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Master's thesis

Markus Heinonen

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ADOPTION OF VR AND AR TECHNOLOGIES IN THE ENTERPRISE

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ABSTRACT

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The objective of this study is to understand the current state of adoption of virtual and augmented reality in the enterprise, and identify 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.

According to this study, there is great interest towards VR/AR and companies are impressed with both performance and possibilities of these technologies, but there are still significant practical barriers for adoption. Three main categories of use cases for initial adoption were identified (Design, Marketing & Sales and Training & Simulations), among them, Design has most favorable conditions for adoption, closely followed by Marketing & Sales and wider adoption for Training & Simulations is still a few years away. The potential of use cases outside of these categories are also presented.

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Tutkimuksen tarkoituksena on ymmärtää virtuaalitodellisuuden (VR) ja lisätyn todellisuuden (AR) nykyinen adaptaatio yrtitysmaailmassa ja tunnistaa näiden teknologioiden käyttöönoton esteet ja edistäjät tulevaisuudessa. Tutkimuksen teoriaosuus on kaksiosainen: ensin nykyistä adaptaation tasoa on tarkasteltu toimialaraporttien ja VR/AR -alan tutkimusten pohjalta, sitten teknologian hyväksymisen teoriat on esitelty keskittymällä UTAUT -malliin. Empiirisessä osassa haastateltiin johtotason henkilöitä sekä loppukäyttäjien että VR/AR -ratkaisujen kehittäjien osalta. Haastattelut toteutettin ja tulokset analysoitiin UTAUT malliin perustuen.

Tutkimuksen perusteella kiinnostus VR/AR teknologioita kohtaan on suuri, mutta adaptaation hidasteena on vielä merkittäviä käytännön esteitä. Nykyiset käyttökohteet on jaettu kolmeen pääluokkaa (Suunnittelu, Markkinointi & Myynti ja Koulutus & Simulaatiot), ja näiden joukossa Suunnittelun käyttökohteissa on suotuisimmat olosuhteet adaptaatiolle, seuraavana Markkinointi & Myynti ja Koulutus & Simulaatio -käytössä VR/AR yleistyy todennäköisesti vasta muutaman vuoden kuluttua. Myös muiden käyttökohteiden potentiaali on esitelty tutkimuksessa.

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Finally, I'd like to express my gratitude to the whole team of Varjo, and especially to Urho and Jussi. Your help was invaluable, for making initial introductions to interviewees, which made the interview process much more convenient. But most of all, I'm extremely grateful to you for this opportunity, and that I was provided with all possible resources, the time, the freedom and advice, which enabled this study to progress smoothly.

Markus Heinonen

Helsinki, October 2017

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LIST OF ABBREVIATIONS

AR	Augmented Reality
BI	Behavioural intention
C-TAM-TPB	Combined model of technology acceptance and theory of planned behaviour
EE	Effort expectancy
FC	Facilitating conditions
HMD	Head-mounted display
IDT	Innovation diffusion theory
MM	Motivational model
MR	Mixed reality
MPCU	Model of PC utilization
PE	Performance expectancy
SCT	Social cognitive theory
SI	Social influence
TAM	Technology acceptance model
TAM2	Technology acceptance model 2
TRA	Theory of reasoned action
UTAUT	Unified theory of acceptance and use of technology
VR	Virtual Reality
XR	Extended reality

1 INTRODUCTION

The potential of virtual reality (VR) was acknowledged already in 1999, when VR pioneer Fred Brooks, Professor of Computer Science at the University of North Carolina, did an extensive study on VR in engineering disciplines. Back then, he announced that ‘’It [VR] now really works, and real users routinely use it’’ (Brooks, 1999). Now eighteen years later, we’re still waiting for virtual reality and augmented reality to cross the ‘chasm’ to majority adoption. What’s different today? For starters, technology have advanced immensely, and world’s largest companies and venture capital firms are pouring money into start-ups in VR/AR space.

Interest in VR started to accelerate again in 2014, when Facebook acquired Oculus (VR hardware company) for $2bn in 2014, which is still the largest investment in this industry. During the same year, Google led a $500mn investment round to an AR company, Magic leap, that has since then raised two additional rounds, with a total of $1.8bn funding (CrunchBase, 2017). In addition to these mega-rounds, other VC investments in the space are rapidly increasing (see Figure 7. pg. 12), and there is additional $18bn in deployable capital for VR/AR waiting for right opportunities (Virtual Reality Venture Capital Alliance, 2017).

These advancements have only caused, expectations towards VR/AR to rise. It is said to be the 4th computing revolution (MerrilLynch, 2016), and could become as game changing as PC and smartphones were (Goldman Sachs, 2016). Although, virtual reality has been around for decades, it has been ignored by the mainstream just until recent years. Progress in technology have made it possible to create better and more affordable devices that might enable wider adoption of VR and AR.

These technologies have the potential to merge physical and virtual world and completely change how we interact with computers. First when PC’s were introduced, we communicated with keyboard and mouse, then became smartphones and tablets with touchscreens and swiping. Now, VR and AR enables the use of natural gestures to communicate with virtual objects as in natural world. Instead of viewing flat 2D images on a screen, with VR and AR, 3D objects can be viewed in an immersive environment.

Despite the great potential of these technologies, they’re adopted by some early adopters in different industries. The ‘killer application’, which will prove the value and accelerate the adoption of these technologies, is still on the lookout. According to both industry analysts and academics, technology and available content still pose barriers for adoption. However, the technology and related content are advancing all the time, and the phase is only accelerating due to increases in investments. Use-cases that were recently thought impossible, are now proven plausible.

1.1 Goals of the study

There is no question that the interest towards VR and AR technologies is increasing. Not only have the investment in this space increased during recent years, but VR/AR technologies have been studied in academia for few decades already. Now advances in technology have brought VR and AR closer to wider adoption. However, these technologies are still in the early adopter phase and distinct use cases for mainstream adoption are still unclear.

This study is about adaptation and acceptance of technology in the context of VR and AR technologies. The purpose of this study is to gain a better understanding of the current and future markets for VR/AR as well as identify drivers and barriers for adoption in different industries.

The study is made for Varjo Technologies, a Finnish virtual and mixed reality company developing the world’s first human eye resolution headset for VR/AR. Varjo’s high-resolution display technology enables various use cases for these technologies, where resolution have previously been the limiting factor. Although Varjo’s headset promises to eliminate one of the most significant barriers for VR/AR use, the readiness and motivation for companies to adopt this new technology is still unclear.

Therefore, the main objective is:

- To study the current state of adoption and future potential of VR and AR technologies in the enterprise.

The sub goals of the main objective are:

- To identify drivers and barriers for future adoption of VR/AR.
- To identify most potential use cases and industries for of VR and AR adoption.
- To examine the current infrastructure for adopting VR/AR.

1.2 Research strategy

The way of conducting this research includes three main constructs that together will construct a view on current and estimation on future adoption of VR and AR technologies, which is presented in Figure 1. The empirical part of this study is a qualitative research conducted as semi-structured interviews concerning adoption of VR/AR with executives and users in different industries. The empirical part is also well supported by literature; theory on technology acceptance research will provide the theoretical foundation to those interviews, and reviews on current uses of VR/AR and industry reports guides the selection of the interviewees and steers conversations to most promising use cases in each industry. Together these three elements will provide an understanding of the current state of VR/AR and offer a prediction of the future's adoption.

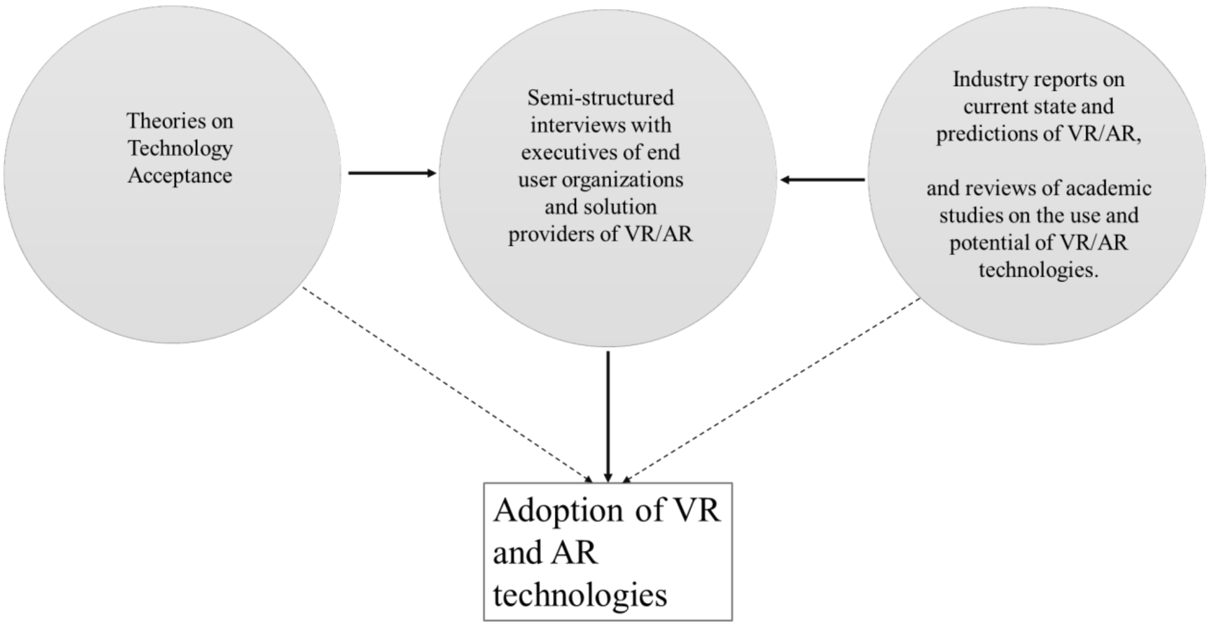

Figure 1. Research strategy

1.3 Outline of the study

This study begins with describing the current state of the markets. An overview of forecasts on VR/AR markets is presented to provide an understanding of the current state adoption. Future expectations towards these technologies is presented, but also limitations and uncertainty in these forecasts of acknowledged. Once the baseline for interest and high potential is demonstrated, potential market segments for VR and AR are presented. Promising use cases and potential industries are identified from academia, industry reports and company announcements. This section will provide areas of interest that will be explored further in the empirical part of this study.

Empirical research is based on theory from technology adoption literature and especially on unified theory of acceptance and use technology (UTAUT) proposed by Vekantesh et al. (2003). This theory is presented in the third section of this study, where literature on technology acceptance research is also reviewed. Evolution of different models for technology acceptance is presented especially in the context of IT-systems. Next, UTAUT -model is presented in more detail. Its validity as a model for this study is proven by the extensive use in technology acceptance research in the context of new technologies and IT-systems. The third section will provide an understanding of different models used in technology acceptance research and more detailed description on the most widely used model (UTAUT). This section will conclude with a research framework that is adapted from UTAUT and used in the empirical part of this study.

The rest of this report is dedicated to the qualitative research part of this study. Various experts from different industries were interviewed to understand existing barriers for VR and AR adoption and factors that will accelerate the adoption of these technologies in the future. The experts were selected based on their knowledge in VR and expertise specific domain to ensure wide coverage of industries. The likelihood for adoption is assessed based on constructs of the research framework. The interviews were conducted using a semi-structural method, so emerging themes from initial interviews could be explored further in subsequent interviews. The report concludes with most important drivers and barriers for VR/AR adoption and recommendations for most promising use cases and industries for initial adoption presented. Table 1. illustrates the structure of thesis as an input-output table.

Table 1. Structure of thesis

Input	Chapter	Output
Overview of the topic and background of the thesis	**1. Introduction**	Research goals, methodology and structure of the thesis
Classification of VR/AR headsets, Industry surveys, Market studies, Funding and acquisition activity, Academic studies and practical applications of VR/AR	**2. VR/AR technologies**	Description of the current state and future predictions of VR/AR, Potential industries and use-cases for VR/AR adoption
Prior literature and research on technology acceptance and adoption	**3. Technology adoption**	Evolution of technology acceptance models, Research framework
Qualitative study method, interview method, theoretical standpoint	**4. Methodology**	Process for acquiring and analysing data
Semi structured interviews based on research framework	**5. Findings**	Description of drivers and barriers for adoption divided to use cases in Design, Marketing & Sales and Simulations & Training
Discussion about the results of the study	**6. Discussion**	The meaning and limitations of the study
Conclusions based on findings	**7. Conclusions and Recommendations**	Research outcomes, Future research and Suggestions for action

2 VR/AR TECHNOLOGIES

Virtual and augmented reality promises to change the way we interact with technology, and they enable to merge virtual worlds with real life, which provides great opportunities to transform current ways of working across industries. In this section, I'll first explain these terms and explain their main differences. Then, I'll review market's expectations towards these technologies to argue the great financial opportunity for companies, but also present the uncertainty concerning current predictions. Last, I will present current applications and future potential of VR/AR in the enterprise to provide a context to empirical part of this study.

2.1 Definitions

Virtual reality (VR) is defined as ''a realistic and immersive simulation of a three-dimensional environment, created using interactive software and hardware, and experienced or controlled by movement of the body'' (Dictionary.com, 2017). In other words, virtual reality is a computer generated artificial environment, where the user is fully immersed and can experience virtual surroundings in a natural way. It is experienced thought a head-mounted display (HMD), which enables the user to explore virtual surroundings by moving one's head. In many cases, the user can interact with the environment with special controllers. In virtual reality, user can view computer generated content or video captured with special 360 cameras. In order to create this virtual world, VR must occlude natural surroundings.

There are currently two main classes of VR headsets, mobile and tethered. Mobile phone is needed with mobile VR, where the phone is inserted in front of the headset and the headset, and these are the lowest resolution alternatives for VR. High-quality HMDs are typically tethered to a pc, because rendering the 3D scene requires significant computational power. The scale of VR headsets is presented in Figure 2.

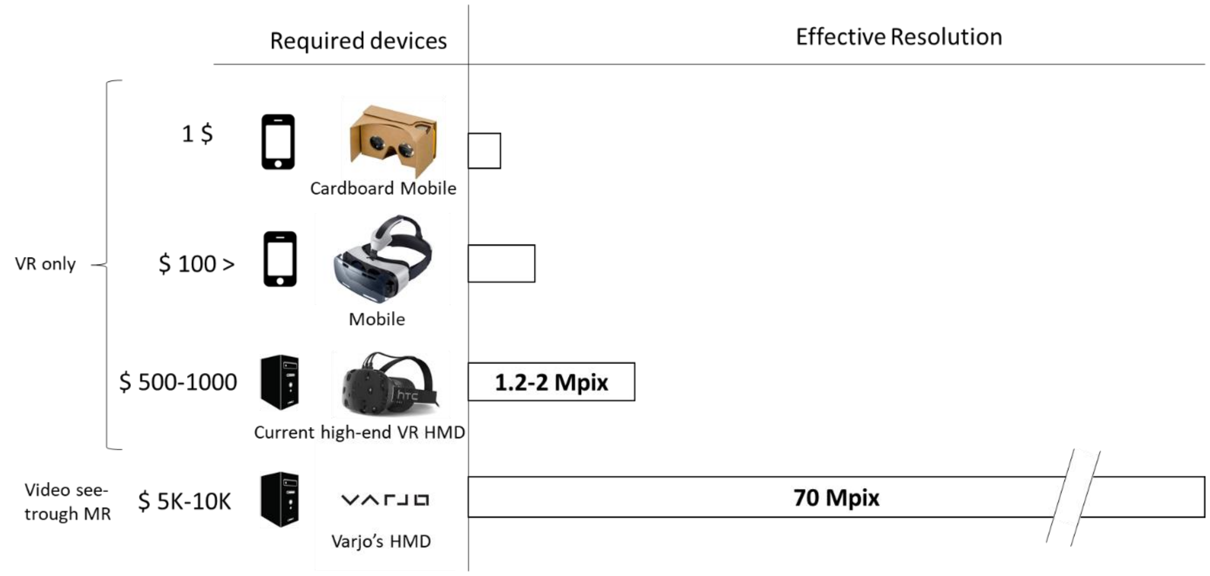

Figure 2. The scale of current VR headsets

Augmented reality (AR) is a different side of the same coin. ‘’AR is an enhanced image or environment as viewed on a screen or other display, produced by overlaying computer-generated images, sounds, or other data on a real-world environment’’ (Dictionary.com, 2017). People can see their natural surroundings in AR, but this natural world is enhanced with computer generated images. AR uses cameras to determine users position in real world and adds 3D graphics in the user’s view. Unlike VR, AR does not block the natural surroundings of the viewer, but only adds digital content in it. AR can be viewed thorough special glasses, or in the simplest way, through mobile phone’s screen, where application uses the phones camera to track surroundings and adds holographic images to the field of view.

Mixed reality (MR) is a combination of VR and AR. Milgram et al. (1994) presented a Reality-Virtuality (RV) Continuum (Figure 3), a scale from real to virtual environment, to illustrate the differences between these definitions. In this scale, they defined MR as anywhere between real and virtual environment, so according to them, AR is part of MR (Milgram et al., 1994).

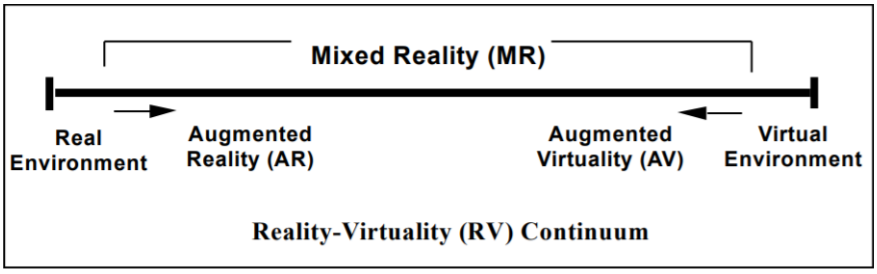

Figure 3. Reality-Virtuality (RV) Continuum (Milgram et al., 1994)

The ability to see natural surroundings is the main differentiator with VR and AR/MR can be achieved with either optical or video see-trough. In optical see trough, user sees natural surroundings trough lenses, just like with normal eyeglasses and digital images are projected to viewer's eyes. With video see trough, the device has cameras that record video from the user's surroundings and combines that video feed in real time with digital content. Just like VR, MR can be either mobile or tethered to PC. Figure 4, presents the scale of current MR/AR devices.

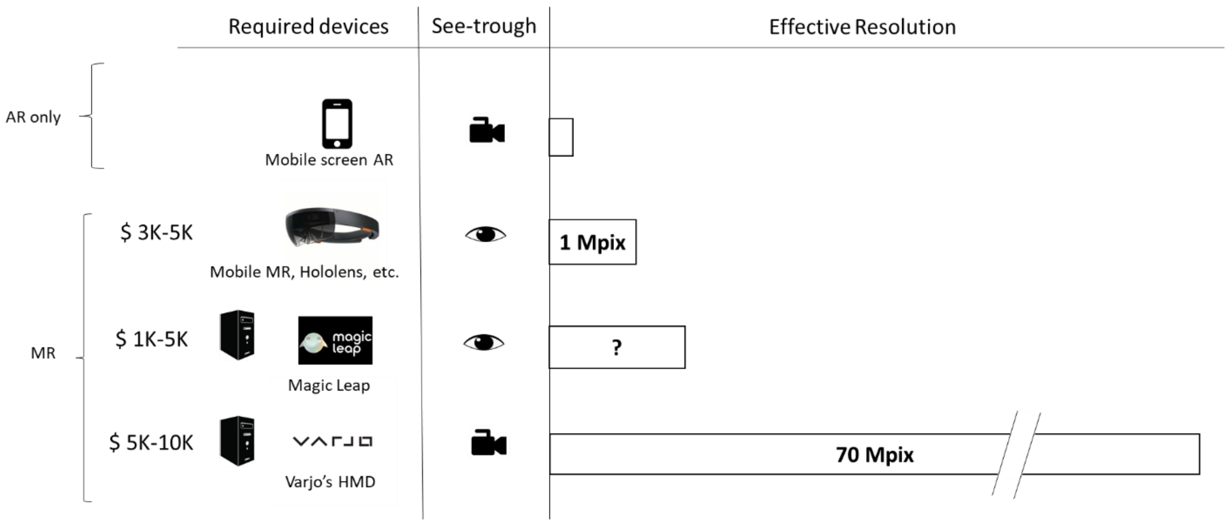

Figure 4. The scale of current AR/MR devices

In common language MR is often considered more advanced version of AR. Graeme Devine, executive from Magic Leap, most highly valued start-up in the VR/AR scene, defined MR's difference with AR as digital content interacting with the user. Therefore, we're in the realm of MR, when the user can, both interact with the virtual world, and see natural surroundings at the same time. MR is experienced trough head mounted displays like VR, and is equipped with see-trough display or cameras that display video, so the user can see the real world, but also interact with digital content. Simply put, it is closest to merging virtual and real worlds. To set these different definitions into perspective, Figure 5 illustrates the modified continuum from real environment to virtual world.

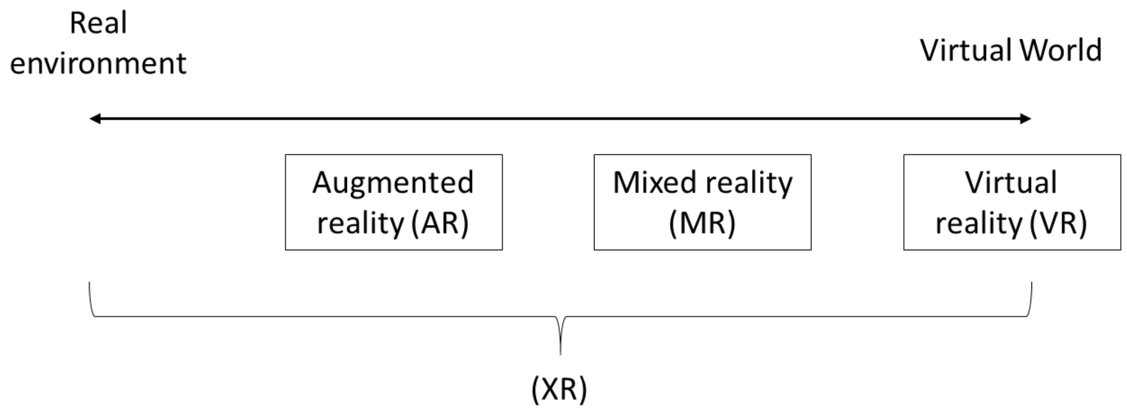

Figure 5. Modified continuum of VR, AR, MR, and XR definitions

These definitions are used so interchangeably that there is a new term (extended reality or XR) emerging in the technology space. It was argued that focusing on one term (AR, VR or MR) or a specific position in the virtual/real -world continuum is a narrow way to define the space, and in the future, people will interact with the virtual world in such a seamless way that none of these definitions will be accurate (Somasegar and Lian, 2017).

Terms VR and AR are mostly used in the future sections of this study, because of the lack of clarity concerning definitions of MR and XR. Also, augmented and virtual reality are clearly distinguishable from each other and they don’t overlap, and these terms are already established in the literature. Terms VR and AR will be used separately, or VR/AR is used to indicate both, since that’s how they are still most commonly referenced.

2.2 The evolution of VR/AR’s outlook

These technologies have been subject to certain degree of excessive expectations in past and failed to perform at the required level, but this is now changing. To provide a view on how the perceptions on VR/AR have been evolving over time, the Hype Cycle is introduced. The technology Hype Cycle is a subjective model created by a research firm, Gartner. The basic idea behind the model is that emerging technologies follow a predictable path from initial discovery to unreasonable expectations, to disappointment, and lastly gradually starts to approach mainstream adoption with more realistic expectations. Gartner have been publishing a new version of its model every year since 1995, and by looking at the consensus over time, the evolution of perceptions regarding VR/AR can be analysed.

The hype cycle has been criticised, because it lacks scientific foundation. Michael Mullany did a compilation for appearances of individual technologies in the hype cycle, and concluded that 25 % of technologies appear in the cycle only once and 20 % of those that have multiple appearances disappear before mainstream adoption. It is natural that most emerging technologies die out before reaching success, yet only a small portion of technologies seem to follow the path proposed by Gartner. Therefore, it can't be used as a predictor of future success of a technology, but merely a consensus of the outlook on individual technologies in certain time. In other words, it presents how individual technologies are perceived relative to other technologies and what are the expectations of their future success at a specific time.

Although the model's predictive power has clear limitations, it does provide a view on the perceptions of emerging technologies at certain time. When these yearly snapshots about the consensus are investigated over time, the hype cycle can provide interesting insights, and it's particularly interesting, when the technologies under investigation have multiple appearances in the Hype Cycle.

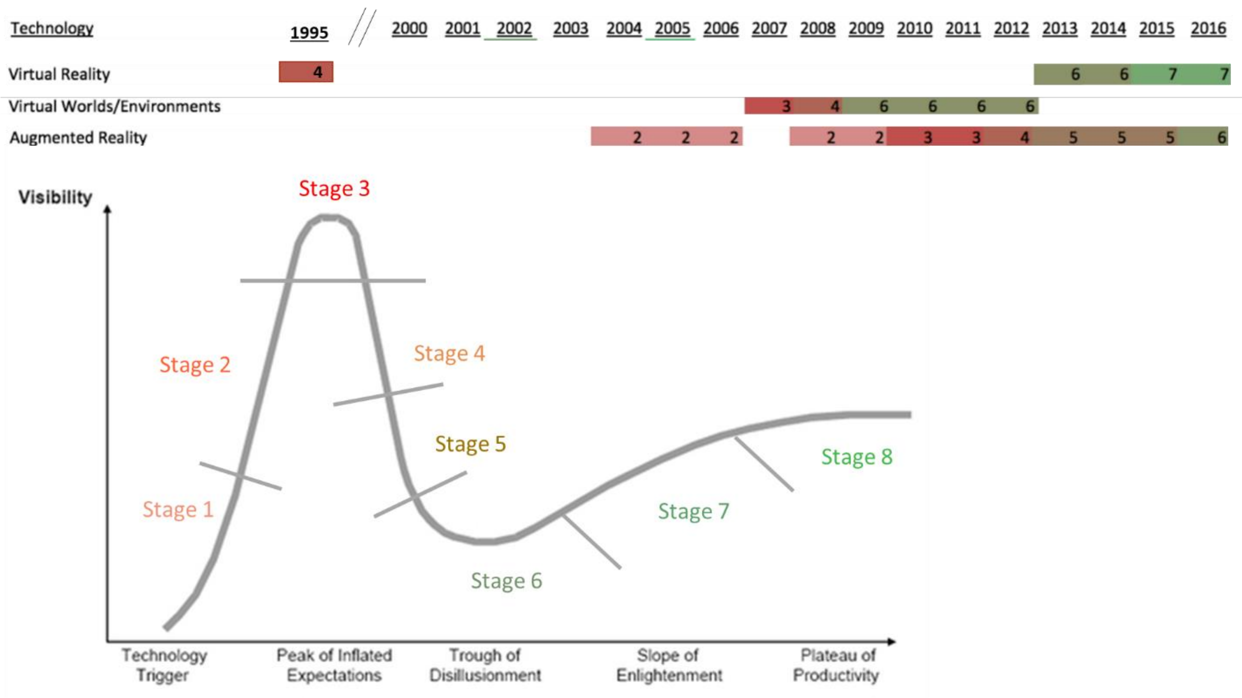

Figure 6. VR/AR's Hype cycle (Gartner, 1995-2016; Mullany, 2017)

Figure 6 is a compilation of each appearance of VR and AR in the cycle, derived from the analysis presented by Myllany (2017) in his article. The cycle is divided into eight sections, and each appearance for VR/AR and their position in the hype cycle for each year is presented. The figure shows that AR is one of the few technologies that have been appearing for 12 consecutive years with only one gap-year in the hype cycle. In addition, AR has been following the graph, unlike most technologies that either appear once or appear for consecutive years, but often in the same part of the cycle. In turn, VR's potential was acknowledged already in 1995, when it made its first appearance in the very first hype cycle, but then disappeared for over a decade, when experiments failed to deliver. This looked just like the other 50 technologies that appeared only once and disappeared for good, but VR was reintroduced in 2007 at the peak of hype as *Virtual Worlds/Environments*. Since then, it has time and again failed to deliver on expectations. However, during last few years VR has been in the *Slope of Enlightenment*, and AR is following close by. It has become clearer how these technologies could benefit the enterprise, more companies are running pilots and the adoption is starting to accelerate. The fact that both VR and AR have been under the radar for multiple consecutive years and companies have been continuing to experiment despite failed attempts, proposes that these technologies are here to stay. They are no longer considered only as 'hype', but more enterprises are running experiments and second- and third- generation products are introduced.

2.3 Markets' current expectations and financial opportunity

There are great expectations to VR and AR markets. Merril Lych describes VR/AR as ''the 4th computing revolution'' and GolmanSach's equity research report (2016) stated that ''VR/AR have the potential to become the next big computing platform''. This means that VR and AR technologies could become as game changing as PC and smartphone were. If this statement proves to be correct, the global VR/AR revenue could reach $183bn by 2025 (GoldmanSachs, 2016). However, it would require that VR and AR technologies will be adopted as a new computing platform across industries. Even if VR and AR would not reach such important position, there are various applications identified across industries, so that even the most modest estimates predict increasing adoption in the next few years. In the following chapters of this section, the current state of VR and AR is presented from the analysts' perspective, the rationale behind ambitious forecasts is explained, and limitations in these estimations are also acknowledged.

2.3.1 Increasing investments in VR/AR space

Funding in VR and AR indicate great interest in these technologies. There was $3.4bn invested in VR/AR as venture capital money during 2014-2016 and the trend is rising (Figure 7) (CBInsights, 2016). VR/AR funding was only $236mn globally still in 2013, which is low compared to the total of $1,8bn invested three years later in 2016. Also, the number of deals has tripled during the same period.

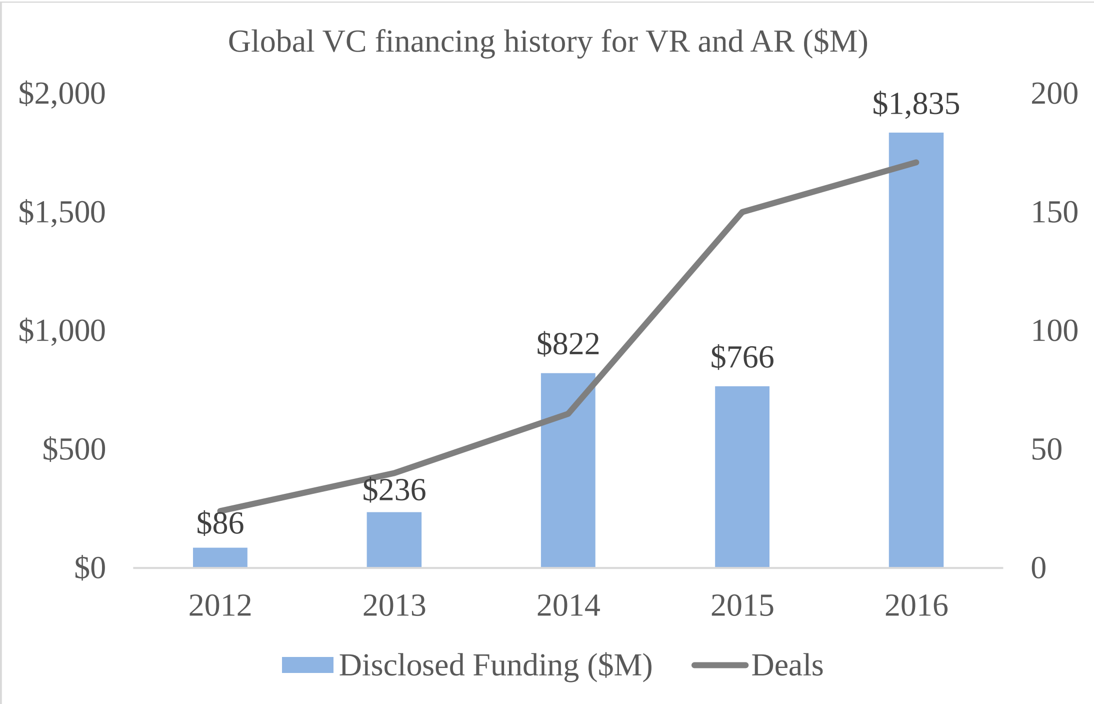

Figure 7. Global VC financing history for VR and AR (CBInsights, 2016)

When investigating the funding and acquisition activity in VR and AR, there are two hardwaer companies that particularly stand out, Oculus and Magic leap. The latter secured $500mn B-round investment led by Google in 2014, followed by Alibaba's $793.5mn C-round in 2016. Just recently, in September 2017, they secured another $500mn round, which puts the total funding for Magic Leap to $1.89bn with $5.5bn valuation (CrunchBase, 2017), and this all has been done without a product or a single customer. In addition to VC funding presented in Figure 7, Facebook acquired Oculus for $2bn in 2014, which is still the largest deal in this space, and it's argued to have been the catalyst for recent advancements in VR and AR industry (Merril Lynch, 2016).

Few notable advancements are also significant investments in the supporting software infrastructure of VR/AR. Unity, which is another one of two major gaming engines that are currently used to create VR experiences, raised a total of $580mn between 2016 and 2017 (CrunchBase, 2017). (The second one is Epic Game’s Unreal engine.) Another noteworthy event in 2017 was a $500mn investment round to a new emerging player, Improbable, which is a similar platform to create virtual and simulated worlds (CrunchBase, 2017). These platforms are essential to building experiences for VR, so their advancement can facilitate content and application development for VR.

There isn’t shortage of potential venture capital either. Virtual Reality Venture Capital Alliance (2017), reported that there is $18bn in deployable capital for VR and AR, which is up from $10bn reported last year, so funding in this space is likely to increase in the future. In sum, this accelerated funding in VR and AR have provided the resources to develop the enabling technology and more content for users. Investments started to substantially increase only few years ago, so the fruits of these investments are now starting to emerge, and the VR and AR industry is progressing at a rapid pace.

2.3.2 High expectations and high uncertainty

There are great expectations to future potential for VR/AR, but revenue estimates for VR/AR by research companies wary significantly, which is presented in Figure 8. Estimations are based on rough assumptions, because it’s still unclear where the real potential for practical applications of VR and AR is and there are very few established markets to use as a benchmark. These estimates presented by industry researchers vary from $28bn to $163bn for global revenue in 2020. The differences in forecasts are explained by assumptions on the time it takes for mainstream adoption, but they all agree on that VR and AR will have a great impact in the next few years.

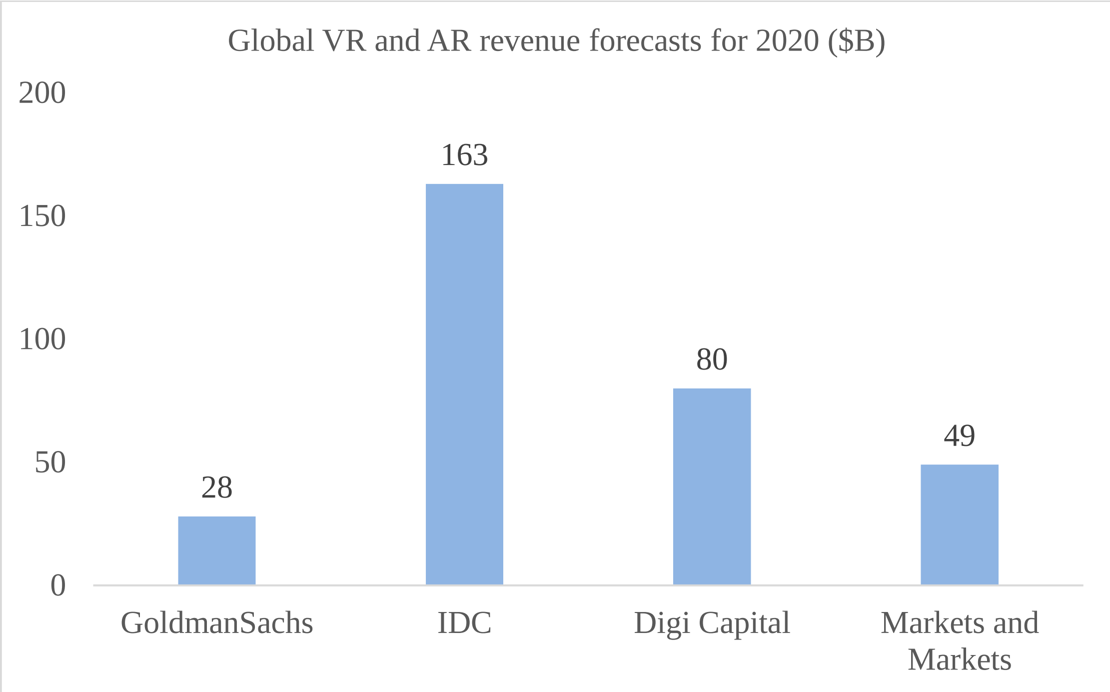

Figure 7. Global VR and AR revenue forecasts (GoldmanSachs, 2016; IDC, 2016; Digi-Capital, 2016; MarketsandMarkets, 2016)

Some industry researchers also acknowledge the inherent uncertainty for forecasting future markets for AR and VR. In the GoldmanSachs's investment research report (2016), they provided three alternative scenarios, with estimates ranging from $23bn to $183bn for VR/AR hardware revenue in 2025. In the ''best case'' -scenario ($183bn), they assumed that VR/AR will become ''the next computing platform'', which assumes that HMD sales numbers would reach the size of today's laptop market by 2025. They also acknowledged the possibility for ''delayed uptake'' ($23bn), in which case VR would stay predominantly adopted for videogames. Lastly, their ''base case'' forecast sets in the middle at $45bn for global VR revenue in 2025 (Goldman Sachs, 2016).

Another example of the unpredictability is Digi capital's estimates. They originally predicted VR/AR revenue to reach $150bn in 2020, but only a year later adjusted the forecast down by 47 % to $80bn (Digi-capital, 2016-2017). Providing accurate forecasts with long time spans to currently non-existent markets is a challenge. It is evident that estimates must be updated in the light of new information, so we are going to see a lot of variance in the forecasts before distinct market segments to VR and AR emerge.

There is also ambiguity in these estimates for two reasons. First, VR and AR terms are used interchangeably, which creates challenges for making the data comparable. Second, some forecasts use only hardware and other estimations include software as well. Forecasts in the chart above (Figure 7.) are taken from reports that consisted of complete VR and AR revenue including in both software and hardware markets.

It is common to all the forecasts that industry researchers are still optimistic about the future potential of VR and AR. These technologies are still in the early adopter phase, and the global VR and AR revenue was only $3,9bn in 2016 (Digi-Capital, 2016), so even the most conservative forecasts assume fast accelerating adoption in next few years. Only the phase of the adoption is debated, and compound annual growth rates (for forecasts presented in figure 8.) range from 64% to 154% during the forecast period of 2016-2020.

These technologies are currently used mostly in consumer settings, but companies have been experimenting with VR and AR for a few decades already. But, only during recent years, has the potential been acknowledged more widely. It’s unclear where VR/AR will disrupt current ways of working, but potential use cases have been recognized across industries. More information about the markets is needed, especially from the end user’s point of view, to estimate the rate of VR/AR adoption more accurately.

2.4 Current state of adoption in the enterprise

It’s still very early days for VR and AR in the enterprise, but industry surveys have showed promising results and indicate accelerating adoption in the next few years. PWC’s 2017 edition of the annual *Digital IQ* -study that measures the adoption and plans with emerging technologies, provides a good baseline to understand enterprise adoption. With 2,216 responses from IT and business leaders, the message is clear; VR and AR are still low on the priority when compared to other emerging technologies (such as IoT, AI and robotics), but the adoption growth rates for VR and AR are promising. In the study, 7% reported that they’re making substantial investments in VR today and 15 % in the next three years, and 10% reported that they’re making substantial investments in AR today and 24% planning to do so in next three years (Figure 9.) (PWC, 2017). These results suggest that number of companies adopting VR increases 29% year over year, and respectively 34% YoY for AR in the next three years.

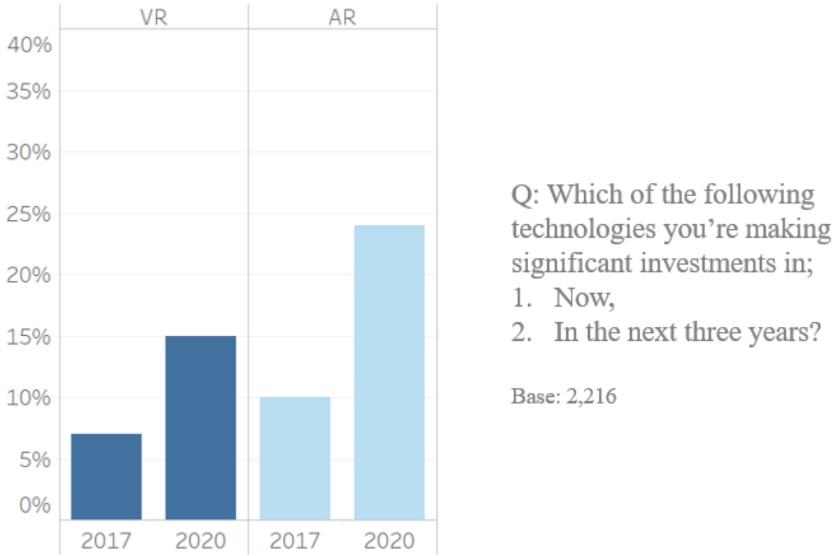

Figure 8. PwC's 2017 Digital IQ survey results

Studies by Tech Pro Research and another study conducted by PWC showed similar results with a slightly more promising adoption rates in the enterprise. Tech Pro Research (2016) found that 13 % of companies were considering VR during the next year and total of 23% in the next three years. PWC had similar findings, when studying VR/AR adoption among US manufacturers. They found that 12.5% were already using VR or AR in some form and 23% were planning to adopt in next three years (PWC, 2016). These latter two studies were both conducted with smaller sample sizes, so any conclusions must be made with caution, however these results point to similar direction than PWC's wider study, so they merely confirm findings of that study. In sum, based on these three studies presented here, current adoption of both VR and AR is at 7% to 13% and estimates for adoption during the next three years vary from 15% to 24%. These studies suggest that VR or AR haven't yet crossed the chasm from early adopters to early majority, but responses suggests that it's only one to three years away.

2.5 Mapping the future adoption

Rogers' Innovation Diffusion theory (see chapter 3.1 for description) have been used to predict how new innovations spread over time. A hypothetical model for VR and AR adoption is presented in Figure 10 by applying current adoption rates with this original theory. Assumptions for current level and the rate of adoption in the next three years are applied from findings in PwCs *Digital IQ* -study (Figure 9). The study had 2,216 responses with wide spread to different industries, therefore it is the most reliable benchmark from available sources.

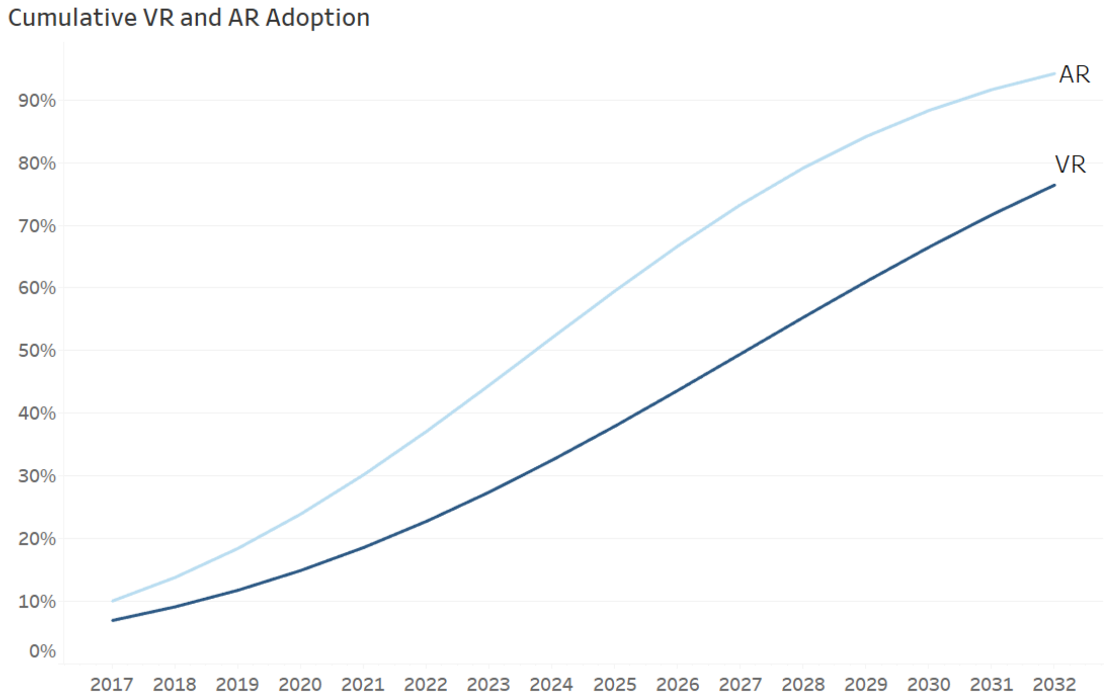

Figure 9. Hypothetical VR and AR adoption curve in the enterprise

AR would cross the chasm in mid-2018 and VR in early 2020 respectively, if those now planning to adopt in next three years follow through on their plans. Then, the peak for adoption rates, when technology is adopted by 50% of the potential adopter base, would be reached in 2024 for AR and in 2027 for VR. According to the original theory, growth rates will start to gradually slow down after the peak.

When compared to recent successful consumer technologies, the curve above seems conservative. It took four years after crossing the chasm (from 15% adoption) for smartphones to reach 50% adoption and only two years for tablet PCs (Goldman Sachs, 2016). However, these technologies were driven by consumer adoption, thus are not directly comparable to VR/AR, where adoption could be driven by enterprise.

PC adoption could provide a better comparison to VR and AR adoption, since it was first adopted by the enterprise followed by consumers a few years later. Above industry surveys demonstrate that the adoption of VR and AR could be driven similarly by the enterprise and followed by consumer adoption later as the price of the hardware comes down. Goldman Sachs presented the historical PC adoption divided to enterprise and consumer shipments (Figure 11).

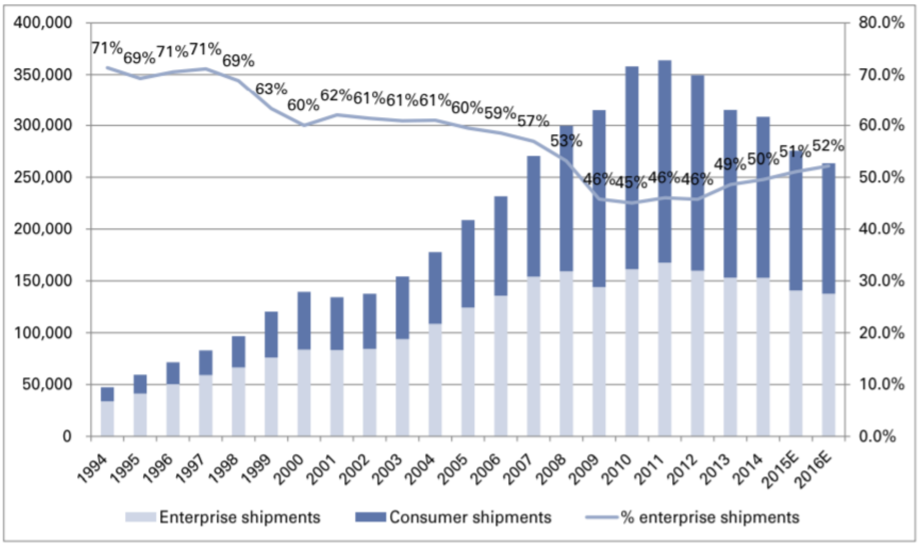

Figure 10. Historical PC shipments by enterprise and consumer (Goldman Sachs, 2016)

The graph demonstrates that enterprise adoption rate is much more gradual than consumer adoption. VR/AR could follow a similar path, where enterprise first accepts the technology, and adoption rates increase significantly when these technologies reach consumer adoption. Depending on the way interpretation, it took 14-18 years for PCs to reach saturation point, which is highly similar than that of Hypothetical VR/AR adoption curve presented in (Figure 10). Since the VR/AR adoption curve presented above does not include consumer adoption, it could be hypothesised that the actual (combined enterprise and consumer) adoption curve would be even steeper.

The VR/AR curve provides a view how total enterprise adoption could progress, but is based on too many generalizations to provide actionable insights. In practise, adoption rates will significantly differ between industries, since some have more favourable conditions to adopt and greater needs for these technologies, thus are more likely adopt faster and vice versa. Therefore, to gain a more robust estimate about future adoption, more information is needed from different industries and use cases within them. In conclusion, surveys in the enterprise indicate that there is a high probability that VR and AR adoption will accelerate in the upcoming years. However, the question remains that in which industries VR/AR will be adopted first and what are the use case(s) that will initially accelerate the adoption.

2.6 Potential industries for VR/AR adoption

Opportunities for VR/AR technologies are found across industries, and analysts and experts say that there is great future potential in enterprise solutions (Goldman Sachs, 2016; Merril Lych, 2016; PWC, 2015). Use cases, where VR is already adopted or seen as most potential was in simulation, training, modelling and sales according to Tech Pro Research, and product design and training stated by PWC. In general, most use cases for VR fall into three main categories, visualizations for marketing & sales, designing for product development or simulations & training.

Companies are still exploring these opportunities with VR/AR and most projects are still in the early stages of development. BOM (2016) conducted a study with developers and users of VR/AR and found that 71% of users are still in the pilot phase for VR/AR. Tech Pro Research (2016) revealed also that lack of specific applications and challenges with integration are most important barriers for companies to adopt VR/AR. VR and AR are still in the early adopter phase, so adopting requires more effort, because the infrastructure isn't developed yet. Evidence suggests that companies are still waiting for the first 'killer application' for VR/AR that will prove the value of the technology. Such application is usually considered so essential that it will drive demand for the larger technology, like Email once did for PC. Although, we may not see similar ground-breaking application in VR/AR space, specific prove of concept is still needed for wider adoption of VR and AR.

Visualizations, design and simulations are some of the use-cases where current ways of working could be redefined using VR and AR. First, visualization in VR and AR can change the way projects are communicated. With VR/AR, 3D models can be transformed into a fully immersive virtual reality experience. It can be used as a sales tool to showcase large projects, where it can reduce the need to travel, and enables demonstration of unfinished projects. Second, VR and AR have been used for design in advanced engineering for few decades already (Brook, 1999), since it can make prototyping faster and cheaper. Shen et al. (2010) demonstrated that designing in VR/AR could reduce time and cost, since objects can be modified in 3D space, and interface is more intuitive and they can accurately create and edit objects with complex bases. Third, potential use cases have been identified in simulations and training use, where users experience a virtual scene or interact with virtual worlds. Here, VR can make learning more effective, because training is more intuitive, and reduce cost, because companies must rely less on expensive machines and reduce the number of training personnel needed (Bernardes et al., 2015; Gavish et al., 2013). Next, I will go through some of the most potential use cases in the enterprise. Following description isn't exhaustive description of all possible use cases for VR and AR, but the purpose is to highlight some of the most promising use cases and studies across industries, and provide an overall view of VR/AR usage today.

2.6.1 Engineering

Engineering has many potential use cases for VR in visualizing processes and designing products. Using VR for design purposes is natural, since companies are already using CAD and other 3D modelling software to create 3D models, and these models can be transformed into VR environment. VR enables professionals to test product, process, or facility designs before anything physical is built. One of the VR's biggest benefits is to identify problems early in the process to avoid costly drawbacks later. Companies in shipbuilding industry are using VR in planning phase to visualize processes or demonstrate a project, which is found to reduce cost by minimizing errors in development stage (Fernandez and Alonso, 2015). In engineering, spotting possible errors early is the greatest benefit of using VR, so it is important to know the know the cost of avoidance to justify costs for developing VR facilities. Lockheed Martin, a global advanced engineering company, estimates the impact of specific findings done with VR to prove the usefulness of VR (Berg and Vance, 2016). An engineering manager from Lockheed Martin, stated in an interview that they're able to save $10nm each year by identifying possible design errors earlier using VR (Russel, 2017). Although, VR models can be costly to make, they're much cheaper than building physical prototypes, and recognizing errors early can achieve significant costs savings.

Companies in automotive industry have been some of the early adopters of VR in their R&D processes, because of the highly competitive nature the industry. There is a high pressure to constantly create new products and shorten the time to market, therefore VR is used to reduce time and costs, and increase quality in product development (Lawson et al., 2016). Daimler and Chrysler for example, saw the value in using VR as part of their design process already in 1999, despite the technology was still primitive (Brook, 1999). VR can provide several benefits for automotive design. Berg and Vance (2016) explained that VR helps automotive companies to examine visibility (how the customer sees inside the car) and ergonomics (how reachable things are inside the vehicle), to spot possible errors and test different designs. Also, aesthetic quality can be tested using VR, because advancements in lightning and material properties enable demonstration of near realistic products in VR. In the same study, A manager from General Motors mentioned, that ''VR has basically eliminated 3D prototyping'' (Berg and Vance, 2016).

There is no doubt that VR has been proven useful for design in engineering industries, but problems still exists that must be overcome to reach the desired utility. First, technology sets constraints for adoption in both hardware and software. Lawson et al. (2016) concluded, that development areas in automotive include higher resolution to work with details better, and improved haptics and motion tracking to study ergonomics more effectively. Berg and Vance (2016) had similar findings concerning hardware, and found also that model preparation and conversion are still problems related to software. Second, there are practical barriers for VR adoption. Establishing a VR laboratory is a significant investment, and professionals might resist change (Berg and Vance, 2016). For engineering professionals, designing in flat screen with traditional tools might still be more practical in many cases, because working in a VR/AR environment would be a completely new process for many. Berg and Vance (2016) described a practise at Lockheed Martin, where they recognized the resistance from engineers, and decided to deploy a person responsible for promoting VR and encouraging engineers to use VR inside the company. They found that it was difficult to get engineers to try VR, but once they did, they were usually impressed, and most of the times, required only one session to prove the usefulness to their work (Berg and Vance, 2016).

2.6.2 Industry and Manufacturing

In industry and manufacturing, potential use cases for VR and AR have been identified in areas of skills training, maintenance, and operations. PWC's study among professionals of US manufacturing industry demonstrated, that among current users of VR/AR 28 % were using these technologies to skills training, and 19% for maintenance and operations, and these were most common uses, right after product design (PWC, 2015). There are a few ways VR can improve maintenance. Authors of DIMECC's study, covering smart technologies for industrial applications, presented a scenario, where virtual reality can provide savings by reducing time spent travelling to site and offer expert help on the field when needed. 360-video provides up to date information from the site, so maintenance technicians can check the status of the site remotely. They are better prepared for repair work, and don't have to spend time on travelling or waiting. VR/AR solutions were tested in practical applications, with promising results. Lead UX designer from Wärtsilä stated, ‘’it has become clear that contextual guidance, remote support and 360-degree VR visualisations have a high potential of impacting the way we educate, prepare and perform maintenance task’’ (Mäkelä et al., 2017). In turn, the potential of AR is recognized in field operations, where it’s used on site to assist work. Presenting useful information in the right context for professionals can make work more efficient and accurate. Richardson et al. (2014) did a study with Boeing, where they used AR with tablets to provide instructions for workers assembling a mock plane, and found that workers with AR instructions performed the job 30 % faster and 90 % more accurately than workers with normal pdf instructions on desktop.

Both VR and AR can make everyday maintenance and operations work more efficient. First, downtime is extremely costly for industrial and manufacturing companies, so fast responding to maintenance tasks is essential. With VR, maintenance workers can be better prepared for the task, and experts can provide remote support without having to travel to the location. Second, operations can be improved by eliminating errors and reducing time used to searching information. Here, AR can provide right information at the right context can help professionals work faster and more accurately. Like in almost any other industry, there is potential for using VR/AR for skill acquisition also in industry and manufacturing. However, infrastructure for VR/AR in training as well as operations and maintenance is still less mature than that of designing, therefore there are more barriers for adopting these technologies also.

2.6.3 Architecture, Construction and Real estate

Design in architecture, improved communication in construction, and virtual visits in real estate are three main ways VR/AR could transform these industries. Architects can benefit from VR in the actual design stage of the work. Portman et al. (2013) reviewed studies covering VR in architecture, and concluded that biggest benefits for VR in architecture are spatial conception and collaboration during design stage. With VR, architects can work in 3D environment and make changes inside an immersive model, which helps them discover ‘lost’ non-accessible spaces that would be unrecognized in traditional 3D models. Another benefit identified is collaboration with design team members and other designers remotely in shared space, which makes the design process more effective (Portman et al. 2013). In construction, more efficient collaboration could be even more important, since project overruns and inefficient communication are common problems. A study by Woksepp and Olofsson (2008) demonstrated that a VR reduced development time by providing more accurate communication between stakeholders of the project, while the total cost of the VR model was only 0.2% of the whole development project. In real estate, it's possible to have a virtual visit in an apartment from a distance with VR. This could reduce time used for home showings when the potential buyer could explore multiple houses from the same location in the virtual showroom. This is especially useful when apartments are placed in remote locations or still under development. For example, new housing is usually sold before it's built, so the decision to buy must be made based on 3D illustrations of the apartment. Prospective buyers can experience how it feels like to be inside the apartment with VR, which could mean faster sales cycles for real estate agents and better customer satisfaction, when possible surprises are avoided.

2.6.4 Retail

VR has potential in retail in two distinct use cases, demonstrating large products in higher end markets, like cars or home interior, and research and marketing tool for retailers in lower end, where effective store design is important. In the first case, mobility is a big constraint when showcasing large product, so with VR, companies can take the product with them virtually to customer's location. In August 2017, Audi announced in a press release that it will start using VR in its retail dealerships more widely in UK, Germany and Spain, with more locations following. They started beta testing the system already in 2015, and due to positive feedback form customers and dealers, decided to incorporate the system as a part of their retail experience (Audi-mediacenter, 2017). In addition, Volvo recently made a virtual showroom to demonstrate their products in VR, and GM have announced similar plans (Goldman Sachs, 2016; Rogers et al., 2016). Instead of large retail locations, this enables companies to showcase their products in small pop-up stores and malls. This could reduce the fixed costs related to large retail locations and holding inventory.

The second use case in lower end of retail markets, where it can be used as a platform for virtual store. Pantano and Servidio (2012) suggest that consumers can be more satisfied with virtual shopping experience and it creates valuable data for retailers. Their study demonstrated that virtual shopping environments can reduce cognitive load by providing intuitive interfaces and more customised experiences for customers. The same study also acknowledged the potential of virtual reality for marketing purposes. Companies can collect data from the shopping event and provide more customized experience for customers (Pantano and Servidio, 2012). An example of possible data collected from VR is eye-movement, which could be used to determine consumers' buying intentions (Bigne et al., 2016). Retailers could use eye-tracking data from virtual stores as a research tool to create more efficient designs for physical store. Although, virtual shopping requires an extensive installed base of VR headsets among consumers before it can be utilized more widely, VR can be used as a research tool for focus group studies already today. Retailers are constantly experimenting with different store designs to create more effective layouts, and with VR, they have possibility to get objective, and new data about user's intentions.

There is interest in virtual reality training for employees also in retail. Walmart, the World's largest employer, announced in May this year (2017) that it will start using virtual reality in all training locations after successful pilot programs. They expanded VR training to 200 locations where 140 000 employees go through their training program each year. VR enables employees to go through situations where they confront customers and are then faced with choices on how to act. It also reduces the personnel needed for training (Harris, 2017). With high training volumes, even small gains in efficiencies could transform to significant savings, because less training personnel is needed. Walmart showed that training in virtual reality isn't limited to flight simulators situations where real life training is impossible or too expensive, but proved that VR can make training more efficient for any operational tasks.

2.6.5 Healthcare

Healthcare is one of the industries, where the use of VR has been studied extensively. Potential applications of VR in healthcare have been studied for 25 years (Takala, 2017), and fist application for VR was developed in the early 1990s, when it was used to assist surgery planning (Chinnock, 1994). Nowadays, potential applications for virtual reality include rehabilitation and treating phobias or post-traumatic stress disorders, training surgeons to perform complex surgeries, visualization of images in 3D models and designing of surgeries (Takala, 2017).

Computer simulated virtual world can be useful when treating patients with post-traumatic stress disorders (PTSD), and make rehabilitation more effective (Gerardi et al., 2008; Howard, 2017). Gerardi et al. (2008) found that by using virtual reality, as a short-term expose therapy, PTSD symptoms were reduced by 56%, but patients were still medically diagnosed with PTSD after the treatment. McLay et al, (2014) had similar findings, and concluded, that VR is effective for treating PTSD, but it doesn’t cure depression or neuropsychological functioning, so it can’t be used as the only treatment. Howard (2017) conducted a systematic literature review on virtual reality rehabilitation programs, and concluded that they are proven to be more effective than traditional programs, but the reason why they work so well still requires more research. There is a lot of research done in VR for medical treatment with very promising results, but it’s not a perfect solution, and can’t replace current treatments (Howard, 2017). However, a recent study by Donati et al. (2016) demonstrated, for the first time, a clinical recovery for severely paralyzed patients by using an advanced VR rehabilitation system. They were able to elevate the clinical status for 50% of chronic (3-13 years) spinal cord injury patients from paraplegia to incomplete paraplegia classification, which means that small degree of mobility was restored to paralyzed patients, and the authors stated that this type of neurological recovery has never been confirmed in studies before (Donati et al., 2016). In addition, there is early commercial activity in this space also. For example, MindMaze, a start-up valued over billion dollars from Switzerland, is making a VR headset that is used to retrain people with brain injuries, and it’s is already a certified medical device in Europe (Mindmaze, 2017).

Second, training is one of the most potential applications for VR in healthcare. Izard et al. (2017) studied use of VR as educational tool, and concluded that it helps improve training in clinical and surgical skills, and stated that ‘’This [VR] undoubtedly represents the future of training in medicine’’. But, they also acknowledged that physical discomforts are still a problem, and haptics should be developed for more realistic experience (Izard et al., 2017). Laparoscopic surgery especially, is one of the use cases where VR training has been studied extensively. Alaker et al. (2016) conducted a meta-analysis on 31 randomised controlled trials comparing virtual reality training to traditional training methods for laparoscopic surgery, and concluded that there is significant evidence that VR training is superior video training or no training. But, when compared to box training, there wasn’t significant difference, because box training still provides better haptic tissue resistance feedback, which is necessary for laparoscopic training (Alaker et al. 2016). Therefore, in addition to visual immersion, haptic feedback has been identified as another key component for crating effective training environments in VR for surgery training. There is interest in developing these systems, because

VR can provide a platform for surgeons and students to train realistically and in a risk-free environment.

Third use case for VR in healthcare is visualizations of 3D images and design. CT and MRI images can be visualized in VR, which enables physicians to explored images in more detail from many angles, which can improve physicians' effectiveness of identifying abnormalities in these images (Robb, 2008). In addition, medical professionals are already using 3D imaging, when planning for surgeries, so these models could be transformed to virtual reality for more immersive examination. For example, Digitale (2017) described in her article in Stanford News, how examining CT images in VR enabled the surgeon to see that they have enough space and make an important decision to perform the surgery. Robb (2008) did and extensive review on the evolution of VR systems in medicine, and according to him, healthcare is still looking for the ''killer app'' also, but he acknowledged that surgery planning or virtual endoscopy are in progress to becoming one. However, the author points out that there are still problems to overcome for VR systems to become more common in healthcare. He suggests that more standardisation is needed, technology must be improved, and more studies to validate these systems must be conducted (Robb, 2008). In conclusion, healthcare is an industry where there are countless possibilities for VR, but also significant barriers to adopt new systems in practise.

2.6.6 Military and Aerospace

VR and AR have the potential to disrupt simulations and training in military and aerospace. For example, training for pilots is usually conducted in expensive simulations, so VR headsets have the potential to provide similar training for fraction of the cost of a flight simulator. HMDs can never completely replace current simulators, but it could be used in the early stages of training, where VR solutions could gain market share from current high-end solutions.

Virtual reality can provide affordable and fast training platform for many other cases in military also. Siu et al. (2016) presented a solution using virtual reality to improve medical skills training in military. In the US military, 100 000 professionals must be trained each year, because medical skills needed in the operational area are different than those used in civilian, so there is a need to quickly acquire skills that are decayed due to infrequent use. In this case, virtual reality provided more affordable, but also faster solution to acquire minimum necessary skills

(Siu et al. 2016). Virtual reality is used to combat training also and potential military applications of VR will exceed training.

MarketsandMarkets (2016) also suggested that adoption of virtual reality training is one of the most important factors driving the growth of military training and simulations markets in the next few years, because virtual training ensures safety and provides cost efficiencies. However, challenges for simulation military and aerospace industries are precision and accuracy of current technology. Also, military has a lot of proprietary technology, so it can be tough market for outsiders to penetrate. These can prove to be attractive markets for VR, when the technology advances enough, because VR can reduce the need for expensive simulators in the early stages of training in both industries, and cut back field training days in military.

2.6.7 Entertainment

The adoption of VR/AR in entertainment have been driven by gaming, but now media companies are seeing the value of VR in video entertainment and live-events. VR can provide an experience of being present in the front row seats. Therefore, media giants like Time Warner, Comcast, and Walt Disney are investing heavily on start-ups, like Jaunt and NextVR, that focus on streaming sports, concerts, and other live events. Time Warner and Comcast were among the backers of NextVR with total of $115,5mn invested in 2015 and 2016, and Walt Disney was the lead investor in Jaunt’s $65mn round of funding in 2015 (Crunchbase, 2017). The funding activity from these big media corporations showcase the interest they have towards VR technologies as a new medium for entertainment. They are not only investing on streaming, but creating their own VR content. However, virtual reality is still in the early stages, because of the lack of supporting devices adopted by consumers. Zillah Watson, who led the editorial development of VR in BBC, created an outlook of VR as a news medium, by interviewing 20 of the industry’s VR experts from leading news organizations in 2017. She concluded that major news organizations are past the initial experimental stage and VR has become more important part of their work, but there are still barriers for adoption in terms of consumer take-up on headsets and the cost of producing content (Watson, 2017).

High-end HMDs are still expensive for consumers, which opens new possibilities for amusement parks and movie theatres to provide consumers more approachable way to the world of high-end VR experiences. GIA (2016) presented that VR is one of the most important trends in amusement park industry, which highly competitive and companies are constantly pressured to create new experiences to attract customers. Industry experts have acknowledged that VR provides smaller parks a way to create attractions with lower cost, since the cost of creating a virtual reality experience can be as low as $15mn, while typical ride at Disneyland costs $250mn (Martin, 2017). However, Nelson (2016) presented that personnel are the bottleneck for adopting VR at scale, especially for bigger amusement parks. Personnel costs can account for up to 50 % of total costs in amusement parks, therefore more people required to operate VR experiences and increased set up time, can turn the ROI negative, even though development costs would be low (Nelson, 2016). In addition, VR arcades are emerging as a new way for people to try out VR without investing on the expensive gear themselves.

Table 2. Summary of the type of applications and different use cases across industries

Industry vertical	**Type of application**	**Use-case example**
Engineering	Design Visualization Simulation & Training	Product design (e.g. Automotive) Product or process demonstrations to get approvals (e.g. showing a new design line to board of directors) Complex data visualizations (e.g. wind tunnels)
Industry and manufacturing	Simulation & Training Design 360 Video	Training for operations or emergency situations, Training engineers to use machinery, Plant operation training, Process design, Product design Maintenance preparation remotely (e.g. Wärtsilä 360 degree VR visualisations), Remote guidance for maintenance or emergency situations
Architecture and Real estate	Design	Building design, Interior design

	Visualization for sales and marketing	Virtual home showings
Healthcare	Visualization Design Simulation & Training	Rehabilitation, treating phobias and PTSDs CT and MRI imaging, surgery planning, prostate design Training for laparoscopic and other surgeries and anatomy education
Retail	Visualization Simulations & Training	Virtual showroom (e.g. Audi virtual showroom), Product demonstrations Eye tracking for market research (e.g. sales customization and retail store design), Operational training for employees in high volumes (e.g. Walmart's employee training)
Military and Aerospace	Simulations & Training	Pilot training, Field medics training, Battle simulation
Entertainment	360 Video Simulations & Gaming	Live-event streaming (e.g. Jaunt, NextVR), News (e.g. BBC) VR arcades, Amusement parks

3 TECHNOLOGY ADOPTION

There are various models developed over the years to explain user acceptance and adoption of new technologies. In this section, I will briefly introduce models that are used when explaining user acceptance of technology to provide an understanding of how these models have evolved over time and point out similarities in them. Then, I will go through UTAUT -model, which is a combination of these models. Lastly, I will present the conceptual model for this study. The model is based on UTAUT and complemented with additional construct that based on previous applications of UTAUT -model.

3.1 Innovation diffusion theory

Innovation diffusion theory (IDT) (Rogers, 1995) have been widely used to explain how innovations spread in certain channels and in a social system. It is used to predict innovation’s adoption by distinguishing different adopter categories among people and examining attributes of innovations.

3.1.1 Adopter categories

IDT explains the adoption of innovations based on types of people that include: innovators, early adopters, early majority, late majority, and laggards. The theory presents a s-curve model for the market’s adoption of innovations over time (Figure 12). First, innovators that account for only 2.5% of the potential market adapt a new technology. They are willing to take a risk to try out new technologies and have the capacity to absorb consequences of adapting a failed innovation. At this stage, it is still unclear whether the innovation will be adopted by more widely. Next, early adopters that include 13.5% start adopting. Early adopters are considered as opinion leaders and are respected among their peers. Other potential adopters look up to early adopters to try out new innovations and early adopters gain esteem for adopting successful and discrete new innovations. After early adopters have adopted an innovation, the phase of adoption starts to rapidly accelerate, when the next group accept an innovation. That group is early majority that accounts for 34% of the potential adopter base. They are deliberate and want to see opinion leaders adopting a new idea before they accept it. They adopt the innovation just before the average number of people. There is a chasm between early adopters and early majority, therefore it’s the early majority’s acceptance of innovation that is considered determining its success. Lastly, late majority (34%) that are somewhat sceptical of new ideas and laggards (16%) that are most traditional adopt the innovation also. (Rogers 1995)

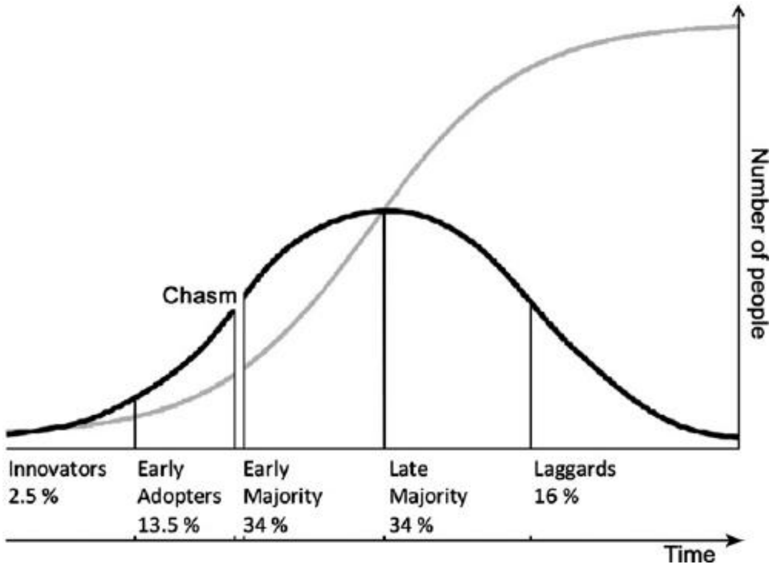

Figure 11. Diffusion of innovations over time (Rogers, 1995)

3.1.2 Innovation characteristics

The theory suggests that there are four attributes that affect the spreading of an innovation: the innovation itself, communication channels, time, and a social system (Rogers 1995). In technology acceptance research, the first attribute from Roger's model, the type of innovation is most commonly utilized. The type of innovation largely determines the rate of diffusion, so it has been also used as a foundation for subsequent models (Moore and Benbasat, 1991). The type of innovation can be divided to its characteristics that facilitate the innovation's diffusion. Innovations with relative advantage (e.g. lower price with same performance), better compatibility (e.g. fit with existing skills or values), less complexity (e.g. easy to use and understand), trialability (e.g. option to try before buying) and observability (e.g. possibility to see benefits) can be expected to diffuse faster.

3.1.3 IDT in the context of IT systems

Moore and Benbasat (1991) used IDT and especially the characteristics of innovation and adapted them to the context of information systems. The aim of the proposed model was to better understand individual level of innovation's adoption. They modified the original innovation characteristics by adding image and voluntariness as additional characteristics, divided observability into visibility and demonstrability and renamed complexity as ease of use. Figure 13 summarises the proposed new model (Moore and Benbasat, 1991).

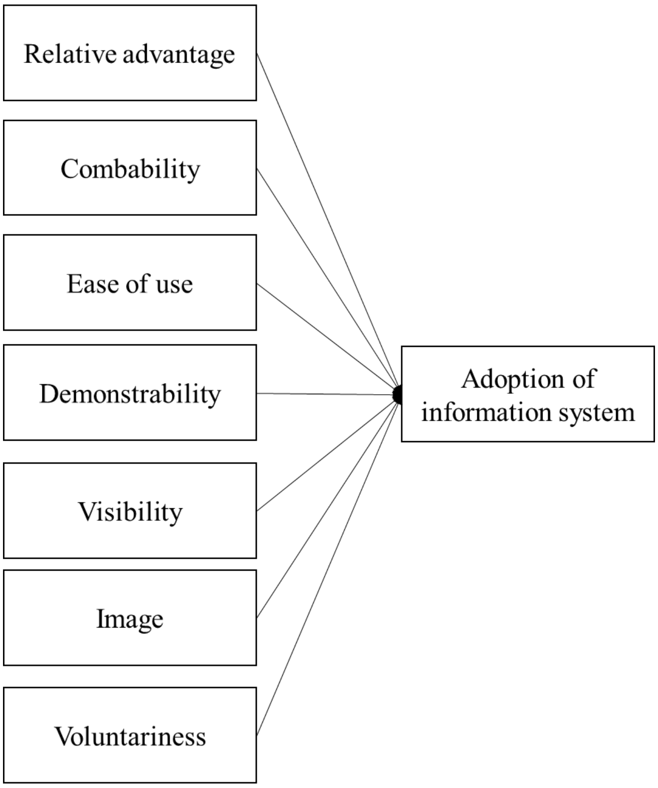

Figure 12. IDT model in IT context (Moore and Benbasat, 1991)

3.2 Theory of planned behaviour

Theory of planned behaviour (TPB) (Figure 14) is a model developed by Ajzen (1991). TPB was an extension to Theory of reasoned action (TRA), developed by Martin Fishbein and Icek Ajzen in 1967 and aimed to improve the predictive accuracy of the original theory. TPB is a general model that attempts to predict user behaviour based on his or her intentions of adopting a specific technology (Venkantesh et al., 2007). The theory suggests that behaviour is determined by person's behavioural intentions and these intentions are affected by person's attitude towards that behaviour, subjective norm and perceived behavioural control. Attitude refers to individual's positive or negative feelings towards a behaviour. Subjective norm is related to social influence and is determined by how the person thinks that people who are important to him or her think about the behaviour. Perceived behavioural control is determined by the constraints that the behaviour might have and the ease of learning that behaviour. The inclusion of perceived behavioural control as an additional construct is the main difference between TPB and TRA. TPB was developed to better explain user behaviour in conditions where the use did not have complete control over their behaviour. (Ajzen, 1991)

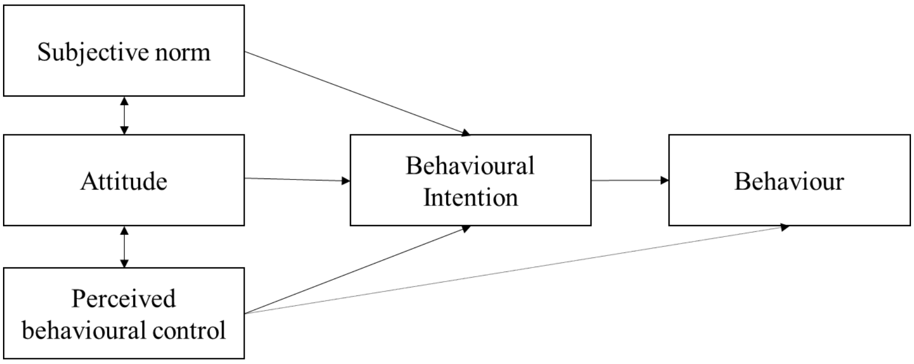

Figure 13. Theory of Planned Behaviour (Ajzen, 1991)

3.3 Technology acceptance model

Technology acceptance model (TAM) (Davis et al. 1989) has been the most widely used theory in technology acceptance research and validated in several different occasions (Venkantesh et al. 2007). TAM was developed specifically to use in information technology domain, therefore it has found to be superior to TPB that is a more general model (Venkantesh et al. 2007).

TAM (Figure 15) demonstrates that behavioural intention is most accurate that factor in predicting user behaviour. In TAM, perceived usefulness (PU) and perceived ease of use (PE) are the two main constructs that affect individuals attitude towards using technology, which is a direct determinant of behavioural intention (Davis et al., 1989). Perceived usefulness is determined by perception of how much using a system would increase one's performance on the job. Perceived ease of use is the measure of how much effort the person thinks that using a system would require. Davis et al. (1989) acknowledged that both PU and PE are mediated by external variables also. The goal of TAM was to develop a model which is general enough, but applicable to explain technology adoption in different situations (Davis et al. 1989). TAM has been used as a foundation to subsequent technology acceptance models.

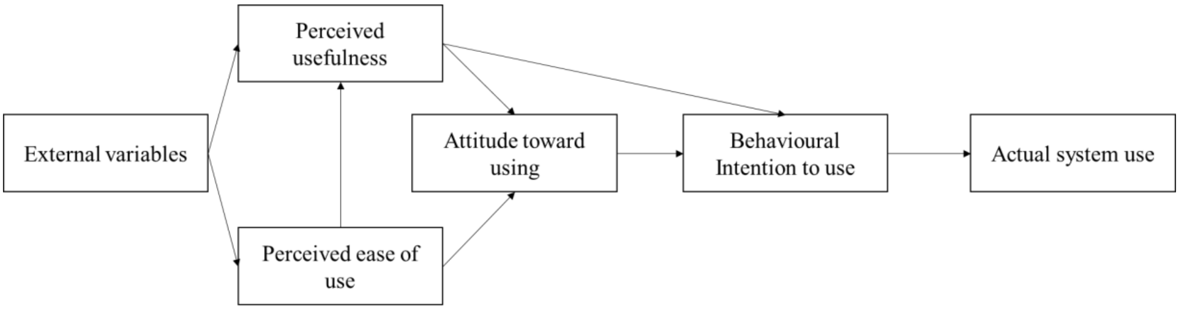

Figure 14. Technology acceptance model (Davis et al. 1989)

The goal of TAM was to develop a model which is general enough, but applicable to explain technology adoption in different situations (Davis et al. 1989). Although TAM is a widely used model in technology acceptance research, its usefulness has been criticised. Bagozzi (2007) reasoned that TAM is too simple model to predict user behaviour for various technologies in different situations, and he argued that researchers using this model have ignored the model's shortcomings. However, TAM has been often used as a foundation to subsequent technology acceptance models.

3.4 Technology acceptance model 2 (TAM2)

TAM2 (Venkantesh et al. 2000), illustrated in Figure 16, was developed to improve the original model's accuracy to predict user behaviour. The new model was built on the original TAM by adding meaningful components from previous models. The original TAM did not consider social influence when predicting user behaviour, therefore subjective norm from TRA was added to the new model. Voluntariness and image were added from IDT. In TAM2, experience and voluntariness are considered as moderators. The model adds several constructs to deconstruct perceived usefulness, so it can be used as a tool to assess how to make information system more useful to its users. The most important difference to the original model was the consideration of social aspects in technology's acceptance (Venkantesh et al. 2000).

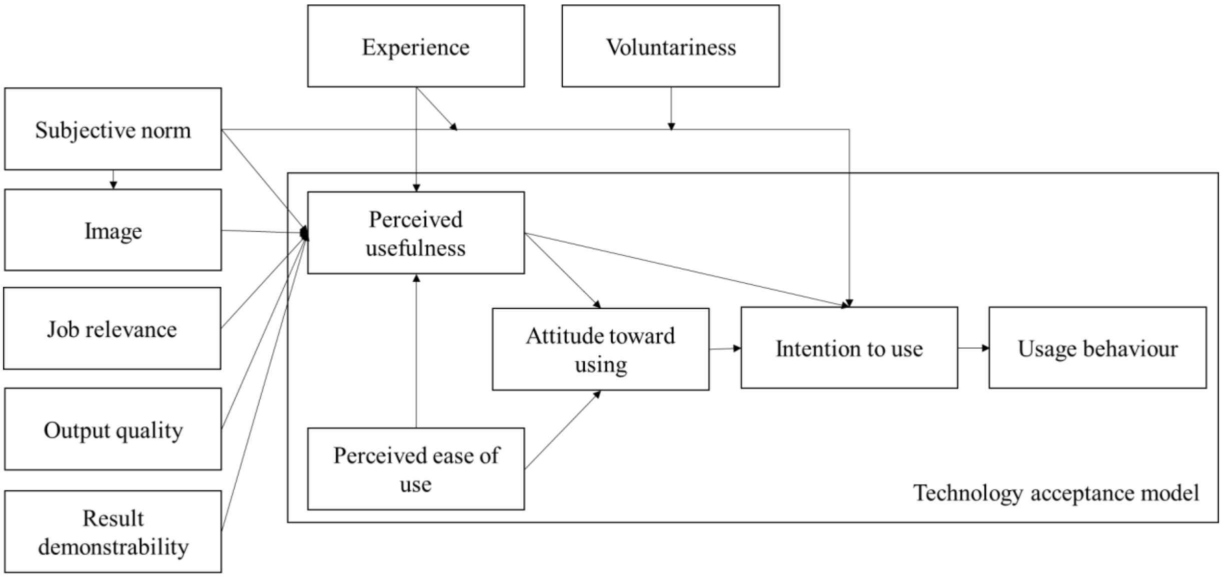

Figure 15. Technology acceptance model 2 (Venkantesh et al. 2000)

3.5 Model of PC utilization

The model of PC utilization (MPCU) (Figure 17), developed by Thompson et al. (1991) is based on the theory of human behaviour, and it was modified to fit in the context of IT. It took a different view to explain use of technology than TBP and TRA. MPCU's way to predict human behaviour is not based on intentions, but it assumes that each construct is a direct determinant of usage of technology. The model is applicable to various situations in context of information systems (Venkantesh, 2003).

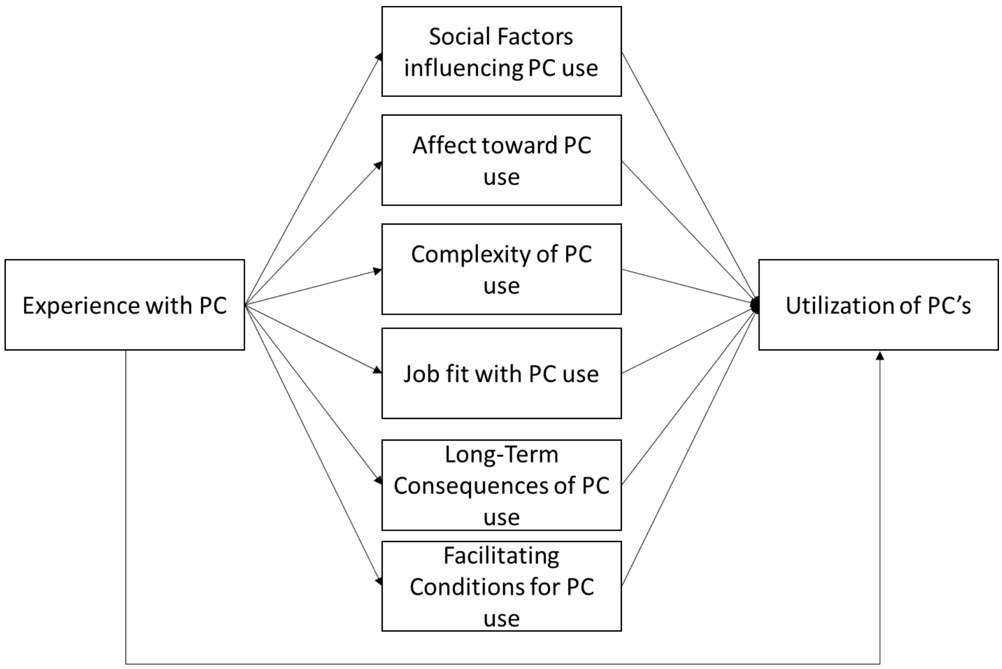

Figure 16. Model of PC utilization (Thompson et al. 1991)

3.6 Unified theory of acceptance and use of technology

Unified theory of acceptance and use of technology (UTAUT) is a technology acceptance model that was developed by Venkatesh et al. (2003). It is a combination of eight different models in technology and innovation adaptation and diffusion research. The eight models cover a wide range of disciplines from marketing and management to social psychology. These eight models include the technology acceptance model (TAM and TAM2), the theory of reasoned action (TRA), the theory of planned behaviour (TPB), a model combining the technology acceptance model and the theory of planned behaviour (C-TAM-TPB), the motivational model (MM), model of PC utilization (MPCU), the innovation diffusion theory (IDT) and the social cognitive theory (SCT). Each model has their own determinants for assessing users' behaviour, but many of these determinants were overlapping, so the need for unified model was found. (Vekantesh et al. 2003)

UTAUT was developed by assessing the similarities in those eight models and combined into one unified model to predict user behaviour for new technologies. The model was then empirically validated by Vekantesh et al. (2003), and it found to outperform eight previously prominent models. The UTAUT model was tested using original data from these eight studies and the new model explained 69 percent of the variance, while those original models explained only between 17 and 53 percent of the variance in users' behavioural intentions (Vekantesh et al. 2003). Since then, the model has been extensively used and empirically validated in different studies assessing users' acceptance of new technologies and applications. Williams et al. (2015) reviewed 174 articles that used UTAUT model and concluded that it was most commonly used for assessing specialized business systems and general-purpose systems. These applications of UTAUT include mobile banking, robot system, tablet PC, web-based virtual m-learning system and smart products, among many others (Williams et al. 2015).

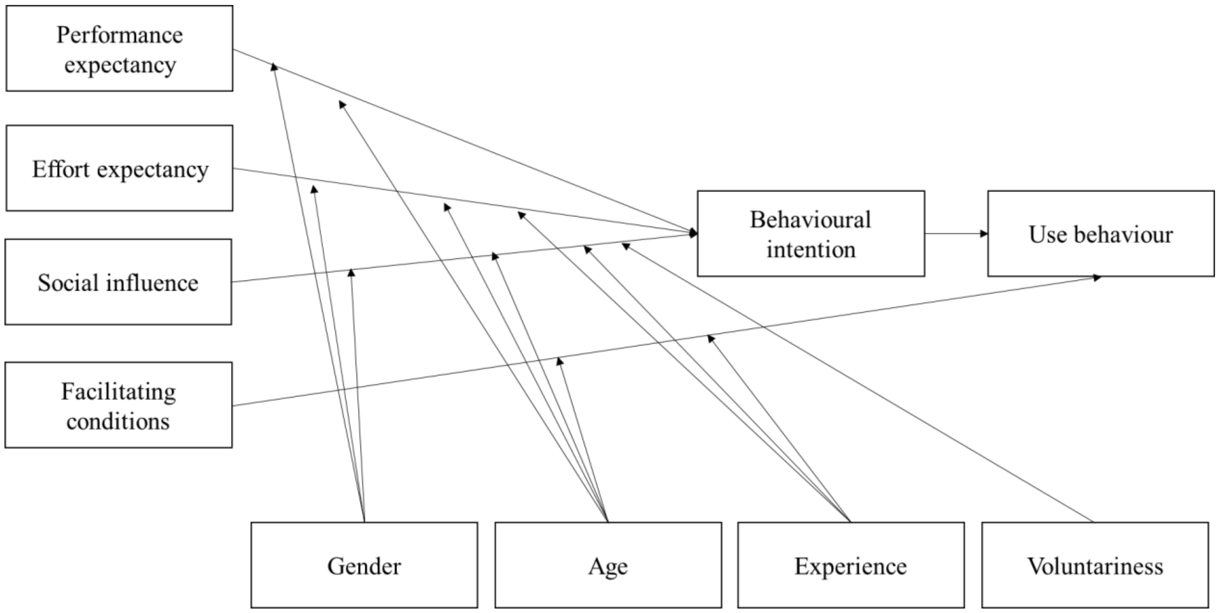

Figure 17. Original UTAUT model (Vekantesh et al. 2003)

The UTAUT model has four main constructs for analysing users' behaviour: *performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC).* These constructs were formulated by assessing similarities in the previous eight models. Connections to these models are presented in Table 3.

These four main constructs weren't sufficient to explain usage behaviour, since they don't always have similar effect on the behavioural intention for different people. For example, effort expectancy plays a more important role for less experienced individuals, and statistically, social influence affects women more. Therefore, four other determinants were added to moderate the effect of the four main constructs. These moderators include *gender*, *age*, *experience and voluntariness of use*. These moderators enable the use of UTAUT in different use contexts and demographics. (Vekantesh et al. 2003)

3.6.1 Performance expectancy

Performance expectancy is a measure for the extent that user believes that the system will improve his or her performance on the job. A person is more likely to adopt a technology, if he or she believes that it will make the job easier, faster or helps to achieve better results. As presented in Table 3, roots for this construct are found in six different models: Perceived Technology acceptance model (TAM/TAM2), Combined technology acceptance model (C-TAM-TPB), Motivational model (MM), Model of PC utilization (MPCU), Innovation diffusion theory (IDT) and Social cognitive theory (SCT). Similar constructs found in these models include Perceived Usefulness, Extrinsic Motivation, Job-fit, Relative Advantage and Outcome Expectations. Performance expectancy (PE) was the strongest individual construct to predict behavioural intention in the original study. (Vekantesh et al. 2003)

Venkantesh et al. (2003) explains that there is valid theoretical foundation that PE is moderated by gender and age. It is found in gender studies that men tend to be more task oriented, so performance expectancy plays a more important role for them. Age, in the other hand is a moderator, because younger workers are seen as more motivated by extrinsic rewards, therefore performance expectancy plays a more important role, especially to the young (Venkantesh et al. 2003).

3.6.2 Effort expectancy

Effort expectancy (EE) is used to explain behavioural intention based on the ease of use of a system. The easier a person perceives the adaptation of technology the more likely he or she is going to use it. EE is based on three constructs from previous research that are presented in Table 3. Perceived ease of use was used in technology acceptance model (TAM/TAM2), complexity in Model of PC utilization (MPCU) and ease of use in Innovation diffusion theory (IDT). (Ibid)

The effect of effort expectancy is moderated by gender, age, and experience. Vekantesh et al. (2003) suggest that women are affected more by effort expectancy, based on findings in other studies relating to gender roles. Age is seen as a moderator, because older people might experience difficulties adopting new technologies. Also, previous experience with the technology reduces the expected effort to adapt a novel technology. Therefore, EE is seen as more meaningful determinant for behavioural intention to women and older and less experienced individuals. (Ibid)

3.6.3 Social influence

Social influence is the construct that explains the effect of that others' have on the behavioural intention. People whose opinion is valued by an individual will affect the actions of that person. Also, how others see him or her as a result of using a technology will influence that person's behaviour. This principle is applicable in the context of technology adaptation. Similar constructs to social influence that were presented in previous studies include: Subjective norm is used in the Theory of reasoned action (TRA), Theory of planned behaviour (TPB) and Technology acceptance models (TAM2 and C-TAM-TPB). Social factors is used in in Model of PC utilization (MPCU), and Image is a construct used in Innovation diffusion theory (IDT). (Ibid)

Social influence is a complex determinant and influenced by several variables. First moderator was age, because older people were found to place more importance on belonging. Second, women were more sensitive for social pressure. Third, others' opinions play a more important role in the early stages of adoption, therefore social influence is greater to less experienced individuals. Lastly, voluntariness has a strong effect on the behavioural intention that social influence poses, so people are more affected by social influence in mandatory settings. (Ibid)

3.6.4 Facilitating conditions

Facilitating conditions (FC) affect the adoption of technology by measuring the extent that the person believes that there is an existing infrastructure to use the technology. Using a technology might require certain resources or help from a mediator to use, so FC as a construct explains the effect of determinants like these on behavioural intention. Similar constructs that were applied in previous studies are presented in Table 3. Perceived behavioural control was used in Theory of planned behaviour (TPB) and the combined model (C-TAM-TPB). Combability is a similar construct in Innovation diffusion theory (IDT). Also, facilitating conditions was used in Model of PC utilization (MPCU).

Facilitating conditions are moderated by age and experience. In case of complex systems, older people and less experienced people tend to require more assistance on the use of technology, therefore facilitating conditions have a more significant effect for in case of older people, especially in the early stages of adoption. (Ibid)

Table 3. Roots for main constructs in UTAUT

Main construct	**Roots**	**Similar constructs**
Performance expectancy	TAM/TAM2 and C-TAM-TPB	Perceived usefulness
	MM	Extrinsic motivation
	MPCU	Job-fit
	IDT	Relative advantage
	SCT	Outcome expectations
Effort expectancy	TAM/TAM2	Peceived ease of use
	MPCU	Complexity
	IDT	Ease of use
Social influence	TRA, TAM2, TPB and C-TAM-TPB	Subjective norm
	MPCU	Social factors
	IDT	Image
Facilitating conditions	TPB and C-TAM-TPB	Perceived behavioral control
	MPCU	Facilitating conditions
	IDT	Combability

3.6.5 Added construct – Trust

In addition to original four constructs, trust have been tested in various studies using UTAUT-model. Williams et al. (2015) investigated studies using UTAUT-model and found that trust was used as an additional construct in 18 occurrences. It has been successfully applied in studies covering mobile banking adoption (Oliveira et al. 2014), consumers' adoption intentions of remote mobile payments in the United Kingdom (Slade et al. 2015) and NFC payments in restaurant industry (Khalilzadeh et al. 2017), for example.

McKnight et al. (2001) explains, that trust is the willingness of a person to take risks and without prior experience or information, so initial trust is an important factor when consumers consider potential adoption of an innovation. Their argued that definitions of trust needed a more coherent explanation, especially relating to new technologies. Their proposed model divided factors that affect trust to institutional, personal and environmental. Institutional factors are related to the firm, it's size, brand and reputation. Personal factors are affected by the person's own propensity to trust. Lastly, environmental factors are situational factors (e.g guarantees) that can reduce the risk of using a product (McKnight et al. 2001).

Kim et al. (2009) developed model for initial trust that is based on definitions proposed by McKnight et al. The model divides initial trust to propensity, structural assurances, firm reputation and relative benefits (Kim et al. 2009). Oliveira et al. (2014) adopted this model as additional part of UTAUT -model, when they studied mobile banking adoption. Slade at al. (2015) used trust as a single construct among original constructs of UTAUT and demonstrated the effect of trust to usage intentions in a study covering adoption of remote mobile banking. Based on these studies and 16 other studies using trust in some form as an extension of UTAUT, it can be argued that literature supports the inclusion of trust in this study.

Trust is important factor to consider in this study, because it is recognized as one of the possible barriers of VR/AR adoption. As with any new technology, security concerns are important. Deloitte (2017) pointed out in their technology trends report that VR/AR devices' security and privacy needs to be ensured, because these new systems will generate a lot of sensitive data. VR and AR systems use multiple sensors that tracks user's location, eye movement and many other sets of data, so leaking and misuse of this data could be damaging to companies.

3.7 Theoretical Research Framework

In this section, I will present the framework (Figure 19) guiding the research. This theoretical framework was developed based on the literature review on adoption and acceptance of new technologies. The goal of this research is to study adoption of VR and AR technologies and UTAUT has been successfully adopted in at least 178 studies covering acceptance new technology and information systems (Williams et al. 2015), therefore UTAUT was found appropriate to examine current perceptions and predict future adoption of VR and AR. Additional construct (Trust) was added original model, since it has been proven in literature to have an effect in usage intentions and it was identified as a possible barrier to adapt VR/AR technologies. Experience was chosen as a single moderator in distinction to four moderators in the original model.

Performance expectancy was found as the most important predictor of future use of new technology based literature review, so it is expected to be significant determinant in case of VR/AR also. These technologies have been around for decades, but only recent advances in technology have made it possible to investigate real use cases across industries. There is a lot of expectations around these technologies, so it is important to discover the real perceptions about the usefulness according to experts and future users of this technology.

Adopting any new technology will always require effort when bringing into use and when learning to use it, but the big question is, how significant the perceived effort is and how it will affect behavioural intention to adopt. Expected effort will be examined on both instances (implementing and learning) and will be studied in terms of financial and psychological effort to adopt.

Social influence is investigated by assessing on how much people think others in their industry are adopting these technologies, and how the firm's culture affects usage intentions. Social influence is a complex construct and it can be hard to measure accurately. It is often unconscious, so people may not even be aware of how it affects their behaviour. Direct questions about social influence isn't likely to produce applicable results, therefore assessment about social influence is focused on the dynamics in the industry and inside the firm.

VR and AR technologies are in such an early stage in development that the ecosystem is still immature. The supply of applications and content for VR/AR is still inadequate, which will likely pose barriers for adoption. Also, the compatibility with existing systems is probably going to set challenges in many cases of VR/AR. Compatibility, as a construct, was first recognized in the original innovation diffusion theory by Rogers already in 1962, and its similarity to facilitating conditions was identified in the original UTAUT model (Vekantesh et al. 2003). Therefore, the effect facilitating conditions for VR and AR adoption will probably be significant.

Trust has been recognized as meaningful construct in other studies covering new technologies and IT-systems and security and privacy were identified as potential barrier for VR/AR adoption. Trust will be measured by assessing experts' perceptions about potential safety threats in VR and AR. Adopting a new technology is always a risk in terms of performance and reliability, so trust on device manufacturers is also studied.

Finally, behavioural intention will be assessed based on answers relating to constructs, but also with direct questions. This framework provides a foundation to guide interviews. It ensures a comprehensive coverage of important themes, but doesn't limit exploration of other topics of interest. It enables to create an overview of the state of VR and AR adoption and helps to identify barriers and drivers for future adoption.

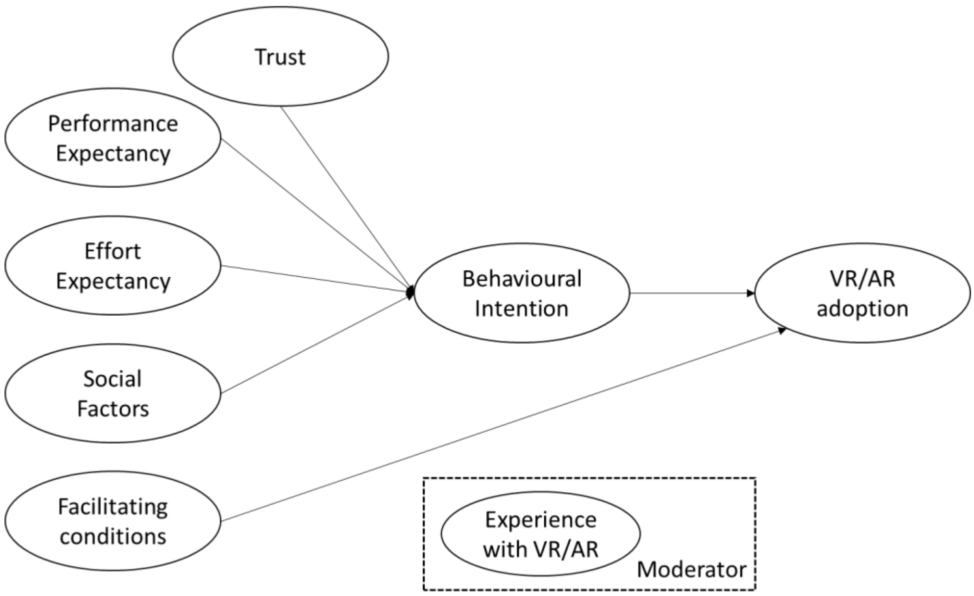

Figure 18. Theoretical Research Framework

4 METHODOLOGY

The empirical part of this study is a qualitive study conducted as semi-structured interviews. The methodology and rationale for selected methods is described in more detail in following chapters. Followed by description of the process of selecting participants, collecting and analysing data.

4.1 Qualitative research

Keegan (2009) explains, that qualitative research methods are used to understand a broader phenomenon, and they explore questions like what, why, and how. They are well suited for exploratory studies, where there is very little previous knowledge and possible unknown unknowns. Examples of such areas where exploratory studies could be applied are entering new markets, developing new technologies, or responding to changes in markets (Keegan, 2009). Qualitative method was chosen for this study, because VR and AR technologies are still in the early stages of development, and more understanding of actual use cases is needed. In contrast, quantitative studies can be used to measure the number of people who act or think in a particular way and uses statistical methods to validate the data (Keegan, 2009). Quantitative could be later used to supplement this study by confirming individual findings or estimating the size of the potential market, for example. However, the nature of this study is exploratory, because there are not many established use cases for VR/AR and new markets are created constantly. It is important to discover motivations and intentions of potential adopters, to gain better understanding of the potential use cases of these technologies first. Since the goal of this study is to examine and understand, rather than measure, qualitative method was chosen to better support the research objectives.

4.2 Case study method

Case study was chosen for this study as a qualitative research method. Hancock and Algozzine (2006) explain that case study method is used to gain an in depth understanding about a phenomenon, and in contrast to other methods, case studies are more descriptive in nature. They aim to examine a certain situation or event from the perspective of the person studied (Hancock and Algozzine, 2006). The use of VR and AR technologies is that phenomenon of interest in this study.

Rather than trying to test hypothesis or prove relationships, case studies aim to identify themes and categories of behaviour, therefore case study research is usually more exploratory than confirmatory in nature (Hancock and Algozzine, 2006). Case study method fits the objectives of this study, since the aim is to understand the VR/AR space and identify themes related to adoption. Data for case studies is often gathered from extensive interviews, which requires more time spent in the study environment, but enables to investigate emerging themes further (Hancock and Algozzine, 2006). This was essential to the study, since there are various use cases for VR and AR and new areas to explore emerged during every interview.

4.3 Theoretical standpoint

There are also different theoretical standpoints related to qualitative research, which are important to consider when designing a study. Keegan (2009) explains, that there are two main categories for theoretical standpoints, positivist and interpretivist. Positivist approaches assume that objective truth for problems can be found through logic and analysis. In contrast, Interpretivist approaches assume that there isn't one unified truth to be found, but knowledge from studies, research outcomes, and views of the participants are their interpretation of the world. It assumes that humans create meaning together and construct our world through our past experiences, rather than perceiving it objectively (Keegan 2009). Interpretivist approach is usually applied to qualitative research, and is applied to this study also, because the goal is to understand the research participants and their motivations. This study is a more of a description of a current state and future potential of VR/AR adoption, rather than set of rules that determine adoption. In other words, it's impossible to determine objective truth about VR/AR adoption, so this way of describing a phenomenon enables to consider the nuances in each interviewee's responses.

In qualitative studies, data gathering, interpretation and forming recommendations are conducted partly at the same time (Blandford, 2013). There aren't hypothesises to be tested, but rather questions to be answered, so themes emerging from the data can be different than expected (Blandford, 2013). There is a theoretical framework guiding the data gathering, but it's possible that the findings may not be what was anticipated. Themes emerging from the data may change original assumptions and steer the research to new areas, and qualitative research designs are better suited for this ambiguity. Qualitative studies also provide more freedom for the researcher, which highlights the importance to use quality standards for the research findings to ensure the legitimacy of the data (Keegan, 2009).

4.4 Interview method

Semi-structured interview was chosen as the method for the study, since it enables to explore emerging responses and themes further. Semi-structured interviews use theoretical framework or method as a structure that guides the interviewer to cover specific areas of interest (Blandford, 2013). This study uses the modified UTAUT-model as a framework to guide the discussion, which ensures that all relevant areas are covered relating to acceptance of new technology. Completely structured interview would not have been appropriate, since multiple industries are covered and potential use cases for VR and AR vary a lot. One clear benefit of semi-structured interview method is that it enables to dig deeper into specific responses and discover motivations and beliefs behind the answers (Keegan, 2009).

4.5 Sampling

Interviewees for this study were chosen from various industries and from different functions, since purpose was to get as broad coverage as possible of potential use cases for VR. Most interviewees were executives or leaders of the business unit responsible for VR, some interviewees were also users of VR in their daily work. What was common for all interviewees, was that all were very familiar with VR/AR and had also experienced Varjo’s prototype. They had either been using VR/AR in their organization in some way, studied their possibilities extensively, or created solutions for these technologies.

The UTAUT -framework is used to study the acceptance of a technology from the user’s point of view, so questions were modified in interviews with developers and solution providers to prompt the impression they’ve had from the end users of VR/AR (i.e. their customers). It was acknowledged that responses regarding usefulness and ease of use might be biased when questions are concerning the systems that they’re promoting to their customers. However, the view of solution providers and developers was considered especially valuable, because they had the broadest view of VR and AR in their respective sectors, and the very reason that they must sell their systems to end users, provides insight on what are the most common objections why people don’t adopt VR or AR in their businesses.

4.6 Approach to analysis and interpretation

Analysis and interpretation of the data was done in all stages of the research while more data was accumulated. This represents the emergent model of analysis proposed by Keegan (2009). There are two ways to structure the analysis of data, classical and emergent model. The classical model is more linear and contains clear steps to analyse data in sequence. Stages of this model include problem definition, gathering data, analysis and recommendations. In contrast, the emergent model assumes that analysis and interpretation of data happens in each stage of the research when more knowledge is gathered. The emergent model considers the way humans construct meaning. Rather than thinking linearly, meaning is constructed in intuitive leaps. Information can't be absorbed without influencing its content and making hypothesises of its meaning. In contrast to the classical model, the emergent model is more like a loop of iterative analysis and interpretation of data. However, these two models of analysis are not exclusive, but elements of both appear in every research (Keegan, 2009). The emergent model fits this study, because data was accumulated from various sources from different actors in VR/AR industry. Initial interviews provided insight to specific topics that were explored further in the following interviews.

4.7 Data collection

All the participants were initially approached via email. The purpose of the study was explained and no prior preparation was asked for the interviews. Interviews were set up and held in most cases (8 out of total 10) interviewee's location, which enabled better investigation of nonverbal cues and attitudes behind the answers also. As a personal observation, it was also easier to encourage interviewees to describe in more detail in and elaborate their answers in a face to face setting. Two interviews were conducted via telephone and skype due to time or geographical constraints, which could set limitation that information acquired form these interviews weren't as complete as the rest.

Interviewees were conducted following a in a semi-structured method. Interviews started with introductions and description of the purpose and scope of the research. Then, interviewees were asked to describe their use of VR, after which, questions were presented based on the interview framework. Instead of asking questions in a survey manner, interviewees were encouraged to freely describe their experiences with VR, and interview framework worked as a guiding agenda for the conversation. Each interview lasted typically from 45 min to one hour. During the interviews, extensive field notes were taken. Right after each interview, conversation was reflected on and a detailed description of that interview was created. Then, field notes were reviewed and sorted based on the research framework. The reflection and sorting of data after interviews was also the first round of interpretation for analysis. Now, the data from each interview was in a form that it was easily accessible for further analysis, and important themes from each interview could be reviewed in short order, when new data was acquired. The analysis of data was an iterative process that started after the first interview and continued in loops after clear patterns started to emerge and significant new data wasn't obtained anymore.

5 FINDINGS

During the interviews, a clear pattern started to emerge. Use cases where VR/AR are currently used, and were identified during the interviews could be divided into three main areas: design, training/simulations and visualizations for marketing and sales. Therefore, interviews were mainly focused on these use cases of VR, because AR or MR weren’t adopted to everyday use in respondents’ organizations. However, the potential of AR and MR was still often recognized, and other potential uses for VR was mentioned also.

In this section, I’ll present findings from ten interviews with 12 experts of VR/AR. Findings are categorized in those three main areas and focusing on the use of VR. Findings for each area are presented based on the UTAUT model. In addition, I’ll briefly introduce other use cases identified for VR, AR and MR, and the main challenges with these applications today. At the end of this section, findings from interviews for each main area are summarised, and the effect for adoption of each UTAUT-construct is presented on a subjective scale.

5.1 Design

> *It [VR] is the biggest revolution in our industry, since 3D design. (Head of yacht design and naval architect)*

VR has already proven useful for design professionals. It is a natural progression from 3D design in flat screens to more immersive environment. VR is used to compliment traditional design process, but it hasn’t replaced traditional working methods. Users adopting these technologies are still early adopters, and there are issues with conversions of models and general usability. However, the benefits of these technologies clearly outweigh current difficulties.

5.1.1 Performance expectancy in design

Spatial conception, the ability to see your relationship with your environment, is recognized as the greatest benefit of VR, because it enables designers to see the product closer to reality early in the development process. This opens a whole new world for designers, because the ability to see the product from a natural perspective enables to perceive things that would normally stay unnoticed.

The greatest benefit of VR is that you can move inside the model and see designs in real perspective. -- When 3D modelling on normal screen, they [designers] might create beautiful lines that might only be visible from a helicopter. (Head of yacht design and naval architect)

Collaborative designing is one of the way VR could improve design process by getting more accurate feedback from customers and other stakeholders in a project. Virtual reality provides a more intuitive way to present 3D models, which makes it easier to collaborate with clients and professionals from other disciplines that have less experience viewing 3D models.

It would be a huge advantage to be in the same space and discuss design decisions in VR and make real time changes to the model. (Head of new business development, Construction)

Our customers are pleased when they can experience how it looks like in the boat, and they can for example point out that ''this thing shouldn't be here'', and we can implement these changes easily early in the process. (Head of yacht design and naval architect)

There are still problems with the current VR are related to tracking. VR systems use tracking systems to determine user's place and movement inside the model and match that to the view inside VR. In addition, haptics could be included for more immersive experiences, but interviewees were sceptical about that being reality anytime soon, thus VR can't replace real life models, in many cases. VR is just another tool in the toolbox for designers.

Inside the model, the space seems like 90 % of the natural size and things aren't exactly where you would expect them to be. -- We are still building wooden models in actual size and continue to do so, because in VR, you can't touch the virtual objects or take support from walls for example. (Head of yacht design and naval architect)

5.1.2 Effort expectancy in design

Incorporating VR to design process is relatively effortless, because 3D and CAD models are already built, so the heavy work of creating content is done already. However, these models still need to be often modified and converted through multiple software programs to make them compatible with VR. Therefore, using VR in design requires some effort, but the utility of viewing models in VR is still evident, so the conversion process just an inconvenience.

> *Transferring existing models to VR is quite easy to do. In total, it takes maybe two hours to transfer the models, even though they must be run thorough four programs each time. (Head of yacht design and naval architect)*

Current models can be converted to VR without significant additional work, but designing for future high-end VR might require substantially more work. Varjo's HDM will be able to reach human eye resolution, which is 70 better than current high-end VR, so to reach the level of resolution that the hardware is capable of, the models must be more detailed. There is conflicting evidence whether this will meaningfully increase designers work, because there are two ways to reach the perception of high detail. Each individual detail can be either added separately, or designers can use textures, where detail is artificially coded into the whole surface.

> *I'm kind of frightened of how much work it would require. We can almost build a real ship with the same money that some companies use for creating a VR experience. (Head of yacht design and naval architect)*

> *It [creating high detail models] is not a problem, because you can add textures to the model. (Director of development, VR/AR Solution provider)*

5.1.3 Social influence in design

Design professionals are among the first ones that have adopted VR as a natural part of their work, but based on interviews, there isn't internal pressure in the shipbuilding industry to adopt these technologies yet. Those already using VR/AR are considered as early adopters.

> *I don't know that other companies are adopting VR in design. Most of them are using it as a marketing tool showing irrelevant content in our industry. (Head of yacht design and naval architect)*

5.1.4 Facilitating conditions in design

Lack of software tools is one of the biggest problems with VR/AR adoption in general, but among these three uses presented here, design is least affected by it. Engineers are more technically oriented, so it's easier for them to adapt a new software and they are less concerned with clumsy user interface. Transitioning to VR is more natural continuation for design professionals.

> *Learning a new software is probably easier for engineering professionals, but sales, marketing and management professionals may find it harder. (CEO, VR Software provider, Construction)*

In addition, there is already a strong software infrastructure in engineering. Global engineering software market is worth $20bn (GoldmanSachs, 2016), and it's dominated by two largest players that together own over 50 % of the total market. Large 3D engineering software providers, like Autodesk or Dassault, strive to own the whole designing ecosystem for engineers, so they are incentivised to develop their tools to match the growing needs for design in VR also, while smaller companies are trying to take their share of this growing market.

5.1.5 Trust in design

Design professionals are clearly concerned about privacy and safety in VR, because models contain a lot of proprietary information that could be exploited when it gets in to wrong hands.

> *This [trust] is a big issue. Our models contain basically everything, and if somebody gets access to our designs they could easily build it themselves. -- We can't use our files for marketing material that is publicly shared. (Head of yacht design and naval architect)*

> *Online models could be safety threats. We have made NDAs with clients, so if any information about future projects gets leaked, it would be damaging to our company. (Sales and marketing manager, Construction/Real-Estate)*

5.1.6 Behavioural intention in design

VR has proven its usefulness for design, and based on interviews, it will continue to become more integral part of designers' work.

The enthusiasm around the technology is going to fade over time and it's just going to become a natural part of visualization. It's here to stay. (Head of yacht design and naval architect)

5.2 Marketing and sales

Product or project visualizations for marketing and sales purposes have been among the first use cases of VR for many companies. These are static models from product concepts, finished products, development projects or real estate for example. Visualizations are probably the simplest way to incorporate VR in any field, because all that is essentially needed, is the model and a device to view it. Therefore, it has been the first experiment with VR for several companies.

5.2.1 Performance expectancy in visualizations for marketing and sales

Based on interviews with professionals, there is a clear benefit in when used as a sales tool to provide more accurate information. Location dependency is one of the greatest benefits of VR, therefore adoption will likely accelerate for VR as a sales tool. It's best suited for situations, where it's impossible to carry with or access the product, and in cases, where the project still under development.

Both home buyers and construction companies have been impressed with the experience. VR provides more accurate information in the development stage, customers are more satisfied and it reduces complaints. -- One construction company mentioned that they're investigating the possibility to get rid of physical demonstration apartments altogether and use only VR. (CEO, VR Software provider/Construction)

We've been using VR for two years. -- It provides about 30 % of the overall benefits of project's marketing. (Sales and marketing manager, Real Estate/Construction)

Outside of real estate, in the industry, VR used to impress customers by providing a new experience and demonstrate innovator status. The technology is still in its infancy and most people haven't experienced VR before, therefore it still has novelty value. It is used for presentations or showing promotional content on trade shows, and it can be debated whether VR will provide actual value in these cases. The motivation to use VR is often to show customers that the company is following technological trends, but over time that value will decrease, and companies must figure out use cases with more tangible benefits.

> *It [VR] is used to 'wow' customers and demonstrate innovator status. -- The technology is in such an early stage that it doesn't matter that much what the content is. It's just about the experience. (COO, Solution provider, Industry)*

> *Currently the experience is more exciting than the product itself, that is why current VR is going to be enough for marketing purposes for the next one or two years. (Key Account Manager, VR/AR/MR Solution provider)*

5.2.2 Effort expectancy in visualizations for marketing and sales

Using the VR systems is effortless, but the cost of creating the content can be too high for many cases. Creating a single visualization solely for VR typically costs tens of thousands, but if there are existing models in 3D that only needs to be converted to VR, adopting VR is substantially more effortless. In terms of actual usage, there weren't significant difficulties reported relating to difficulties to the actual use of VR for visualization. From the end user's point of view, all that is essentially needed is to plug in power and strap on the headset.

> *Setting up a VR showroom is easy. It takes only one to two hours of demonstration and the company can use it independently. (CEO, VR Software provider, Construction)*

> *We're all quite tech-savvy guys here, so it has been easy for everyone to learn to use VR. (Sales and marketing manager, Real Estate/Construction)*

Most effort is required in the development or conversion of the model. The cost of the model depends on the size and detail.

> *It currently requires a lot of manual work to convert 3D models to VR. We're building a solution to automate this. (CEO, VR Software provider, Construction)*

> *Visualizations are too costly to use in all projects. Building a VR -model for a project requires different experts for creating and optimizing the model, thus development costs for a single model can reach tens of thousands (€). (Head of new business development, Construction)*

Cad models usually contain too much information and this information needs to be sorted before it can be transformed to VR. – Converting a single model could cost anywhere from one to tens of thousands of euros. (COO, Solution provider, Industry)

5.2.3 Social influence in visualizations for marketing and sales

Companies in the industry are waking up to the potential of VR/AR, but technical knowledge of these technologies is still lacking in many companies, therefore visualizations can be an easy entry to adopting these technologies. There is general interest towards these technologies, and industrial companies are reaching out to solution providers to create VR experiences for them. Static visualizations are relatively affordable in contrast to more complex simulations, therefore it's often easier for managers to get support for these smaller projects. In real estate, VR has been adopted as a sales tool by few early adopters, and social support for adoption is often firm dependent.

VR is emerging at a high speed and other companies are experimenting with these technologies also. (Head of new business development, Construction)

Companies are reaching out to us, and ask if we can create VR solutions for them. - - Industrial companies are currently struggling with digitalization, and tend to move slowly in these situations. (COO, Solution provider, Industry)

We've been using VR for two years, and other companies are waking up to the potential now. (Sales and marketing manager, Real Estate/Construction)

5.2.4 Facilitating conditions in visualizations for marketing and sales

Software is capable for most use cases, but it needs to develop to reach desired utility and wider adoption. Problems with software are related to conversion of models and user interface. 3D model conversion should be automated and user interface made easier and more intuitive to drive adoption.

It requires too much enthusiasm towards these technologies and early adopter mentality to use VR and AR. It should be made easier to implement, and without all the hassle VR and AR can be more widely adopted. (Head of new business development, Construction)

5.2.5 Trust in visualizations for marketing and sales

There is a lack of concern towards security and privacy of VR/AR, but it was acknowledged that companies should be more careful, because VR models contain a lot of information. There weren't any distinct barriers to adoption. However, trust in system is often related to the person's own knowledge about security and privacy, thus not many conclusions can be made on the matter here.

> *I haven't encountered any problems with security and privacy. I think that possible issues are similar to problems with traditional software. (CEO, VR Software provider, Construction)*

> *Our customers aren't concerned about privacy, although they should be. VR model can include all the information and trade secrets of the company, so it can be easily replicated, if models get into wrong hands. (Director of development, VR/AR Solution provider)*

5.2.6 Behavioural intention in visualizations for marketing and sales

VR has proven useful in real estate. It's not considered essential yet, but has clear benefits to be used more widely, and adoption will continue to accelerate in the future, when barriers related to model conversion are solved.

> *VR is a natural part of our sales process. Of course, we would sell projects without it also, but it's the last blow to get the deal. (Sales and marketing manager, Real Estate/Construction)*

In industrial use cases, companies interviewed were solution providers that revealed that companies are increasingly experimenting with these technologies. Most projects in the industry are still related to visualizations, but these experiments can act as a gateway to other use cases, such as training.

> *The problem is that not many people have tried VR. VR or AR needs to be experienced for people to realise it's possibilities. In one case, we made a product visualization for a customer, and when they saw the visualization, they realized how it could be transformed*

to training for product assembly, and asked us to create it for them. (Director of development, VR/AR Solution provider)

In sum, based on interviews, there is a clear benefit in when used as a sales tool to provide more accurate information. Location dependency is one of the greatest benefits of VR, therefore adoption as a sales tool will likely accelerate. VR provides most value, when the product/project is impossible access or to carry with, and in cases where it's still under development. Therefore, VR is most likely first adopted in large and complex projects, and it will gradually spread to more affordable and simpler products. In addition, VR is used to provide a 'wow' experience for customers. The technology is still in its infancy and most people haven't experienced VR before, therefore it still has novelty value. It is used for presentations or showing promotional content on trade shows, where it can be debated whether VR will provide much value to companies. The value in most cases is just to show customers that the company is following technological trends, but over time that value will decrease, and companies must figure out use cases with more tangible benefits. In this manner, VR will most likely be used for couple more years, and can also act as a gateway to adopt VR in other use cases like training. Currently, companies without VR/AR experience need to turn to solution providers to create visualizations from their existing products. However, software tools are constantly developing, thus usability will be improved and model conversion to VR made more automatic.

5.3 Training and Simulations

Training and simulations are least adopted among these use cases explored in this study, but the potential is acknowledged, especially in the industry. Training in VR can reduce the need for expensive machinery for live training and eliminate the need for travelling to training locations. Virtual training environment is also modifiable, so it can be used to train for emergency situations or other rare events that are difficult to replicate in real life.

There are still significant barriers for adoption that need to be overcome before virtual training becomes more widely adopted. It requires significant investments, to create a training environment compared to static models. In addition, there is often lack of technical knowledge about these technologies and no tangible proofs for cost savings, so upper management can be resistant to back up these projects. In other cases, upper management can be indeed excited about these technologies, but middle management lack the tools to implement, because there aren't software platforms or reference cases to use as an example.

5.3.1 Performance expectancy in training and simulations

> *It is like the early days of digital-cameras, when Olympus 8000 was released; you were able to take pictures, but when you look at those pictures today, you see how far we've come. I think same thing will happen with VR and AR technologies. (Head of sales, Nuclear services, Energy)*

Use cases that were explored in this study, were related to power plant operation, manufacturing assembly, military training and sports training. Current VR is suitable for training in situations where the participants role is more observatory and require relatively little interaction with the content. These situations could be training for a manufacturing assembly where people perform relatively simple tasks and work at a moderate pace. Current hardware technology becomes a bottleneck when the demand for detail increases, like in situations where dashboard buttons must be seen accurately. Finally, when interaction inside the model increases and accurate mind and body control is essential, such as sports training, VR isn't the right tool for learning.

> *There is high potential for training in VR, because it provides tangible savings, by eliminating location dependency. For example, in one case, we had a company that flies their employees to Finland to train for engine assembly, and by incorporating pre-training in VR they were able to cut the training days from five to two. That's a 60 % savings. Others have gained similar results and percentage gains are always in the double digits. (Key Account Manager, VR/AR Solution provider)*

However, the resolution of current hardware limits usage in situations, where it's important to see detail, such as reading instructions or seeing buttons in a dashboard. This is the space where Varjo's upcoming headset could solve the problem and provide great value.

> *These technologies are now barely good enough to use. -- We had a white paper made in this subject, and the conclusion was that resolution is still a problem, this [Varjo's HMD] could solve the issue. -- It's important to see monitors and the text displayed there, and with this technology you must go very close to be able to read the text. (Head of sales, Nuclear services, Energy)*

But, technology isn't ready for the demands of sports training that requires faster framerates, or medical training in military, where realistic haptics is important.

> *In baseball for example, framerate isn't good enough to track the ball. You only see it when it leaves pitchers hand and next time you see it it's in front of your face. Sports require very accurate mind and body connection, and current VR can't provide that. If you train in VR, you become better at playing in VR, but not in real life. (Analyst, Market research, VR training technology)*

> *Military is trying to find ways to increase use of simulations, because days spend on field are extremely expensive. - - We have been experimenting with Hololens for medical training, but in our area of expertise [medical,] realistic touch is very important, and that's what current technology hasn't solved yet. (Head of simulation, Defence)*

It was also acknowledged that one of VR's distinct benefits is that VR creates data about the training session, so performance can be studied and managed more effectively. VR can also have an advantage over traditional training, when learning assembly of a large object, since individual pieces are more easily modified in virtual environment and overall structure comprehended faster. However, VR can't eliminate real life training altogether, but it can be used in the early stages of training to significantly reduce the overall cost of training.

5.3.2 Effort expectancy in training and simulations

There wasn't evidence that learning to use VR would set any meaningful barriers for adoption, but It was mentioned that training in VR is a new way to operate and controls aren't yet as intuitive as they should be.

> *It could take time for people to adopt a new way of working and learn how to move inside the model, and the controls aren't intuitive yet. (Head of sales, Nuclear services, Energy)*

5.3.3 Social influence in training and simulations

Based on interviews, social influence is still a major barrier for VR/AR adoption in the industry. An emerging theme was that industrial companies are rarely the first ones to bet on new technologies, and are slower to adapt new technologies. Companies would rather wait and see others implement these technologies than bare the risk that comes with being the innovator.

The first question from CTOs or CIOs is usually: 'Who's done this before?', and when we tell that they're the first in the world, they become hesitant. Companies need more courage to try. (Key Account Manager, VR/AR Solution provider)

Even if technology managers are impressed about these technologies, it can be a hard sell to the upper management, because decision makers in the industry generally know very little about these technologies or they could have prejudices based on VR's earliest applications.

Knowledge about these technologies is still very low in most organizations. VR started off as this gaming thing, and this is how many people still see it. -- You can't explain it's potential for business, because VR must be experienced to realise its possibilities, and the truth is, not that many people have seen it yet. (Key Account Manager, VR/AR Solution provider)

5.3.4 Facilitating conditions in training and simulations

Second major barrier for VR adoption in training use is the lack of suitable applications. Training and simulations applications are more complex to create than static visualizations, companies often lack the tools and knowledge on how to apply these technologies in practise. Same gaming engines are often used to create these applications, but in addition to technological expertise it requires operational knowledge to create meaningful training & simulation solutions in the industry.

In many companies, executives are excited about these technologies, but middle managers are frightened, because there aren't real use cases to implement these technologies. (Head of sales, Nuclear services, Energy)

There is some hype around the technology, and actual operational use cases for VR and AR are few years away from becoming a reality. (COO, Solution provider, Industry)

5.3.5 Trust in training and simulations

There weren't any distinct barriers related to trust in training use cases. It was mentioned that training models often contain confidential information, but they aren't supposed to be shared outside the company, so the security and privacy concerns were minimal.

5.3.6 Behavioural intention in training and simulations

There is clear interest towards these technologies, but wider adoption use for training purposes is still a few years away. Many pilot programs are currently in motion, and several others were planned for next year.

> *We're going to keep up with the trends, but we aren't betting on the technology to become a success in few years, but we plan to be ready when that happens. (COO, Solution provider, Industry)*

> *We'll have pilot programs during next year. For example, we're part of VARPU.info -project that is starting next year, which brings together industrial companies, researchers and developers to solve bottlenecks for content production and interaction. -- We're not there yet, but a lot will be happening in next years, and it's certain that these technologies will be adopted more widely in the future. (Director of development, AR/VR Solution provider)*

Based on interviews, there is a great potential with using VR/AR as a training tool, but the industries that most need these solutions are rarely the innovators that will push the boundaries of new technology. There are still structural barriers that must be overcome for VR and AR become more widely adopted in the industry. According to experts, it's not a matter of if the change will occur, but matter of when it will happen. Estimations point to one to three more years before we see VR and AR everyday use for training purposes in the industry.

> *There are not many early adapters in the industrial space, but companies are waking up to the potential of these technologies and transformation period is on the way. (COO, Solution provider, Industry)*

5.4 Other use cases

The use of AR and MR in the enterprise have been barely touched so far, and for a good reason. These technologies are still in such an early stage that technological problems and cost still often prevent the everyday use. Since these technologies weren't adopted yet and distinct use cases were unclear, they couldn't be analysed under the UTAUT framework. However, the potential was often mentioned, so they can't be ignored. It will likely take more time to these other use cases to be adopted in the enterprise, but they're not by any means less important. In this section, these other use cases are briefly introduced. In addition, it will be explained why MR could be the technology of choice in the future, and VR is the intermediate technology that can provide most benefits today.

5.4.1 AR for field operations

The potential of AR was acknowledged in field operations, where it can be used to provide accurate contextual information or guidance. For example, maintenance workers can have step by step instructions, and in theory, this could eliminate the need for highly trained professionals. It would also make operational work more efficient, because workers don't have to spend time looking for instructions, as proven by Boeing's experiment (Richardson et al., 2014).

Though it's technologically possible, it's very hard to accomplish in practise. It requires building 'digital twins' of the physical environment, which means that there is a digital representation of a physical object. There must be a perfect replica of every physical object in digital environment, and all related data is accessible in the same place in digital form. By integrating this IoT-data with AR devices, workers on field can access relevant data on when needed. In addition, when they make alternations to the physical it will be recognised by cameras on AR goggles and updated automatically to the digital model. In this way, the digital and physical are perfectly in synch. The digital model is always up to date, and enhances the work on the field when needed.

In addition to structural barriers, AR is unlikely to be adopted widely before the cost of devices comes down. Currently, the cost of AR goggles is several thousand a piece, and the price of Dagri, the leading AR helmet, reaches $10,000.

> *It's hard to imagine companies investing these sums of money on a fragile piece of technology that is operated on rugged conditions in the field. (Key Account Manager, VR/AR Solution provider)*

5.4.2 360-video

360-video viewed in VR isn't only good for streaming sports, but the potential is recognized in the enterprise for training, maintenance and remote supervision also. 360-video could improve communication in emergency situations for example.

Experts rarely have time to get to the scene fast enough, so communication must be done using technology, phone or video. There is normally a status update created by setting up cameras when the first persons arrive to the site of fire. This could be done with 360 cameras and VR. (Chief marketing technologist Service Provider, Defence and Industry)

In addition, 360-video could be used in any operation, where there is a remote command centre involved.

There is already a lot of cameras on the field with police for example, so all of these cameras could be 360 and used for VR potentially. (Chief marketing technologist Service Provider, Defence and Industry)

Lastly, 360 cameras could be installed in any places that are hard to access physically, like oil rigs or wind turbines. Maintenance professional could then inspect problems remotely and save time by eliminating unnecessary travelling to the site. In addition, production halts can extremely expensive for any manufacturing companies, so it's important to solve problems and restore production as fast as possible. Sometimes required level of expertise isn't available at close range, then any maintenance personnel at the infected production site could go and check the problems wearing 360-camera, and the expert on the matter could diagnose the problem remotely and provide instructions to the person on site.

Current camera technology is preventing wider adoption of 360-video and part of that already low-resolution footage is lost in the conversion process to VR.

Even the current HMDs could display higher resolution, but the cameras are low-resolution. -- Unity is a bottleneck, because the resolution is lost in the process. (Head of sales, Nuclear Services, Energy)

5.4.3 Transition to mixed reality

When the technology advances, the boundaries between definitions of VR/AR/MR technologies will blur over time. Virtual reality can already provide benefits of utilizing 3D environments for designing or visualizations, but the user experience still has some distinct issues. For example, designers can today explore models in a fully immersed environment in VR, but then they're forced to be isolated from outside world. It's not comfortable to wear a bulky headset in a social space and be isolated on what's happening around you. In these cases, mixed reality could offer the solution, because it enables people to see what's happening in their real environment and interact with other people, while simultaneously examining the virtual model. MR can be often used as an advanced version of VR, but standard VR is still easier to implement, therefore VR will probably be the main tool of choice for the next few years, but mixed reality could be the future.

Mixed reality also enables to create completely new use-cases and transform the environment that people are used to work in. MR could potentially change the standard user interface that people are accustomed by replacing monitors with windows placed in 3D environment. For example, designers could work completely immersed in a 3D environment, instead of making alterations to 3D objects in a 2D screen, as it's done today. However, creating an intuitive user interface for MR is a challenge, because it's not yet clear what's the best way to interact with digital content. People are accustomed to interacting with mouse and touch with flat screens, but it will probably require lots of studies and experimentation to create great user experience for MR. In addition, learning to work and interact with technology in a completely new environment takes time and effort, and it could in fact lower productivity for specialised professionals.

> *3D designing is like learning to play the piano, and it takes years of practise to become good at. I have nothing against that if someone would like to design entirely inside VR, but I don't see it happening anytime soon, because it would be impossible maintain their speed of working. (Head of yacht design and naval architect)*

Also, most of digital content is still in 2D format, so the initial mixed reality working environment will probably be combination of 3D objects and virtual 2D screens.

5.5 Summary of findings

Findings from interviews are summarised in Figure 20, which presents a view of each construct and its influence for adoption in studied use cases. Findings are presented in a subjective seven-point scale, where dark orange represents a strong negative influence, dark blue represents a strong positive influence on adoption, and absence of measurement bar means neutral.

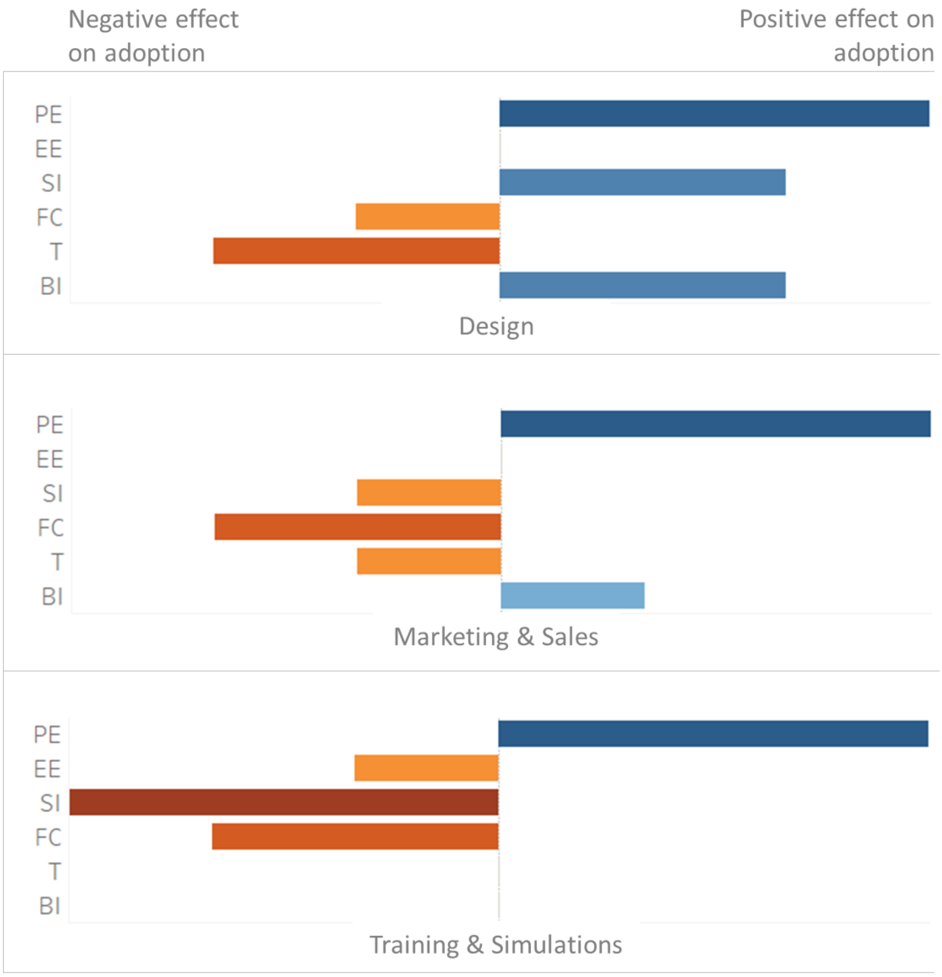

Figure 19. Influence of each construct on VR/AR adoption in studied use cases

What's common for all studied use cases, is that performance of VR was the biggest driver for adoption in each use case. This finding suggests that interviewees acknowledged the great potential of VR, which supports the view from secondary research that VR will be adopted more widely in the near future. However, expected performance isn't sufficient to solely accelerate adoption. With other factors considered, design has most favourable conditions for adoption.

5.5.1 Design - most favourable conditions for adoption

Design was the only use case with positive *social conditions* for adoption. This can be explained that designers and engineers are typically more technical people, therefore adoption of new technologies is more encouraged among them. The *behavioural intention* to use was also strongest in design, because many of them are already working with 3D virtual objects, therefore VR is a natural extension to current tools instead of completely new way of working. People in design were also the only ones concerned about the *trust* of VR systems, because these models contain lots of proprietary information. In conclusion, drivers for adoption outweigh barriers, therefore VR adoption likely accelerate, and design is also well positioned for future next generation MR adoption, when HMDs evolve.

5.5.2 Marketing & Sales - users intend to adopt soon

Behavioural intention to use VR, which is the best determinant of future usage (Vekantesh et al. 2003), was positive in marketing and sales, which supports the view for accelerating future adoption. This intention was driven by expected gains from better conversions for sales. VR is location independent, so it enables to showcase projects that aren't transportable, such as real estate, industrial machinery, or yachts. Another trend driving VR usage was using it as marketing tool to demonstrate innovator status. VR is used in trade shows and presentations, sometimes with irrelevant content even, because it still has novelty value, and it's a simple way to experiment with this new technology. This use case can work as a gateway to other use cases in the future, such as training. However, there are still significant barriers for using VR as a sales and marketing tool. *Facilitating conditions* are still the biggest barriers for adoption, because external help is often needed either in the development new or conversion old of models. If a new model is made solely for marketing purposes, the cost is often too high to justify the gains, since creating a single model can easily reach several tens of thousands or much more depending on the level of detail. Even if companies have existing 3D models in some form, the conversion process is still laborious.

5.5.3 Training & Simulations - adoption is still a few years away

In terms of volume and possible cost savings, training and simulations have the most potential among these use cases, because it could be applied to any industry. The potential for especially acknowledged in industrial use cases, such as operating expensive machinery, learning a manufacturing assembly, or simulating plant operations. The biggest benefits compared to physical training are that VR simulation is scalable, location independent, easily modifiable and it generates data. Also, when compared to other virtual training, it provides more immersive experience, which is found to increase the effectiveness of learning in several studies. However, training and simulations still have most barriers for adoption. *Facilitating conditions* pose significant barriers, because creating training applications is much more laborious than only transferring static 3D models to VR. The infrastructure to create training solutions is still immature, thus adopting VR for training in the industry requires significant investments on either internal or external development. Solving these issues with facilitating conditions is possible, but it requires the will and support from both the decision makers and the managers responsible of executing in the company. Which brings us to the next barrier, *social conditions*. According to the study, insufficient social conditions for adoption seems to be the most significant barrier for adoption in training. This was reported to be due to lack of knowledge about these technologies and the nature of the industry as generally sluggish to adopt new technologies. *Behavioural intention* to adopt VR/AR for training purposes is neutral, because the potential and interest towards these technologies is high, but barriers to adopt are still significant, therefore it will likely take a few years for adoption to accelerate.

6 DISCUSSION

The purpose of this study was to identify drivers and barriers for VR/AR adoption in the enterprise to provide information about in which use-cases and industries these technologies are likely adopted and at what pace. Based on secondary research and primary interviews, current use-cases of VR could be sorted in three main categories; Design, Visualizations for marketing & sales, and Training & Simulations. This is by no means an exhaustive categorization, but a useful framework to look at different use cases in VR today. Most of these use cases are transferable to mixed reality and some of them to AR as well, but it is acknowledged that this categorization did leave out many future potential use-cases for future adoption in VR/AR space. As stated before, the boundaries between these technologies are blurring, and technology advances so fast that the future 'killer application' could be something that isn't even considered yet. With that in mind, this three-part categorisation provides a framework to assess how these immersive technologies are adopted now, and how they're likely utilized in the near future.

Different factors affecting VR/AR adoption in each use-case were then identified using UTAUT-model as a guiding framework for interviews and analysis. These factors, that were categorized based on UTAUT-model, where measured in a subjective seven-point scale based on their effect for future adoption. Since the ranking of these factors is subjective and based on a limited number of interviews, individual findings shouldn't be considered an objective truth, but rather as a potential hypothesis to be tested in a more targeted and potentially quantitative research.

There are two limitations on that should be considered before making managerial decisions based on these findings. First, the scope of this study was broad, which caused that use cases studied weren't homogeneous in all situations. Every interviewee had distinct conditions for using VR/AR, so selected interviewees may not be representative in terms of adoption of the whole industry or group that they belong in. It is possible that some of the reported barriers are only characteristic particularly for that company, in which case, single findings could distort the measures presented in the summary above (Figure 19). Therefore, one must be cautious without making too many generalizations based on single findings in this study. However, interviews were spread across many different industries and functions for a good reason. The purpose was to gain an overall understanding of the state of adoption today and estimate the future potential in different industries. Therefore, each individual finding could be used as a hypothesis to be tested in a more targeted research.

Secondly, there are limitations that are characteristic to qualitative studies. Findings are inherently affected by the author's own perceptions to some extent when data is transformed from interviews to reported findings, and it is possible that some details get lost in the process. To alleviate this problem, each interview was carefully coded and responses categorised right after each interview. This immediate reflection helped to consider nuances in responses that might have been lost in the interview situation. Yet, it's clear every individual answer can't be included in the report, so quotations chosen for this report may not represent the complete view of that person. All in all, important themes identified in this study are supported by broad evidence and they provide a foundation for future research to build up on. The nature of this primary study was exploratory and the purpose were to examine and understand this phenomenon, therefore findings should be also considered accordingly.

7 CONCLUSIONS AND RECOMMENDATIONS

In this final chapter, conclusions of this study are presented, after which, managerial recommendations are proposed based on this work.

7.1 Conclusions

Companies have been generally impressed with the performance and possibilities that VR provides, and the technology has potential to transform many existing ways of working. However, there are still some practical barriers related to technology and structural barriers in organizations before VR/AR can be more widely adopted. Nevertheless, it’s no longer a question whether these technologies will be adopted more widely, but when and in which use-cases.

Current use-cases of VR in the enterprise were sorted in three main categories; Design, Visualizations for marketing & sales, and Training & Simulations. Based on findings in these three categories studied more specifically, VR/AR will be most favourably adopted in Design, followed by use cases in Marketing & Sales, and lastly adopted in Training & Simulations, which has most barriers for adoption.

AR or MR were less often used in practise, because the still pose major technological to reach the desired utility, but their potential was constantly emphasised. When the technology advances, many use cases of VR can be transformed in to MR, but VR is currently simpler alternative, therefore it’s more likely to be adopted first. In the future, HMDs will likely support both VR and MR, therefore the distinction between these technologies will dissolve over time. AR in turn, has great potential in field operations, but wider adoption still has significant practical barriers. Creating the underlying infrastructure of digital twins for physical objects is a major challenge, and the usability of AR glasses still must be improved.

7.2 Recommendations

Based on findings from both secondary research and primary interviews as well as considering limitations of this study, there are four main recommendations that can be made. These recommendations are formed considering high-end headset manufacturers, such as Varjo, but can be applicable to any company operating in the VR/AR space. Also, for companies whose core business isn't related to VR/AR this can act as a useful framework to assess how they compare against consensus in VR/AR, and provide ideas, how to potentially stay ahead of the curve.

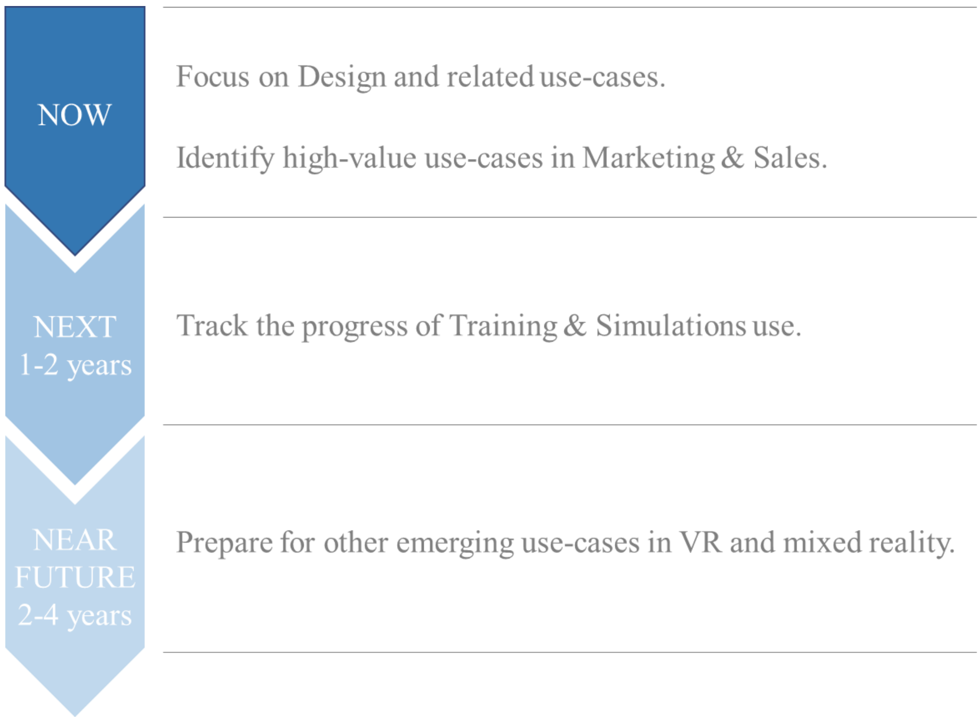

Figure 20. Recommendations

7.2.1 Now - Focus on Design and related use cases

Adoption in design related use cases is most advanced, and it has most favourable conditions for adoption. These are usually more technical people inside the organization, so adopting new technologies is generally more effortless for them. They're also used to designing in 3D, so VR/AR provides them with an extension to their current toolset, rather than a completely new way of working. Therefore, it can be assumed that adoption for VR/AR will be fastest in design related use cases in the near term.

7.2.2 Now – Identify high value use cases in Marketing & Sales

Benefits of VR/AR are also proven in marketing & sales, but the performance of high resolution, to the extent that Varjo's HMD is capable of, isn't required in every use case. VR is at such an early stage that few people have had the chance to try out VR, so these people are often occupied with the experience and the content is less relevant. This trend will likely change over time, when people get more familiar with VR and start to demand higher resolution. Viewing higher detail models also requires developing models in greater detail, which is more expensive. However, there are already plenty of use cases, where high detail is essential. Therefore, it's proposed that Varjo should identify those companies who are willing to invest to showcase more detailed models to their customers.

7.2.3 Next – Track the progress for Training & Simulations use

There is vast future potential in training and simulations, because it can be applied to any industry or use-case. These are also complex applications to execute in practise and have most barriers to adoption, so wider adoption is still a few years away. Therefore, less attention should be focused to training & simulations now, but the progress in these use cases should be tracked.

7.2.4 Near future – Prepare for emergence of other use cases in VR and mixed reality.

The empirical part of this research largely ignored mixed reality and other use cases outside the three main categories, because there weren't yet distinct use cases that could have been evaluated using UTAUT -model. However, the potential was often recognized, and most virtual reality use cases described could be transitioned to mixed reality, when the technology enables it. Therefore, the value of mixed reality could be a topic of another study. Among specific industries, secondary research highlighted promising advancements in healthcare, which wasn't covered in the empirical part. Healthcare has very distinct characteristics, with significant regulations and other structural barriers, so the potential could be further evaluated as a study of its own. In addition, the technology currently progresses extremely fast in VR/AR industry, so other use cases, such as applications of 360-video or virtual desktops, could be feasible in the near future. Therefore, it's proposed that companies should also examine the progress of these emerging use-cases outside of three main categories presented above.

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APPENDICES

Appendix 1. Interview guiding framework

Performance expectancy	- In what kind of situations are you using VR/AR in your work? - How important VR/AR is in your work? - What benefits are you getting for using VR/AR? - How VR/AR system is performing compared to traditional methods? - How does it affect productivity?
Effort expectancy	- How difficult was it/you think it would be to learn to use VR/AR? - What are the most difficult things in learning to use VR/AR? - How long you think it would take to learn using VR/AR in your work?
Social influence	- Do you think others in your industry are adopting VR/AR? - What is the general atmosphere towards these technologies in your industry like? How does it affect your intention to use VR/AR? - What does board/investors/people you report to think about adopting VR/AR? - Does people that have a high profile in your industry use VR/AR?
Facilitating conditions	- How do you think about the current infrastructure for adopting VR/AR? - How is the software matching your needs?

	- How is the hardware matching your needs? - What should be developed for you to benefit from VR/AR? - How likely you see the development of these applications/devices to adopt VR/AR? - Do you think you would have the recourses to adopt VR/AR? Why/Why not
Trust	- How do you think about the security and privacy of VR/AR? - How does it affect your plans to adopt VR/AR? - What are the biggest security threats? - How do you think about the trust of VR/AR device manufacturers?
Behavioural intention	- Are you planning to adopt VR/AR technologies in the future? Why/Why not? - How are you planning to use VR/AR in the future?

Appendix 2. Summary of interviewees

Interviewee(s)	**Function/Industry**	**Company description**
1. Head of new business development	Construction	Mid-size construction company in Finland

2. CEO	VR Software provider/Construction	Virtual reality studio developing immersive experiences
3. COO and 4. AD	Solution provider/Industry	Provides software services aimed at industrial process plants and the sales organisations that supply them.
5. Sales and marketing manager	Real Estate/Construction	Develops alternative real estate with novel construction methods that combine marine, land and modular construction techniques.
6. Chief marketing technologist	Service Provider/Defence & Industry	Creates special networks for emergency workers, companies and other institutions. Companies/institutions that use their solutions include emergency workers, police, oil companies, etc.
7. Head of yacht design and naval architect/Partner	Design/Naval	Nordic design and innovation agency in naval industry.

8. Head of simulation	Defence	Simulation department in defence industry
9. Head of sales, Nuclear Services	Energy	Services range from electricity & heat provision to expert services for power plants.
10. Analyst	Market research, VR training technology	Sports market research and advisory firm focusing on use of VR/AR in sports training. They're objective voice organizing, evaluating, and recommending sports technology products and services.
11. Key Account Manager 12. Director of development	Solution provider, 3D/VR/AR/MR	Experts in smart product communication that is interactive, makes use of lifelike 3D visualisation, incorporates multimedia product info and even IoT data. Creates interactive product experiences using AR, MR, and VR.