, equipment and techniques. The diffusion of innovations theory was then introduced in the 1960's by a communication theorist and sociologist Everett M. Rogers. Diffusion is the process by which an innovation is communicated through the channels over time among the members of the social system, characterised by a special type of communication concerned with new ideas. The ideas can be invented, diffused, adopted or rejected through either a spontaneous spread or planned actions. Therefore, the diffusion of innovation is gradually worked out through a process of different social constructions and the novelty of the ideas influence the diffusion with a degree of uncertainty (Rogers, 2010).

Diffusion occurs through a five–step decision-making process, through various communication channels and over a period of time among the members of a joint social system. Rogers' five stages or steps are described as knowledge, persuasion, decision, implementation, and confirmation (earlier known as awareness) interest, evaluation, trial, and adoption; both models leading to either rejection or accepting. The model describes the first group to use a new product as "innovators", followed by "early adopters". After them come “the early majority” and “late majority” and the last ones to finally adopt a product are called or “laggards” or sometimes phoebics. The tipping point or the saturation level for the product or service is when the early adopters and early majority groups together create a critical mass of users. This usually means profitable business, growth and increasing market share, but also indicates that the company needs to introduce yet another innovation or an improved update, since the early adopters and innovators are already moving away from the mainstream product looking for something new (Rogers, 2010).

2.1.3 The Technology – Organization - Environment TOE framework

The process of a technological innovation is often time taking and costly. It includes many intermediate steps and can hold a lifespan of decades before reaching the general use and becoming mainstream; starting from the actual innovation, basic research, applied research and development, continuing with further testing, manufacturing and marketing into real products and services. There are several factors influencing the longitudinal set of processes, either speeding up or slowing down the progress of diffusion. The TOE framework was developed in 1990, identifying three aspects in the context of the enterprise that influence the process enabling the adoption and implementation of a technological innovation: technological context, organizational context, and environmental context (Tornatzky and Fleischer 1990). See figure 4 below for an overview of the framework.

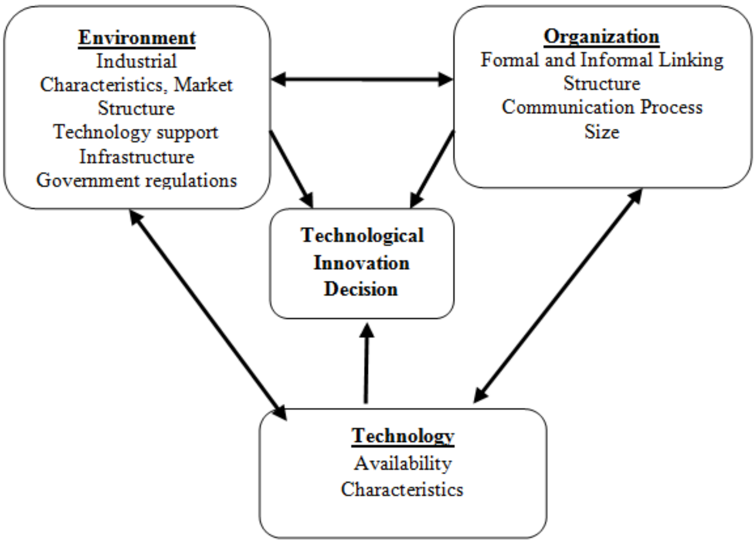

Figure 4: Technology, organization, and environment framework (Tornatzky and Fleischer 1990)

The technological context includes internal and external technological capabilities of a company. The organizational context are factors such as processes, scope, size and managerial structure. The environmental context contains industry, competitors and government regulations, all together predicting the success of an adoption and decision-making (Molinillo, 2017).

This framework has been applied to studies exploring the technological adoptions within SME companies, i.e. showing that TOE factors influence the adoption of enterprise applications and that TOE model indeed is a supportive tool for predicting the adoption process flow. Three contexts of this framework; technological, organizational, and environmental, are connected to each other, but the emphasis of the particular TOE factor can be shifted greatly depending entirely on the company and the use case. The model can assist the researchers as well as marketing professionals to understand why some SMEs choose to adopt innovations, while seemingly similar ones in similar market conditions do not (Ramdani et al. 2013).

As an example, one study of an adoption of cloud services was significantly influenced by factors as relative advantage, uncertainty, geo-restriction, compatibility, trialability, size, top management support, prior experience, innovativeness, industry, market scope, supplier efforts and external computing support, again not enough evidence was found to show competitive pressure standing out as any significant determinant (Alshamaila et al. 2014). Another research paper by Hung et al. (2014) made a deep exploration study into SME e-readiness showing how awareness of corporate website, senior executive commitment, corporate website governance, human resources, technological resources, government e-readiness and market e-readiness were the variables having a significant positive effect on the degree of corporate website acceptance and implementation in SMEs. A systematic literature review covering evidence from 10 years of research on the factors influencing new information systems (IS) adoption in small and medium-sized enterprises (SMEs), identified that among the most stated factors in the analysed articles were the expected relative advantage, top management support, organizational readiness, IS knowledge and innovativeness (Hoti, 2015).

In order to establish a more comprehensive view and to increase the level of understanding the variety of critical factors, the Technology Organization Environment framework can be combined with other frameworks, such as the already mentioned Diffusion of Innovation Theory (DOI) (Chiu et al. 2017). The TOE framework includes the environment context, which is not included in the DOI theory, so it covers better the involvement of intra/extra relationships in the innovation adoption, social process of communication and construction about the new idea. It can be beneficial to combine more than one theoretical model to achieve a better understanding of the IT adoption phenomenon, especially with an emerging, new technology adoption (Oliveira, 2011).

2.2 AR technologies and its concepts

AR technologies terminologies and history can be summarized as follows. Augmented Reality (AR) employs computer generated perceptual vision, image processing and computer graphics techniques to merge digital content into the real world enabling real time interaction between the user, real and virtual objects. AR may be used for example to embed 3D- graphics into pictures or live video stream presenting the virtual elements as part of the real environment (Siltanen, 2017). Early remarks from the potential use of AR technology came from science fiction literature and illustrations, it can be said that the basic idea behind the technology to go back surprisingly long. The first reference of overlaying metadata over people’s face in a form of a letter as a sign of their true character by using magical spectacles, was mentioned already in a 1901 novel “The Master Key” about a boy empowered by a “Demon of Electricity”. The book was written by L. Frank Baum, the author of a classic novel The Wonderful Wizard of Oz (Baum, 1901).

Augmented reality is different from virtual reality, although AR has evolved from VR technics originating from simulators, who in turn were invented already in 1920s, as the Linktrainer Flight Simulator by Edwin Link was introduced in 1929. It simulated plane movements and operated through pneumatic pumps giving the pilots a closes to reality experience of space flight. Telesphere mask, the first Head Mounted Display developed by cinematographer and VR pioneer Morton Heilig in 1961, was a remarkable technological advancement. (Ahmad, 2018) The first motion tracking Head Mounted Display for surveillance through telepresence was introduced also in 1961 (Comeau, 1961). Sensorama, introduced in the 1950s and patented in 1962, was the first machine with AR elements combining multiple sense techniques of sight, sound, smell and touch with 3D images and it was mostly used for military training purposes (Heilig, 1962).

The more recognisable use of Augmented reality was introduced to wider audience in the early 1990s, by an AR system prototype in a form of a monocular see-through head-mounted display overlaying graphics of the real world on the user's view (Feiner et al. 1992). Aviation industry was the pioneer for exploiting the possibilities of AR, as US

Air Force investigated the computer generated Virtual fixtures overlaid on top of the reflection of a remote workspace in order to enhance human performance (Rosenberg, 1992). Boeing also used head-mounted displays instructing all specific wirings per each aircraft type for the factory floor workers as an alternative to large boards, diagrams and marking devices (Caudell, 1990).

Milgrim and Kishino presented the concept of "Virtuality Continuum" in 1994, this continuum set Mixed Reality (MR) between two extremity ends of Virtual Reality (VR) and Real Environment (RE). An application mixing real world elements and virtual elements together is an MR application, Augmented reality (AR) is a smaller subset of MR, with less virtual elements than real ones (Suominen, 2017). In virtual reality, the user is immersed in a totally artificial environment, while mixed reality combines elements from both ends, see figure 5.

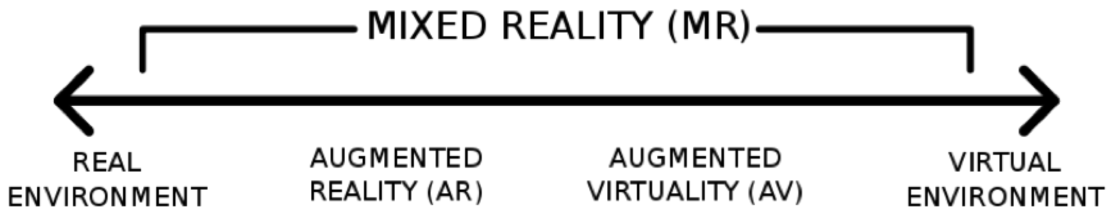

Figure 5: Simplified representation of a Virtual Continuum. (Milgram et al. 1994)

The first AR innovations were not widespread or commercially successful, mainly due to high cost, complexity of use and scalability limitations (Martínez, et al. 2014b). Notwithstanding the clumsy first generation headsets paved the way for the success of future devices, according to Interaction Design Foundation (2019), the most notable breakthroughs in augmented reality between the past and present include the at least the following steps:

- 2000 Bruce Thomas developed an outdoor mobile AR game called ARQuake
- 2009 a design tool called ARToolkit was made available in Adobe Flash
- 2013 Google announced its open beta of Google Glass (a project with mixed successes)
- 2015 Microsoft announced their own AR headset HoloLens and support for AR

Master Thesis work by Heinonen (2017) from Lappeenranta University of Technology "*Adoption of VR and AR technologies in the enterprise"* covers in general the current state of adoption of virtual and augmented reality in the enterprise and identifies barriers and drivers for future adoption. The theoretical part of this study is twofold; first the state of adoption is presented based on industry reports and on studies on virtual and augmented reality in different industries, then theories of technology acceptance are presented by focusing on Unified theory of acceptance and use of technology (UTAUT). The empirical contribution consists of semi-structured interviews with executives from both end user organizations and solution providers of VR and AR, where interviews and analysis were based on UTAUT -model. Heinonen (2017) points out in his study that using simply mobile phone's camera combining real surroundings with video feed and digital content in real time is possible for "lighter" AR usage only. The possible future use cases and potential of AR in field operations are also discussed, despite the identified current structural (such as the resolution requirements, creating and constantly updating real life and digital environment replicas in real time) and financial barriers (high purchase cost of wearable devices). According to Heinonen (2017) AR has great potential in field operations, although wider adoption is facing barriers of practicality, as implementing the digital duplicates for the real life physical infrastructure is not yet technically supported for many cases and the usability of AR wearables still needs improving.

2.2.1 Application of AR technologies in different industries

Augmented Reality technologies can still be found implemented for numerous stages of business, supporting operations regardless of the fields of application. Especially in Manufacturing industry, where processes are often complex, requiring several steps, and mistakes can be costly, AR can deliver the right information at the right time to factory workers thereby reducing errors, enhancing efficiency and improving productivity. AR can also capture information from different sources and make visible important monitoring and diagnostic data about each machine or process, so engineers and factory workers can understand problems better and undertake proactive maintenance actions preventing costly downtime (Porter & Hepplemann, 2017).

According to Porter & Hepplemann (2017) AR technologies can add value in every stage of the product and service supply chain:

- Product development (3-D models can be visualized as holograms instead of computer screens, enhancing the ability of engineers to evaluate and improve design)
- Logistics (AR improves the picking process by instructing the workers to the right locations with optimized routes and warehouse layouts)
- Marketing and sales (showrooms, product demonstrations and revolutionizing the customer experience)
- After-sales service (AR dashboards show predictive analytics data for proactive repairs, visually guiding and connecting onsite support with remote experts for optimized procedures).

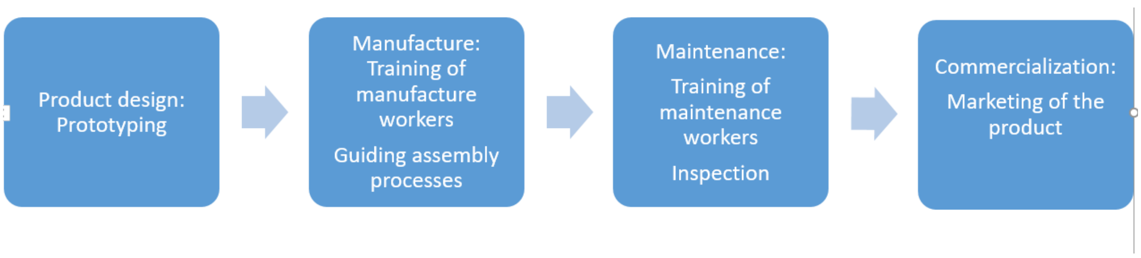

Figure 6: Presenting the product pipeline and the use of AR (source Martínez et al. 2014)

Current research indicates that professional opportunities for AR assisted solutions lie in virtually every industry, according to Paine (2018), the best use cases for AR technology that are set to emerge in the near future can be described as follows:

Medical training & Health services: Simulation-based medical training has been introduced for i.e. bone and dental surgery, intubation procedures, eye surgery, and minimally invasive and endoscopic surgery (Ruthenbeck et al. 2015). The development of interactive information software assisting medical practitioners in simplifying and enhancing the retrieval, visualisation and analysis of medical data with the intention of improving the overall system leading to an improved service for the user and patient experience (Salsabeel et al. 2013)

Retail: Augmented reality applications in interior design retailing improve the customer experience by visualizing the furniture in different interior spaces, therefore presenting design options prior to purchasing (Sandu et al. 2018). Improved customer satisfaction can be achieved through high quality AR attributes: enriched augmentation (realistic view and telepresence), elevated level of informativeness and interactivity, the availability of crucial utilities (search features, narration, quick response, and need for touch), connectivity (social features), and entertaining attributes (Poushneh et al. 2017).

Repair & maintenance: Field service: Fujitsu IoT Solution called Smart Field Service is offering a complete suite of support capabilities through combined hardware and software solutions, video remote support and augmented reality processes by delivering information and data from various knowledge databases to onsite field workers (Fujitsu UK). Augmented Reality is recognized as a most promising technology to help mobile workers with improved situational awareness and reducing the workers' need to shift their attention from the work target to external devices or manuals. (Woodward et al. 2014)

Design & modelling: AR applications and handheld mobile devices offer new possibilities for measuring and monitoring work progress using building information modelling of construction process (Zaher, et al. 2018) Virtual 3D models and realistic augmented prototypes can be manipulated like real objects in design and assembly (Ng, et al. 2013). The analysis of what customers really want (aka capturing the Voice of the Customer VOC), is one of the strategies used to establish effective product development processes and in line with increasing demand for product variety and customization. With virtual prototypes, it is possible to transform customer needs into the functional and psychological requirements of the product, already at the early stage in the beginning of the product development process (Carulli, et al. 2013).

Business logistics: Industrial 4.0 logistics solutions based on wearables (Smart Glasses), communication units (Smart Server Unit) and web-based remote service portals (Augmented Portal) provide hands-free guidance and real time ERP intelligence for storage and logistics workers (BMWI, 2018). Automation, data processing and exchange, cyber-physical systems, Internet of things and cloud technology have impact not only in the organization of production, but to procurement and distribution processes in the entire supply chains (Szozda, 2017).

Tourism industry: Tourist attractions can implement sensory data to complete information about the environment, improving the perception of information and further increase the appeal of the territory. (Bogomazova et al. 2017) The opportunities of implementing augmented and virtual reality with 3D printing into the visitor experience of cultural heritage places has been surveyed as well (Jung, et al. 2017)

Classroom education: Augmented Reality can be used to increase the attractiveness of the educational process for children belonging to vulnerable groups and therefore decrease the risk of school dropout among these children (Urcanu et al. 2018). The SAMR (Substitution, Augmentation, Modification, Redefinition) framework as a pedagogy has been evaluated to enhance student learning about augmented reality and improve students' digital skills. (Frydenberg, et al. 2018).

Public safety: Emergency vehicles can be equipped with smart devices offering route guidance, real time data about the disaster, dangerous conditions and environment in order to improve public safety and emergency services. The AR devices and cameras attached to the helmet enables firefighters to see and hear through fire, smoke and bad weather. The AR applications and devices can also be used to guide citizens on safe routes and offer assistance in case of emergency. (Adăscăliţei, et al. 2018). Wearable technology such as police body cameras represent the possibility of a transparent democratic society, serving the public interest by holding both officials and citizens accountable for their actions (Healey et al. 2017).

Gaming&entertainment: The most well known AR application, free-to-play mobile game Pokémon GO uses real-world mapping and public spaces, embracing social connectedness in local communities and surrounds as well as encouraging players to engage with other players (Vella, et al. 2017). Augmented reality mixing real life environment with virtual objects provide new value to video and computer games, as well as adds playful features to traditional training environments by allowing the review of a game process or replaying the impressive scenes and sharing the experience with others after the game finishes (Yamabe et al. 2013).

It can be stated that immersive technological revolution is not ahead, but already happening all around, according to an Accenture Technology's (2019) report. The applications have previously been limited to games and entertainment, but the balance is shifting towards more corporate usage. The use cases are broadening and deepening as companies begin to realise the full potential and the devices become more affordable. The improved productivity is expected to be gained from performing prior manual tasks with the XR tool and improvements are looking to be available across all industries. As VR is especially well suited to learning, improving the learner's behavioural and social skill sets through simulated environments with critical scenarios, AR is considered to be better suited to building technical skills on the job. Research analysis of national workforce data covering 432 occupations across 14 industries in 14 G20 countries showed that the combination of physical real life environment together with complementary digital content indicated a positive influence in work completion time, as visual information allows for example an engineer or surgeon to perform procedures without having to look away. Expected productivity boost through XR Technologies is estimated to be significant, with the average percentage share of 21% of work that could be augmented through XR technologies (Accenture 2019).

2.3 AR technologies in Maintenance

Accorinding to Palmarini et al. (2018) AR Maintenance operations characteristics consist of tasks that can be performed utilising AR, four main categories are as follows:

- Disassembly /Assembly
- Repair
- Diagnosis
- Training

The Hardware characteristics consists of the devices used in the AR assisted maintenance operations, six main categories of devices are as follows:

- Head Mounted Display =HMD
- Hand Held Display =HHD (including mobile phones and tablets)
- Desktop PC
- Projector
- Haptic =*3D touch and touch-related capabilities, including the ability to sense the position and movement of one's limbs, commonly called kinaesthesia or proprioception* (Robles-De-La-Torre, 2009)
- Sensors

More than one of these hardware options mentioned above can be selected and used simultaneously to capture data from the environment of other devices. In general the complex technical environments and growing requirements in terms of time, errors, safety and costs look to be the key driving forces motivating companies to implementing and utilising AR- based solutions (Palmarini et al. 2018).

Maintenance process can be considered an important aspect of competitiveness and profitability. Training and assisting unskilled operators during an assembly task can be considered an innovative and efficient method to achieve time saving, error reduction, and accuracy improvement by enabling operators to immediately accomplishing the assembly task simply with the help of hand held devices (Chimienti et al. 2010; Fiorentino et al. 2014). Applying AR looks to resolve two issues of traditional maintenance by transforming manuals into electronic multimedia and providing a tool for assisting and shortening the training of new technicians (Didier, 2005). Assembly guidance can be enhanced with AR based easy-to-use tool creating colour coded virtual buttons, text and arrows over the real environment (Yuan et al. 2008). AR based techniques aim to convey spatially consistent information about the observed scene, displaying the augmented view including animations, step-by step guidance and suggestions (Palmarini et al. 2018). On-screen instructions, attention-directing symbols, overlaid labels, graphics and animated sequences enables the mechanics to locate tasks more quickly, allowing them to focus to tasks performed with less overall eye and head movements (Henderson, 2009; Reinhart et al. 2003).

Training special skilled workers is a time taking and expensive process in all fields of industry; i.e. in aviation it can take up to 2000 hours to be a fully trained maintenance inspector (Hincapie, 2011). Traditional methods of training, such as time and effort taking on-the-job training, may not even meet the fast advancing requirements and future trends (Haritos et al. 2005). Products with long service lives and very complex configurations characterize aviation industry. Challenges arise, as the profitability should be gained not from the sales of aircrafts, but from maintaining over a lifespan expectancy of thirty-plus years. Providing service to only required parts, as opposed to servicing all units, allows the aircraft operator to ensure safe operation at minimal operating costs, still increasing profitability (Lee at al, 2008). The usage of manuals while carrying out complex assembly tasks can cause frustration and poor performance amongst operators. AR can provide economical value by lowering the operational costs while sustaining through faster transfer of knowledge and better understanding of the maintenance processes (Hincapie, 2011). AR assisted virtual layers has been introduced for maintenance operations in order to both ensure safety and remove the costly human errors' impact (De Crescenzio et al. 2011).

Another use case for far-reaching business with long lifecycles is the construction industry, where the maintenance has been identified as the longest period of lifecycle, covering up to 85 % of the total lifecycle costs (Koch et al. 2014). Service and maintenance are mobile activities by necessity, so mobile support through a lightweight wearable or camera (tablet, phone) is a necessity. AR visualisation technologies with a location-sensitive and speech-driven interface have been introduced to address the industrial needs for navigation and interaction in complex environments (Goose et al. 2004). It is relevant for the field engineers to locate the target area as soon as possible. Facility documentation and maintenance data is predominantly dispersed, unformatted and still paper-based, causing operators to spend work time only on navigating and locating the target. AR based natural marker detection for tracking improves efficiency with a more holistic and user experience oriented approach (Neges et al. 2017).

Other complex environments to use AR visualisation are urban underground utilities and installations (gas pipes, data cables, sewer/fuel/electric/water lines) providing damage prevention during construction or excavation operations. The failure to detect and map subsurface utilities is a severe risk, as it can lead to great financial losses, unexpected maintenance service breaks for public and puts the security of onsite engineers in jeopardy, even causing accidental deaths (Behzadan, 2009). Maintaining nuclear power plants is expensive and complex with no room for errors. Mobile AR systems can serve as an alternative to all paper-based instructions and checklists, as economic factors force operators to minimise the downtime putting pressure on the service window for maintenance. At the same time, strict safety regulations require the regular periodic inspections and maintenance of critical subsystems to be executed and outcome of these activities to be documented accordingly (Klinker et al. 2001). AR applications help replacing human intervention in hazardous facilities or radioactive areas where maintenance activities are performed from distance (i.e. using a remote handling crane operator in the collimator exchange process) to ensure the safety of the workers (Martínez et al. 2014a). Operations may be performed in buildings, transportation, power and virtually any field where components are needed at remote or high-risk locations (Guo, et al. 2015).

AR based platforms provide a more interactive way for collaborative maintenance work between the more experienced expert (remote) and local technician (onsite) for any given industry with differences in worker skillsets. Local onsite may understand even the complex, customised maintenance processes more efficiently compared to reading paper manuals or traditional over the phone assistance (Wang et al. 2014). Several activities in the industrial field are suitable for remote collaboration or even full exploitation of remote engineering during design and set up stages, such as operator professional training, optimal assembly sequence seeking or on-field teleconferencing, all reducing the completion time and the knowledge gap between engineers and manual operators (Liverani et al. 2006).

AR-based maintenance and repair procedures have been introduced also for end-users on consumer electronics devices (Lamberti et al. 2014). Even with the non-expert consumer maintainers, both time used and errors can be reduced compared to using paper-based instructions (Sanna et al. 2015). In order to create wider use cases and adoptions, the authoring tool creating the AR process (or plug-and-play software add in) as mentioned earlier, needs to be adaptable by any user without any profound computer programming skills (Havard et al. 2015). Such simple AR based solutions can attract also the mainstream (consumer electronics end-users) with effective and customisable support for a large selection of applications by only using personal computing devices such as smartphones and tablets (Lamberti et al. 2014). The high user acceptance looks to be one of the key success factors, therefore AR system functionality must be ensured and proved that it actually makes the user more efficient in order to ensure the successful use case. Preferably, the task must be complex enough, or even almost impossible to complete at least for a less experienced operator, for the user to see the worth in using the AR system. Advantages need to be introduced from the user's perspective, emphasising also the quality improvements through the built-in control against human mistakes and assembling errors (Syberfeldt et al. 2015).

2.3.1 AR aided Remote Support of Maintenance Work in Finland

There are several AR solutions for businesses introduced in Finland in several industries as Education, Marketing, Content management, Design, Heavy Industry, Training, Healthcare and Maintenance, consumer entertainment and game development solutions are well represented too. AR solutions especially linking to maintenance and remote support include product launches like SiteVision, high-accuracy augmented reality system for surveying by Trimble; POINTR, Industrial AR remote collaboration solution by Delta Cygni Lab; XReach, customized remote support platform by Softability, Glue, an universal collaboration platform, by Fake Production, just to mentioned few. (Suominen et al. 2017)

As discussed earlier, the maintenance and repair work costs are a big part of the expected product lifespan expenses, especially for products with long lifecycles, as buildings. It is increasingly expensive to perform annual mandatory inspections and repair work of maintenance incidents, and as shown below, the Index of real estate maintenance costs including cost items like repairs, use and maintenance and maintenance of outdoor areas has been steadily growing year after year, described in figure 7.

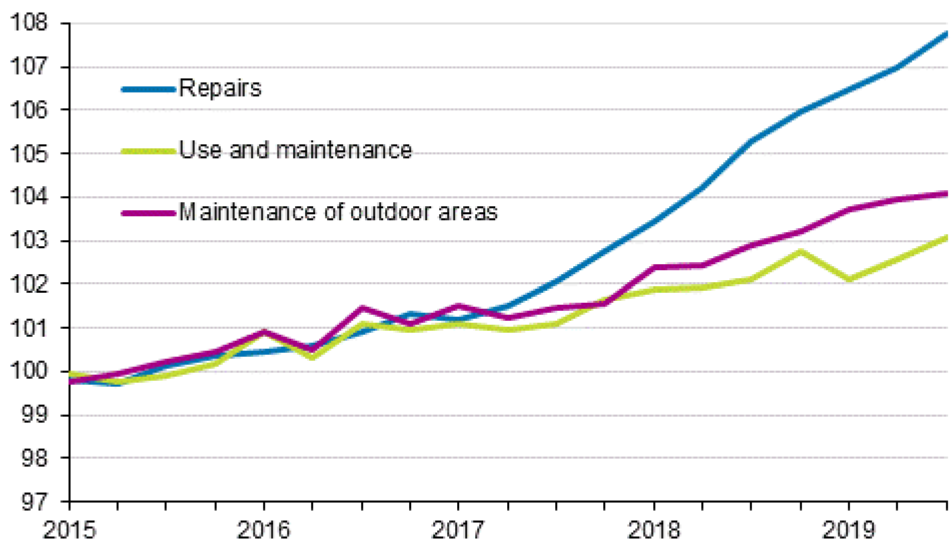

Figure 7: Index of real estate maintenance costs 2015=100, Cost items: repairs, use and maintenance, maintenance of outdoor areas (source Statistics Finland, 2020)

In Finland alone, repair work and maintenance cover more than 10% of the workforce and the annual contribution to Finnish economy is estimated to be even 26 billion euros annually (Päiviö, 2018). There is room for improvement in both efficiency and precision, as on average it takes 1.5 visits for the service worker to fix the problem. The first field service visit fails in one out of four cases, typically because of poor preparation, not being equipped with the right spare parts and a lack of expertise or simply missing the common language for trouble shooting and problem solving. Delays in maintenance and repair activities can cause significant financial losses for the customer's business. Furthermore, incorrect fixes may damage the equipment or can even make it hazardous to use the machines. Some companies have started to address this problem through solutions in mobile and VR/AR technologies, because technical systems become ever more complicated and globally distributed while expertise is limited effecting the timely availability of suitably skilled personnel whenever and wherever needed (Heiskanen, 2019).

The tangible business benefits of remote support solutions and training that XR technologies have brought to the Finnish businesses and the productivity of the organization have already been acknowledged by many companies as technologies have progressed well and use cases have become more diversified (Nirhamo, 2019). Remote support provides (almost) real-time assistance in solving fieldwork tasks without the need for an expert to travel on site. Field technicians may need help, when they start a new job, encounter difficult or rare equipment faults or when they have to work with the latest manufacturer's features and functionalities, which are not yet understood by a specialist. AR Diagnostics & Active Schematics tools help maintenance and repair diagnostics to recognise faults and errors, as AR visualises the location of faulty component and Active Schematics provides the related wiring information (Luukkonen, 2019). Reported advantages of Advanced Remote Assistance include the following factors: Immediate and more accurate response to problems; Minimising the costs of downtime and traveling; Improvements in employee productivity and job security; Faster use of inexperienced workers in productive work with less errors; Transferring of know-how between experienced and inexperienced employees; Improved customer satisfaction (Softability, 2020).

Experimental, government funded project "*Asennuksen, kunnossapidon ja kenttähuollon VR/AR- palveluhanke",* "was exploring the possibilities of using VR and AR solutions for field service and remote assistance. Sovelto, along with technically highly qualified partners like FAKE Production Oy, HP, Microsoft and Trimble, provided an application for pilot companies with various maintenance and field service operations for construction and maintenance of real estate's industries (Sovelto, 2018a). The solution allowed the expert to see the view of a service technician remotely, as being present, the image was transmitted via AR glass, creating an interactive Helpdesk experience back to the technician working on site (Lukkari, 2018).

According to the pilot feedback, the benefits included reductions in travel costs and hours of work, delays, damage or downtime due to errors and skill development i.e. through recorded sessions for further training purposes (Sovelto, 2018). The scalability to other use cases in different industries i.e. for health care purposes and for the emergency rescue personnel was identified as well, but on the other hand, the thesis study around the findings from the pilot project by Linturi, (2018) revealed several obstacles mostly related to technical issues and comfort of use. It was noted, that devices targeted for consumers may be tested, but they unlikely are applicable to be used in high security operations in military, advanced industrial environments or tough field conditions all with higher requirements for safety, heat, dust, humidity and vibration resistance (Linturi, 2018).

The mentioned obstacles included the compatibility of devices and the risk of premature outdating due to fast development curve causing a significant financial risk to the investments involved. AR devices typically convey more information about their user and the environment than traditional devices, so security issues are very important. The study indicated that challenges may occur in terms of weight, or size, as devices do not fit everyone equally and wearing AR glasses with own eyeglasses can be difficult. Long-term use of inconvenient and heavy device may cause pain and increase the risk of strain injuries for example in the neck. Wired connection required by some devices may cause limited mobility, or even tripping and falling, and short battery life limits usage or causes unnecessary interruptions. Inadequate telecommunication connection availability in some locations would be interfering the sending and receiving of live video broadcast feed, which is referred as technically the most demanding requirement for a successful AR experience, therefore preventing the full remote assistance service described earlier (Linturi, 2018).

Deficiencies in resolution or increased latency due to low refresh rate or delays in video compression can be uncomfortable, as it may cause travel sickness like nausea for some people and can understandably lead to misinterpretation of details and what is displayed in general. Particularly when used outdoors, differences in focus distances of the real world and AR glasses due to high dynamic range of light contrast can be problematic with distorted views instead of seeing the real world and the virtual object naturally at the same time. In any case, it was stated that the solution was found to be beneficial for further development and introduction and the technical problems related to remote assistance could be solved (Linturi, 2018).

AR systems can be useful for supported information and knowledge sharing and enhancements of social media like features for adding and sharing comments, notes and pictures to other users, as long as the quality and accuracy of the information content is ensured (Aromaa et al. 2017). Working in customer premises may offer only limited or no access to paper based instructions, therefore augmented information for field technicians on site can be considered as improvement and become well accepted by users. As AR technologies have not yet been evaluated for long term use, safety of use, human factors, wellbeing and ergonomics need to be empathised, hence maintenance tasks are usually carried out in challenging conditions and difficult postures (Aromaa et al. 2018). However it can be stated that service technicians are most likely to welcome AR technology and new solutions, which are making their work and reporting duties easier, more effective and focused on the task at hand (Woodward, et al. 2016). It can be concluded that further cooperation between hardware and software developers in evolution of AR solutions is needed. All the parties involved need to aim towards applications that work perfectly not only indoors in test labs and demo rooms situations, but also in demanding field service conditions. The improved features should make AR fast to adapt and easy to use, which will play a critical role in user acceptance and as a vital future success factor (Heiskanen, 2018).

2.4 Barriers of AR technologies

Although the expected business benefits from augmented reality (AR) applications may be high, it is important to raise awareness and examine all viewpoints related to the expanding usage of new emerging, immersive technologies, AI, IoT as well as VR/AR. These technologies look to be heavily growing and industry spending on AR/VR is expected to be outstripping consumer spending in upcoming years, see figure 8.

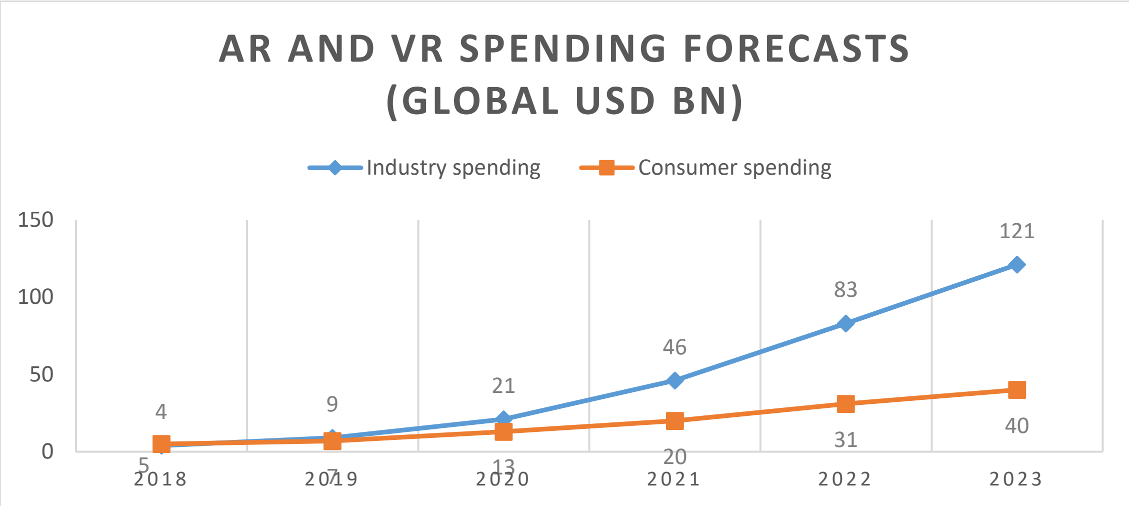

Figure 8: Forecasted Industry spending on AR and VR (Source Accenture Technology 2019)

So responsible practices and business models need to be embedded by default to secure trust and drive sustainable growth (Ovanessoff et al. 2019). In order to guarantee a successful implementation of AR, organizations need to recognise and work with the potential dangers already in the early planning stages. Risk factors including the stressful information overload through massive amounts of data from various sources, AR glasses and lenses impairments causing distraction, which is especially dangerous while performing activities like driving or surgeries and privacy issues of sensitive, personal data collected and people being viewed through the devices, need attention. AR having a basis in wirelessly connected technology is vulnerable to security threats and unauthorised access by hacker attacks and malware messing with data integrity, causing service breaks or leading to even severe, catastrophic accidents, i.e. during nuclear reactor maintenance (Joshi, 2019).

Reports have already shown how location based games like Pokémon GO can pose both opportunities and threats to the safety and physical wellbeing of children. Benefits include increased exercise, socialisation and outdoor activity; on the other hand, negative effects include increased risk of injury, trespassing, violence and unexpected cost (Serino et al. 2016). Another alarming downside of pinpointing services is that some governments (regimes) can have constant surveillance on its citizens for political profiling and i.e. use cutting-edge tracking technologies, familiar from advertising industry, to target people at rallies and demonstrations interfering them via threatening text messages (Kramer, 2014).

There is yet very little research done around this topic, but frequent and prolonged exposure to virtual environments could also be potentially damaging to human mental health. It has been discussed that internet addiction and the widespread adoption of social media, particularly among young people, cause distortion to the concept of real world human interactions by offering escape routes to wearisome digital 24/7 life and defining the personal value just by the number of attracted likes and followers. Using AR in public places can be fun and exciting, but data breech of the online profile may cause unauthorised payments through identity theft and it can also expose the user to unwanted or unsuitable embedded material, extremist political views or even terrorist actions through online radicalisation (Marr, 2019). Risks of criminal or malicious use of AI can be a threat to human safety, as manifested through privacy violations, internet 'Deepfakes' (manipulating voices and likenesses of other people) and algorithmic bias caused by bad data or weapons automatisation. Less directly life threatening, but still important to mention is the rise of socioeconomic inequality through automation-spurred job loss, as AI will create jobs, but many of those will be elusive to less educated members of the displaced workforce (Thomas, 2019).

From a technical barriers' perspective, the AR cloud as the ultimate core enabling technology in the form of standard AR operating system, infusing all the layers of metadata and input from smart objects, is required to function in order to accelerate the further commercial and professional uses of the AR. Currently AR cloud stands for a digital version of spatial properties of the realm in which the positions and orientations of subjects are established, at least to a reasonable extent. In spite of the fact that AR cloud is only as good as the underlying mapping and positioning, robust and affordable setups are essential for realistic interactions with digital objects in the merged space of persistent AR and real world (Koetsier, 2019).

Allowing users to download and upload data much faster than older technologies, is expected to shift consumer behaviour and how smartphones, communications, IoT, gaming and AR/VR applications are viewed and used (Desjardins, 2018). As mentioned, the further optimal adoption of AR business solutions are strongly related to infusion of IoT with both opportunities and risks, again many related to implementation of 5G. 5G will enhance without fail the benefits of IoT by increasing the amount and speed of data flow between multiple devices, and may even remove the need for fiber-optic backbone. Much of the discussion around 5G revolves around the commercial sector as the driving force behind the rollout, as 5G ecosystems of technology can revolutionise networks and information processes, enable new concept of operations and allow larger volumes of data to be shared in (at least close to) real time across geographically dispersed systems. However, 5G also presents a serious potential risk as majority as critical systems grow to be more and more depend on international 5G infrastructure networks built on perhaps unknown components with possible product backdoors and vulnerabilities, putting devices and data (both personal and corporate), or even national security at jeopardy. The larger volume of data being transferred will complicate the security monitoring tasks, so it could be difficult to detect severe security issues and malicious traffic on network. As the speed, volume, and latency of data transfer will depend on the spectrum bands used, and the context of network usage being fixed or mobile, there is still a risk of connectivity interruptions and service breaks (Medin, 2019).

Hundreds of scientists from dozens of countries have also expressed their “serious concerns” regarding the ubiquitous and increasing exposure to EMF generated by electric and wireless devices already before the additional 5G rollout (The 5G appeal). They refer to the fact that ”*numerous recent scientific publications have shown that EMF affects living organisms at levels well below most international and national guidelines*”. Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders and negative impacts on general well-being in humans, also with growing evidence of harmful effects to both plants and animals (EHTrust, 2017). According to WHO, there are approximately 25,000 articles published over the past 30 years in the area of biological effects and medical applications of non-ionizing radiation and based on in-depth reviews of the scientific literature. WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields. However 5G will use mmWave (millimeter wave) high-frequency band with wore spectrum and more advanced radio technology (WHO).

The Novel 5G technology can be described as “emerging”, with diversity of opinions on the potential adverse both for and against the possible harmful effects of 5G and human RF-EMF exposure (radiofrequency electromagnetic fields). It can be noted that the range and magnitude of potential impacts of 5G technologies are under-researched, with little or no profound evidence available for comparison. Introducing 5G technology to several densely populated areas, potential long time usage and effects to chronic health or environmental impacts have not been evaluated and followed yet (Miller et al. 2019). The evolution of wireless networks, showing 5G maximum speeds growing up to 100 times faster compared to 4G described in figure 9.

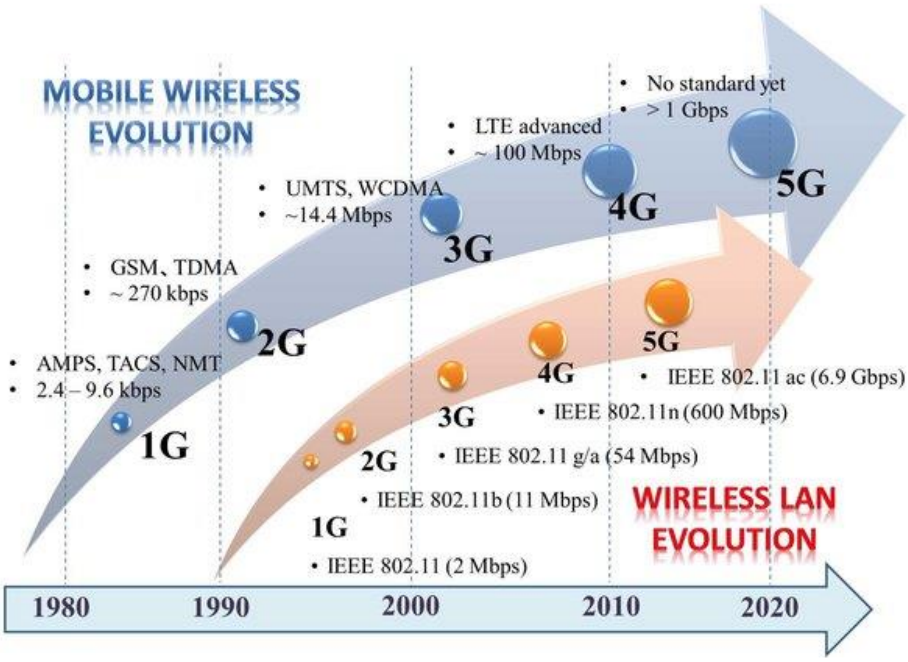

Figure 9: Wireless technology evolution (Source Surantha et al. 2017)

2.5 Summary of AR drivers and barriers in maintenance

Table 1 enclosed is a summary of studies related to AR technology, drivers of adoption and obstacles of adoption. The outcome of the literature review and findings from the studies provided guideline for the authors' interview questions and important topics to be covered in expert interviews. Nevertheless, the TOE framework will stand as the main framework supporting the data analysis of the expert interviews.

Source	**Study**	**Drivers**	**Obstacles**	**Other relevant factors**
Behzadan, 2009	Interactive Augmented Reality Visualization for Improved Damage Prevention and Maintenance of Underground Infrastructure	reducing the high risk of inadvertently damaging the existing subsurface while excavation operations (safety) utilities		
Chimienti et al, 2010	Guidelines for Implementing Augmented Reality Procedures in Assisting Assembly Operations	significant reduction of time and a lower investment in human resources		
De Crescenzio et al, 2011	Augmented Reality for Aircraft Maintenance Training and Operations Support	reduced errors due to procedure violations, misinterpretation of facts, or insufficient training		
Didier et al, 2004	AMRA: Augmented Reality Assistance for Train Maintenance Tasks	tool for assisting and shortening the training of new technicians		
Fiorentino et al, 2014	Augmented reality on large screen for interactive maintenance instructions	reduced overall execution time and error rate		
Goose et al, 2004	Speech-enabled augmented reality supporting mobile industrial maintenance	SEAR empowering the industrial maintenance thus allowing any maintenance technician to carry out the plant maintenance (improving effiency)	technical issues in complex, noisy environments such as factories	service and maintenance are by necessity mobile activities
Guo, et al, 2015	Augmented reality based component replacement and maintenance	maintenance done in efficient and timely manner by any user		May be implemented in any industry, where field workers and other personnel are required to wear safety glasses in any high risk location
Havard et al, 2015	Augmented reality maintenance demonstrator and associated modelling	helping disassembly operations (improving effiency)	difficulty of creating AR applications without computer programming skills	providing AR tools for non technical users

to be continued in the next page

Source	Study	Drivers	Obstacles	Other relevant factors
Hincapié et al, 2011	An introduction to Augmented Reality with applications in aeronautical maintenance	improved human performances leading to many benefits: cheaper costs, higher reliability thus, less failures and subsequent accidents	following text manuals or handbooks leading the maintainer to frustration and a low quality performance	serious flaws that undermine AR implementations in the industrial context.
Klinker et al, 2001	Augmented maintenance of powerplants: a prototyping case study of a mobile AR system	Improving plant maintenance set of primitive tasks	issues with online access, analysis and visualization of information issues	3D-dynamic and static contents cannot be generated through annotations.
Koch et al, 2014	Natural markers for augmented reality-based indoor navigation and facility maintenance	improving efficiency via digitally supported facility maintenance		
Lamberti et al, 2014	Challenges, Opportunities, and Future Trends of Emerging Techniques for Augmented Reality-Based Maintenance	maintenance industries needing cost maintenance reductions + AR-based maintenance and repair procedures available also for end-users on consumer electronics devices	custom maintenance procedures required	Mobile devices, smartphones and tablets, playing a key role in the exponential growth of AR solutions.
Liverani et al, 2006	Interactive control of manufacturing assemblies with Mixed Reality	proficiently reducing the skills gap between engineers and manual operators		
Neges et al, 2017	Combining visual natural markers and IMU for improved AR based indoor navigation	improving effiency in operation and maintenance phase via Inertial Measurement Unit (IMU) based step counter and visual live video feed for AR based indoor navigation support		operators can spend 50% of their on-site work on target localization and navigation
Reinhart et al, 2003	Integrating Augmented Reality in the Assembly Domain - Fundamentals, Benefits and Applications	improving spatial perception thus increasing productivity via reduced eye and head movements		
Sanna et al, 2015	Using handheld devices to support augmented reality-based maintenance and assembly tasks	reducing completion times and errors made while executing a maintenance procedure		non-expert maintainers using AR
Syberfeldt et al, 2015	Visual Assembling Guidance Using Augmented Reality	improved efficiency for high enough complex tasks	acceptability of AR systems to be improved	key factor for breakthrough is high acceptance by the users
Wang et al, 2014	An augmented reality based system for remote collaborative maintenance instruction of complex products	achieving efficiently guidance from remote expert		
Yuan et al, 2008	Augmented reality for assembly guidance using a virtual interactive tool	providing efficiency for assembly guidance without shifting attention between the object to maintain and the instructions		

Table 1: Summary table of drivers and barriers for organizations in field engineering and maintenance for AR in field operations and maintenance

3 METHODOLOGY

The chosen research method approach for this master thesis will be qualitative, an exploratory expert interview study. Qualitative research is considered suitable especially for studies where the “Who, what, where, how many, how much” -questions are asked about contemporary set of events, over which the research has little or no control (Yin, 2018). The purpose of this study is to discover how AR is applied in the repair and maintenance business and to explore the drivers and obstacles for broader AR adoption.

3.1 Expert interviews as a data collection method

The research interview in various forms is one of the most used methods for obtaining information. It is a very flexible and used method as interviews can be done from many points of view and can take many forms (Hirsijärvi et al. 2001). Expert interviews can be quoted as standard method of qualitative approach in the social sciences, although the methodological reflections about the expert interviews are still claimed to be lacking. (Bogner et al. 2009) The main purpose of expert interviews seem obvious: the reconstruction of expert knowledge and the term “expert interview” already denotes the distinctive feature is not a specific form of interview, but the fact that experts (of some field) are being interviewed (Pfadenhauer, 2009).

There have been disputes about how expert interviews can be placed, since there is no standard model, the conversations with experts constitute a particular social situation that is receptive to interferences; the factor invalidating the basic principles of how interviews should be conducted in general and limiting the range of prescriptive methodological rules available. It is also argued that interviewers are always biased, having their own particular interest in subject under investigation, affecting the presentation of questions they are seeking to answer. The researchers in scientific and technical circles are currently rethinking what really constitutes an expert and where the “relevant” knowledge comes from. Therefore, it is essential to be able to identify the role of the experts, the required field of expertise in question, interviewer’s role as well as to detect the most suitable interview strategy for a particular interview situation (Bogner et al. 2009).

The qualitative interviews may be conducted in a relaxed atmosphere and appear very casual, but they differ from ordinary conversations, where both parties can come up with new topics, ask questions and share their feelings, thoughts and perceptions. There are more pre-defined roles in the qualitative interview sessions, where the respondent (interviewee) provides the information, whereas the representative to a study (interviewer) is accountable for setting the direction of the conversation to the topics relevant to the study (Weiss, 1995).

Expert interviews may seem to offer more rapid and straightforward access to objective data making them appealing option for many empirical researchers. An emphasis needs to be put for a legitimisation of the interview methodology used, as there are several types of expert interviews. The exploratory expert interview is primarily used for providing orientation, the systemizing expert interview is targeted at the systematic retrieval of information and the theory generating expert interview is mainly for reconstructing social interpretative patterns and orientation criteria of subjective nature (Bogner et al. 2009).

3.2 Data collection

Primary data can be consistent of questionnaires, surveys and studying primary data sources such as speeches and written publications (Vartanian, 2011). Primary data for this study was collected through interviews focusing on target individuals identified through web search of experts with experience in AR solutions in field engineering and maintenance in Finland. The chosen primary data collection mode was expert interviewing, either by phone or personally face to face. Invitations to interviews were sent by email beforehand to seven people from which four people wanted to attend. Interview time was agreed to last one hour, in the end the interview sessions varied from 40 to 75 minutes. Three of the interviews were done by phone and one interview was conducted face- to-face meeting in person. The semi-structured interview guide is enclosed in appendix 1.

Potential advantages of personal interview are the possibility to engage fully to respondent questions, being presence and observing visual cues. However, it is likely to be challenging in terms of resources, more costly and time taking to meet everyone personally. With phone interviews, the data collection period was shorter, as the interview timing could be agreed upon with more flexibility. Once again, phone interviewing requires active listening skills and the transcription to be completed from the notes directly after the interview in order to maintain the highlights of the conversation. Email survey was not considered as a suitable data collection method in the first place, due to the expected low response rate, also because the nature of expert interview is more free-flowing narrative around the interview topics rather than a predefined survey questionnaire that could be sent and presented beforehand (Fowler, 2011).

3.3 Thematic data analysis

Different variables are monitored, controlled and varied from interviews, primary and secondary data in the collection and presentation of qualitative data analysis. Qualitative researchers need to demonstrate that data analysis has been conducted in a precise, consistent and exhaustive manner through recording, systematizing, and disclosing the methods of analysis with enough detail to enable the reader to determine whether the process is credible, in order for the study to be accepted as trustworthy. Each qualitative research approach has its own specific techniques for conducting, documenting and evaluating data analysis processes; it is the responsibility of each individual researcher to choose a proper one related to the study at hand and to assure accuracy and trustworthiness. There are numerous examples of how to conduct a qualitative research, however only a few suitable tools are available for conducting a rigorous and relevant thematic analysis (Nowell et al. 2017).

Thematic analysis (TA) is a method for capturing patterns or themes across qualitative datasets, and the method was applied in this study in order to understand the users' mind sets and perceptions of the phenomenon in question (Guest et al. 2011). Through identified key concepts, different orientations and practices, TA is often better understood as a top-level term, used for somewhat quite different approaches, than a single qualitative analytic approach (Braun et al. 2019). The detailed description of the actual qualitative data analysis process can be challenging to find, as many textbooks explain mainly the general philosophies of the tradition and the theoretical groundings behind them, but show no or little support for suitable method to be used, such as coding and methods to evaluate data code reliability (Belotto, 2018). Code is at technical term based on the analytical procedure signifying the named concept, as the data indicators are sought from the phenomenon being studied (Mayring, 2004). Challenges may arise as qualitative research interview data text is consistent of multiple meanings, depending on the context and open to interpretation, therefore unlikely to be processed merely by standardised set of measurements, compared to working with quantitative data like numbers and forms. In order to be able to decode this type of data, the interviewer is required to interpret the answers and the conversation, so it is essential to have sufficient background knowledge in the content of the subject being interviewed (Cambell et al. 2013).

With a lot of flexibility in interpreting the data, thematic analysis is well suited approach for a researcher to discover a wide range of topics, opinions, knowledge, experiences or values from data as interview transcripts (Caulfield, 2019. Thematic analysis is widely used, but as mentioned, not clearly agreed upon or how to proceed about doing it correctly. It can be described as an iterative process, as researcher needs to adapt an active role, constantly reflecting, making conscious choices, frequently going back and forth the data sets and further interpreting various aspects of the research topic, so clear view on process used and practice of method is vital (Braun & Clarke, 2006). There are various approaches to conducting thematic analysis, one of the common forms is the following six-step process by Braun & Clarke (2006), which has been applied to this study.

Familiarising your data: The author gained a thorough overview of the data by transcribing the interviews converting speech to text and going through the notes.

Generating initial codes: After the interview texts were transcribed, sections of the text phrases and sentence were highlighted creating abbreviations or labels ("codes") describing the content, each code presenting the factor expressed in the interview. There are commercial coding softwares available for qualitative research, but in this case Microsoft Office were chosen for coding due to low amount of data to be processed. The coding was done through inserting comments in Word, saving the document (print) to .pdf format and exporting the commented codes to Excel. Work was repeated for each interview transcript and in the end the exported codes were merged into one code Excel sheet with altogether 352 codes. The data was colour coded and the number of the code indicated the location of the interview script for further follow up, see table 2.

Commenter	Codes
Commented1	[VT46]
Commented2	[VT25]:
Commented3	[VT61]
Commented4	[VT67]:
Commented4	[VT110]

Table 2: Colour coding of the codes created- example

Generating themes: The author identified patterns of drivers and barriers from the codes created, combining and turning them into broader, common themes.

Reviewing themes: In order to ensure the themes used were valuable and precise the themes created need to be evaluated with closer look. As there looked to be inconsistencies with the first interview coding (codes used were illogical), the author revisited the data set for more accurate configuring and created an updated version of the first interview.

Defining and naming themes: Definitions of what is meant by each theme were highlighted and figured out how it enables the author to understand and interpret the data. See table 3 for the themes created.

Themes created from codes used	Sum of Codes
Barriers	**74**
Perceived barriers	48
Perceived importance of compliance	1
Perceived risks	25
Drivers	**109**
Compatibility	19
Complexity	3
Perceived benefits	34
Perceived ease of use	10
Relative advantage	30
Trialability	13
External factors	**57**
Competition	8
Customer pressure	1
Customer readiness	9
External pressure	12
Government policies	8
Market uncertainty	2
Third party	17
Organizational capabilities	**112**
Financial readiness	6
Firm size	5
Internal needs	4
IT expertise	14
IT resources	11
Organizational readiness	34
Technical competence	15
Technological readiness	23
Grand Total	**352**

Table 3: Screenshot of the themes created from the codes

Producing the report: After reviewing the results, the study is complemented with written introduction, literature review and chosen methodology reflecting the data presented and findings from the results, ending with the conclusions related to the topic discussed.

3.4 Summary

Table 4 summarizes the elements of the method used in this study.

Type of Methodological Approach:	Qualitative
Research method:	Expert interview
Type of research:	Exploratory
Type of analysis:	Thematic analysis
Type of reasoning:	Induction
Technique:	Expert interviews
Primary source of information:	Individual expert interviews, existing research papers, case studies and surveys
Instruments used:	Semi-structured interview questionnaires
Number of informants:	Four informants:
	· Business Finland Senior advisor · Leadership & Technology Education Executive · Technology Research Center, Scientist D.Sc. (Tech) · AR using industrial corporation in manufacturing, D.Sc. (Tech)
Duration of interviews:	mean 60 minutes
Main topics of interview:	AR in Maintenance and Field Engineering, Drivers and barriers of AR usage, Future of AR, risks or any other insights
Interview conduction:	phone, face-to-face
Data storage:	Recordings and notes

Table 4: Summary of used method (table applied from Arbussa et. al, 2017)

4 RESULTS

The results from the expert interviews are presented according to Technology-Organization-Environment framework. Figure 10 summarizes the identified factors according to the number of times mentioned in expert interviews. As seen from the figure 3 the codes are grouped within the TOE framework. The total number of codes were 24; the total count of comments produced from the interview transcripts using the codes were altogether 352.

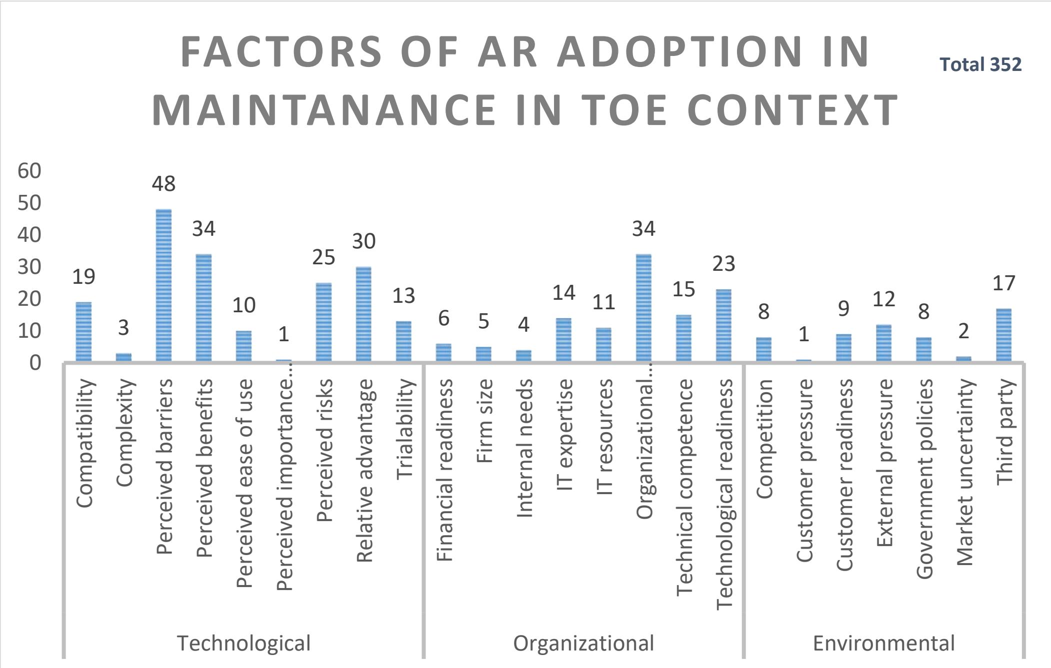

Figure 10: Summary of the factors mentioned in comments, total of 352.

Technological context and factors related to both technical benefits and barriers seem to be of most importance in adoption of AR in field engineering and maintenance. There were both driving and limiting factors mentioned in the Organizational and Environmental context, as i.e. the lack of proper internal IT resources and skills can either be a driver or a barrier for AR adoption, depending on the strategic actions taken from the situation. The most important factors interpreted from the expert interviews are presented in in the following section, embedded expert interview quotes are indented with quotation marks *in italic.*

4.1 Technological factors

Perceived benefits along with a range of possible use cases are identified. The overall experience around the concept of using AR glasses in field work is very interesting and holds a lot of potential. AR is seen useful while working in tough conditions like basements, during renovations and completing documentations and reviews, bringing added value and help with all kind of “hands busy” type of work. AR is seen as the additional element for humans functioning in real life, introducing new elements for more practical, hands on training methods and more learning at work. AR may increase efficiency decreasing the cost caused by interruptions, as the wait time expenses, shutdown of service, or damage caused, can be terribly expensive. Remote assistance was mentioned as an important factor driving the adoption of remote tools while reducing the need to travel and time required for it. Growing sustainability values, travelling is reconsidered to be reduced, as companies cannot be sending technicians to far away countries and hard to reach places like oilrigs or vessels in the middle of the ocean forever. Pandemics like the active Coronavirus outbreak are examples of extreme travel bans.

> *“All types of assembly tasks, in construction industry, or design drawings. Everything in development stage that can be observed beforehand via AR/VR” P2*

> *“The option of having remote expert available assisting the technician is crucial. Remote support will guide the operation and the real life recordings will produce the instructions for further use.” P3*

> *“It is difficult to update the competence by traditional training; we need more new kind of material supporting the learning by doing approach.”P4.*

The shift into service business as a strong driver. Instead of just selling the products, the companies dealing with long life cycles need to consider how they operate the maintenance business as well, so industrial maintenance work is being transformed into information work. AR acts as a driver in industries with long lifecycles and complex products, that are often tailored according to customer requirements, so there is a large range of products and the arsenal to be maintained is quite challenging. Long lifecycles require frequent system updates, which are often automated and carried out though input from AI, as IoT is introduced more and more through smart products. Products can also be customized and updated from competitor products, meaning that the product itself is not the same throughout the lifecycle, but that new features and components are introduced throughout the lifespan and all this information should be accessed by the service personnel. The additional complexity arises as industrial maintenance work and many service functions are outsourced and run by partners. The scheduled maintenance can be carried out with more clear instructions and specific tasks, but the service breaks caused by failure require diagnostics and problem solving skills. The original instructions may not be valid for the latter type of ad hoc maintenance situations. AR is expected to smooth out knowledge gaps or language barriers in any field of business that is now bound by skilled personnel, as anyone can do the work more effectively with help from glasses, CAD modelling, video instructions.

> *"We are moving into more agile world and way of doing and life cycles are shorter, every six months the markets are introduced with new versions. The product itself is not the same throughout the lifecycle, new features and components are introduced."P4.*

Trialability was mentioned as driver, as it is possible to test and pilot several models and brands with vendors, as AR was still considered to be in a testing and piloting stage for many organizations and innovative companies like to test and at least give it a try. Piloting can be easy to start just with the existing devices like smart phones. Nevertheless, mobile phones may not be the ultimate solution for the best user experience, as AR should work well with the added content and large documents can be difficult to observe with a small display.

> *"Mobile phones are working fine a tool, through taking and sending pictures etc, using phones works as partial solution for many companies" P2.*

The descriptions of barriers of AR adoption were pointing out to devices not being optimal for professional maintenance use, at least for challenging industrial environments with noise, echo and limitations to safe movements. The limitations of AR devices were emphasised to safety issues and ergonomics for continuous use, low battery life or charging wires causing usage issues and glasses being too heavy, possibly covering something crucial of the users real life view. The price-quality ratio of AR glasses was not considered attractive either. AR smart glasses were considered too expensive and the benefits non-existent compared to just using a smart phone.

> *“In order to be working we would need to have all the sufficient data, high quality cameras. The computing power is just not enough.. The devices are not up to date for further expansion.”P1*

Working in customer premises is also challenging, as there are restrictions concerning cameras and internet connection availability for security reasons. Occupational safety was considered as a factor to be further researched before deployment, since long term and wider use with protective eyewear or eyeglasses has not been studied enough. On the other hand, some risks can be turned into opportunities, as AR can also improve safety, as with AR it is possible to i.e. show with colour coding, if the premises are not safe. The risk of possible security breaches like hijacking of computer traffic along with standard questions of liability, as the overall authenticity and correctness of instructions, were also mentioned as a barrier of usage. Content creation from paper-based manuals or current databases was mentioned as costly, manual coding task, with no possibility for automated transferring or standard methods now. It is not possible to make instructions for all the imaginable situations, also the user rights related to accessing the data and the ownership of the data are often unclear. It was also stated, that AR tools may not even be adapted without collective negotiations, as some of the features related to i.e. remote usage and recording are restricted by the legislation in Finland.

> *“The screen reduces the field of view of the real world, meaning it is blocking something from the view, so it becomes a safety risk in the field and that probably cannot be tackled.”P4.*

Future scenarios and possible trends were discussed. The rise of AI and other emerging technologies were not considered futuristic, but being already here and continuing to be developed in our lives, as in search engine and analytics. The continuum with robotics and humans remote controlling not just other humans, but robots was mentioned. 5 technology, the hype from new technologies and the urge to act as an example to others is a driver. Experts talked about their future visions, breaking down the strict boundaries of VR/AR and blurring the line between definitions and use cases for mixed reality solutions. The future development of AR could actually be just reinventing the smart phone, forgetting about AR as a term and functioning just as a surface, added display with all the intelligence in the smart phone.

> *"Simply a display board, a new type of communicating device, where the device itself is irrelevant and the content is what makes the difference." P1.*

AR could be a competitive tool in executing the business benefits from rising, emerging technologies in a form of "AR Uber" that can create completely new businesses, in any field of business now relying on skilled personnel, as finding suitable work force is no longer self-evident. It looks to be difficult to get enough skilled work force in certain countries, on ther other hand, in other countries the jobs in maintenance can be considered not so appealing for workers. With AR you can get visual guidance, for "on demand learning" and with AR platform, the differences between skills and knowledge would be flattened.

> *"The hype from new technologies and the urge to act as an example to others is a driver."P3.*

4.2 Organizational factors

Organizational capabilities in the form of organizational readiness and disagreements of the common goal looks to be a significant barrier. There is lack of shared view and communication between different parties causing partial optimization. Conflicts of interest and lacking communication between parties (software developers, vendors, subcontractors) may lead to unclear goals, as definitions and specifications around the required solutions do not meet eye to eye. It was stated that many workers and subcontractor companies resists AR and they may not see the point in the travel cost cutting, because they are afraid they might lose their jobs. The conflicts can be caused also by unclear responsibilities and differences in skills between internal departments (R&D, IT) concerning end user support and trouble shooting. On the other hand, the shortage of adequate technological competence and lacking internal IT expertise or resources requires companies to look for solutions, as it is not possible for a single technician to cope with the enormous device spectrum, with all possible errors. While the staff is aging and retiring, a risk of losing a lot of silent information can be a real threat for many companies.

> *"Companies need to identify the right targets, the most common and beneficial ones. Requirements are so multitudinous with constant changes."P3*

> *"Competence of IT department is not up to date to support AR solution the same way they provide support for laptops and phones."P4*

Some barriers mentioned were related to overall technological readiness and AR not being able to meet the actual user needs. Companies' requirements are so multitudinous with constant changes for AR technology to keep up with. The quality- price ratio was not considered satisfactory, and even the large international industrial companies find it hard to justify the investments, not to mention the small start-ups then. Companies are looking for the price to go down , before the real business cases will start to emerge.

> *"We are dealing with such small actors."P2*

4.3 Environmental factors

External pressure from either customers or governmental authorities was considered only as a minor factor, partly because the politicians are not familiar with AR and proper legislation has not even been introduced yet. The legislation of emerging technologies appear to be not up to date and it is difficult to figure out requirements arising in the following next years to come. It was mentioned, that there are not mandatory factors or strong enough motivations to do things differently than how it has always been done. Customer demands was stated as a driving force, and as mention there are a lot of PoC (proof of concept), but real life customer success stories are in short. Lacking standards and wider customer readiness was quoted as a barrier, although many manufacturers are supportive and may offer the devices for testing. Finding solutions for specific issues is often a joint effort. Cooperation between several parties, either through ecosystems of other start-up companies, researchers, with manufacturers or service partners was mentioned as a vital factor for further development, especially during piloting phases.

> *"Creativity strives from conditions that are free from forced expectations." P1.*

The use cases look to be limited to testing, with expectations of more suitable consumer products to be introduced to markets. Companies are looking what is happening with the consumer markets, although AR is expected to be introduced to professional use first, followed by the consumer market. Just as well, it may be the other way around, as consumer products are often claimed as an adoption channel for familiarity. Questions were raised whether users even want AR glasses the way they are now. AR adoption is will continue to face challenges, if the devices are not up to date for further expansion or gain end users acceptance. It was discussed that mass adoption of AR is looking to be happening a bit further away, if ever.

> *"Seeing what is happening with the consumer markets, will the glasses break there first, after that they will automatically be transferred into work life. "P4.*

5 DISCUSSION AND CONCLUSIONS

The research aim was to explore what are the main drivers and barriers of a broader AR adoption in companies for field engineering and maintenance. Core findings from this study are reflected in the light of TOE framework.

5.1 Technology

A majority of the barriers identified were related to fundamental technical constraints. As mentioned, perceived benefits along with a range of possible use cases for improved training and remote assistance were identified, but the price of AR glasses was considered too high for wider adoption. In addition, the limited features of the AR glasses and their impropriety for demanding industrial environments and continuous day-to-day use are major barriers. AR has been claimed to be the next major computing platform replacing physical devices (phones, computer screens and televisions) with a pair of smart glasses. However, the delay in the release of improved consumer products does not help the situation, as i.e. the launch of Apple’s smaller pair of AR glasses suitable for continuous use is expected to be postponed from 2020 to 2023 (Haselton, 2019).

The uncertainty around product innovations continue, preventing companies from making further investments, as the required improvements for more affordable, lighter glasses with longer battery life, is not expected to occur in the near future. Google’s Glass Enterprise Edition 2 was introduced in 2019 and instead of consumer markets; it was targeted to attract mainly businesses with a notable price tag of $999 apiece. Google glass raise critical opinions pointing out that they are not actually blending real and digital data. Users can see through the glasses, but they are still not capable of producing “real” augmented reality. AR features look to be exaggerated, glasses being merely a hands-free tool for accessing the power of connected smartphone and cloud-based data (Davies, 2019).

The findings in this study seem to align with prior research. Martínez et al. (2014b) also found the drivers and bottlenecks in the Adoption of AR Applications and consumer reactions towards them, by studying the companies with current operations and pilots related to AR aided engineering, training or remote assistance. They concluded that the companies must be large and capable enough or function in cooperation with suitable partners. Alternatively, the tasks in question need to be complex enough, or even almost impossible to perform at least with lesser experience and skillset, for companies to see the worth in using the AR system. In conclusion, the Reduction of costs, Fast learning curve, Curiosity and Fun (of use) were identified as the key drivers for AR application usage. On the other hand, No standard and little flexibility (no support for multipurpose use, new applications require additional effort and time), Limited computational power (complex computer vision algorithms), Inaccuracy (AR techniques still not accurate enough to provide a robust localization of the virtual content) were seen as obstacles. Social acceptance (especially glasses) and Amount of information displayed (and possibly disturbing forced advertising) were also mentioned as the key bottlenecks for further AR application adoption (Martínez et al. 2014b).

5.2 Organization

The expert interviews referred to the organizational readiness for piloting along with the need for improved efficiency accelerating the strategies around AR adoption. The identified challenges lacking skilled personnel resources acts as a positive driver as well. AR was still considered to be in a testing and piloting stage in many organizations with several PoCs, but with no actual start-ups. On the other hand, not having mutual business goals looks to be a barrier and favouring only your own business creates short-term planning and contradictory goals, as for example decreasing costs may be a goal for one company, but not for their maintenance subcontractor, whose business relies on work and travel time based invoicing. According to a report by PwC (2019) some of the biggest challenges to the adoption and use of VR and AR by businesses may be cultural. Apathy or distrust of new technologies look to be common reactions, as well as the confusion around the possible use cases, how it works or what the expected experience is like. For some companies stepping into a virtual world may appear too much of a leap of faith for some, so strategic conversations need to be grounded in what is possible now, not distant promises (PwC, 2019).

Along with mentioned functional devices, user friendliness plays a key role, as deficiencies in user interface, ergonomics or external factors such as poor network connections will likely cause strong resistance amongst the users during piloting, leading to failed experiments. The AR adoption process requires strategic planning, commitment, visions and leadership. The current environment and target state have to be adequately addressed, as the offered solution needs to fit or should be tailored into the existing processes and business architecture of the company. Selecting skilled partner(s) and performing advanced project management all the way from the planning stage is vital. Pilot workshops, feedback sessions, training and support already in the test phase are recommended activities before making the production transfer (Softability, 2020).

In order to make AR truly functional and drive a long-term return on investment, the top management's commitment and support is required. One of the key challenges is that AR may represent radical new ideas about the profound ways many companies will operate into the future. New ideas and new technology are often confronted with strong opposition from an organization, especially by the stakeholders with vested interest in keeping things in an unchangeable state. AR must represent a long-term investment for a company, albeit for many early adopters it has not been too expensive to start an AR pilot project. Many of the first use cases are focused on testing the AR experience, which can be accomplished utilising existing software and hardware on hand, such as smartphones, tablets and current CAD or instruction databases. Linking AR implementation to the possibilities of IoT will be a critical game changer solving business issues and not just ICT issues. Therefore companies must consider how AR experiences will drive fundamental digital transformation within an organization instead of concentrating solely on the technical part, the selected applications and hardware (Mainelli, 2018).

5.3 Environment

Ecosystems and cooperation between different actors was considered beneficial for changing knowledge and experiences. The hyped new technologies and the urge to at least try to act as a technological forerunner to competitors is a driver. It looks though that the real customer demands are not driving the AR adoption, as AR looks to be a technology not driven by users. Effective business use will require the introduction of 5G technology, as it will assure the bandwidth and massive capacity at low latency needed for running AR services in mass-market volume (Lundbäck, 2018).

Although AR solutions are expected to be introduced to enterprise use first, followed by the consumer market, the end user experiences are indicating the readiness to use wearables and the familiarity for business use as well. Smart phones with watches and fitness trackers are among the smart device applications that have already been widely accepted by a larger audience and user groups. The importance of esthetics, social pressure, personal accountability and gamification were amongst the identified driving factors to purchasing and using a wearable fitness tracker for leisure time activity, indicating the ease of use, fun of use and social acceptance to be important drivers for any wearable device to be successfully adopted (Vooris et al. 2019).

It looks that more supporting drivers need to be introduced either through surprising innovations, toughening competition or start-up ecosystems around specific solutions. It still might be early days, but new start-ups are paving the way for the future of mixed reality and AR device playfield is still quite open for any “innovation trigger” contributor looking to win wider mainstream awareness; taking Tesla as example how they took the leadership position early in the electric car market (Smith, 2019). One “forced” trigger could be a result from the conditions related to preventions of Corona virus pandemics introduced to Finland in March 2020. The extreme restrictions of commuting and international travelling can be viewed not only creating severe impacts to doing business as before, but also as an opportunity forcing the digital leap. Even the most reluctant companies need to figure out now how to work also in times when employees are banned from travelling and cannot come to the office (Yle, 2020).

5.4 Managerial implications

Based on the main results, it can be stated that companies would need to see the barriers of adoption lowered in order to be able to take advantage of the drivers identified; lower purchasing prices, more durable, safe devices fit for robust industrial use and workers being more acquainted with wearables in everyday use. However new, unpredictable and unforeseen the future is, businesses should still explore the possibilities of AR, since most likely it’s not the new technologies that will replace the leaders, but the leaders that use new technologies will replace those who don’t (Hyacinth, 2017, p.154). Global distractions of unpredictable scales like total travel restrictions are affecting the cost structures and livelihood of companies of all sizes, now transforming the business prerequisites like never before. Emerging technologies could expedite the recovery and play a vital role in turning the obstacles into new business opportunities (Marr, 2020).

There is a significant disconnection between the richness of digital data available and the physical world in which to apply it today. This gap between the real and digital worlds is limiting the ability of companies to take advantage of the flood of information and insights produced by billions of smart, connected products worldwide. AR systems consist of various components; hardware, software and prerequisites for the viewed data services like connectivity and storage, so AR solutions fit the description of smart products with three core elements: physical, smart and connectivity components (Porter & Heppelmann, 2014). Conceptualisation of AR systems and services could be one way to adopt AR solutions as “smart product bundles”. In a service system concept, Smart Products can be presented as boundary objects, an artefact residing at the interfaces of different parties, enabling cross-boundary information and knowledge transfer at a given boundary (Carlile, 2002). Service design and conceptualisation of smart services and smart service systems is essential in order to provide the fluent basis for the integration of service users’ and providers’ resources and activities, ultimately aiming the use of smart products leading to technology-mediated, continuous and routinized interactions (Beverunge et al. 2019).

An exemplary of comprehensive bundled solution package is “Trimble SiteVision”, a high-accuracy AR system running on AR-supported Android mobile device using Integrated Positioning System for empowered spatial visualisation. The system includes hardware, software and annual/monthly subscription service (Harrington, 2020). The system has been acknowledged in various businesses all over the world, also awarded the first price by bringing innovative solutions to complex business challenges (NZSEA, 2019). The story of Trimble SiteVision also supports the hypothesis of long lifespans from technical innovations to real products presented in TOE framework (Tornatzky & Fleischer, 1990), as the first patents were filed already over 20 years ago: on a centimetre accuracy handheld surveying system in 1997 and on augmented vision for survey and machine control in 1999 (Trimble Site Vision, 2019).

5.5 Limitations and future research

Due to the limitations of a targeted research subject, time and expert resources available, this study should be observed only as exemplary, a sample from the AR in field of field engineering and maintenance. The chosen method of thematic analysis of expert interviews is based on rich data interpretation and considered useful for providing orientation for the research questions in hand. With no standard model, the actual role of the expert interviews in individual research design, their form and the methods used to analyse the results might vary from case to case (Bogner et al. 2009).

For further research some of the following questions could be raised: What is the future of AR business in Finland like? Who are the game changers of any particular industry of choice in Finland? How do Finnish companies compete with international competitors, could the exploitation and usage of AR technology be another success factor for global business expansions? How to help more AR companies in making and breaking into markets and influence the user adoption intention? What is the impact of travel restrictions during pandemics and will this eventually boost the digitalization along with the utilising of more AR innovations for Finnish companies? Discussion around the drivers and obstacles of further AR adoption arising from the results should continue and be further researched.

Some perspectives for promoting possible future success factors for further AR adoption, is driving the end user acceptance. The mixture of consumer devices, app stores, the cloud and technically capable people entering the workforce, provide a classic illustration of disruptive technology for enterprise IT. The IT consumerisation encompasses the phenomenon of more and more employees bringing their own IT into the workplace and starting to use these tools for work purposes (Harris et al. 2012). It can be expected that over the upcoming next 5 to 10 years, the virtual world technology moves into second and third generations and the current young users age. As the demographic of users accustomed to AR/VR technologies will mature, adoption and use will likely be more widely accepted. While the virtual gaming generation continues to enter the workforce, their expectations of virtual possibilities will fundamentally change the ways of working and socializing, even to the extent that most likely the borders between working, playing and learning are blurred or at least changed (Wasko et al. 2011).

Successful consumerisation of IT is claimed to be defined by the achievements of increased range of affordable devices, free services and content aimed at consumers making technologies easier to use. Consumers should be comfortable with a wide range of digital technologies and services that develop and change rapidly, shaping technology themselves through new open development approaches such as beta software, open APIs, mashups and the power of the crowd. The future studies should explore, whether the IT consumerisation enables the blurring of boundaries between working, learning, playing and socialising with users doing all these activities on their devices (Ley, 2010).

5.6 Conclusions

The aim of this study was to identify drivers and barriers of the adoption of AR solutions for organizations in field engineering and maintenance in Finland. The most mentioned technological drivers look to be related to perceived benefits; possibilities of training and remote assistance and piloting being easy with existing devices. Perceived barriers again look to relate to glasses being not suitable for demanding industrial use to begin with, safety risks and yet unknown hazards of long term use. Organizational readiness looks to be inadequate, as companies are lacking common goals, both external support and internal capabilities needed to drive the adoption. Situation looks to remain static, unless revolutionary improvements to both device quality, compatibility and pricing are introduced. The drivers and barriers of a broader AR adoption in companies for field engineering and maintenance in Finland look to be aligned with findings from prior studies of AR technologies in maintenance, as by Martínez et al. (2014b) and Palmarini et al. (2018). Many future benefits can be identified, but on the other hand, many fundamental obstacles related to usage of AR devices in challenging industrial conditions are preventing a wider adoption also in Finland at the moment.

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APPENDIX 1

Expert Interviews' semi constructed interview questions were presented as follows:

How can AR solutions be applied in field engineering and maintenance?

Can you talk about Your solutions/Real life examples?

From Your perspective, what are the main drivers for further AR adoption in field engineering and maintenance

How about risk or barriers of a broader adoption?

Do you see any other possible factors or risks arising?

How do you see the Future trends?