TURUN YLIOPISTO

VR, AR and XR enterprises and related demand and supply in Finland

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Contents

Keywords: VR, AR, XR, innovation, enterprises, Finland

January 2021

[1] BIIDEA (Blended Interactive Innovation Distance Ecosystem Architectures) inspects innovation processes in spaces of extended reality. The focus is on how innovations emerge and develop in virtual (VR), augmented (AR) and mixed realities (MR) and in their combinations in blended hybrid spaces of extended reality (XR) in which physical environment, people and mixed reality meet and blend into something novel and useful for the innovation processes. BIIDEA is funded by the Business Finland and Geography Section at the University of Turku. The viewpoints of this report do not necessarily correspond with those of these funding agencies. See: https://sites.utu.fi/biidea/en/

Abstract: VR, AR and XR enterprises and related demand and supply in Finland

The report examines virtual reality (VR), augmented reality (AR) and extended reality (XR) as regards enterprises in Finland at the beginning of 2021, as well as their demand and supply regarding VR, AR and XR in Finland. The report also pays attention to whether and how enterprises apply these realities in their innovation activities. In the report, virtual reality (VR) means experiencing a simulated world with VR glasses and other digital technology devices. Augmented reality (AR) means complementing the actual physical environment with digital 3D characters and elements. In extended reality (XR) physical, augmented and virtual elements of reality and people interact and this immersion is supported by technological devices.

The findings of the report are based on the analysis of enterprises databases and interviews conducted in December 2020 – January 2021. Regarding the supply of VR, AR and XR, from databases were identified 140 Finnish enterprises that were substantially involved in providing VR, AR and / or XR products and / or services. Of these, 58 enterprises had VR, AR and / or XR as their main economic activity. Furthermore, 26 enterprises supplying VR, AR and / or XR for individual customers, private and / or public sector were interviewed. In addition, 7 broader organizations were interviewed. As regards the current use and demand for VR, AR and XR in Finland, in total 51 Finnish enterprises of different sizes covering various economic sectors were interviewed. All data were analyzed quantitative and qualitatively with content analysis.

VR and AR are used in Finland by thousands of enterprises of various sizes in many fields. The interviewed enterprises used them, for example, to provide services such as the presentation and marketing of end products. Tangible products were converted into digital form, so that they can be used regardless of time and place (e.g., in the design of products under development or training regarding end products). In contrast, XR was used in only a few companies because a suitable use had not yet been found or that the enterprise perceived that technology is not sufficiently advanced yet.

In 2019, there were 70 VR-, AR- and/or XR-related enterprises (of which 24 specialized in these) in Finland with a turnover of more than EUR 100,000 and 38 of them (of which 12 specialized) had a turnover of more than EUR 1 million. The capital Helsinki is the site for many such enterprises. In 2021, as regard the 27 interviewed enterprises specialized in VR, AR and / or XR in Finland, for 39% their main market area was Finland, 19% in Finland and abroad and 42% abroad. The majority (58%) had less than 10 people with a task to develop VR, AR and / or XR technologies. Of these enterprises, three out of four (73%) completed the first VR, AR and / or XR product or service at least five years ago. The enterprises had different opinions on the impact of the COVID-19 pandemic on the demand for VR, AR and / or XR in Finland during 2020. Of them, 42% thought that the demand rose, 27% that it declined, 23% that it both increased and declined and 8% did not know how to answer.

Already thousands of Finnish enterprises use VR and AR in their operations (the use of XR is scarce), although they make little use of them in innovation processes. Some enterprises used these technologies and applications when an already conceived product or service was worked on but not to generate innovations. The restrictions on movement and assembly and the growth of distance working brought about by the COVID-19 pandemic increased the need to support innovation processes at distance, and many enterprises are interested in using VR, AR and XR more effectively to support their innovation activities.

Only a few Finnish enterprises, whose main task is to develop VR, AR and / or XR, have looked more deeply what potential VR, AR and / or XR have for developing innovations in enterprises or other organizations, including their own enterprise. They rarely proactively develop products or services for utilizing VR, AR and / or XR in innovation activities. The enhanced use of VR, AR and XR, including in innovation processes, would support the development of Finnish enterprises. A better match between the potential demand and possible supply of VR, AR and / or XR would bring business opportunities for Finnish enterprises that develop VR, AR and XR. Significant growth opportunities exist in global markets.

1. Introduction

In the 21st century, virtual reality (VR), augmented reality (AR) and extended reality (XR) have become increasingly part of businesses, public administration and people's daily lives. At the same time, the development of related technologies, products and services have become very important economically. The size of the global VR and AR market in 2019 was estimated at over $ 10 billion. The wider commercial and content breakthrough of VR, AR and XR technologies will take place in the 2020s. It has been suggested that the market for these technologies could increase fivefold or even eightfold by 2027 (Global Industry Analysts 2020; Grand View Research 2020). Such rapid market growth could take place as early as by 2024, as restrictions on movement and assembly related to the COVID-19 pandemic have substantially accelerated the deployment of virtual distance work applications and telecommuting events (Statista 2021a). At the same time, sales of equipment related to VR and AR technologies are rapidly multiplying. It has been suggested that sales of VR / AR devices would increase fivefold from about 5 million devices in 2020 to about 26 million devices in 2023 (Statista 2021b). In the forthcoming future of the 6G networks in the 2030s, the sensing, imaging and highly accurate positioning capabilities with mobility will be a new framework in which XR becomes the everyday reference for billions of people capturing entire life experiences and detailed physical environments (see Latva-aho and Leppänen 2019). The turnover of companies involved in digital modifying of reality is estimated to grow by billions of euros in the 2020s. The industry's technology and products are developed by specialized companies such as Oculus VR (owned by Facebook) and HTC, as well as many other major technology companies in the world, such as Microsoft, Alphabet / Google, Samsung, Unity Technologies, Sony and Facebook already mentioned.

There are dozens of companies in Finland that develop technology in the VR, AR and XR fields and dozens of companies that offer related products and services. The development of such industry in Finland was accelerated in the 2010s by the Mixed Reality program, which was implemented in 2017–2019 in cooperation with Business Finland / Tekes, Finnish Virtual Reality (FiVR), VR Finland, Neogames and companies in the field. The program provided innovation financing and internationalization services to Finnish companies that developed virtual reality and augmented reality solutions and utilized them in their business. In addition, companies, research organizations and other public actors in the field were networked. The goal of the program was to create the world's leading companies producing VR / AR technology and content in Finland and for Finnish companies to be global pioneers in developing and utilizing VR / AR technology. In addition to games and entertainment, healthcare and all major industries were included. The goal was also for the Finnish VR / AR ecosystem to be closely linked to other similar major ecosystems in the world (Business Finland 2020). In connection with the program was conducted a survey, which was answered by 60 companies related to the sector in Finland (FiVR 2017). Now at the beginning of 2021, there may already be thousands of companies in Finland that utilize VR, AR and / or XR technologies, products and / or services in their business to some extent. VR, AR and / or XR will in one form or another become part of the operations of a large number of Finnish companies in the 2020s.

The value chain of VR, AR and XR technologies and applications is long and extends from the production of parts and devices to operating systems and commercial and non-commercial software development packages. Today, an increasing number of devices can also be used mobile as wireless data transfer speeds increase and device connections become more common due to efficient cloud services and distributed cloud computing. From equipment, systems and software, the value chain continues to applications in various industries and content production until the finished product or service reaches the end users (Business Finland 2021). End users are ordinary consumers as individuals and various organizations such as companies, public administration and organizations both globally and in more specific target areas such as Finland or defined target groups (Figure 1).

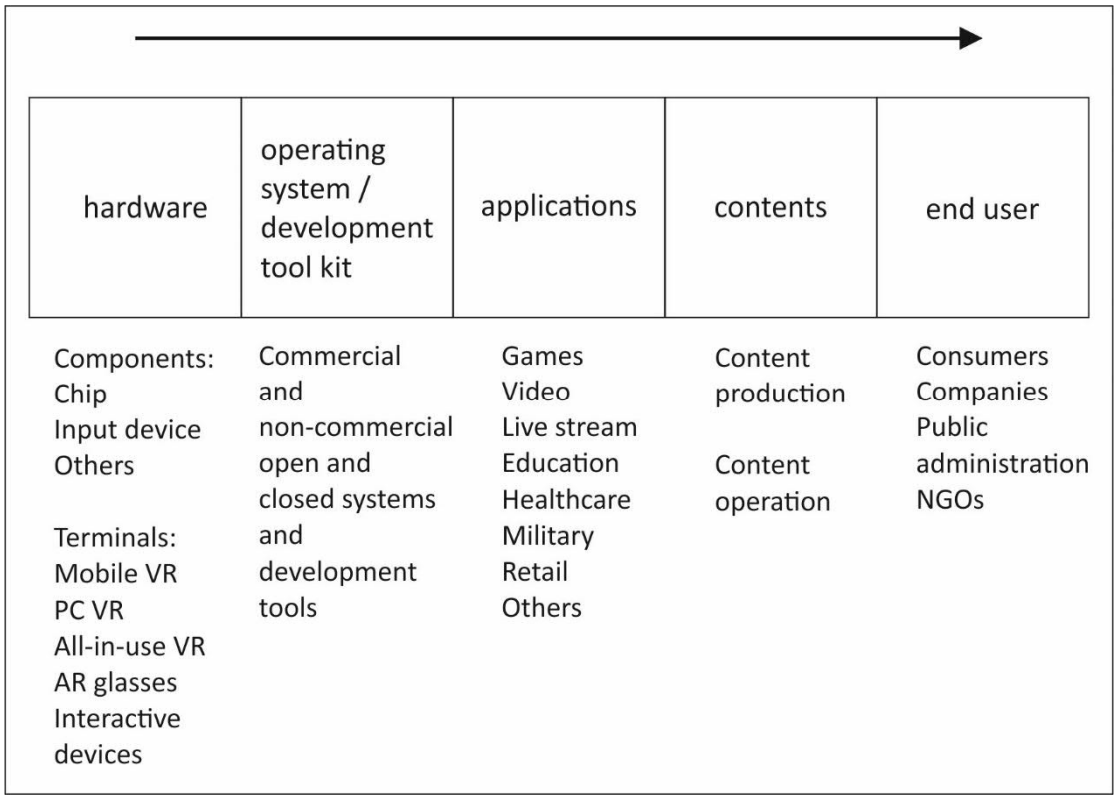

Figure 1. Value chain of VR, AR and XR technologies. Modified from Business Finland (2021).

In 2019, approximately half of the global VR, AR and XR markets for applications and content production were related to the gaming and entertainment industries, including a wide range of gambling and other betting-related games. One-third of the market was related to other consumer applications, and the remaining few percent to businesses, the defense industry, healthcare, and other purposes each (Grand View Research 2020). Entertainment is and will be by far the largest value-adding industry for VR, AR and XR technologies. The demand and supply of VR, AR and XR products and services developed for business use is growing relatively faster than for entertainment purposes, but the absolute growth will continue to be the largest in the entertainment use for a long time to come.

The significant and rapid growth in the number of VR, AR and XR users has also increased concerns about how different (mobile) VR and AR applications will also enable more extensive and accurate data collection about users and their environment (Freedman 2020). With the proliferation of the Internet of Things (IoT), artificial intelligence (AI), and distributed cloud computing (CC), VR, AR, and XR technologies and applications may become as common globally as smartphones today. It has been talked for a decade how these reality-shaping and reality-enhancing technologies are achieving a global breakthrough. However, the development of technology has not progressed at exactly this pace. However, the COVID-19 pandemic had a significant impact, with global demand increasing very rapidly, while supply began to respond to this demand.

This report examines virtual reality, augmented reality and extended reality companies in Finland at the beginning of 2021, as well as the demand and supply of VR, AR and XR in Finland. There is demand and supply in Finland, but they do not always meet. On the one hand, companies do not always know how to ask for the right product or service, on the other hand, technology developers do not always extend their products or services to the emerging opportunities to which VR, AR and XR would bring new added value.

The report briefly discusses the differences and similarities between physical and other kinds of realities and how they are at present and in future an increasingly integral part of innovation processes. Attention is also paid to whether Finnish companies apply these realities and in what way in their innovation activities.

The main questions of the report are:

- what are virtual, augmented and extended realities?
- what kind of Finnish enterprises develop virtual, augmented and extended reality technologies, products and services?
- what kind of Finnish enterprises use and for what they use virtual, augmented and extended realities?
- how Finnish enterprises see the potential of virtual, augmented and extended realities for innovation processes in their enterprise?

The report targets Finnish companies in whose business the development of VR, AR and / or XR and / or products and / or services are significant. In some companies, these form the main activity, in some they bring significant business by-products to the company. Basic information about companies (such as turnover, earnings, personnel, operations and location) is obtained from the latest freely available company databases. In addition to this, interviews were conducted with the companies. The interviews were conducted by Katriina Eskola, Eveliina Kuurne and Joona Silvola, who acted as trainees in the BIIDEA project, and who also assisted in the analysis of the material.

In December 2020, 51 companies of different sizes from different industries were interviewed by telephone regarding the (possible) use of VR, AR and / or XR in their business and their views on the possibilities of using VR, AR and / or XR in innovation. At the same time, the effects of restrictions related to the COVID-19 pandemic on companies' innovation activities were also asked. In addition, seven interviews were conducted with various umbrella organizations in the sector on the impact of the pandemic on the business field and innovation in the sector and on how VR, AR or XR could support business development.

Another research topic was Finnish companies in which VR, AR and / or XR played an important role. In total 140 companies in the sector were identified, for which basic information was obtained from company-related databases on the Internet. Of these, 58 companies had VR, AR and / or XR as their main activities. In addition, in January 2021, were interviewed 26 specialized companies that developed VR, AR and / or XR. The interviews concerned the company's development activities, the effects of the COVID-19 pandemic restrictions on the demand for VR, AR and / or XR and the use of VR, AR and / or XR in innovation activities. Of the interviews, 21 were conducted by telephone and 5 companies answered the same questions by e-mail.

The report was prepared at the beginning of 2021, when the importance and use of VR, AR and / or XR were growing in the operations of Finnish companies, especially due to disadvantages of the COVID-19 pandemic. Some companies had not yet identified opportunities to take advantage of these. The umbrella organizations in the sector had identified both the advantages and disadvantages of the COVID-19 pandemic in the sector's innovation activities, and had identified some opportunities to exploit VR, AR and / or XR to support innovation processes. Few companies made effective use of the opportunities offered by these VR, AR, and XR technologies, especially in innovation activities and to generate innovations. On the supply side, significant companies focused on the development of VR, AR and / or XR have emerged in Finland. The turnover of these was usually still quite small, at most a few million euros a year. A very significant number of companies in the sector were small, i.e. their annual turnover was EUR 100,000 on both sides. The Helsinki metropolitan area, and especially Helsinki, was a large concentration of companies in the sector. There is a development potential in companies in the sector and opportunities for a better match between the demand and supply of VR, AR and / or XR in Finland.

2. Virtual Reality (VR), Augmented Reality (AR) and Extended Reality (XR) and their connections to innovation activities

The development of technology and the wider digitalization have made it possible to combine digital elements with physical material reality and also to create a reality consisting only of digital elements. Figure 1 shows the different dimensions and intersections of physical and digital realities. At the same time, the dimensions of reality are increasingly becoming linked to the emergence and development of innovations. In addition, the more precise definition of terms is made challenging by the fact that developers and commercial users of these technologies often use these terms in slightly different ways (Çöltekin et al. 2020). The "boundaries" of realities, i.e. the differences between them, are fuzzy, i.e. it is a continuum between physical material reality and imagined reality. The human imagination has never been limited to the physical environment, but the development of technology connects material reality and digitally produced reality into an increasingly closely blended environment. In the world of human experience, there is no longer a "mere" physical material environment without an associated digital dimension.

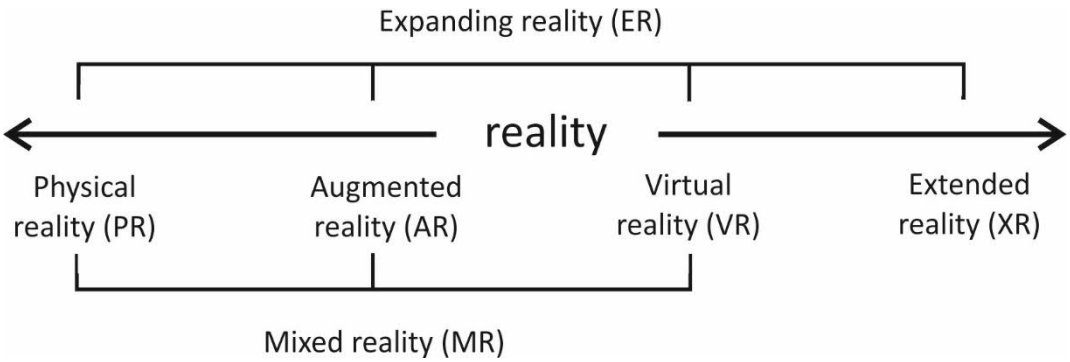

Figure 2. Model of reality dimensions.

Reality is constantly expanding due to various technological applications. This can be called expanding reality (ER) (Figure 1). What was technologically possible to experience as a reality in the 1990s was much narrower than what is now experienced in the 2020s. Most obviously, the situation will change with the advent of the 2050s, when times, places, physical, virtual, and apparently also human and machine, are much more diverse in their interrelationships. The widest possible reality is not just about a world of scale and experience. It expands from immediate experience of the surrounding environment to a reality in which the imaginations and aspirations of individual, community and society are intertwined. The goals of various commercial actors are also present in shaping realities. Even today, the most important of these commercial large technology corporations both analyze and direct the people connected to the VR, AR, and XR worlds and their experiences and behaviors. Artificial intelligence algorithms can be used to predict human behavior and, if necessary, direct human behavior in the direction of prediction. The forecast does not need to be corrected because the reality can be adjusted to match the (preferred) forecast.

An essential feature of this expanding reality is the intertwining of the material and digital environments. With the help of computer graphics, it has long been possible to create a three-dimensional digital environment that a person uses with a variety of tools. With the development of technology, a person is also able to influence his or her environment and as the data transfer speed increases, the devices work without delay, supporting the intertwining of the person, the devices and the perceived reality. Their joint impact is enhanced by influencing the senses of the person using the devices. The most important are sight, hearing

and tactile, but special means and accessories can also be used to bring smells and, if necessary, tastes into the experiences of a mixed environment. Immersive experience is associated with both physical and mental states (Sherman & Craig 2018).

VR (virtual reality) is how the simulated world is experienced with the help of digital technology devices, for example with VR glasses. In it, people "dive" into a completely virtual world. The first ideas about virtual reality were presented as early as the early decades of the 20th century. The applications include many advanced virtual games since the 1990s. Recently, digital virtual platforms have increased in popularity. A person can use their own avatar to participate in seminars and congresses and various events, such as concerts. VR applications for learning and entertainment purposes are also popular. For example, they can be used to learn about history, geography or human anatomy, or to visit virtually different places around the world (for example, through Google Earth VR). The more advanced VR environment covers all five senses, but usually the applications cover the visual, auditory, and tactile senses.

AR (augmented reality) is the term more clearly connected to the physical world. It complements the physical environment of real material world with digital three-dimensional characters and other elements. However, the interaction between virtual digital elements and the physical environment is minimal, i.e., the digital elements are in a way superimposed on physical reality. Typically, augmented reality can be used with a great many devices, such as a smartphone. An example of this is the globally popular Pokémon Go mobile game released in 2016.

MR (mixed reality) as a term is used to describe a combination of virtual reality and augmented reality. The digital objects in it can interact better and meaningfully with elements of physical reality, and the connection of digital parts to the physical world seems more realistic. The digital and material environments are better mixed, resulting in a "more authentic" experience of this mixed and augmented reality.

XR (extended reality) as a term refers to a situation where the physical material environment, people with their bodies and senses, and mixed reality meet, interact, and become more and more intertwined. This creates an intense immersive expanding state of experience that transcends physical and virtual reality. This reality thus comprises the intertwined relevant elements of physical reality, augmented reality and virtual reality. A person not only looks at it, but feels that he or she is in this reality (Çöltekin et al. 2020). XR encompasses wearable displays (such as lightweight VR glasses) and interaction mechanisms that create and maintain sensory illusions. Users will live in an immersed reality that enhances their ability to consume media, search the Internet, explore real and virtual worlds, collaborate on work projects, connect with family and friends, and engage in restorative activities. With the increased speed of information transfer, at least with the introduction of the 6G network, all user-specific computation and intelligence may move to the edge cloud. The context sensing, imaging and highly accurate positioning capabilities with mobility will be integrated together opening a multitude of new applications (see Latva-aho and Leppänen 2019).

In the everyday life, the digital dimensions of reality are increasingly intertwined with the physical material world. Thus, experiences, needs, and responses to them also occur in this mixed or expanded reality, which is thus constantly expanding with the development of technology (expanding reality, as discussed above). This means that the emergence and development of innovations (new product, service, organization, successful way of working, etc.) are linked to these different dimensions of reality. Thus, it is essential to exploit these different dimensions of realities in innovation processes.

Looking at the innovation process in a compressed way, the knowledge based on learning and experience becomes a new idea through the interaction of key actors and the interpretation of previous knowledge. This idea is put into a suitable context and formulated into a product or service that, when penetrating the market and used by people, becomes an innovation (Jauhiainen 2021). The innovation process from learning and experience to innovation is presented as a simplified model in Figure 3.

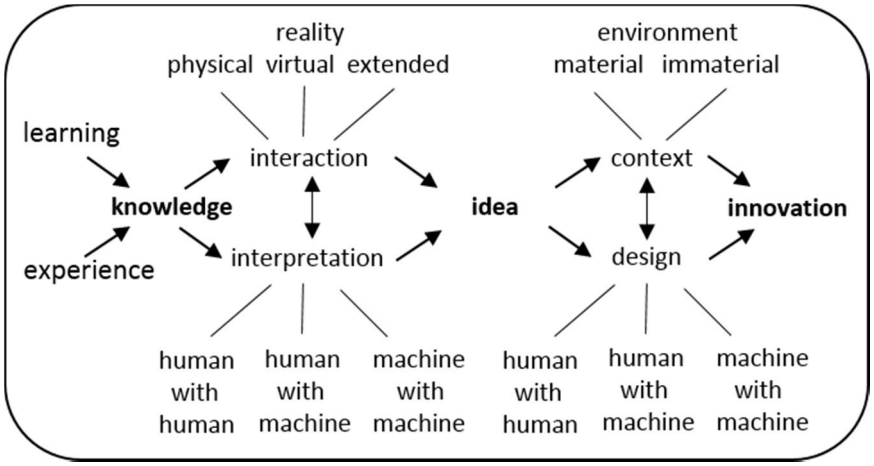

Figure 3. Model of innovation processes. Source: Jauhiainen (2021).

The interaction of generating a new idea can take place in the physical material world, for example, by gathering in the same place and discussing there, or by communicating, for example, by telephone or computer in different places. It is also possible to engage in this interaction in virtual reality, where avatars as digital characters represent the people in a digitally created environment. Due to the restrictions brought about by the COVID-19 pandemic, various events implemented on virtual platforms have increased, in which the exchange of information, acquisition of new knowledge and ideation play a key role (Jauhiainen 2020: Jauhiainen 2021).

In contrast, the development of innovation processes in extended reality has not yet been significantly implemented (El-Jarn and Southern 2020). However, there is a growing interest to address the early stages of the emergence of innovations in the current world of virtual applications and this will be exploited by many global companies (Dziallas 2020). Achieving cognitive proximity (understanding) is significant, and it is also possible in virtually interconnected groups that are physically distant from each other (Hung et al. 2020). Digital technologies also help to obtain the necessary knowledge as well as structure it in open innovation processes (Urbinati et al. 2020). In this case, the importance of virtual digital connections will increase even more and may even change the significance of face-to-face innovation activity that is still considered essential today.

Linking extended reality to innovation processes would go beyond the limitations imposed by the physical presence in near-by material environment and distorted reality of the digital virtual world (e.g., not properly felt experience of one's own body or surroundings). Thus, innovation in an extended reality could free the creativity of the individual and groups from many preconceptions and limitations based on everyday experiences in one’s own body and prejudices in the physical world. In an extended and expanding reality, new perspectives and opportunities emerge, and these lead to new ideas and innovations. Thus, connection and conscious connecting to augmented, virtual and extended realities will become central to the innovation processes in the 2020s. Reality is expanding with various digital and technological applications, so innovation processes must also be involved in this process, both in developing it and in intertwining it, because people anyway intertwine in this expanding reality.

3. Supply in Finland: VR, AR and XR enterprises

There are many companies in Finland with focus on developing virtual, augmented and extended realities. On the one hand, there are companies with the aim to develop technologically these digital-related realities. On the other hand, there are also companies whose main economic activity is related to something else than the development of these technologies, but which nevertheless have some significant VR, AR or XR technology or application developed or acquired by them, which they sell or provide a service. Both types of companies are studied in this report. However, not all Finnish companies that apply existing VR, AR and XR technologies have not been taken into account because they are already thousands.

The data from companies developing VR, AR and / or XR technology, products and services were obtained from two sources. First, the basic company information comes from free databases available on the Internet (such as finder.fi, Suomen Asiakastieto, Fonecta, etc.). This basic information includes the company's year of establishment, industrial activity, turnover and its development, profit and its development, number of employees and its development, and the main products. Through this, were identified 140 companies in Finland, whose activities in 2020 essentially included the development, products or services of VR, AR and / or XR. The Appendix 1 lists the companies whose essential function is the development, products or services of VR, AR and / or XR in Finland, including enterprises specialized in VR, AR and / or XR. Of these companies, 58 (41%) were specialized companies that focused mostly on the development, products or services of VR, AR and / or XR and the remaining 82 companies (59%) were those having VR, AR and / or XR development, products or services but not as their main activity. In 2017, the survey conducted identified 98 companies in the VR, AR and XR sector in Finland (FiVR 2017).

In addition to the basic information on companies obtained from the register presented above, telephone interviews were conducted with companies developing VR, AR and / or XR technology, products and services in January 2021. For the interviews were selected 27 companies that represent well all companies operating in Finland. Of the interviewed companies, 16 had turnover of more than one million euro. Companies with profit and those with loss were included. With regard to VR, AR and XR functions, the interviewed companies operated in various fields as technology and application developers. The VR, AR and / or XR companies interviewed reflect well the situation in the sector in Finland at the beginning of 2021.

Table 1 shows largest Finnish companies that have significant task in the development or providing products or services of VR, AR and / or XR (as their main task or not as their main task) and that have at the same time a turnover of more than one million euro. Of these 38 largest companies in the field, 9 (24%) had been established before 2000, 13 (34%) in 2000–2009 and 16 (40%) in the 2010s. Of these companies, 5 (13%) had a turnover of more than 50 million, i.e., they belonged into the official category of large enterprises. Of the companies about 8 (21%) belonged to the category of medium-sized enterprises, i.e. having the turnover of 10–50 million euro and around 50 employees at least and the remaining 25 companies were small enterprises (66%). In the Table 1 is presented information of the main parent company in Finland, i.e. it does not include the international (or national) sub-units of corporations. Therefore the turnover and the staff of the largest companies in the list, such those of Ponsse, Tietoevry and Elomatic in particular but also those of Sitowise, Siili Solutions, Vincit etc., would be much higher than here if the whole corporation would be included.

The median turnover of these 38 largest companies in the VR, AR and / or XR field in Finland was 3.0 million euro in 2019. The growth of the company in the sector takes time, as only one company established after 2010 was among the 12 largest. Of the companies, 21 (55%) made a profit in 2019 and 17 (45%) made a loss. The median result in 2019 was close to zero (0.15 million euro). However, of those VR, AR and XR sector's Finnish companies with annual turnover more than 10 million euro, 85% were in profit which situation was substantially less (44%) among enterprises with turnover of 1 to 10 million euro. Of the companies, 13 (34%) had more than 50 employees and these accounted for 15% of the companies established in the 2010s. It thus

takes usually more than a decade for the sector's companies to grow to become a significant employer. Of these 38 largest companies in the field, 12 (32%) has VR, AR and / or XR as their main activity.

Table 1. Largest companies in Finland that developed or sold VR, AR and XR technologies, products or services in 2019.

Name	Founding year	Turnover mill. euro	Net profit mill. euro	Number of employed	Technology VR	AR	XR	Main VR, AR or XR product or service
Ponsse	1992	531,523	50,329	941	x			Forest machine simulators
TietoEVRY	1968	136,998	87,082	130	x		x	Applications
Sitowise	2010	123,645	- 1,089	1224	x		x	Virtual modelling
Siili Solutions	2005	72,832	0,897	488		x		Application services
Insta Automation	1988	62,539	1,308	419	x	x	x	Programme consultation
Futurice	2000	40,873	-1,535	374	x	x		Web- and mobile development
Vincit	2007	39,069	0,797	323	x	x		Consultation, products
HiQ	1987	37,975	7,107	227		x		AR movle applications
Elomatic	2004	34,228	4,109	128	x		x	Training environments
Wapice	2000	23.093	0.972	323	x	x		IoT TICKET
Optofidelity	2005	18.945	1.499	102	x	x		VR and AR HMD testing
Etteplan MORE	2012	16.600	0.938	173	x	x		Introduction consultation
Geotrim	2001	14.562	0.017	34	x	x		Trimble import
Visual Components	1987	8.049	2.120	49	x			3D-visualization
Futuremark Oy	1997	7.637	1.685	35	x			VRMARK testing
Basemark	2015	6.223	-0.085	28	x			Rocksolid Engine
Softability	1996	5.628	0.192	69	x		x	XR applications
Valo Motion	2016	4.008	0.752	-			x	Mixed Reality e-sport
Wakeone	2018	3.292	-0.034	35	x	x	x	Browser-based AR/VR
Upknowledge	1995	2.741	0.172	9	x			Training environments
Tietoa Finland Oy	2000	2.726	-0.081	30	x	x	x	Information model
Sofokus	2019	2.607	0.198	34	x	x		Digitalization consultation
Varjo Technologies	2016	2.378	-22.629	126	x		x	VR/XR development
Vivid Works	2006	2.235	-0.703	31	x			3D/VR visualization
CSE Simulation	2012	2.130	0.064	13	x			Mixed Reality e-sport
Innogiant	2011	2.090	0.190	19	x	x	x	VR/AR/XR solutions
Nanocomp	1997	1.936	-0.786	27		x		Optical film solutions
Dispelix	2015	1.843	-3.100	34		x		AR waveguide display
Umbra	2005	1.666	-0.263	-	x			Ultra-wide 3D
Make Helsinki	2010	1.447	-0.013	15	x	x		AR/VR solutions
Flatlight	2013	1.327	-0.068	15	x			Description services
Iceflake Studios	2007	1.289	0.308	17	x			VR game "Ice Lakes"
Stereoscape	2006	1.263	-0.131	10	x	x	x	Productized services
Fake (Glue)	2009	1.154	-0.171	29	x	x		Glue platform
Pikseli Arcade (Virva VR)	2016	1.130	-0.022	6	x			VR amusement parks
Zoan Oy	2010	1.130	0.012	8	x	x		Customized products
3D Talo Finland	2016	1.048	0.003	28	x	x		Spatial and regional planning
Superapp	2015	1.005	-0.005	17		x		Mobile applications

Source: The Internet databases of Finder.fi, Asiakastieto.fi and Kauppalehti.fi. In bold the names of those companies having VR-, AR- and / or XR as their main activity. Information regards the main parent company in Finland, i.e. it does not include the international (or national) sub-units of corporations.

In the European Union (EU) statistics, the enterprises are divided into different types according to the number of employed staff and the annual turnover. In this category, large enterprises are those that have at least 250 employees or the annual turnover more than 50 million euro. Medium-sized enterprises are those that have

50–249 employees and annual turnover up to 50 million euro. Small enterprises are those that have less than 50 employees and the annual turnover up to 10 million euro. As a sub-category of small enterprises are micro enterprises that have 1–9 employees and annual turnover up to 2 million euro.

Based on this EU statistical categorization, of the 140 Finnish VR-, AR- and / or XR-related enterprises studied, 5 enterprises (4%) were large, about 8 (6%) were medium-sized and the remaining 123 (71–90%) were small enterprises, including 67–74% belonging to the category of micro enterprises (i.e., having less than 10 employees and annual turnover up to 2 million euro). There were 26 companies (19%) whose turnover data for 2019 were not available, however, many of them were new and small (Figure 4). Of all companies, 59 (42%) were over five years old (i.e., founded in 2015 or earlier). In 2017, the share of companies older than five years was in practice the same, i.e., 43% (FiVR 2017).

The combined turnover of studied 140 companies involved the VR, AR and XR sector was 1,235.0 million euro. As mentioned, there were also 26 companies of which information of turnover for 2019 was not available but this amount was small. The combined turnover of large companies (turnover more than 50 million euro) was 927.5 million euro (75%), that of medium-sized companies (turnover 2–50 million euro) was 277.1 million euro (23%), that of small companies (turnover less than 2 million euro) 30.4 million (3%) (Figure 4). A very significant part of the sector's turnover (almost 99%) comes from companies with an annual turnover of more than one million euros.

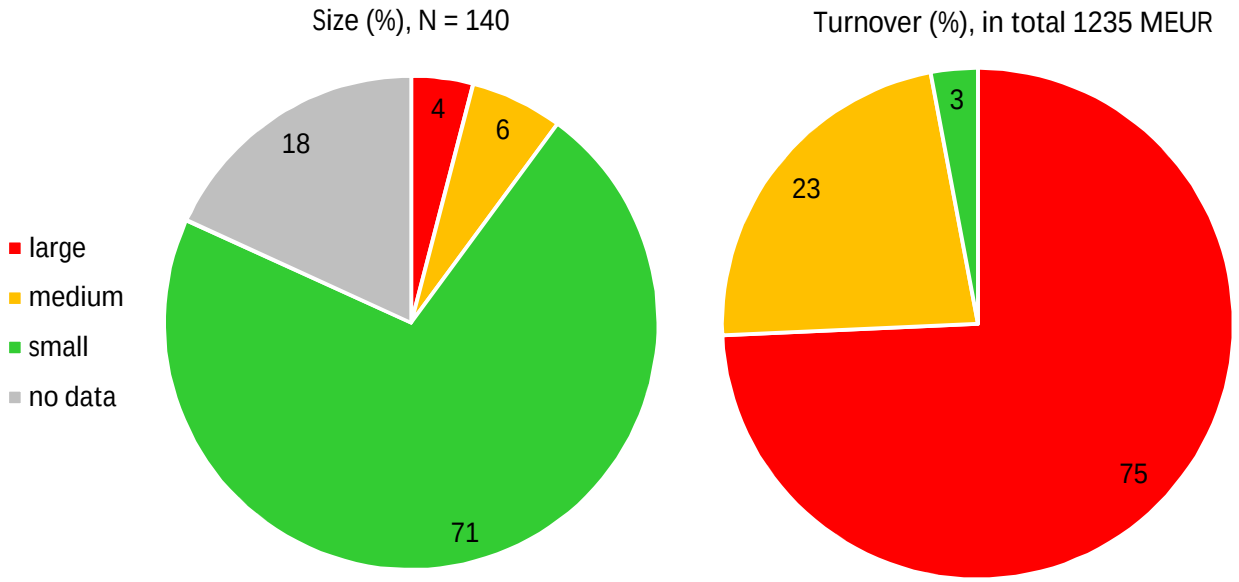

Figure 4. VR, AR and XR companies in Finland in 2019 according to their size (on the left) and turnover in companies of different sizes (on the right). Includes all 140 companies having important development or selling of VR, AR and / or XR products or services, but the companies may also have other more important businesses. Large enterprise has turnover of more than 50 million euro, medium-sized enterprise from more than 10 to 50 million euro, and small enterprise up to 10 million euro.

In 2019, of specialized 58 companies developing or selling VR, AR and XR technologies, products or services as their main activity in Finland, none (0%) of the companies were large and 2 companies (3%) were medium-sized (however, by the number of employees but not by turnover). Almost all (75–97%) were thus small enterprises having turnover with less than 10 million euro and less than 50 people employed, and 55–77%

being micro enterprises. The turnover of 13 companies (22%) from 2019 was not known but estimated to be small (Figure 5). Of all these companies, 23 (40%) were more than five years old (i.e. founded in 2015 or earlier). The share of young companies is slightly larger (55% vs. 60%) among companies specializing in VR, AR and XR compared with those companies having their main economic activities other than VR, AR and XR. VR, AR and XR technologies are being absorbed into economic activities of large and long-established technology-intensive companies.

Of the 58 companies specializing in the sector, their combined turnover was 30.8 million in 2019. This is about 3% of the turnover of all companies involved substantially in the VR, AR and XR sector in Finland. This means that in general the turnover of the specialized enterprises is relatively small. However, in this report is not specified how much of the turnover of all enterprises that have substantial activities in the VR, AR and / or XR sectors comes from these sectors and how much from the activities in which VR, AR and / or XR are not involved in. Of the turnover of the specialized enterprises, the share of large enterprises was 0.0 million (0%), that of medium-sized enterprises was 8.0 million (26%) and that of small enterprises was 22.8 million (74%). The combined turnover of tiny enterprises (having less than 100,000 euro annual turnover) was 1.0 million (3%) (Figure 5).

The 2017 report identified 5 companies in the industry with a turnover of more than EUR 1 million, of which 2 companies accounted for the majority of their turnover from VR, AR and / or XR technology, products and / or services. A few years later the number of such enterprises is much higher (being 12–38 depending on the criteria of the enterprise). This means that many companies in the sector have grown (although they are globally still small in size). However, it is not possible to compare directly the samples between 2017 and 2020. In 2017, about half (52%) of the companies in the field were tiny (with a turnover of less than EUR 100,000), and some had just started operations (FiVR 2017). A few years later, the relative share of these tiny companies had decreased to around one third (30–36 %). The average size of the companies in the field have thus increased over the last years.

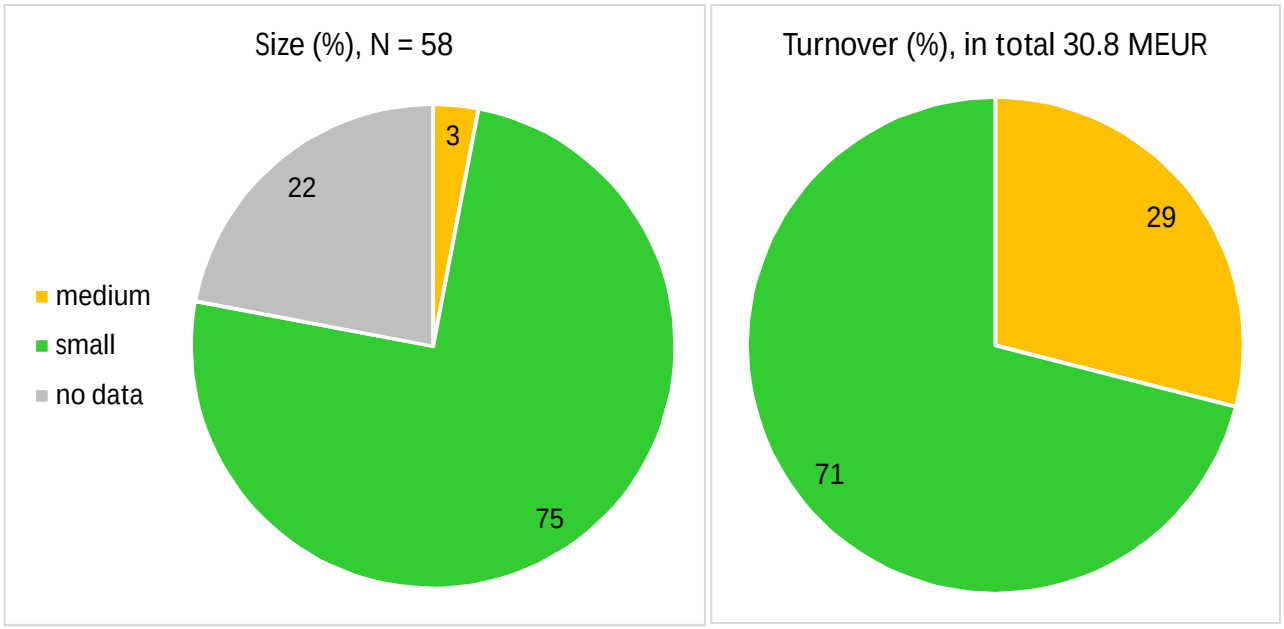

Figure 5. Share of specialized VR, AR and XR companies in Finland in 2019 according to their size (on the left) and turnover in companies of different size (on the right). Includes 58 companies with VR, AR and / or XR technologies, products and / or services as their main activity. Large enterprise has turnover of more than 50 million euro, medium-sized enterprise from more than 10 to 50 million euro, and small enterprise up to 10 million euro.

In 2019, there were 32 companies with turnover from 100 000 to 1 million euro in the VR, AR and / or XR industry. They were 12 fewer in 2019 compared to 2018 (8 companies had grown to a million turnover companies and 7 companies had fallen below the threshold of one million euro turnover and 3 companies had risen to more than 100,000 euro turnover, including two new companies). In 2019, there were 12 specialized companies in VR, AR and / or XR in that category. It was 4 fewer than in 2018 (5 companies had passed the threshold of one million euro and 4 companies had fallen below it and 5 company had passed the 100,000 euro threshold, including 4 new ones). To pass over this threshold of 100,000 euro is slow among tiny enterprises in the VR, AR and / or XR fields. In 2020, the number of enterprises with more than one million euro turnover might fall due to the general economic downturn caused by the COVID-19 pandemic. During 2020, companies in the sector also went bankrupt, as in previous years, and there were mergers. On the interviewed VR-, AR- and / or XR-related companies had different opinions on the impact of the COVID-19 pandemic on the demand for VR, AR and / or XR in Finland during 2020. Of them, 42% thought that the demand had risen, 27% that it had declined, 23% that it both increased and declined and 8% did not know how to answer.

Geographically, the Helsinki metropolitan area is a significant concentration of companies in the VR, AR and XR sectors (Figure 6). There are dozens of companies in the industry and hundreds of workers in the industry. A significant number of technology developers and companies in the field are located in Helsinki. This was already the case in 2017, when Helsinki was identified as the most significant concentration in the industry and almost half (48%) of the companies in the industry were located in Uusimaa (FiVR 2017). In the Helsinki Metropolitan Area, it is possible to achieve co-operation, division of labor and a skilled workforce moving from one company to another and information exchange. This would create a clear creative cluster for the development of the sector in the Helsinki Metropolitan Area. There is also the Helsinki XR Center, which is a virtual and augmented reality development network that also offers business premises and expert services to companies in the field (HXRC 2021). The formation of subcontracting chains may also be easier due to geographical proximity. On the other hand, coding and other activities that are not site-specific in development can also take place abroad. This is also increasingly the case, as skilled and affordable labor is available in many countries. At the same time, marketing may require a presence in key market areas, so key companies in the industry become network-like across many national borders.

Outside the capital region in Finland, there are only a few smaller concentrations in a few localities. According to the 2017 report, other concentrations of companies in the sector (however, being significantly smaller than that of Helsinki) were in Tampere, Oulu, Turku and Kuopio (FiVR 2017). Looking at all companies that had significant development of VR, AR and / or XR technologies or sales of these products and services in 2020, outside Helsinki, smaller concentrations of companies in the field were Tampere, Espoo, Turku, Oulu and Vantaa. When looking at companies specializing in the development of VR, AR and / or XR technologies, products and / or services in 2020, Helsinki was by far the largest and Tampere was a slightly larger concentration for those companies (Figure 6). The development of VR, AR and XR technologies is therefore very strongly focused on Helsinki and the rest of the Helsinki metropolitan area.

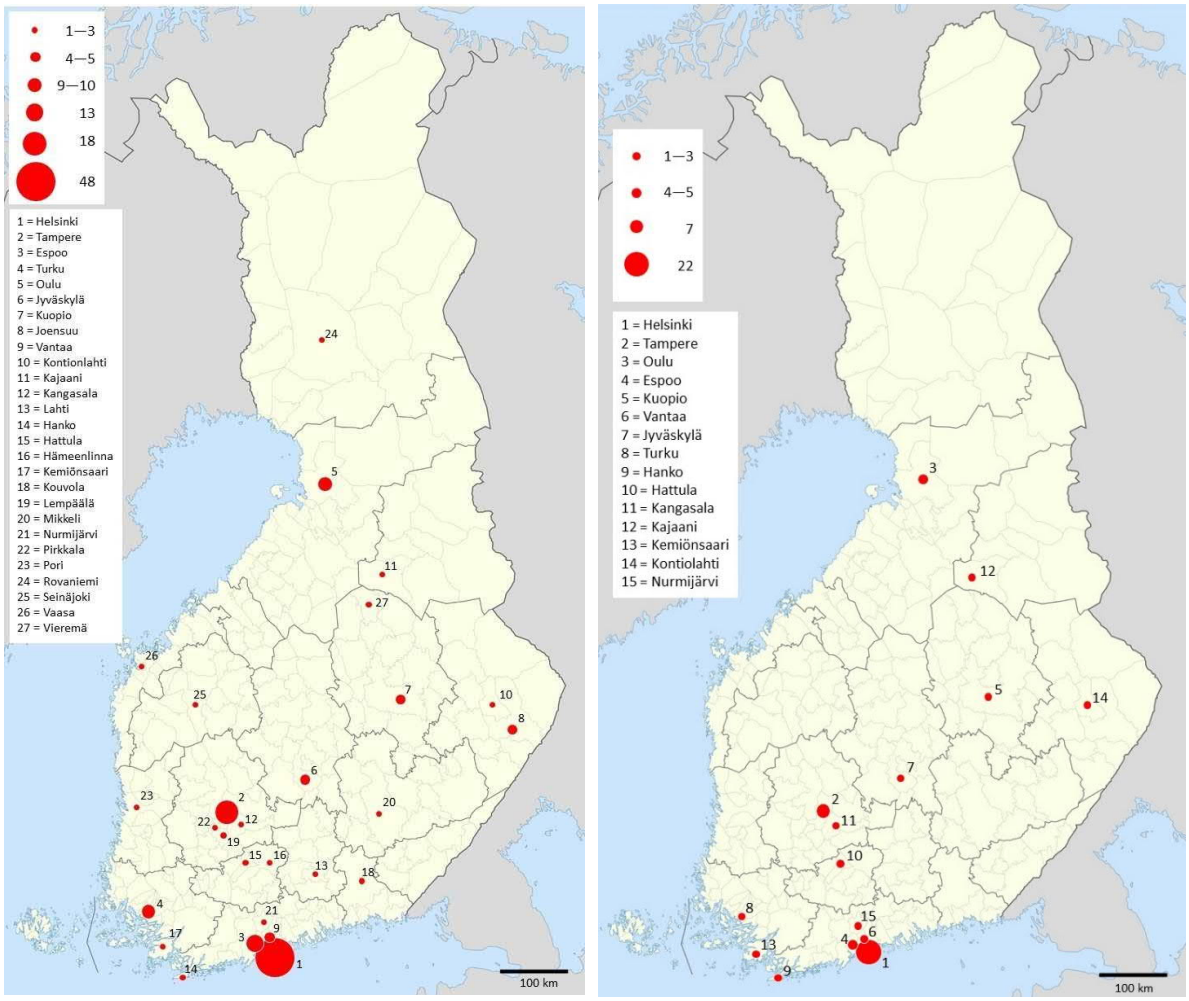

Figure 6. Location of VR, AR and / or XR companies in Finland in 2020. On the left, 140 companies having important development or selling of VR, AR and / or XR products or services, but the companies may also have other more important businesses. On the right, 58 specialized companies having important development or selling of VR, AR and / or XR technology, products or services as their main task.

There were changes in the turnover of VR, AR and / or XR companies in Finland between 2017 and 2020. In general, the turnover of many companies increased until 2019 and then decreased in 2020 due to the side effects of the COVID-19 pandemic. In 2021, as regard the 27 interviewed specialized VR, AR and XR enterprises in Finland, for 39% their main market area was Finland, for 19% in Finland and abroad and for 42% abroad, so both national and global economic developments affect the operations of these companies. On the other hand, the turnover of these companies, which are clearly aiming for a global market, can grow rapidly because of the on-going and expected rapid growth of demand in the sector.

Looking at the turnover of all companies developing or selling VR, AR and XR technologies, products or services, it can be seen that from 2017 to 2018 turnover increased in less than half (44%) of companies in the sector (the median increase was EUR 153,000 of those companies of which the balance was available) and turnover decreased by about one fifth (19%) companies (the median decrease was EUR 58,000 of those companies of which the balance was available). From 2018 to 2019, turnover increased in less than half (48%) of companies in the sector (the median growth was EUR 160,000 of those companies with the balance available), but the turnover decreased in about one out of four (23%) of companies (the median decrease was EUR 48,000 of those companies of which the balance was available). The growth from 2018 to 2019 was relatively the most common in large companies, then in medium-sized companies and less common in small

enterprises (Figure 7). In January 2021, there was not yet enough comprehensive information on turnover for 2020 that was impacted by the Covid-19 pandemic.

It is challenging to estimate the ratio of turnover to the number of employees for these Finnish companies because it also depends who in the corporate structure is calculated as an employee, what is the difference between the parent company and the rest of the corporation, and how much of the company's activities are conducted in Finland. In 2019, in all studied 140 companies related to VR, AR and / or XR, the turnover averaged around EUR 168,000 per employee in companies having at least one million euro turnover, around EUR 68,000 per employee in companies with turnover from 100,000 to one million euro and around EUR 23,000 per employee in tiny companies with turnover less than 100,000 euro. Thus, larger companies in the sector sell much more products and / or services, which means that more workers are needed, who in turn produce more products and services, and add value to the company. Small businesses take their time before their operations are financially viable and financially support the people who can then work for them full time.

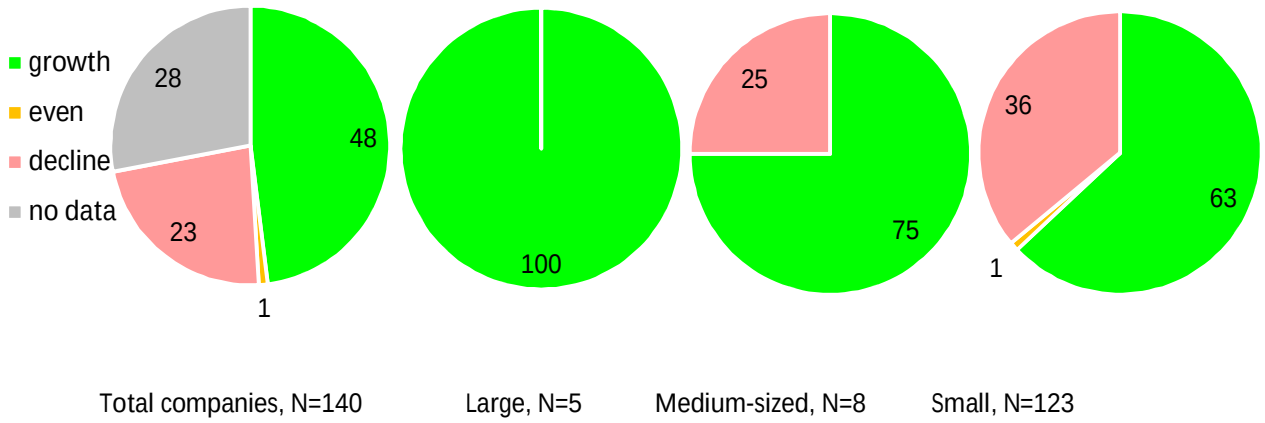

Figure 7. Turnover development in VR, AR and / or XR companies of different sizes in Finland from 2018 to 2019 (%). Includes all 140 companies having important development or selling of VR, AR and / or XR products or services, but the companies may also have other more important businesses. Large enterprise has turnover of more than 50 million euro, medium-sized enterprise from more than 10 to 50 million euro, and small enterprise up to 10 million euro.

Looking at the specialized companies having VR, AR and XR technology, products and / or services as their core business, from 2017 to 2018, the turnover increased in one third (36%) of companies (the median growth was EUR 232,000) and decreased in every sixth (17%) company (the median decrease was EUR 60,000). From 2018 to 2019, the turnover increased in below half (45%) of these companies (the median growth was EUR 77,000) and in one out of four (24%) of companies the turnover decreased (the median decrease was EUR 35,000) (Figure 8). In January 2021, there was not yet enough comprehensive information on the companies' turnover for 2020.

Like for all companies, also for specialized Finnish companies for VR, AR and / or XR, it is challenging to estimate the ratio of turnover to the number of employees. In 2019, the turnover was estimated to be about 114,000 euros per employee in companies with turnover of more than one million euro, 40,000 euros per employee in companies with turnover of 100,000 to one million euro and 27,000 euros per employee in tiny

companies with turnover less than 100,000 euro. Comparing the turnover per employer of companies having VR, AR and / or XR as a secondary source of income with those specializing in VR-, AR- and / or XR-technologies, it became evident that in companies with more than 100,000 euro annual turnover, the added value of staff was smaller in specialized companies.

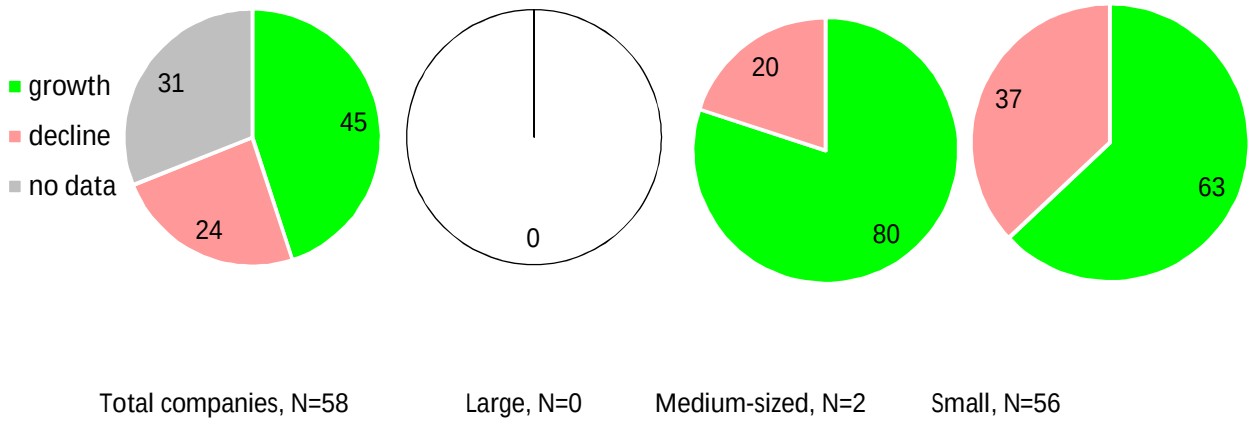

Figure 8. Turnover development of specialized VR, AR and / or XR companies from 2018 to 2019 in Finland. Includes 58 companies having development or selling of VR, AR and / or XR technology, products or services as their main task. Large enterprise has turnover of more than 50 million euro, medium-sized enterprise from more than 10 to 50 million euro, and small enterprise up to 10 million euro.

VR, AR, and XR are areas that are still evolving in many ways. Thus, some companies in the industry need still to focus on the development of these technologies, products and services before they are widely commercialized to the market. This results in high costs relative to turnover. In 2018, 37% of all companies that develop or sell VR, AR and XR technologies, products or services were profitable in terms of turnover (45% loss-making, for the remaining 18% there is not accurate information about it). Of the profitable companies, the median profit was 7% of turnover and 30,000 euro. In the following year, in 2019, about 40% of the companies in the sector were profitable in terms of turnover (2% even, 48% were unprofitable, the exact information for 10% of companies is not precisely known). Of the profitable companies then, the median profit was 8% of turnover and 31,000 euro. So among companies making profit, there are many in the industry with very low profits and at the same time very few companies with very high operating profits, including a few making several million euro profits.

On the contrary, in 2018, of the companies making loss, the median loss was 34% of turnover and 40,000 euro. In the following year, in 2019, about 48% of the companies in the sector were making loss in terms of turnover. Of the loss-making companies then, the median loss was 41% of turnover and 53,000 euro. So among companies making loss, the median is much higher than the profit of companies making profit. Nevertheless, only very few enterprises made loss of several million euro.

In 2019, 20 companies made a profit of more than 100,000 euro and 27 companies' loss was higher than 100,000 euro. In 2019, 58% of companies with more than 1 million turnover in the sector were profitable, 52% of companies with 100,000 – 1 million euro turnover and 30% of smaller companies. As the overall size of the company increases, clearly more will end up profitable (Figure 9). Data on corporate business performance in 2020 was not yet available in January 2021. However, according to company interviews,

turnover had decreased in many of them, which also leads to a decrease in operating profit and an increase in the number of loss-making companies.

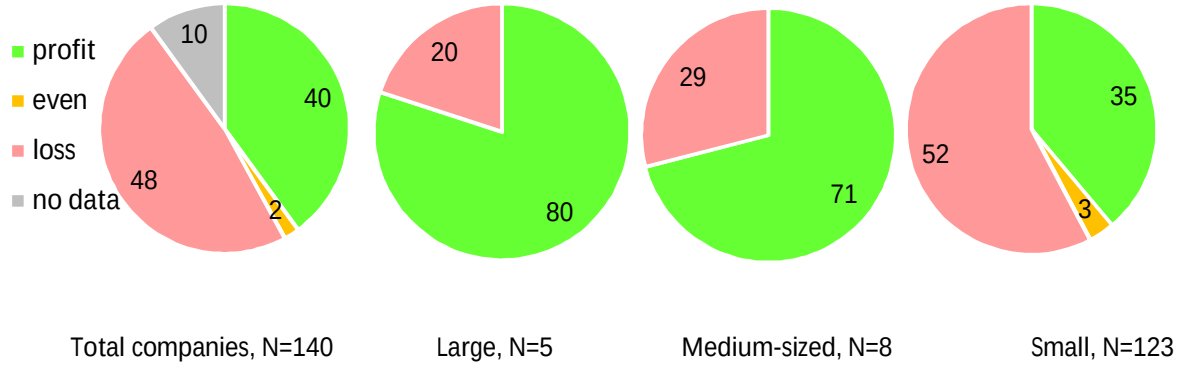

Figure 9. Economic profitability of VR, AR and / or XR companies in 2019 in Finland. Includes all 140 companies having important development or selling of VR, AR and / or XR products or services, but the companies may also have other more important businesses. Large enterprise has turnover of more than 50 million euro, medium-sized enterprise from more than 10 to 50 million euro, and small enterprise up to 10 million euro.

In 2018, of all 58 specialized companies whose core business was VR, AR and XR technology, products and / or services and their development, 36% were profitable in terms of turnover (loss-makers 38%, with zero profit 2%, no data 22%). Of the profitable companies, the median profit was 6% of turnover and 15,000 euro. In 2019, 28% of the companies were profitable in terms of turnover (53% unprofitable, 19% no data). Of the profitable companies, the median profit was 3% of turnover and 5,000 euro. In general, the profits are on the average very small and in 2019, only 3 companies made a profit of more than 100,000 euro.

On the contrary, in 2018, 38% of specialized companies made loss and of the companies making loss, the median loss was 65% of turnover and 70,000 euro. In the following year, in 2019, about 53% of the companies in the sector were making loss in terms of turnover. Of the loss-making companies then, the median loss was 49% of turnover and 40,000 euro. So among companies making loss, the median is much higher than that of companies making profit as well as the absolute loss. From the year of 2017 to 2019 the losses were getting smaller but in 2019 still 13 companies' (22%) loss was higher than 100,000 euro. Data on corporate business performance in 2020 was not yet available in January 2021. However, according to company interviews, turnover had decreased in many of them, which also leads to a decrease in operating profit and an increase in the number of loss-making companies. Among specialized companies, the growth of the company does not necessarily lead into profitability as it was more common among less-specialized companies using VR, AR and / or XR to back up their turnover (Figure 10).

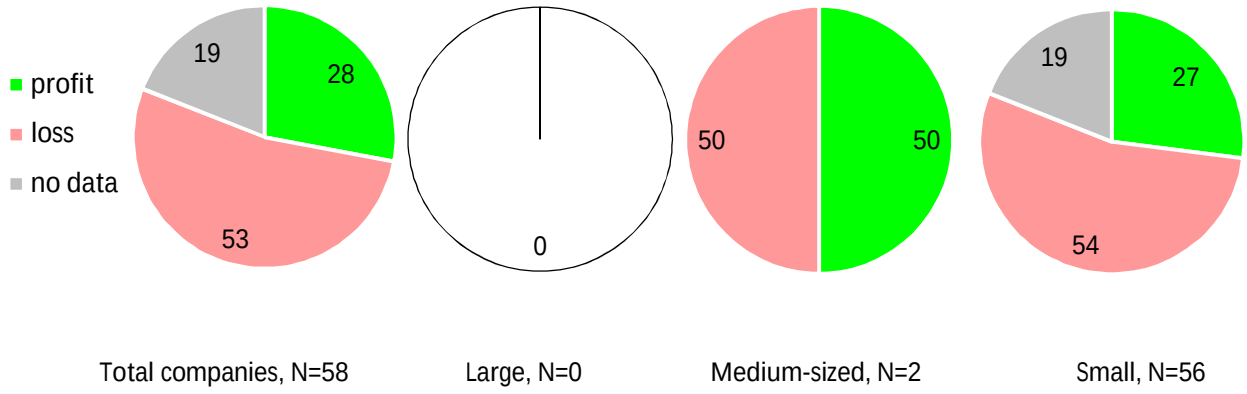

Figure 10. Economic profitability of specialized VR, AR and / or XR companies in 2019 in Finland. Includes 58 companies having development or selling of VR, AR and / or XR technology, products or services as their main task. Large enterprise has turnover of more than 50 million euro, medium-sized enterprise from more than 10 to 50 million euro, and small enterprise up to 10 million euro.

The number of employees in VR-, AR- and XR-related companies cannot be easily estimated because it is reported differently by the companies. Some companies present their personnel in person-years, others in terms of persons employed during the year. The general feature is that very few companies have more than 50 employees and very many companies have only a few employees. The development of the number of employees is broadly in line with the development of turnover, especially in terms of turnover growth.

The largest companies in the industry that develop or sell VR, AR and XR technology, products or services in Finland have more than 100 employees. In 2017, four of these companies were identified (FiVR 2017). By 2021, the number of these companies can be seen to have increased (there were at least 13 of them). Such change is not so much because new large companies would have entered the sector or fairly large companies would have grown very large. Instead, VR, AR, and / or XR have become secondary products or services sold by some large companies that were not before involved in that sector. Furthermore, an examination of the total number of employees in these companies does not give an accurate picture of the extent to which the company focuses on the development of VR, AR and / or XR.

According to the interviews, of the medium-sized specialized companies with core business VR, AR and XR technology, products and / or services and their development, employed a maximum of more than 100 people who were specifically VR, AR and / or XR development positions. In small companies their number was 2–10 people. Typically, in small companies in the sector, almost all employees work at least part of their working time in VR, AR and / or XR development tasks. In contrast, in larger companies, the work tasks are specialized and some employees focus full-time on the development of VR, AR and / or XR.

The majority of specialized companies in the sector were involved in the development of VR or AR. The development of XR was carried out full-time by only a few companies. On the other hand, in the development of technology, the differences between VR, AR and XR may be small, so the classification of companies' activities into only one technology is only indicative. The tentative categorization of companies' main activities indicate that they had their activities in VR (43%), AR (19%), XR (7%) on in the combinations of these

(31%). According to the interviewed companies, their development activities had changed during the COVID-19 pandemic. Substantial changes were an adaption to the new ways of working and a shift of focus to more in the future and in the needs of the clients. For larger companies in the sector, this meant, for example, postponing the project implementation schedules at the request of clients and reducing the number of projects in the project portfolio due to slower and fewer new orders. For many small companies in the industry, it meant the complete cessation of development activities.

The usual industries were consulting services, software and application services, and various design services (see Table 1). Typical products of these companies were marketing products, video and photography, various industrial products, and games and entertainment products. For specialized companies in the sector whose core business was VR, AR and / or XR technology, products and / or services and their development, the usual industries were software and application services (Table 1). Typical products of these companies were industrial products, marketing products, gaming and entertainment, and simulations and modeling.

Very few companies carry out an active, systematic and extensive analysis of what is going on in different economic activities and consider what kind of products or services could be proactively offered to them (see also Chapter 4 on the use and demand of Finnish companies' VR, AR and XR products and services). Products are developed for customers on a demand-driven basis, i.e., what is ordered is also developed and produced. As a result, companies in the sector have given little systematic and in-depth reflection on how virtual, augmented or extended reality products or services could be used to develop innovation in companies or other organizations.

The interviewed companies reflected that some VR, AR or XR products and services are utilized in innovation processes, especially in the final stages of processes, when, for example, service functions are renewed or a prototype is designed into a material form. In contrast, little attention has been paid to the use of VR, AR or XR products and services in the early stages of innovation processes, such as generating ideas from prior knowledge through stakeholder interaction, knowledge interpretation, contextualization and innovation service design. VR, AR and XR products and services can be well and effectively adapted to promote the development of innovations, which are supported by the interaction of people and machines in combinations of physical space and virtual space (Jauhiainen 2021). According to company interviews, companies in the sector themselves do not utilize VR / AR / XR applications in their own innovation activities.

4. Demand in Finland: VR, AR and XR use by companies

VR, AR and XR are emerging technologies that can be utilized in many ways in companies in a wide variety of industries and services. These technologies can be used at different stages of the production process, starting with the ideation of a product or service and the sourcing of the necessary raw materials. The process continues with the development of ideas, products and services and always their design, testing and marketing. Ultimately, a company can use VR, AR, and XR applications to get feedback from the market that leads to further development of a product or service or recycling of used products.

The use of VR, AR and XR applications in Finland is limited only by the imagination of companies utilizing them to come up with uses that support the company's operations, its ability to utilize them economically sensibly in business operations and the bending of these technologies to companies' needs. The context in which the products and services are received is also important. With the development of technology, various VR, AR and XR devices also operate independently without the need to connect them to a computer. As data transfer rates increase, 5G networks become common as well as cloud services such as load-balancing and cloud-balancing of data transfer making devices, programs, and applications more efficient and convenient to use.

In order to determine the demand for VR, AR and XR technologies in companies, interview material was collected in December 2020 – January 2021. A total of 51 companies were asked about their (possible) use of VR, AR and / or XR in their business and innovation activities. The effects of distance working and restrictions related to the COVID-19 pandemic on companies' innovation activities were also asked. Companies of different sizes and at different stages of development from Finland in the primary production, processing and services industries were selected for interview. The industries were agriculture, fisheries, forestry, energy, logistics and transport, technology, forest industry, paper industry, mining, machinery, metal industry, construction, trade, healthcare, tourism, banking, education, restaurant and entertainment. In addition, it was ensured that among the companies planned to be interviewed, the companies included those mentioned to be the most innovative in Finland in various rankings. From each industry, one leading company in the industry, usually of international importance, one medium-sized company with a national or at least regional significance in Finland and one small company with a predominantly local significance were selected for interview. The companies were located in different parts of Finland. This sample provided an overview of the use of VR, AR and XR by Finnish companies and the potential demand among companies, whether the company had used these technologies before or not. The names of the companies interviewed are not mentioned in this report to guarantee their anonymity.

In addition, 7 interviews were conducted in December 2020 with the umbrella organizations in different sectors on the impact of the COVID-19 pandemic on the business field and innovation in their sector and how VR, AR or XR could support business development in the sectors represented by the organizations.

4.1. Use and demand of VR and AR in Finnish companies at the beginning of 2021

By the 2020s, virtual reality technologies and augmented reality have become common as technologies, products and services in the use of Finnish companies, so it is not possible to give an overview of the situation in Finland in this report. In addition, the use of VR and AR is increasing year by year, so the description of the situation will become obsolete within a few months. At the beginning of 2021, there may already be thousands of companies in Finland that utilize VR or AR technology and applications in their operations in some way.

The view of several of the companies interviewed was that business processes that can be easily digitalized could be brought within the scope of VR and AR if this is considered to be of economic benefit to the company. There are particular benefits to saving time and material costs. Companies also respond to

demand, i.e., as VR and AR become more widely known and used by other companies, public administration and the general public, VR and AR will also be used as an interface from companies to current and future customers. VR and AR technologies and products used must meet the needs of companies.

One third (34%) of the companies interviewed had used VR or AR technology or applications in some way in their operations and two out of three (66%) had so far not used them. In general, large and especially international companies were those where the use of VR and AR applications was already common, and they also felt that these technologies were useful. The cases presented below concerning Finnish companies from different industries are only examples and do not describe the situation of the entire industry in Finland.

The international examples of the VR and AR use in various industries presented here base on dozens of freely available websites and descriptions of technology developers and development reporters and marketers in the field. These sources are not further identified in this report. Examples of the use of VR and AR technologies in different industries are individual products or services that have already been implemented and do not necessarily describe the most common use of these technologies in the industry. In addition, recent key studies examining the applications of VR, AR, and XR technologies in different industries were reviewed (see Berg et al. 2018; Damiani et al. 2018; Gerup et al. 2020; Hsieh and Lee 2018; Martinetti et al. 2019 ; Ong and Nee 2004; Palmarini et al. 2018; Rejeb et al. 2020; Wagler and Hanus 2018; Wolfartsberger 2019; Yung and Khoo-Lattimore 2019; Zhang 2018).

In the agriculture and fisheries sector, some of the Finnish companies interviewed saw that VR and / or AR was becoming part of, for example, product marketing. At the same time, other companies acknowledged that they had not yet found use for VR and / or AR applications, so they had not yet deployed them. On the other hand, technologization was already an integral part of agricultural and fisheries activities, and the companies interviewed considered, for example, the utilization of artificial intelligence in their own operations. Internationally, there are examples of the use of VR and / or AR in agriculture, for example by better visualizing the fertilized crop area or where pesticides have been applied in the fields, how growth varies in the cultivated area or where there are pests. Simulation and training of the right farming or fishing techniques are also possible with these applications. Product marketing and interest can also be increased by making virtual applications of production processes, for example, by showing how concrete farming or fishing has taken place. This can also be combined with spatial information, i.e., accurate geographical location-based information about the elements of the environment. AR can also be used to present products without the need of consumers having to see the right material product and, for example, visualize the nutritional value of the product with three-dimensional digital images. If desired, the customer could go virtually to the field or the sea or even inside the cultivated product or fish.

In the forest and paper industries, many of the Finnish companies interviewed had VR and / or AR applications in use. These related to, for example, the design and maintenance of machines. In addition, they were utilized in training and in the presentation of the company's products and production processes, as well as in customer service. Some companies also have virtual projects, such as a virtual forest, where anyone can get acquainted with the operating environment of this industry virtually and see the effects of forest measures in the short and long term, or even get to know the forest's diverse ecosystem. Applications for business partners and other customers are also of interest. The VR or AR application should be able to easily and cost-effectively present customers with products that are still at the design stage. This would provide quick feedback on the prototype without making a concrete physical product and reduce the need to travel to present the product to different parts of Finland and the world. Some large companies develop VR and / or AR technology and applications in their own laboratories. Internationally, there are examples of VR or AR applications that allow the company's partners or customers to get to know the plant or its operating environment in detail, for example, before negotiations or investment decisions are made.

In the mining industries, many of the Finnish companies interviewed already use VR and / or AR in product development and modeling. This can be applied to the training of workers, the practice of new activities or, for example, the simulation of the effects of explosions on the environment. Digital visualization helps to better understand, for example, the progress of drilling within the bedrock and to make constant use of new data on bedrock properties. The virtual simulated environment also allows the companies to operate in situations where it is not possible to see the object one is working on or provide visual information about, for example, the adequacy of batteries or fuel and the remaining time while the user focuses on his or her demanding work task. Also in the equipment maintenance and repair, VR and / or AR provides the ability to receive precise instructions so that the repairing person can use both hands simultaneously for the repair tasks.

In the metal and machinery industries, the use of VR and / or AR in the Finnish companies interviewed has become more common in recent years. Especially in the machinery industries, the use of VR and / or AR is common in product development and these technologies are also added to end products. It is common to make a 3D model of a prototype of a final product into a virtual space where it is viewed. VR glasses are also utilized to help the preparation of a developed product. However, VR is not used for actual innovation activities. In applying AR, quality per price ratio is often the deciding factor, and the technologies are not yet good enough for some of the companies interviewed. In the metal industry, the application of VR and / or AR is less common. On the other hand, many global industries, such as the automotive, aerospace, oil, gas and defense industries, generally use VR and / or AR technologies in their operations. This technology is also increasingly integrated into a number of end products in these sectors.

In the energy sector, the Finnish companies interviewed apply VR and / or AR, for example, in the maintenance of factories and equipment. Factories can be operated, serviced and maintained more cost-efficiently with these technologies. It is also possible to better visualize energy production processes, identify potential risks in advance and provide interactive guidance on different activities. The Finnish companies that already use VR and / or AR technologies have plans to expand its use and many other companies intend to introduce it. It is also of interest to apply the use of these technologies in innovation. One of the leading companies in the industry has a complete virtual factory.

In the transport and logistics sectors, the Finnish companies interviewed had not yet used VR and / or AR in their operations because they had not recognized the benefits. At the same time, companies mentioned that if these could be meaningfully integrated into existing products or services, the applications could be deployed. Internationally, VR has been used as a planning tool when designing new logistics chains. Suppliers also have AR solutions. Internationally, VR and / or AR has already become an integral part of logistics companies. As in many other fields, it is used for training, streamlining production processes and reducing errors in advance. For example, it is possible to plan the packaging and transfer of goods (from small goods to containers) to be efficient in time and space, and to guide the operation of the logistics chain from the very beginning to the delivery at the destination.

In the technology sector, the Finnish companies interviewed mentioned, somewhat surprisingly, that they had not used VR and / or AR in their own operations, but were interested in this possibility. On the other hand, many companies in the industry produce these technologies and services for the specific needs of other companies, so that utilizing this technology designed for another context in one's own company does not usually make sense.

In the construction industry, the Finnish companies interviewed had applied VR and / or AR in, for example, education, training and design in the industry. Utilizing these technologies, for example, helps in planning the various phases of a demanding construction project by visualizing the phases or alternatives. This can be used to facilitate collaboration with both partners and customers. International examples show that the design of the building can also be carried out simultaneously from different parts of the world. The

applications also make it possible to identify possible errors in the construction process in advance. It is also possible to practice various demanding construction situations in advance and in this way increase safety and efficiency on construction sites. Remote access to machines and robots will also be made possible with new VR and / or AR technologies.

In the retail sector, the Finnish companies interviewed had made very little use of VR and / or AR applications. Possibilities of use in customer service, staff training and evaluation of customer behavior were mentioned. Internationally, applications in the field have grown tremendously in recent years. Potential customers can familiarize themselves with the products in advance by seeing them digitally in three dimensions through augmented reality. The customer can customize the look of the product by adding elements to it before making a purchase decision. Elements of augmented reality can be used as part of the advertising or use of products, thus increasing loyalty to that product. It is also possible to walk through a three-dimensional virtual store and shop there by selecting and picking products like in a physical store. With the help of AR, instructions for use or tips about their various possibilities can be added to already purchased products.

In the healthcare industry, the Finnish companies interviewed still found VR and / or AR technologies to be slightly underdeveloped to have a relevant use in their core competencies. Deployment of a useful application is possible if this investment makes economic sense. Internationally, virtual simulations are common, and they can be used to practice healthcare situations, for example in accidents or surgical situations in different conditions. The effects of medical drugs on the human body can also be demonstrated through VR and / or AR applications as well as the spread of diseases, such as coronavirus. The applications also allow one to enter virtually the human body and organs, up to the molecular level if needed. VR and / or AR applications have been used, for example, in psychology to treat fear states.

In the financial sector, the Finnish companies interviewed had not yet used VR and / or AR technologies in their operations. There would be interest in using it if a suitable application could be found. Internationally, there are already examples where the three-dimensional visualization of data about the financial development increases the understanding of complex interactive financial-related processes. This can be presented more effectively to customers as well. Holographic workstations are one way to do this.

In the education sector, the Finnish companies interviewed have utilized VR and / or AR in many ways in their area of core competence, i.e., in education and training. Many activities that previously required physical traveling or material objects have been taken to a virtual space where training takes place. Interest in the wider use of these technologies is growing, especially due to the constraints brought about by the COVID-19 pandemic. The positive effects are seen to be that distance learning and meetings reduce travel costs, save employees time, and reduce climate impact. Projects developed in the field show how the virtual environment can be widely used as a substitute for classroom-based education.

In the restaurant industries, the Finnish companies interviewed had not yet used VR and / or AR, partly due to the fact that they had not yet found a suitable topic or a service provider working on an interesting topic. Internationally, the use of this technology has already become widespread in the day-to-day operations of many restaurants and cafes. As in other sectors, this can be used to train employees in different functions or customer service. Menus or available products can be presented using AR applications to facilitate pre-selection, or products can be accompanied by images, stories, information about their nutritional value, and other elements that make them more appealing. One can learn more about them while waiting for one's order to arrive, or offer AR games that can be used with a smartphone during the waiting time. It is also possible to get acquainted virtually with the manufacturing process of a product, such as a burger, from the production of raw materials to the final product. In this way, VR and / or AR technologies are used to support and strengthen the customer experience. Another possibility is also to provide a visual experience by using AR to customize the restaurant environment with augmented reality application to what each customer wants at the time of use.

In the travel and tourism industries, the Finnish companies interviewed had only made little use of VR and / or AR. For some companies, this had been utilized in the advertising of travel destinations, for example, showing the key sites with the 360VR. Internationally, digitalization and VR are increasingly present in the tourism industry. Various VR and / or AR applications are common internationally, and they can be used both in travel destinations and before or after a trip. Before the trip, tour operators can tell about their destinations and market them more visually interesting ways with the help of AR technology, or the person considering the trip can get to know the destination in a virtual environment. Visual descriptions of the real environment of the travel destination using 360VR applications are common. At the destination, the traveler can get more information about the hotel, resort or travel destination using AR technology on their smartphone. The tourist can also receive messages (advertisements or information) when he moves in the vicinity of certain places (for example, museums, restaurants, shops, etc.) by utilizing the beacon applications. Digital technology allows for accurate access to the details of objects. It is possible to take a trip only in a virtual environment. These trips may be the only option for people whose physical travel is impossible due to age, health, or other considerations. With technology and materials, it is possible to make trips to the past, i.e. to desired historical periods, for example in an ancient city. There are already virtual journeys by means of travel such as airplanes built for this purpose or train carriages that do not physically move. Travel agents and offices can be moved to virtual space and, in this context, make planning and booking a pleasant experience inextricably linked to the trip. After a virtual or physical trip, one can visit the desired destinations again in a virtual environment and revisit sites one have already seen or learn new details about them. Prior to the COVID-19 pandemic, virtual tours were not considered realistic alternatives to physical travel, but with the pandemic, trips to interesting travel destinations in a virtual environment alone have increased in popularity.

In the entertainment industries, some of the Finnish companies interviewed had utilized VR and / or AR in their operations and others were planning to do so. The organization of various virtual events and related services has become widespread due to the movement and assembly restrictions because of the pandemic. Some of these services will remain in place even if the pandemic restrictions are lifted. VR and / or AR applications were originally developed specifically for entertainment purposes, so it is impossible to list these uses in this context. A significant evolving theme is the tailor-made services and opportunities for individual consumers through VR and / or AR applications, as well as the intensive experience of community at large VR events.

4.2. Use and demand of XR in the Finnish companies at the beginning of 2021

Extended reality (XR) is part of the expanding reality (ER). This reality comprises interconnected elements of physical reality, augmented reality, and virtual reality. The physical material environment, people with their bodies and senses, and digitally enhanced reality interact with each other. The user is able to operate in a material environment with the addition of digital elements that he or she is able to use as if they were part of a usual environment. Integrated digital elements can shape the user's experience of the material environment through devices (virtual glasses, headgear, gloves, etc.) connected to the user's body. This creates an intense immersive state of experience that is more than just an experience related to physical, augmented, or virtual reality.

In the beginning of the 2020s, XR is still in rather initial phase but it may become the common reference during the 2020s, and especially when the 6G networks will be established in the 2030s. Then many comprehensive technologies will surround an increasing number of people around the world capturing entire life experiences and detailed physical environments into an immersed blended environment. According to Latva-aho and Leppänen (2019), for this are needed several supporting technologies that are not yet entirely

available, at least for mass consumption. These include, among others, imaging devices such as light field, panoramic, depth-sensing, and high-speed cameras; biosensors for monitoring health conditions such as the heart rate, blood pressure, and neural activity; specialized processors for computer graphics, computer vision, sensor fusion, machine learning, and AI, either in the device or in the surrounding network infrastructure; and fast wireless technologies including positioning and sensing.

In general, it can be stated that the use of XR in the business or development of Finnish companies was mostly insignificant at the beginning of 2021. On the basis of the companies interviewed, it has also not yet been used much in innovation activities, i.e., to generate or develop innovations. The application of XR is still in the experimental stage. Many companies see it as a technology that is only about to break into wider use in the near future. Some companies and organizations recognized that XR will become part of their operations, but XR is still a potential future phenomenon for many companies' operations. Some companies felt that the technology was not yet sufficiently developed. On the other hand, it was considered essential that when XR is integrated into the business, it should have a concrete target, objectives and results. XR is not a technology that companies are starting to apply for fun, but it must have a clear business benefit.

Interest in the application of XR is growing among interviewed Finnish companies. At the same time, there are not always clear boundaries between XR, AR and VR technologies, and companies may not specify whether the technology they use is XR or other VR and AR applications in a mixed reality (MR) principles. Companies recognized that XR is more than only VR or AR or their combination. Besides interviewed companies, there are also many other companies using XR in Finland. Furthermore, the sample was not made for focus on specifically companies that use XR. Instead, the aim of this report was to provide an overview of XR's use in companies of different sizes and not to focus on companies that are significantly more advanced. Outside Finland, there are more examples of how XR has been used in different industries, but these examples are not discussed in this report.

In the agricultural industries, some of the Finnish companies interviewed mentioned that XR has not yet been used because the companies have not identified how XR could be directly related to the company's operations. One company in the field has considered the application of XR to advisory activities.

In the fisheries industries, none of the Finnish companies interviewed mentioned the use of XR in the company, and at least it was not yet considered relevant. The related industry association highlighted the possibility of using XR in the demonstration of production environments and related exercises.

In the forest and paper industries, some of the Finnish companies interviewed saw XR as an interesting topic, but its direct benefits for business were not yet seen. However, there was interest in solutions that would be commercially viable. The interest was greatest in the most international large companies that already had experience using various virtual reality applications. Companies that do simpler mechanical work did not see the meaning of XR in their activities.

In the mining industries, some of the Finnish companies interviewed were interested in XR's possibilities. Some companies had already considered in more detail what in XR would be suitable for them at different stages of the business process. XR technology could be suitable, for example, for mining technology training and simulation, as well as for precise product development processes.

In the metal and machinery industries, the views of the Finnish companies interviewed were divided on the use of XR. In companies representing the more traditional metal industry, XR was not seen to bring any additional benefit. A product supported by XR could only work if it would be cost-effective enough and used to fulfil some pre-defined need. On the other hand, XR is already in use in more specialized engineering companies. It is seen as having a wide range of applications, but not necessarily in innovation. XR has been used, among other things, in the prototype development and the maintenance tasks of machines. Some

companies felt that XR will be a technology that will be more widely adopted in the near future. However, this is expected to take a few more years.

In the energy sector, the companies interviewed already apply XR. For example, they use it in the maintenance of energy flows and larger equipment, such as factories. It is of interest to expand this even more in these areas and to connect XR to innovation processes as well.

In the transport and logistics industries, the Finnish companies interviewed were still in a pending position with regard to XR. The use of XR had been considered, for example as part of traffic route signs. However, demand is expected to emerge and then respond to it with a XR application.

In the technology industries, the Finnish companies interviewed had not themselves used XR in their own operations, other than developing such technologies for others. At the same time, there has been a growing need to introduce XR in the companies' own development process.

In the construction industry, the Finnish companies interviewed had not yet used XR much. They had considered how it could be used, for example, in urban planning or building design, as well as in teaching these design processes. The related industry association also highlighted the possibility of using XR in design companies and component manufacturers.

In the retail sector, the Finnish companies interviewed showed interest in utilizing XR. On the other hand, one company interviewed mentioned that current XR applications are not yet sufficiently advanced in terms of technology and content.

In the healthcare industry, the Finnish companies interviewed saw that the current XR applications are not yet technologically advanced enough. At the moment, it seems that applications can be considered in a few years. On the other hand, if there would be already some useful applications, then their use could be considered. XR is also an investment issue. Internationally, there are already examples of how healthcare services can be implemented remotely using XR technology. In principle, more demanding measures such as surgeries could also be implemented using XR technology and robots.

In the financial sector, the Finnish companies interviewed had not yet identified the use of XR technologies in their industry, but were in principle interested in this. Internationally, there are already applications in the XR use specifically for the financial sector. It is possible to view, transfer and combine data in three dimensions so that everyone can see and modify the financial transactions simultaneously and combine the development of stock exchange with other developments.

In the education industries, the Finnish companies interviewed have taken advantage of virtual reality and related technological applications in many ways. On the other hand, the companies did not mention the details regarding the use of XR. The industry umbrella organization stated that XR can open up opportunities in, for example, education export. This could include, for example, the possibility of providing education from Finland to foreign students without the students having to be physically in Finland. Extended reality could allow for better interaction than current online learning platforms.

In the restaurant industry, the Finnish companies interviewed had not taken advantage of XR's use and had not yet identified a suitable service provider.

In the travel and tourism industry, the Finnish companies interviewed had not taken advantage of the use of XR, but were interested in the service. With the limitations of physical tourism during the COVID-19 pandemic, the XR, which offers a more immersive experience, may remain the only option to explore many destinations on the Earth.

In the entertainment industry, the Finnish companies interviewed showed significant interest in leveraging XR. Some companies suggested that XR will be a significant part of the industry. At the same time, companies are looking for exploitation opportunities and suitable XR tools for this. As with VR / AR applications, the use of XR will become the fastest growing in entertainment-related issues. The mix of physical and digital / virtual experience will increase with the development of technology, allowing XR to become an integral part of many entertaining experiences as we move into the late 2020s.

4.3. The impact of the COVID-19 pandemic on companies' innovation activities

In March 2020, the Government of Finland imposed various restrictions on the movement and assembly of Finns to prevent the spread of the coronavirus. As a result, many companies switched to distance work. It marked a change in many routines and usually face-to-face formal and informal meetings had to be postponed to the event either by phone or via the Internet. The number of Zoom, MS Teams, Google Meet and Skype meetings increased dramatically. Of the 51 companies interviewed, only two had not introduced at least partial teleworking, i.e. 98% of companies applied distance working to a certain extent.

Slightly more than half of the companies interviewed (53%) estimated that distance work had a negative impact on the company's innovation activities, a third (34%) estimated that it had no effect and one in six (13%) reported that switching to distance work had increased innovation in the company. On the other hand, as many as three out of four (74%) of the companies interviewed had produced an innovation related to the context of the COVID-19 pandemic (22% had not received, 4% could not say) – to the new context or to the virus prevention itself. This demonstrates the rapid ability of many Finnish companies to respond to a changed situation. On the other hand, the companies that did not innovate in the context of the COVID-19 pandemic were those that were significant players in their field, and in any case their end products or services were in strong demand. On the other hand, there were also smaller companies that performed quite simple basic tasks that had not been affected by the pandemic per se at all.

The innovations related to the COVID-19 pandemic (between March and December 2020) in companies were related to the internal organization of the company on the one hand, and in relation to customers and the market on the other hand. The positive effects on companies had arisen from a new context that has forced companies to rethink their operations, products and services in a new way. As a result, the companies and their operations had been reformed all the way to the end products. Dictated by restrictions, many companies had made a significant digital leap. For example, they had replaced a variety of previously face-to-face meetings and negotiations with digital tools. Many companies had found that this saved significant time and money because they no longer used the essential resources to travel or move from one place to another. Global mobility constraints also made it easier for companies to connect remotely to customers and partners using appropriate technological tools. Some companies had noticed how their international operations and connections had increased substantially during the pandemic.

Others also mentioned that their own operations had accelerated and become more efficient as long meetings had decreased. Employees were also able to focus better on their tasks. A culture of trust had emerged, where it was noticed that work could be done even if the upper management would not know where each employee was and what exactly he or she was doing at any given time. At the same time, many companies have made internal arrangements and organizational reforms, as the market also changed or they had to reorganize the supply of products and services to customers. For some companies, this brought new markets, for others new products and services and more efficient business. Many of these new solutions were related to digital remote connections. Some companies had also launched products directly related to the fight against the coronavirus. The pandemic was an external factor that forced many companies to

rethink their operations in a new way. In this context, flexible and innovative companies took advantage of this as an opportunity for “creative destruction” from outside.

Many companies also mentioned the disadvantages caused by the COVID-19 pandemic. Such disadvantages were mentioned more often but the answers tended to repeat similar issues. These included a reduction in communication between employees that was considered to be a serious setback. Employees no longer occasionally met face-to-face, leaving fewer opportunities to throw new ideas in free-form encounters. Spontaneous meetings bringing in new ideas had been substantially reduced, thus that hampered the emergence of innovations. There were also perceived greater challenges in the transfer of tacit knowledge within the company. Although digital distance communication tools such as Teams enabled conversations and meetings, many companies saw it and other technological means of communication as more rigid and selective discussion platforms compared to the inherent face-to-face interaction. Many companies felt that innovation processes had slowed down as a result. The longer-term effects of the pandemic situation will only start to show in companies and in Finland with a delay of a year or two when it becomes clear what effects the initial changes will have on the company's development and their innovation activities.

5. Conclusions

VR, AR and XR as technologies will develop substantially in the 2020s. Their applications become part of the operations of companies and public administration, and their use is becoming more common both at work and in leisure time. The global market for the sector is growing very significantly, and the annual business associated with the sector will grow by perhaps hundreds of billions of euros from the current market of just over 10 billion euros.

From the perspective of the global market, Finland is a small region due to its small population - smaller than dozens of cities around the globe, not to mention countries. On the other hand, the special features of Finland, one of the most important of which is the Finnish language, affect the fact that there is also local demand for VR, AR and XR in Finland. The best way to answer this is with products and services that have been developed or modified in Finland. Instead, the markets of companies seeking significant turnover are located outside Finland and often in the context of global competition. On the other hand, Finnish companies specializing in the development of VR, AR and / or XR can also find smaller and narrower markets around the world, provided that supply meets demand. In Finland, many companies do not know how to ask for the right VR, AR or XR product or service. On the other hand, technology developers do not always extend their products or services to the emerging opportunities to which VR, AR and XR would add value. Supply must feed demand at this stage, when demand for VR, AR and XR in many companies and public administrations is still low. VR, AR and XR for entertainment remain globally still the main purpose of use for these technologies and applications. Relatively faster than this, VR's, AR's and XR's applications for business and public administration services, such as marketing of corporate products and healthcare services, are growing. As a result of the 2020–2021 COVID-19 pandemic, a wide range of applications related to distance work, meetings, learning, entertainment and tourism will develop rapidly quantitatively and qualitatively.

At the beginning of 2021, there are an estimated 140 companies in Finland, in which VR, AR and / or XR play an important role in their business – most often VR or AR. Of these, 82 are companies whose main businesses are other than VR, AR and / or XR but they earn a significant revenue from these technologies of applications. The number of these companies can be expected to grow significantly in the 2020s, as VR, AR and / or XR become intertwined as part of their “normal” operations. In some companies this brings significant by-products to their core business. In preparing this report, we identified 58 companies in Finland whose core business is the development of VR, AR and / or XR and related technologies, products and / or services. The number of companies providing VR, AR and / or XR services and products can be expected to increase as many “ordinary” Finnish companies and the Finnish public administration wake up to the situation that VR, AR and XR applications are an important part of the services they provide. About half of the companies focused on developing VR, AR and / or XR technologies, products and / or services are very small companies, often with only a few employees, with a turnover of less than € 100,000 per year. Thirteen Finnish companies specialized in VR, AR and / or XR have achieved a turnover of more than one million euros, and several of these are globally noticeable in their respective fields. The global market and the internationalization of development, production and marketing processes are essential for the growth of these companies.

Reality has expanded in recent decades and continues to do so. Physical material reality is increasingly intertwined with digitally added, supplemented, mixed, and augmented reality. VR, AR and XR expand the world of human experience and become part of monitoring, analyzing and influencing human activities. Thus, market-driven augmentation of reality also has its downsides that need to be addressed by individuals as well as society and legislation. VR, AR and XR can attract people to consume more, but their application can also support sustainable development by reducing unnecessary mobility and the production and use of physical products. As VR, AR, and XR become part of people’s everyday lives, they become an important part of knowledge formation and the emergence of new ideas and innovation processes. Finnish companies developing VR, AR and / or XR technologies must find products and services that make VR, AR and XR more effectively part of Finnish companies' innovation.

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Appendix 1. VR, AR and / or XR companies in 2019 in Finland. Companies with important development or selling of VR, AR and / or XR products or services, but they may also have other more important businesses. Companies with development or selling of VR, AR and / or XR technology, products or services as their main task are bolded.

360Mediatalo Oy
3D Talo Finland
3DBear
3rd Eye Studios
ADE Oy
Alter
Anarky Labs
Arilyn
Ataverti
Augumenta
Avains
AXiiO
Barracuda Disaster
Basemark
Brighterwave
Caffeine Overdose
Citor3 Entertainment Studio
Clusterloop
Collaprime Oy
Critical Charm
CSE Simulation Oy
Ctrl Reality
Deeptale
Delicode
Delta Cygni Labs
Dispelix
Eligo.Studio
Elomatic
Etteplan MORE
Event Horizon Designs
Exerium
Fake / Glue
Finpeda
Finwe
Fitness Village
Flatfish Games
Flatlight
flyAR
Flycam
Futuremark Oy
Futurice
Fuusio Labs
Geotrim
Granity
Grib
Group Builder Oy
Happy Hobgoblin
Harha XR
Harhama Games
HipFire Games
HiQ
Hurja
Hypermemo
Iceflake Studios
Immersal
Innogiant
Insta
JJ - Net Group Oy
KollektiWe
Lumous Interactive
Lyfta
M.A.D.
Make Helsinki
Mantisbite
Mekiwi
Memorandum Unlimited
Mobiteos
Morrow Games
Nanocomp
Nordic XR Startups
OiOi
Optofidelity
Osgenic
Peili Vision
Pikseli Arcade
Pinovuo
Player Entertainment
Ponsse
Portaali
Practigame
Premode
Process Genius
Radical Rabbit
Rakka
Rakka
Reality Crisis
Refine Reality
Reform
Reski
Revulon
Rockodile Games
Sciar
SeeTrue Technologies Oy
Sense of Space
Shipyard Games
Siili Solutions
Sitowise
Skeleton Conductor
Sky High VR
Smile Audiovisual
SnowFall
Sofokus
Softability
Sovelto
Stereoscape
Superapp
Teatime Research
TechLemon
Thinglink
Ticca
Tietoa Finland Oy
Tietoevry
Tridify
Umbra
Unitc
Upknowledge
Uplause
Wakeone
Valakia
Valo Motion
Wapice
Varjo Technologies
Vast Reality
Versoteq 3D Solutions
VimAI
Vincit
Virtuaalikuvaus 360
Virtual Air Guitar
Virtual Circus

Virtual Dawn
Visual Components
Visumo Oy
Viversion
Vividworks
Voyant Pictures
VR Cinema
VR4Healthcare
VRETA
XR Marine
Zaibatsu Interactive
Zoan Oy