Deliverable

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D5.3 - Market analysis report

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ABSTRACT

The present deliverable describes the status of the market as of December 2020 for the audio-visual immersive products, with an emphasis in social VR platforms and related technologies. In addition, it provides a set of recommendations based on the market and customer research aiming to provide insightful and meaningful data towards the elaboration of an improved exploitation plan of the project results.

REVISION HISTORY

Revision	Date	Author	Organisation	Description
0.1	20/11/2020	Pascal Perrot	Viaccess-Orca	Revision of Market Analysis and Market Segments
0.2	23/11/2020	Bart Kavelham	Artanim	Comments and Feedback Provided throughout the document
0.3	31/11/2020	Tom de Konick	TNO	Comments and Feedback Provided throughout the document
0.4	8/12/2020	Sergi Fernandez	i2Cat	Comments and Feedback Provided throughout the document
1.0	22/12/2020	Romain Bouqueau	Motion Spell	Final revision and wrap-up

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LIST OF ACRONYMS

Table 1 | List of Acronyms

Acronym	Description
AI	Artificial Intelligence
APAC	Asia-Pacific
APP	Application
AR	Augmented Reality
AT	Austria
AUS	Australia
B2B	Business to Business
B2BC	Business to Business to Consumer
B2C	Business to Consumer
B2G	Business to Government
BN	Billion
CAD	Computer Aided Design
CAGR	Compound Annual Growth Rate
CCS	Cultural and Creative Sectors
CEO	Cheif Executive Officer
CG	Computer-Generated
CGI	Computed Generated Images
CH	Confereration Helvetique
COVID	Coronavirus Disease
CPU	Central Processing Unit
CT scan	Computed Tomoraphy scan
CTA	Consumer Technology Association
CZ	Chech Republic
DK	Denmark
EBU	European Broadcasting Union
EC	European Comission
EdTech	Education Technology
EHR	Electronic Health Record
EIF	European Investment Fund
ES	Spain
EU	European Union
FDA	Foog and Drug Administration

FIVR	Finish Virtual Reality Assosiation
FN	Finland
FOV	Field of View
FR	France
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GE	Germany
GMP	Good Manufacturing Practices
GPU	Graphics Processing Unit
GR	Grecee
HMD	Head-Mounted Display
Hz	Hertz
ICT	Information and Computer Technologies
IoT	Internet of Things
IRE	Ireland
IT	Italy
JP	Japan
KTN	Knowledge Tranfer Network
LiDAR	Light Detection and Ranging
M	Millions
M&A	Mergers & Acquisitions
MR	Mixed Reality
MVP	Minimum Viable Product
NA	Not Applicable
NL	Netherlands
NRI	Network Readiness Index
OECD	Organization for Economic Cooperation and Development
PC	Personal Computer
PWC	Price Waterhouse Coppers
px	pixels
R&D	Research & Development
RGB	Red Green Blue
ROI	Return on Investment
RU	Russia

RWW	Real Wold-Web
SE	Sweden
SLAM	Simultaneous Localisation Mapping
SOP	Standard Operating Procedures
UK	United Kingdom
UN	United Nations
USA	United States of America
VC	Venture Capital
VPS	Vision Positioning Systems
VR	Virtual Reality
XR	Extended Reality
YoY	Year-over-Year

1. SCOPE OF THE REPORT

1.1. PURPOSE OF THIS DOCUMENT

1.1.1. FOREWORD

Virtual Reality (VR)/Augmented Reality (AR) is a key field of the new-generation information and communications technology, which features large application space, huge industry potential, and wide technical span.

In fact, the VR and AR technologies have the potential to transform the way we work, move, communicate and experience things. Not only will these technologies have an impact on our daily lives but are also underpinning the creation of a multi-billion-euro industry. Both, Start-ups, large companies and even governments could benefit from VR and AR.

These technologies have the potential to build on our society creativity, skills and cultural diversity and impact on various industrial and service domains – from manufacturing, engineering, and education to healthcare, arts, entertainment and culture.

The VR/AR industry is now in an exciting development and maturity stage. After years of research and development, technology has reached a tipping point where it is accessible to both consumers and industry and allows large-scale market introduction and adoption. New market opportunities are being created every day, with new ideas on how VR can be used, new start-ups, increased investment and new projects, and they all build on the growing expectation of what VR/AR technology can offer.

1.1.2. OBJECTIVES

The purpose of this deliverable is to map the VR/AR industry and provide an in-depth analysis of the dynamic VR/AR market ecosystem, to address the question of how big the consumer and business market opportunity is and how the technology is evolving across the different categories.

The VRTogether efforts resulted in this deliverable that provides a snapshot of the state of the fast-paced VR/AR market and industry both, globally and in Europe in 2019/2020. It aims to analyse the VR/AR industry, mainly from a business perspective, to examine its current and likely future in the short term (1-2 years) and medium term (2-5 years). Thus, being applicable to gain market understanding, to identify growth opportunities, to understand the competitive landscape, to identify use-cases and the most relevant business components in the context of the VRTogether's project.

As a result, the deliverable:

- Provides guidance on current challenges.
- Raises concerns to be aware of and understand, now and in the future.
- Makes recommendations to leverage opportunities and mitigate concerns.

And, ultimately, the deliverable will contribute to the definition of the joint VRTogether exploitation strategy (D5.6) by:

- Providing guidance on how the solution should be transformed into a viable product.
- Providing insightful and meaningful recommendations for the future development of an exploitation strategy.

On behalf of the VR Together team, **we would like to thank** all the people, industry participants, VR/AR entities, policy makers, support institutions, researchers and other experts **who supported us with valuable insights on this industry.**

1.2. FINAL SCOPE OF THIS DOCUMENT

The present document will be alive during the whole project period, that is, during the 3 iterations of the project. Three different versions will be formally submitted to the European Community and uploaded to the project website.

The first version (Deliverable 5.1) focused on providing an in-depth overview of the immersive audio-visual market. A second iteration (Deliverable 5.2) of the document aimed to provide an update on some of the topics stated in the first version. Additionally, the document focused on new market opportunities like Augmented Reality (AR).

At present, this third version focuses on the presentation of the VRTogether solution, the enabled use cases and on a set of recommendations to ensure a successful launch on the market. The document will particularly highlight:

- Pinpointing the optimal product-market fit. In other words, how the solution could or should be transformed into a minimum viable product (value proposition, functional set-up, value network and financial model).
- The conditions for a successful exploitation of the proposed solution and the associated optimal go-to-market strategy.

1.3. RELATION WITH OTHER VR TOGETHER ACTIVITIES

This document is framed in Work Package 5, one of the objectives of which is to maximize the impact of the VRTogether platform on the VR market and research domain. The results of the project are expected to have a significant impact on the audio-visual market. This WP will:

- Determine overall conditions for **successful exploitation** of the proposed solutions, such as standardization, additional stakeholder involvement, etc.
- Identify **optimal go-to-market strategies** of products using VRTogether technologies. The project should take into account specific requirements of each of the stakeholders and be translated into feasible and viable exploitation plans.
- Organize **maximal visibility for the proposed solutions** by attending major relevant events and setting up direct contacts with potential customers.
- Implement a **communication strategy** aligned with the exploitation strategies of the consortium partners.

2. VR/AR OVERVIEW

2.1. WHAT IS VR & AR AND WHY IT MATTERS

Approximately every decade since the 1970s, there seems to have been a major technological transformation. Each transformation is typically illustrated by a leap forward in how we interact and apply technology and data in our daily lives, redefining the way we communicate, learn, entertain and even work.

The 1970 saw the initial transition from centralised mainframes to personal PC. Then we have seen the eras of server computing, transforming the way business operate; and the rise of the Internet allowing the share of data globally. In the last decade, the explosive success of the smartphone led to a complete transformation of how we interact with technology, first with touch screens and later, by voice becoming our primary interface. In this decade, we are moving into the next technological transformation, where our means of communication and interface are expected to blur the physical and digital worlds, only to become as one.

In this technical premier, we refer to the broad-spectrum of **Virtual reality (VR), Augmented Reality (AR)**, Mixed Reality (MR), 360 degree-video, and immersive experiences as **Extended Reality (XR) or digital reality**.

To comprehend digital reality, we need to understand the concepts that it encompasses. Despite the growing number of acronyms in the VR/AR industry, the terms VR and AR have been used as these terms are simpler and well-known amongst users and the public. VR and AR are spectrums (rather than singular points) containing different types of content, some of which are more immersive or powerful than others. Formal definitions considered in this document are below:

- VIRTUAL REALITY |(VR)
  Refers to a completely immersive virtual and aural world that a user experiences, usually through a head-mounted display (HMD). The research considers 360-degree media to be a form of content within the spectrum of VR.

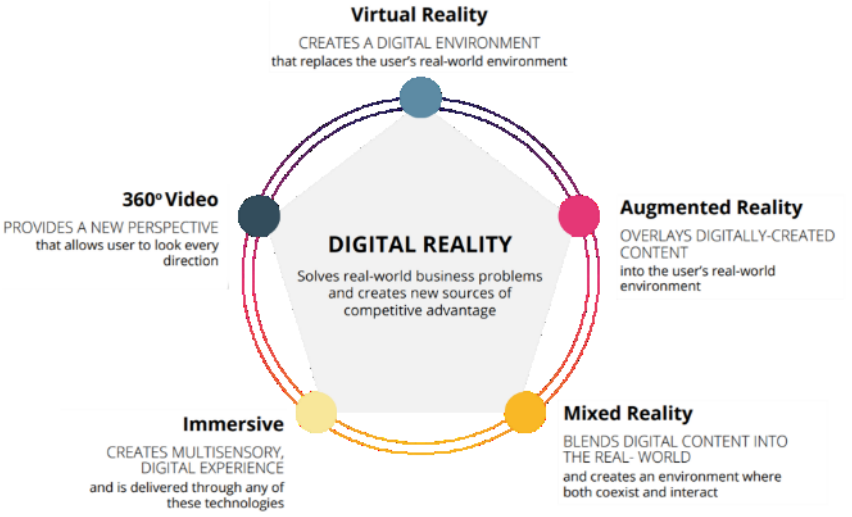
- AUGMENTED REALITY |(AR)
  Refers to a real-world environment on which digital objects and/or information is overlaid either through a head-mounted display (googles, glasses or specialized visors) or via a handheld device with a camera such as a smartphone or tablet. Devices and applications that simply layer digital elements on top of the real world and those that are able to place such objects and data in context with the environment (e.g. on top of tables) are both considered within the spectrum of AR.

On this premise, while VR enables users to immerse themselves in artificial surroundings that portray actual places or imaginary worlds, AR overlays contextual information on the actual physical environment users see, thus combining digital components and experiences with real life[1].

[1] Nelson Kunkel, Steve Soechtig, Jared Miniman, and Chris Stauch, Augmented and virtual reality go to work, Deloitte University Press, February 24, 2016. Available from: https://www2.deloitte.com/uk/en/insights/focus/tech-trends/2016/augmented-and-virtual-reality.html Accessed: 07/07/2020 10:11 CET.

On the other hand, MR characterizes the controlled impact of the AR/VR and the Internet of Things (IoT) trends. MR brings together the virtual and real worlds to generate new environments in which both digital and physical objects—and their data—can coexist and interact with one another[2]. 360° video provides a new perspective that allows users to look in every direction. This is achieved by shooting with an omnidirectional camera or a collection of cameras. Last, immersive experience creates a multisensory digital experience that can be delivered using VR, AR, MR, and 360° video, among other technologies.

Figure 1 | The Digital Reality Ecosystem



Although they by definition are different, VR and AR share common processes and technologies, such as audio software and data processing. They also tend to concentrate in the same business and research topics, hence creating overlapping ecosystems. This deliverable is primarily focused on VR; however, we sometimes talk about VR & AR ecosystems or industries – this is because the VR & AR communities and their development are so interlinked, that in some instances it is also impossible to separate them.

In addition, the convergence of other cutting-edge technologies, such as the Internet of Things and Artificial Intelligence (AI) with immersive technologies is propelling even further the potential of VR, to create a single form of technology that offers possibilities seemingly endless.

VR is used within a wide array of areas, ranging from the gaming industry and entertainment, to training and simulation, including training in the medical field. Other areas of application include education and culture, sports, live broadcasting, real estate, advertising, architecture and arts. More areas of application are still to come. AR has an almost limitless range of uses in a wide variety of areas, be it commerce, technical applications, work processes or education. VR & AR serve both consumers and professional users that can be private and public.

2.2. THE GLOBAL VR & AR LANDSCAPE

2.2.1. VR INDUSTRY – THREE KEY REGIONS

As with many new and disruptive technologies today, VR and AR are industries characterised by global value chains where activities, ranging from R&D, hardware or software production and content creation, are spread out across the globe. Within the global context, three main regions

[2] . Nelson Kunkel and Steve Soechtig, Mixed reality: Experiences get more intuitive, immersive, and empowering, Deloitte University Press, February 7, 2017. Available from: https://www2.deloitte.com/us/en/insights/focus/tech-trends/2017/mixed-reality-applications-potential.html Accessed: 07/07/2020 10.14 CET.

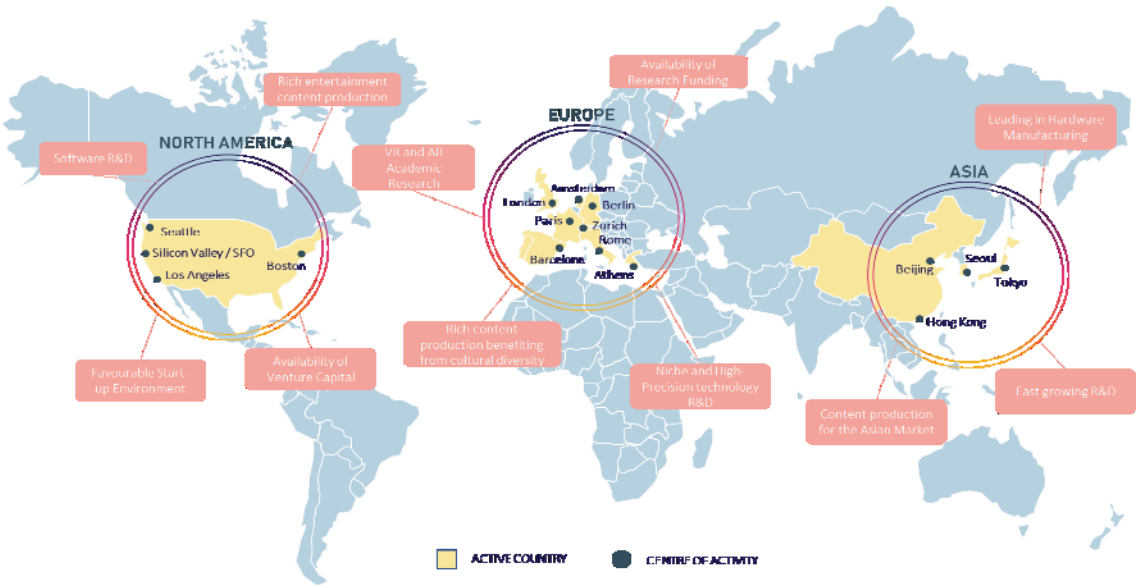
stand out for their major importance in both, in terms of market size, growth and adoption being Europe, Asia and North America.

In this regard, a recent report by the consultancy firm Ecorys[3] highlights each region strengths and weaknesses related to VR and AR industries. The report emphasizes the **European** position within the global VR/AR market having a rich tradition in academic VR & AR research and the place where niche and high-precision technologies are being developed. These technologies can be used for industrial purposes or in specific areas such as manufacturing, medical trainings or engineering development. At the same time, Europe is diverse in terms of languages and cultures, which inspires creative content creation. Across Europe there are various VR & AR hubs where people with different backgrounds share expertise to create new VR and AR applications. European companies and research institutes benefit from research funding from both national and EU sources.

Second, **North America**, and mainly the United States of America (USA), are leading the global VR/AR market. This specific region concentrates most of the R&D in the field in terms of hardware and software, specially centred around Silicon Valley (California) and Seattle (Washington) with the IT giants such as Google, Apple, Facebook or Microsoft. The content production is also boosted by world-renowned gaming studios and production studios. Thus, the USA offers the perfect ecosystem and favourable conditions for the development of VR & AR industry, especially for start-ups. In fact, the country has the most active Venture Capital (VC) funds in the field who are willing to invest in early-stage technology start-ups. Under such premise, is the reason why commercial VR and AR companies started in the USA earlier than elsewhere in the world.

Finally, in the **Asian** market many VR and AR companies are popping up in China, Japan and South Korea. Major Asian technology firms such as Samsung, Sony or HTC are active in the mass manufacturing of VR and AR hardware and are propelling the market. The Asian VR and AR market has been growing at a high rate also driven by the support of local governments.

Figure 2 | The Global VR and AR Landscape: Creative Hi-Tech Europe, Strong USA and Fast-Growing Asia



Adapted from: Virtual Reality and Its Potential in Europe. Ecorys, 2017.

[3] Bezegová, E. *et al*., 2017. Virtual Reality and Its Potential for Europe. Ecorys International B.V. Holland. Available from: https://ec.europa.eu/futurium/en/system/files/ged/vr_ecosystem_eu_report_0.pdf

Focusing into the **European Region**, by which we understand not only the 27 states of the European Union (EU), but also Switzerland, Norway, Iceland, Lichtenstein, the Balkan countries, and Eastern Europe, it has a number of **particular strengths** that enable it to be an important player in the global VR/AR industry.

› STRONG RESEARCH AND DEVELOPMENT

Since the early 1990s, and according to EU funded Ecorys Report, research funds have supported more than 450 projects dedicated to VR and AR, with a total of over €1 billion. Due to the availability of public research funding (European Union and national public funds), European universities and research centres have been experimenting with VR and AR since the 1970s and are well advanced in coming up with successful applications.

› THE CULTURAL DIVERSITY IN EUROPE

One of the founding principles of the European Union is respect for its diversity. The upheavals of European history show the importance of protecting national minorities and allowing different religious, cultural, linguistic and ethnic identities to flourish. Such cultural diversity enables rich storytelling that provides an excellent basis and inspiration for VR content, ranging from films to gaming. This makes European content stand out on the global VR scene. European creativity in VR has been described as rivalling USA and is promoted by public broadcasters who are already actively exploring the artistic and educational potential of VR/AR.

› A HIGHLY SKILLED WORKFORCE

A skilled workforce makes it relatively easy for companies to find employees and grow. Europe has many highly skilled and qualified workers capable of 3D modelling and creating computer-generated (CG) content for the gaming industry and VR animation. European universities teach developers to approach VR from different perspectives, including art, design, industrial production, film, game design etc.

› EUROPEAN CITIES ARE HISTORICALLY DIVERSIFIED

European cities attract people and experts from different backgrounds and cultures. They offer excellent breeding grounds for VR and AR technologies that will be used for different aspects of work, living and creation. The unique multidisciplinary and culturally diverse nature of cities in Europe is an important asset. VR and AR applications arise when creative people meet with engineers, programmers, and editors, who in turn meet with people from application domains in industry who work closely with marketing and business experts.

› COLLABORATION SPIRIT

For the time being, the spirit of collaboration seems to outweigh that of competition within the VR communities in Europe, as well as between different industrial sectors. In fact, collaboration can be considered as the new form of competition by means of dynamisms and open and changing ecosystems. This is largely thanks to the funding of collaborative research in Europe (such as that of VRTogether), the increasing number of European associations, incubators and accelerators, and many spontaneous VR/AR meetups and events where networking takes place (e.g. World VR forum or Mobile World Congress).

› HIGH-PRECISION AND NICHE TECHNOLOGIES

Europe stands out for its well established and robust development pipeline of high-end, emerging and niche technologies. The European region is strong particularly in middleware and software, both of which are soon expected to emerge as the areas of true value for VR. On the user side, several industries are positioning as early adopters of VR and AR technologies, such as the European automotive industry, machinery and entertainment just to name a few.

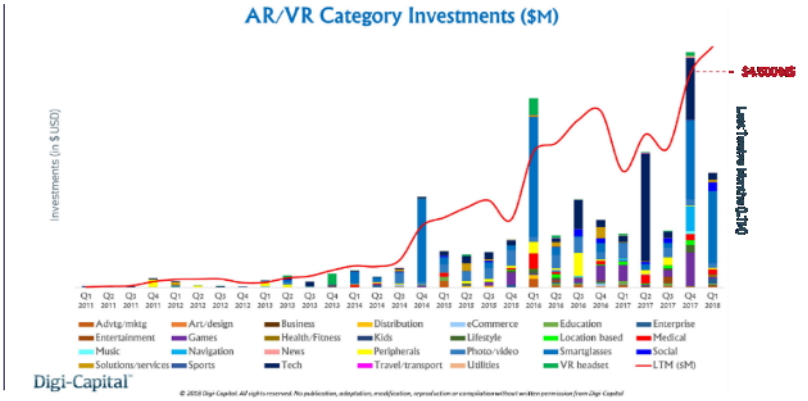
2.3. CONTINUOUS GLOBAL INVESTMENT IN VR/AR IN THE PAST YEARS

All in all, the VR/AR industry is booming and not just in the USA or in Asia. Europe has known a slower start but has definitely got up to speed during the past couple years. In fact, the **European VR/AR ecosystem** continues to expand rapidly with an ever-increasing number of companies who have rushed into the market. This has prompted local and international investors to invest in these segments and a prosperous breeding ground for VR solutions is being created.

According to Digi-Capital, the world-leading VR, AR & MR (Digital Reality) intelligence company global VR/AR investment reached the $4.5 billion[4] peak in 2017 only second to the $6 billion record-high of 2018[5], driven by large, late-stage deals in China. Such trend is further corroborated by Price Waterhouse Cooper (PwC)[6], with funding reflecting an upward shift of 85% from 2015[7]. This investment has been tied to specific hardware producers in the market, most noticeably Magic Leap, which secured $1.39 billion from its backers in the last 3 years[8].

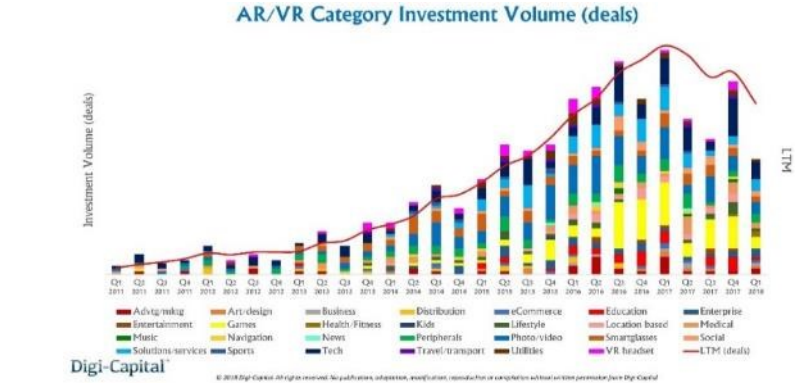
In terms of individual investment sectors, AR/VR technology and smart glasses took a third each, while games, navigation, medical, social, photo/video and peripherals made up the bulk of the remaining investments. Deal volume grew quarter-on-quarter up to the fourth quarter of 2017, before declining in the first quarter of 2018.

Figure 3 | Digi-Capital's AR/VR Category Investments ($M)



The games and technology sectors took over 10% of the total deal volume, with the rest spread across photo and video, peripherals, smart glasses, advertising and marketing, art and design, VR headsets, entertainment, navigation, news, sports, travel and transport, and video sectors, among others.

Figure 4 | Digi-Capital's AR/VR Category Investment Volume (Number of Deals)



[4] Digit-Capital, 2019. Record over $3B AR/VR investment in 2017 ($1.5B+ in Q4), Digi-Capital, January 5, 2018. Available from: https://www.digi-capital.com/news/2018/01/record-over-3b-ar-vr-investment-in-2017-1-5b-in-q4/

[5] Digit-Capital, 2019. AR/VR Investment Stabilized in Q4 2018. Digi-Capital, January 31, 2020. Available from: https://www.digi-capital.com/news/2019/01/ar-vr-investment-stabilized-in-q4-2018/

[6] PwC, 2017. An Introduction to Enterprise Virtual Reality. May 2017. Available from: https://www.pwc.com.au/consulting/assets/technology/virtual-reality-may17.pdf

[7] AR/VR Funding In 2016 Already Sees 85% Growth On 2015". CB Insights - Blog. N.p., 2017. Web. 16 May 2017. Available from: https://www.cbinsights.com/research/augmented-virtual-reality-funding-trends-q2-2016/

[8] Magic Leap - Funding Rounds | Crunchbase". Crunchbase.com. N.p., 2017. Web. 18 May 2017.

Latest Digi-Capital Investment Report tracked through its Analytics Platform **$4.1 billion in AR/VR investment in 2019**, the third-highest virtual reality investment and augmented reality investment year on record after 2017 and 2018[9].

However, investment dropped significantly in Q4 2019 compared to the previous quarter in terms of both deal volume (i.e., the number of deals) and deal value (i.e., the dollars invested). AR/VR deal volume looked like it had stabilized in Q3 2019, but it declined significantly in the fourth quarter. Total investment volume dropped by 27% in 2019 compared to 2018.

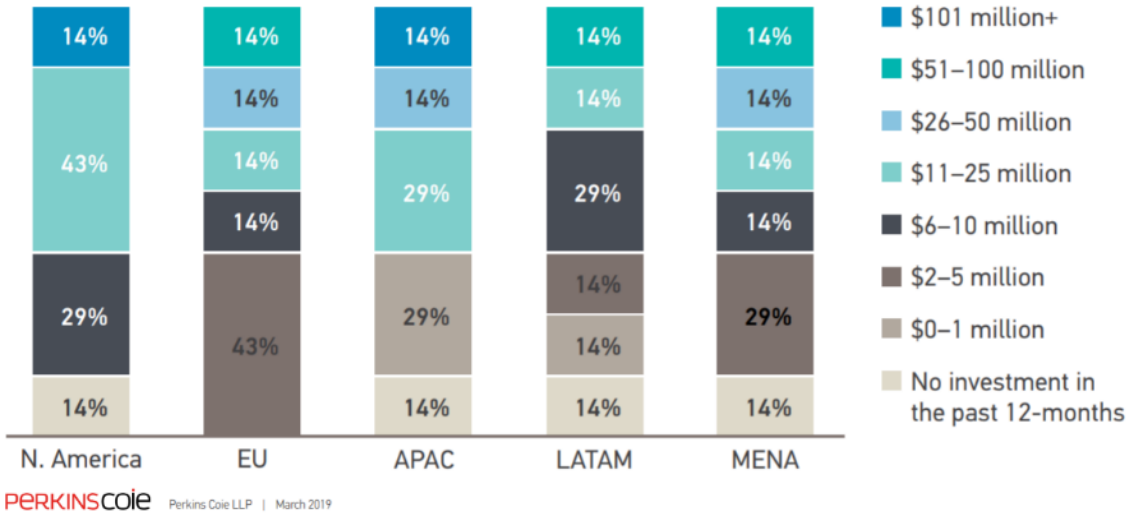
Categories with the highest volume of deals in the last 12 months were AR/VR tech, games, education, smartglasses, medical, enterprise software/services (excluding hardware) and solutions/services. All other categories had fewer deals last year.

AR/VR investment value in 2019 saw a decline of 35% from 2018. As above, deal value dropped significantly in Q4 2019 compared to the previous quarter, which together with a lower Q1 2019 led to the drop in overall investment for the year.

When it comes to deal sizes in 2019, according to Perkins Coie 2019 Augmented and Reality Virtual Survey Report[10], investment rounds in the lower end $0-10 million range dominated in the European, Latam and Mena regions. Interestingly, 43% of the VR/AR investment deal sizes in Europe were located in the $2-5 million range, corresponding to the availability of public funding most of which sit on that deal range. A further 14 percent of respondents highlighted that their organization had received investment of between 51 and 100 million U.S. dollars.

On the other hand, investment rounds in the upper limit of $11-25 million all the way up to $101 million+ ranges dominated dollars invested in the North America (namely USA) and ASIA (referred to as APAC) regions according to Perkins Coie and Digi-Capital.

Figure 5 | Level of Investment in the last 12 months (base year March 2019)



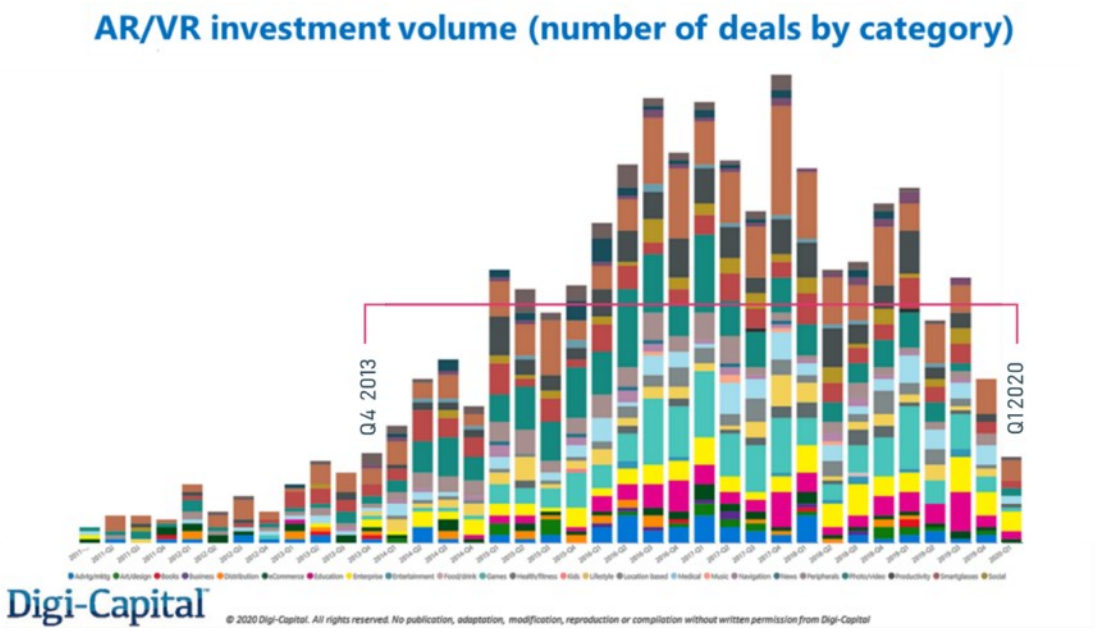
[9] Digi-Capital, 2020. VR/AR Investment at Pre-Facebooj/Oculus levels in Q1 2020. Digi-Capital, May 10, 2020. Available from: https://www.digi-capital.com/news/2020/05/vr-ar-investment-pre-facebook-oculus-levels/

[10] Perkins Coie LLP., 2019. 2019 Augmented Reality and Virtual Reality Survey Report. March 2019. Available from: https://www.perkinscoie.com/images/content/2/1/v4/218679/2019-VR-AR-Survey-Digital-v1.pdf

Regarding the first quarter 2020 AR/VR, both volume and deal value have dropped drastically at a quarterly level seen back in 2013 according to Digit-Capital[11]. Such negative trend is the result of COVID-19's impact on world economy and specially in all startup investment.

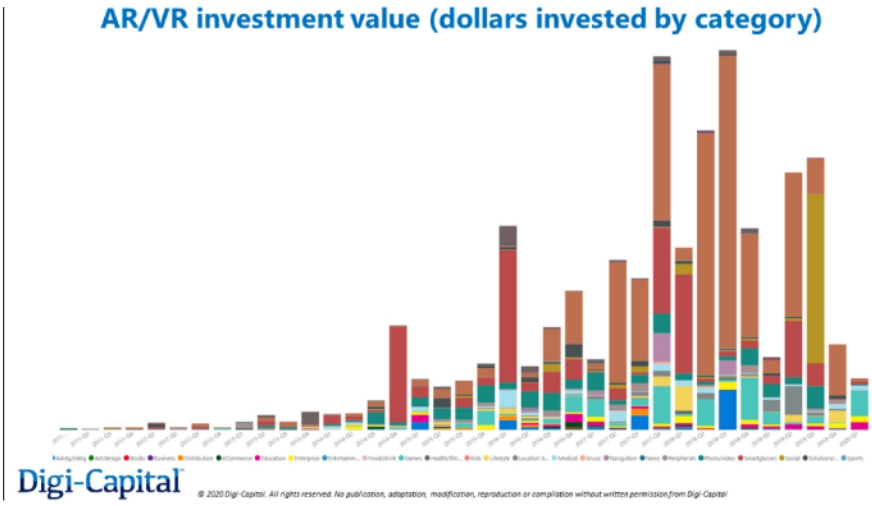
AR/VR investment volume (number of deals) declined significantly in the last 2 quarters. Total quarterly investment volume in Q1 2020 was at a similar level back in Q4 2013, before VC interest in the current wave of AR/VR was sparked by Facebook acquiring Oculus. Categories with the highest volume of deals in the last 12 months to Q1 2020 were AR/VR tech, education, games, enterprise, medical and smartglasses. All other categories had fewer deals in the last 12 months.

Figure 6 Digi-Capita'ls AR/VR Investment Volume Q1 2020.



As above, AR/VR investment value (dollars invested) dropped significantly in the last 2 quarters, with Q1 at a level similar to Q3 2015. Again, the impact of COVID-19 on the wider tech investment market appears to indicate at least a medium-term trend. AR/VR tech and social categories each raised the largest amounts in the last 12 months to Q1 2020, with Smartglasses, location-based entertainment, games, photo/video and lifestyle categories also significant. Other categories also saw investment, but at a lower level.

Figure 7 \| Digi-Capital's AR/VR Investment Value Q1 2020



[11] Digit-Capital, 2020. VR/AR investment at pre-Facebook/Oculus levels in Q1. Digit-Capital. May 10, 2020. Available from: https://www.digi-capital.com/news/2020/05/vr-ar-investment-pre-facebook-oculus-levels/

In the current augmented and virtual reality market, start-ups might be most focused on short term revenue generation and managing burn rates through 2020/2021. Public funding opportunities are also an excellent investment stream to further develop the technology and promote growth. On the other hand, leveraging Venture Capital investment to accelerate growth may prove more challenging given the current situation.

Despite it may be too early to tell whether the investment peaks of AR/VR from recent years might return after the coronavirus pandemic crisis has reached a resolution, IDC corporate still expects global spending to grow steadily, mainly driven by accelerating investments up until 2023[12].

2.4. THE VR/AR MARKET OUTLOOK: SIZE AND POTENTIAL

2.4.1. STATE OF VR/AR MARKET: AN EMERGING TECHNOLOGY

Virtual Reality (VR) and Augmented Reality (AR) are changing our daily lives faster than it could be predicted. Both technologies are now **nearing maturity**, going far beyond its early exploratory stage and being increasingly accepted and demanded by both end-use customers and businesses.

Even though VR has been in the technological panorama for a few decades now, having started out as stereo displays, immersive entertainments and simulated environments, it has only become more viable as a consumer product these last few years. Initially, the user required complex camera systems, hardware and computational power.

For instance, head-mounted displays (HMDs) or headsets were either too clumsy, or even too expensive having numerous technological impediments such reduced field of view, latency and needed to be powered by large-scale computers. As a result, VR was mostly restricted to large corporations in engineering or digital industries or by specialised research centres, hindering the widespread adoption of the technology.

Be that as it may, **VR is now finally reaching a tipping point for large scale adoption.** Today, HMD have become affordable and powerful. In addition, in today's hyper-connected world, powerful smartphones, 5G connectivity and Edge-Computing are further extending the wide-spread adoption of the technology.

The fact that VR is likely to enter a period of accelerated growth can be illustrated with a well-known typology of the acceptance of new technology, the **Gartner hype cycle**[13]. The hype cycle is a graphical representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting new solutions.

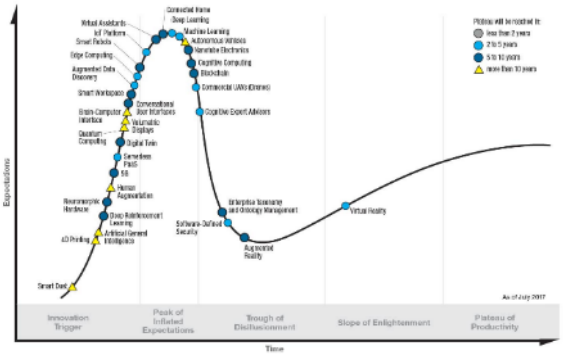
Hence, taking a look at the industry life cycle, both VR and AR have already passed the peak of inflated expectations and significant part of the population is expected to adopt VR technology in the upcoming 2-5 years (5-10 for AR).

[12] IDC, 2020. Commercial and Public Sector Investments Will Drive Worldwide AR/VR Spending to $160 Billion in 2023, According to a New IDC Spending Guide. IDC. June 4, 2020. Available from: https://www.idc.com/getdoc.jsp?containerId=prUS45123819

[13] Gartner, Inc., 2020. Gartner Hype Cycle – Interpreting Technology Hype. Available from: https://www.gartner.com/en/research/methodologies/gartner-hype-cycle. Accessed in 23/07/2020.

Figure 8 | Gartner Hype Cycle for Emerging Techonolgies

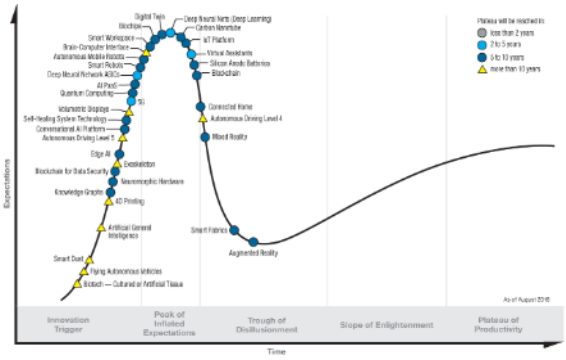
Gartner Hype Cycle for Emerging Technologies, 2017



gartner.com/SmarterWithGartner

Gartner

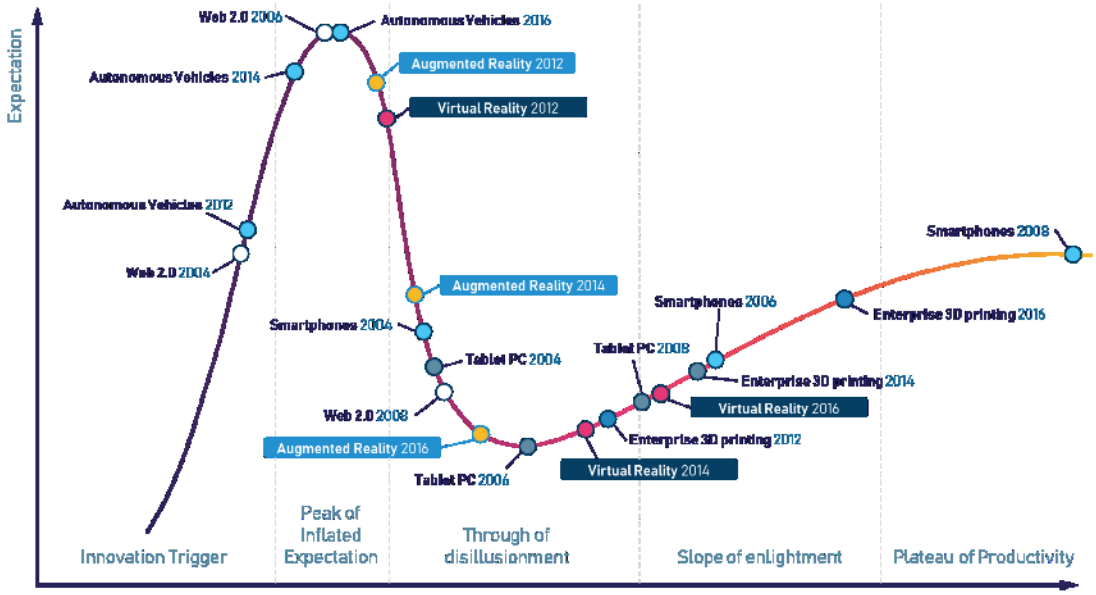
Hype Cycle for Emerging Technologies, 2018



gartner.com/SmarterWithGartner

Gartner

Customized Gartner Hype Cycle for Emerging Digital Technologies



Adapted from: Gartner Hype Cycles and Ecorys.

Foot Note | This Customized Gartner Hype Cycle represents the maturity and adoption phases of selected digital technologies and applications. Current expectations of the VR potential are close to what public expected from smartphone between 2006-2008.

To put this in perspective, while similar technologies such as the smartphone had reached market maturity a long time ago (in 2008), VR is in now entering the "**slope of enlightenment**" phase[14,15].

[14] Gartner, Inc., 2017. 5 Trends Emerge in the Gartner Hype Cycle for Emerging Technologies, 2018. August 16, 2018. Available from: https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/ Accessed: 23/07/2020

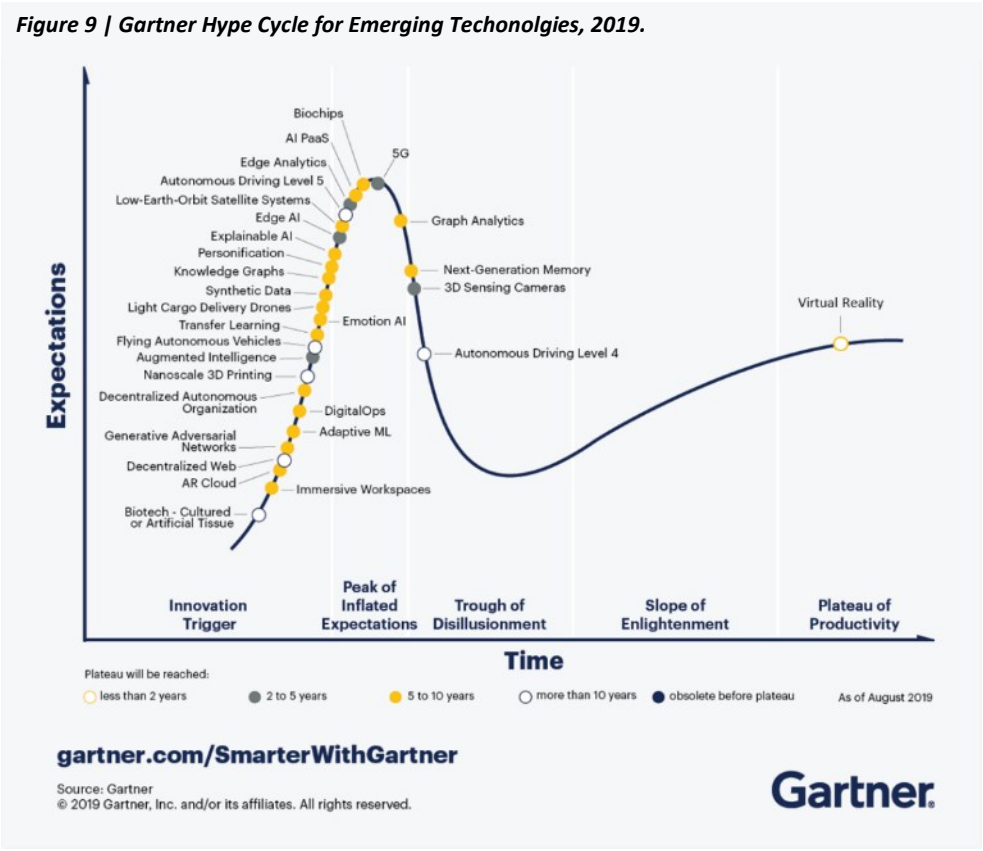
[15] Gartner, Inc., 2018. Top Trends in the Gartner Hype Cycle for Emerging Technologies, 2017. August 16, 2018. Available from: https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/ Accessed: 23/07/2020

Such phase is characterised by a growing number of instances of how the technology can benefit the enterprise and end-customers start to crystallize and become more widely understood in the market. This is a period where second- and third-generation products are launched by technology providers and an increasing pilot are usually funded by key industry enterprises.

Be that as it may, the most recent Gartner Hype Cycle - dating of 2019 - considers VR to have already achieved the "**plateau of productivity**" phase in which broad market adoption starts to take off and in which the technology broad market applicability and relevance are clearly defined and understood[16].

On the other hand, Augmented Reality is lagging a couple years in terms of maturity as seen in Gartners Hype Cycles 2017 and 2018. According to Gartner, AR is still in the "**through of disillusionment**" phase characterised by the waning of interests as experiments and implementations fail to deliver in time.

Figure 9 | Gartner Hype Cycle for Emerging Techonolgies, 2019.



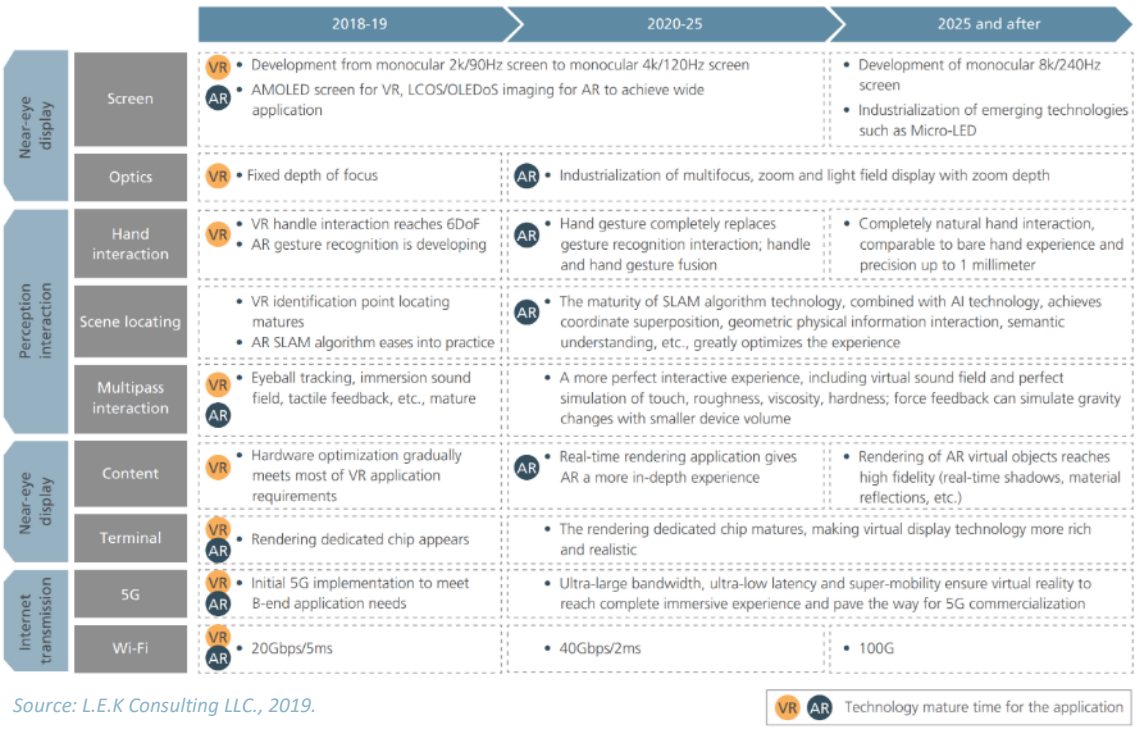
Overall, we can affirm that for both technologies, VR and VR, a viable technology development road map has been defined and, in the case of VR, most developments have already been accomplished. In fact, L.E.K consulting[17] expected most VR key technologies such as near-eye display, rendering processing, data transmission to be fully developed for mass adoption for this year.

[16] Gartner, Inc., 2018. 5 Trends Appear on the Gartner Hype Cycle for Emerging Technologies, 2019. August 16, 2018. Available from: https://www.gartner.com/smarterwithgartner/5-trends-appear-on-the-gartner-hype-cycle-for-emerging-technologies-2019/ Accessed: 23/07/2020

[17] L.E.K. Consulting LLC, 2019. Executive Insights – Capitalizing on the Opportunities in VR/AR. Volume XXI, Issue 8. Available from: https://www.lek.com/sites/default/files/insights/pdf-attachments/2108-English_Capitalizing-Opportunities-VR-AR_1.pdf

Augmented reality, as previously mentioned, has made great progress on multichannel interaction and network transmission but, other technologies such as simultaneous localization mapping (SLAM) algorithms and relevant peripherals and optical displays still having a long road ahead before it can be introduced to the market.

Figure 10 | VR/AR Technology Maturity Road Map

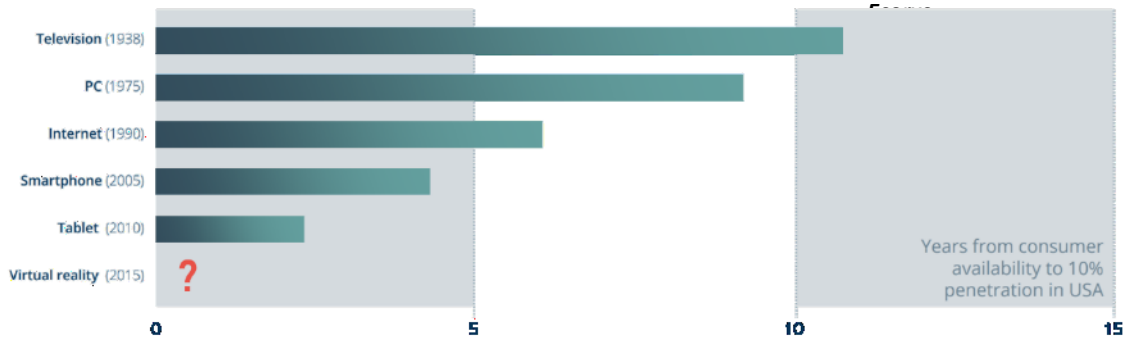


Source: L.E.K Consulting LLC., 2019.

Following on the smartphone example, it took 8 years to reach a 50% adoption rate by consumers in Europe after where VR is standing now. Today, roughly four decades after the introduction of the first mobile phone, almost every developed country has at least 90% mobile phone penetration, and a 80% smartphone penetration, according to Deloitte[18].

What is more, this is an extremely lucrative market with global sales reaching $522 billion in 2018 according to GFK[19]. This took less than 10 years. In addition, a growing industry for the development of mobile apps is connected to the rise of smartphones. This has brought a revenue of €16.5 billion to the EU economy.

Figure 11 | Adoption of New Technologies Over Time ***Source: Adapted from***



[18] Deloitte Touche Tohmatsu Limteed, 2017. Global Mobile Consumet Trends. 2n Edition. Available from: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/technology-media-telecommunications/us-global-mobile-consumer-survey-second-edition.pdf

[19] GfK SE., 2019. Global Smartphone Sales Reached $522 billion in 2018. Nuremberg. February 22, 2019. Available from: https://www.gfk.com/press/global-smartphone-sales-reached-522-billion-in-2018

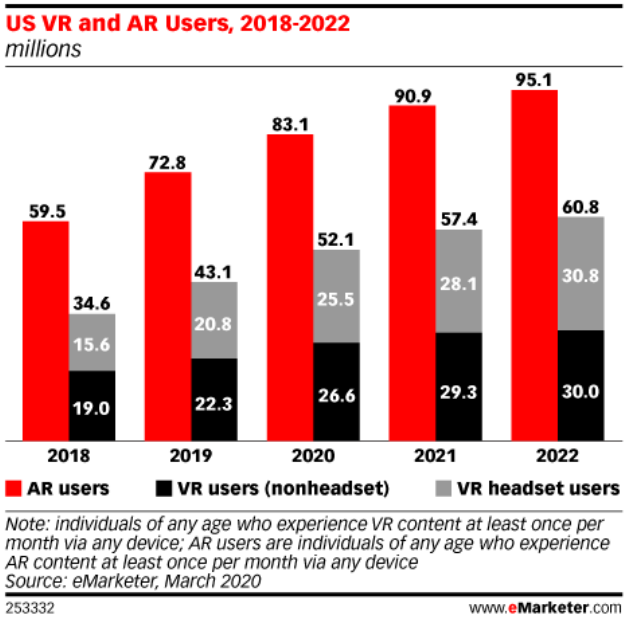
In fact, the San Francisco based Venture Beat tech news magazine defines Mixed Reality (VR and AR) as "the next computing frontier after the emergence of personal computers in the 1970s, the world wide web in the 1990s and the smartphone in the 2000s[20]". Perhaps, it could be argued whether this may be the most unique of those technological shifts since VR and AR are the first technology to blend the digital and physical worlds.

A mixed reality interface combines varying degrees of real and virtual elements on the same display to create immersive experiences, and the device is hyper aware of its real-world surroundings. This means mixed reality has the potential to replace our smartphones, computers, TVs, and other common computer interfaces.

VR is currently ahead of AR when it comes to realistic expectations and real potential of use in various consumer and business areas. And its adoption can happen very quickly as the timespan needed for adoption of new technologies has been systematically decreasing. For instance, the AR game *Pokémon Go* reached 50 million users globally in only 19 days[21].

Today the reality is that, according to eMarketer[22], VR and AR continue to evolve and are gaining traction among consumers and businesses. eMarketer anticipates that 52.1 million people in the USA will be using VR and 83.1 million will use AR at least once per month in 2020. This represents 15.7% and 25.0% of the USA population, respectively.

Figure 12 | VR and AR demographics in the USA.



In the light of these numbers, it becomes clear that the use of both technologies is growing, but different forces drive their uptake. VR growth is being propelled by advances in hardware, including, *inter alia*, higher-quality, lower-cost headsets, 5G connectivity, Artificial Intelligence, IoT and Edge Computing. AR growth is being fuelled by software development and the creation of standardized platforms on which to create new applications.As VR and AR continue to prove their worth, we are going to notice an increasingly rapid pace customers and business accepting the technology and actively requesting VR/AR solutions.

[20] Don Stein and Paraj Mathur, 2018. Mixed Reality is Ready for Investors. May 7, 2018. Venture Beat. Available from: https://venturebeat.com/2018/05/07/mixed-reality-is-ready-for-investors/

[21] SensorTower, 2016. Pokémon GO Hit 50 Million Downloads in Record Time, Now at More Than 75 Million Worldwide. Jul 25, 2016. Available from: https://sensortower.com/blog/pokemon-go-50-million-downloads

[22] eMarketer, 2020. US VR and AR Users, 2018-2022. March 1, 2020. Available from: https://www.emarketer.com/chart/234406/us-vr-ar-users-2018-2022-millions

2.4.2. MARKET SIZE, SHARE AND GLOBAL MARKET FORECAST

OVERVIEW: GLOBAL MARKET SIZE

In order to understand the reach of the global digital reality in terms of market size and future potential, a thorough and in-depth market analysis was provided in Deliverable 5.2 focusing on the analysis of the core AR/VR elements of the digital reality ecosystem.

As mentioned in such document, the VR/AR is on the cusp of becoming the next technological revolution, but it has remained niche for many years due to technological limitations and insufficient quality content.

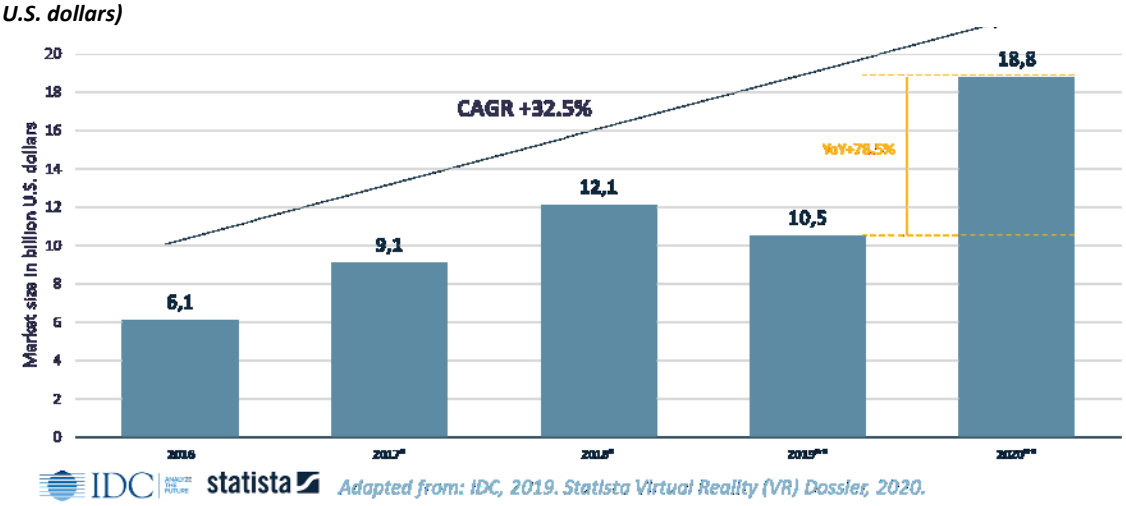
However, the VR/AR market has experienced a major increase in both, market growth and global investment. Not only this but also the COVID-19 pandemic appears to have changed the technologies fortunes, as homebound people search for ways to entertain themselves and connect with others and businesses search for new technologies to facilitate and adopt e-work.

To determine the impact of the growing demand for VR & AR on both a global scale and on the European economy, an assessment of the current and future market size of the VR/AR industry has been conducted. This has been based on an analysis of a wide range of different market studies.

Given the short time frame between the submission of D5.2 and D5.3 (both taking place in 2020) few changes have been noted in terms of VR/AR market size and trends. Hence, a brief summary of the latest estimates is here provided.

Worldwide spending on augmented reality and virtual reality (AR/VR) is forecast to be $18.8 billion in 2020, a year-over-year (YoY) of 78.5% over the $10.6 billion that International Data Corporation (IDC) [23,24] expects will be spent in 2019. The latest update to IDC's Worldwide Augmented and Virtual Reality Spending Guide also shows that worldwide spending on AR/VR products and services will continue this strong growth throughout the 2019-2023 forecast period, achieving a five-year compound annual growth rate (CAGR) of 77.0%.

Figure 13 | Forecast augmented (AR) and virtual reality (VR) market size worldwide from 2016 to 2020 (in billion U.S. dollars)



[23] IDC Corporate USA, 2019. Worldwide Spending on Augmented and Virtual Reality Expected to Reach $18.8 Billion in 2020, According to IDC. Nov 27th, 2019. Available from: https://www.idc.com/getdoc.jsp?containerId=prUS45679219

[24] Statista, 2020. Virtual Reality (VR) Statista Dossier. Article number: did-29689-1. Released: 2020. Available from: https://www.statista.com/study/29689/virtual-reality-vr-statista-dossier/

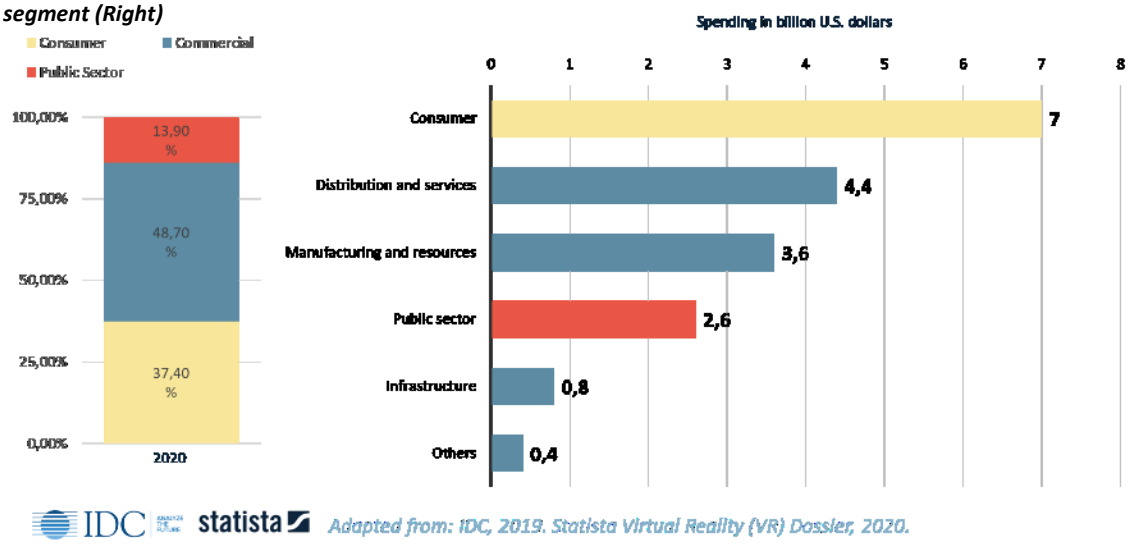
Worldwide spending on AR/VR solutions will be led by the commercial sector, which will see its combined share of overall spending grow from 48.7% in 2020 to 68.8% in 2023, accounting for $8.02 billion in 2020. By commercial segment, distribution and services will account for $4.4 billion, followed by manufacturing and resources, infrastructure and other with an estimated 2020 size of $3.6, $0.8 and $0.4 billion respectively.

Within these segments, the commercial industries that are expected to spend the most on AR/VR in 2020 are training (2.6 billion), retail ($1.5 billion), discrete manufacturing ($1.4 billion) and industrial maintenance ($914 million). Fifteen industries are forecast to deliver CAGRs of more than 100% over the five-year forecast period, led by securities and investment services (181.4% CAGR) and banking (151.9% CAGR).

On the other hand, consumer spending on AR/VR will be greater than any single enterprise industry ($7.03 billion in 2020) but will grow at a slower pace (39.5% CAGR). Consumer spending will be led by two large use cases: VR games ($3.3 billion) and VR feature viewing ($1.4 billion).

However, consumer spending will only account for a little over one third of all AR/VR spending in 2020 with public sector use cases making up the balance with a 13.9% of the market share, or roughly $2.6 billion market size in 2020.

Figure 14 | Forecast share of augmented and virtual reality (AR/VR) spending worldwide in 2020, by segment (Left) Augmented and virtual reality (AR/VR) forecast spending worldwide in 2020 (in billion U.S. dollars), by segment (Right)



IDC statista *Adapted from: IDC, 2019. Statista Virtual Reality (VR) Dossier, 2020.*

Hardware will account for nearly two thirds of all AR/VR spending throughout the forecast, followed by software and services, as estimated by IDC. Services spending will see strong CAGRs for systems integration (113.4%), consulting services (99.9%), and custom application development (96.1%) while software spending will have a 78.2% CAGR.

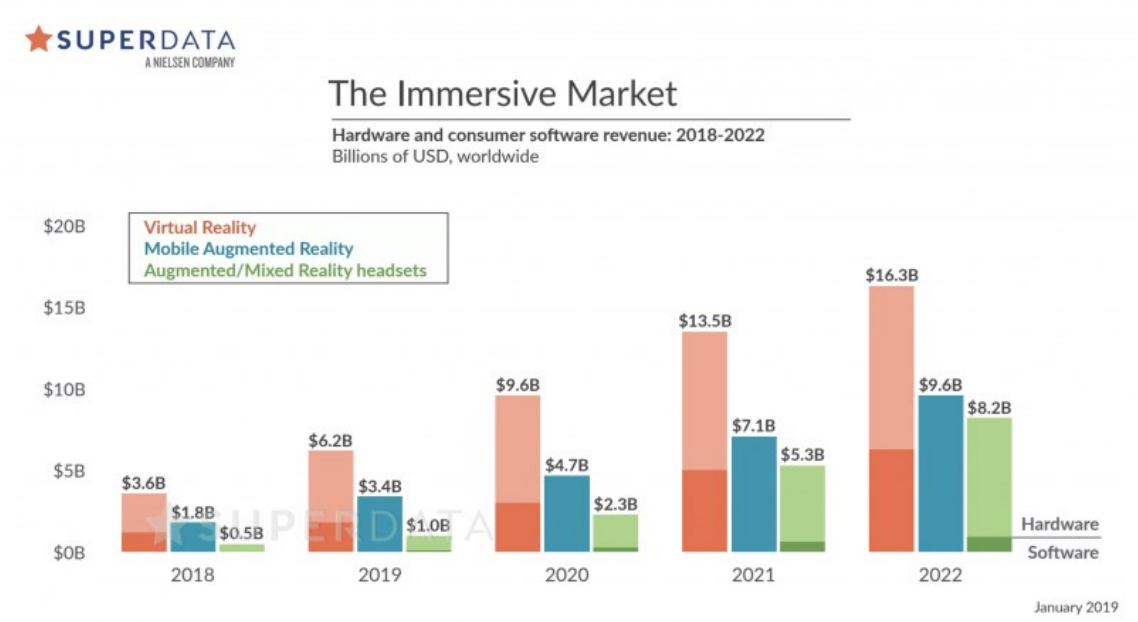
According to IDC, of the two reality types, spending in VR solutions will be greater than that for AR solutions initially. However, strong growth in AR hardware, software, and services spending (164.9% CAGR) will push overall AR spending well ahead of VR spending by the end of the forecast.

Such dichotomy is in fact explained by the fact the AR is nowadays more widespread among consumer, while VR still has its limits in not just portability, but user friendliness. However, it is important to mention these technologies should not be played off by each other, but instead should be regarded as complementary. In fact, there is also the possibility that we may see the two mediums eventually start to overlap or even merge completely. Some experts believe that as more equipment is developed, the line that delineates the two will actually start to get blurry.

On a geographic basis, China will deliver the largest AR/VR spending total in 2020 ($5.8 billion), followed by the United States ($5.1 billion). Western Europe ($3.3 billion) and Japan ($1.8 billion) and will be the next two largest regions in 2020, but Western Europe will move ahead of China into the second position by 2023. The regions that will see the fastest growth in AR/VR spending over the forecast period are Western Europe (104.2% CAGR) and the United States (96.1% CAGR).

A similar trend is estimated by SuperData Research[25], a leading market research company in the field of digital technologies and gaming. The source expects the consumer market for immersive technology (including, VR, AR and MR) will generate $10.6 billion dollars in revenue globally by 2019. However, in contrast with IDC estimations, the single largest segment of the market is Virtual Reality (VR) which will account for $6.2 billion of the total, while Mobile Augmented Reality and Augmented/Mixed Reality headsets will bring in around $4.7 billion combined.

Figure 15 | The Immersive Market – Hardware and Consumer Software Revenue: 2018-2022.



The immersive technology market is forecasted to steadily grow to a $34.1 billion market by 2023, driven by technological improvements and as the consumer electronic devices, which enable the use of this technologies, becomes increasingly available.

The forecasted estimates are underpinned by VRs explosive growth, expected to expand at a Compound Annual Growth Rate (CAGR) of +45.87% for 2018-2023 period. The drastic expansion is expected to result in a $16.3 billion VR market by the end of the forecasted period. Concomitantly, the Mobile Augmented Reality and Augmented/Mixed Reality (AR/MR) headsets are forecasted to grow at an impressive CAGR of +51.97% and 101.24% respectively, to ultimately reach by 2023 the $9.6 and $8.2 billion market size milestone.

[25] SuperData via ViAR, 2019. Virtual Reality Market Size in 2018 with forecast for 2019. January 2019. Available from: https://www.viar360.com/virtual-reality-market-size-2018/

MID-TERM VR/AR MARKET FORECASTS

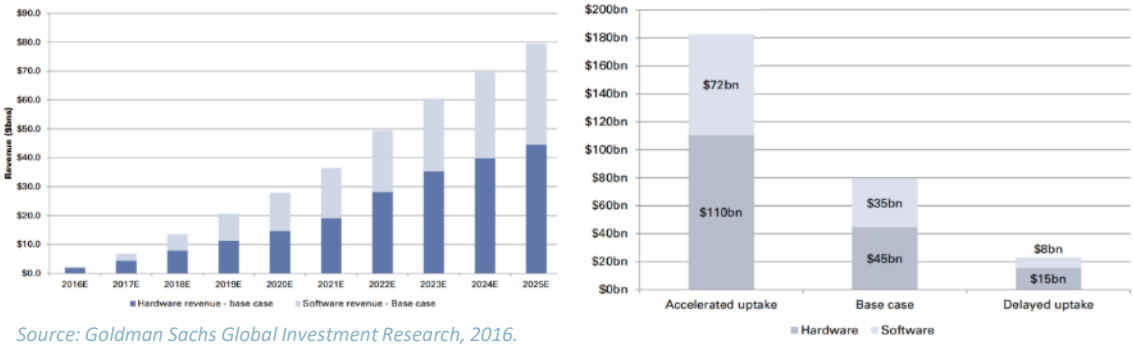
As we have seen, VR/AR is no longer science fiction. It is integrated in our present and, in the coming years, it will lead to advances that will shape the future. In fact, as previously mentioned, VR is one of the technologies with the highest projected potential for growth.

According to the latest mid-term forecasts by Goldman Sachs[26], the global VR/AR market could reach the **$80bn burden** ($45bn in hardware and $35bn in software) in its **base case scenario**. This is assuming that HMDs gain popularity as VR/AR technology improves over time but are still limited in terms of mobility meaning the use cases would be mostly confined to stationary mobility.

However, Goldman Sachs estimates that VR/AR market could potentially reach the staggering **$182bn market size by 2025** if HMDs evolve from a niche market device to a generic computing platform and as the user experience of VR/AR technology improves over time coupled with breakthroughs in connectivity and mobility. In such **accelerated uptake scenario**, Goldman Sachs, expects VR to proliferate from vertical markets to horizontal market adoption.

On the other hand, a **delayed market uptake scenario** needs to also be considered, despite its probability of occurrence, especially in the light of the COVID-19 long-lasting effect in the field, remains low. In such case, it is estimated that the global VR/AR market would settle in the $23bn mark ($15bn hardware, $8bn in software) assuming that user experience improves at a slower pace due to hindrance in adoption from latency, display, safety, privacy and other issues for it to have a widespread effect. As such, VR/AR will primarily only succeed in the videogaming and entertainment use cases.

Figure 16 |Progression of VR/AR Base Case Hardware and Software Market Forecast (Left); Combined 2025 VR/AR Hardware and Software Scenarios (Right)



Source: Goldman Sachs Global Investment Research, 2016.

Similarly, Research & Markets[27] mid-term forecast expects VR/AR to reach the $94.4 billion by 2023. Key growth driver according to the source is the rising smartphone penetration. AR and VR technologies are reaching out to the masses through different devices and platforms. Increasing penetration of smartphones and tablet computers among the consumers is providing a stable platform for augmented reality and virtual reality products. Additionally, smartphones can also be used as input devices for controlling the VR environment.

In addition, according to L.E.K Consulting[28] in the first half of 2018, mobile AR, AR glasses, all-in-one VR and PC-VR equipment all enjoyed a more than 50% growth rate. L.E.K. expects the

[26] The Goldman Sachs Group, Inc., 2016. Virtual & Augmented Reality: Understanding the Race for the Next Computing Platform. The Goldman Sach Group, Inc. Published January 13, 2016, 64 pgs. Available form: https://www.goldmansachs.com/insights/pages/technology-driving-innovation-folder/virtual-and-augmented-reality/report.pdf

[27] Research & Markets, 2018. Augmented Reality and Virtual Reality Market by Devices, by Component, by Application by Geography - Global Market Size, Share, Development, Growth, and Demand Forecast, 2013 – 2023. ID: 4600360. Available from: https://www.researchandmarkets.com/research/6w5hhb/global_augmented?w=5

[28] L.E.K. Consulting LLC, 2019. Executive Insights – Capitalizing on the Opportunities in VR/AR. Volume XXI, Issue 8. Available from: https://www.lek.com/insights/ei/capitalizing-opportunities-vrar

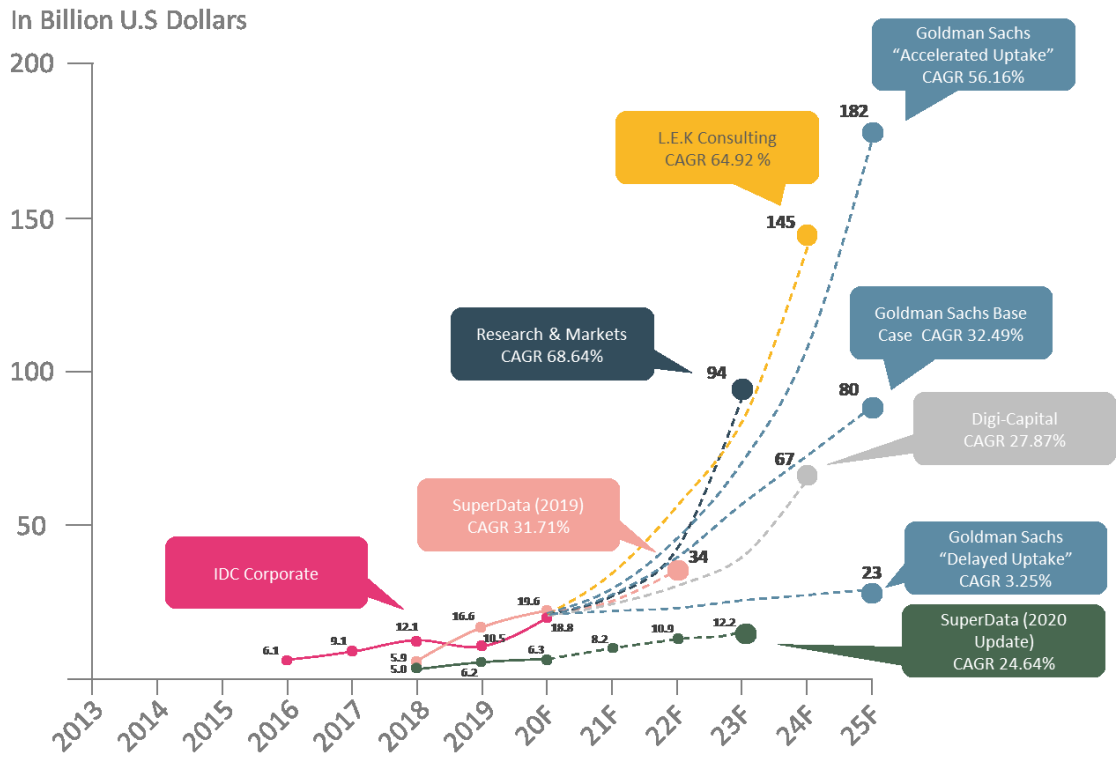
inflection point of the VR/AR market will arrive in 2019-2020 and the market will reach $145 billion by 2025.

However, it is worth noting the fact that the abovementioned forecasts did not take into account the major disruption the COVID-19 pandemic has generated in both terms, the negative economic impact and the unprecedented behavioural change towards digitalisation of the society. As a result, despite their valid estimations in terms of expected market size and growth of the VR market, we should expect small revisions of the estimates in the upcoming months, with a short-term contraction in sales but an exacerbated growth in the mid future as a result of increased digitalisation.

A recently published forecast by Digi-Capital (as of August 3, 2020)[29] does consider the potential impact of the pandemic on the VR/AR ecosystem estimating global revenue to grow from over $13bn this year to more than **$67bn by 2024**. Digi-Capital expects the market to keep evolving beyond its early stage of offering related point solutions to specific problems, to becoming a fully functioning ecosystem in the upcoming years.

Overall, when combining all the forecasted data can observe a polarisation of figures depending on the source and its publication date. However, a clear trend can be observed consisting in a high potential growth for the market with expected compound annual growth rates (CAGR) well above the +20% threshold. This is a clear indicator of the high growth potential of the market and the lucrative opportunities for the upcoming years.

Figure 17 | Combined VR/AR Mid-Term Market Forecast (2016-2025)



METHODOLOGY *|To determine the base year figure to be used for the calculation of the Compound Annual Growth Rates (CAGR) of future forecasts, two separate market VR/AR market size reports from reliable sources have been utilised consisting of IDC Corporate, SuperData 2019 market reports. In addition, a third Super Data 2020 Update market reports has been included to reflect the market adjustment due to COVID-19 pandemic. However, in order to avoid any possible bias, this last figure has been excluded when determining the base year for the CAGR calculation given that most of the market forecast for the upcoming years were conducted prior to the pandemic. Instead, the base year has been calculated as the average between the 2020 market size figures from IDC and SuperData 2019 reports.* ***Figure by Authors in collaboration with FI Group Spain.***

[29] Digi-Capital™, 2020. The AR/VR ecosystem – are we there yet?. August 3, 2020. Available from: https://www.digi-capital.com/news/2020/08/the-ar-vr-ecosystem-are-we-there-yet/

2.4.3. THE COVID-19 EFFECT ON VR/AR MARKET

In both cases, IDC and SuperData market estimations were reported prior to the COVID-19 global outbreak across developed countries. With this crucial caveat, some trends can be seen. A recent update from SuperData[30], as of April 27th, 2020, predicts the immersive technology market size to be of $6.3 billion, down from a prior projection of $7.7 billion [31,32,33]. This is mainly due to the impact of COVID-19 on the industry, though certain sectors are poised to experience rebounds as early as the second half of 2020 and reshape the future of VR/AR market.

The updated forecast by SuperData suggests a less optimistic market growth and size for the upcoming years. The estimates suggest that this market will generate $12.2 billion in revenue by 2023, underpinned by VR technology with a market size of $5.3 billion, followed by AR/MR Headsets with $4.4 billion and Mobile AR with $2.8 billion.

The unfortunate market contraction due to COVID-19 has been mainly driven by supply chain disruptions which caused sales of major VR headsets to fall drastically. In parallel, location-based VR revenues, which enjoyed steady growth, have been heavily impacted due to restrictions.

However, this caveat is a special case of the general market contraction truth since COVID-19 has changed our lives in many ways including the way we work, socialise and has even affected the way we use technology. It is triggering economic and social consequences without precedents forcing companies and users to adapt to a new scenario that demand fundamental measures.

A NEW DIGITAL ERA

To make it through the pandemic, business and consumers are embracing **digitalization** more than ever before. Across all industries, increasing numbers of companies are adopting videoconferencing tools and project management platforms to provide their employees with remote work options. With classrooms closed around the world, educators are moving to online learning models and private users embrace digital social environments amidst the pandemic.

Such behavioural change and digitalization adoption are illustrated by the Consumer Technology Association™(CTA) and its COVID-19 Impact specific Biweekly Tech Use and Purchase Tracker[34]. CTA monitors de consumer usage and purchases across technology categories, including online services and devices during the pandemic.

From the charts below, a clear trend is identified. All categories and services studied including streaming/download entertainment, online food or grocery delivery services, and other services have seen an uptick in demand and sales. Such upward trend is especially noticeable in the video and conference call platform services with an increase from 12% to up to 24% in less than 2 months. Also, online education courses, online health services and social media platforms seem to have experienced an increase in demand. Importantly, given the long-lasting impact of COVID-19 and social distancing measures, a second wave in depend is expected after the summer period - coinciding with school reopening and end-of-holidays period - which is not depicted in the abovementioned charts.

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[30] SuperData, a Nielsen Company. SuperData XR Q1 2020 Update on Worldwide XR Revenue. Available from: https://www.superdataresearch.com/blog/superdata-xr-update

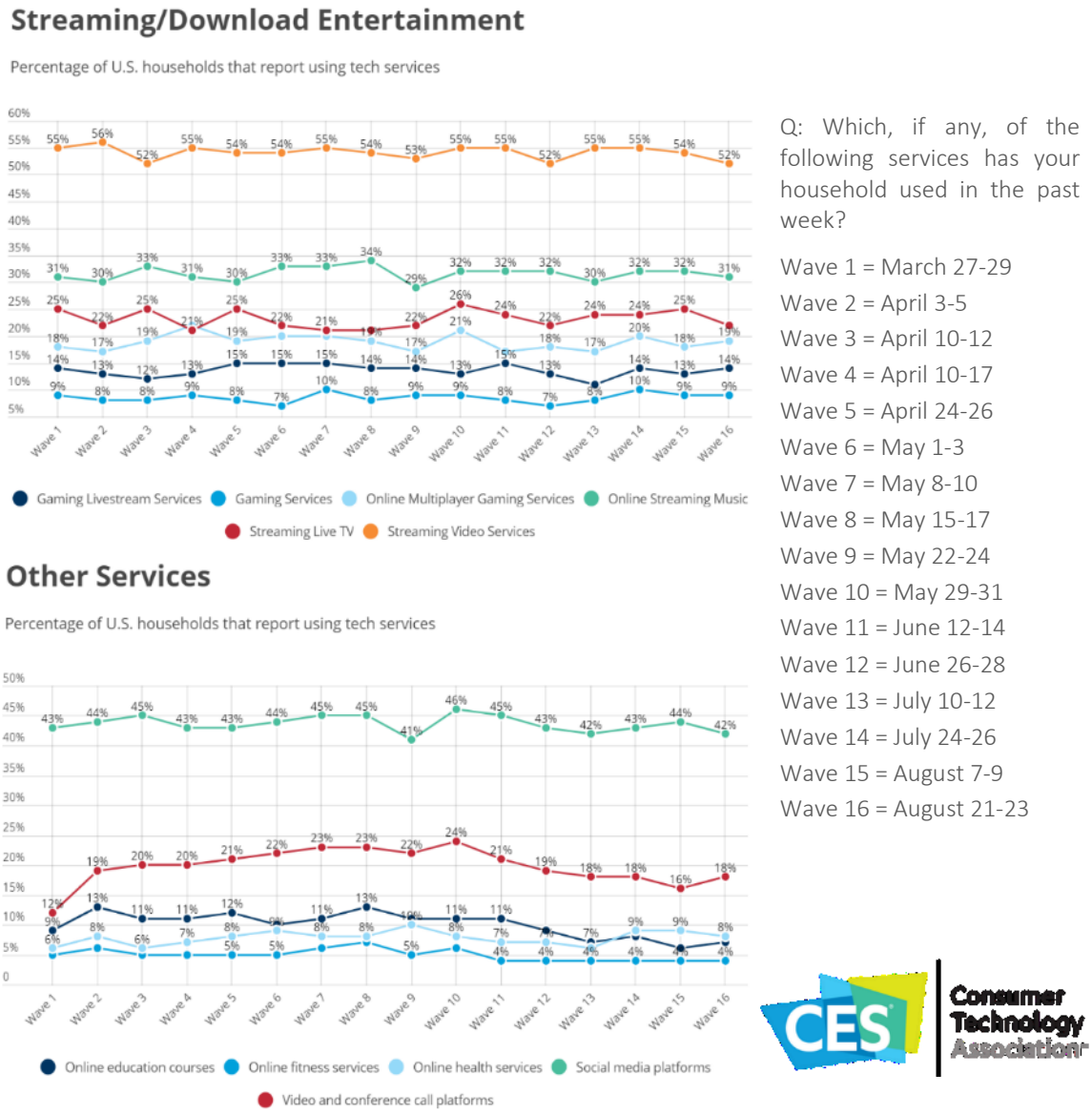
[31] SuperData via ViAR, 2019. Virtual Reality Market Size in 2018 with forecast for 2019. January 2019. Available from: https://www.viar360.com/virtual-reality-market-size-2018/

[32] IDC Corporate USA, 2019. Worldwide Spending on Augmented and Virtual Reality Expected to Reach $18.8 Billion in 2020, According to IDC. Nov 27th, 2019. Available from: https://www.idc.com/getdoc.jsp?containerId=prUS45679219

[33] Statista, 2020. Virtual Reality (VR) Statista Dossier. Article number: did-29689-1. Released: 2020. Available from: https://www.statista.com/study/29689/virtual-reality-vr-statista-dossier/

[34] Consumer Technology Association™, 2020. Biweekly CTA Tech Use and Purchase Tracker: COVID-19 Impact. Wave 16, August 26. Available from: https://www.cta.tech/Resources/Research-and-Forecasts/CTA-Tech-Use-and-Purchase-Tracker

Figure 18 | Biweekly CTA Tech Use and Purchase Tracker: COVID-19 Impact - Services Used in the Past Week.

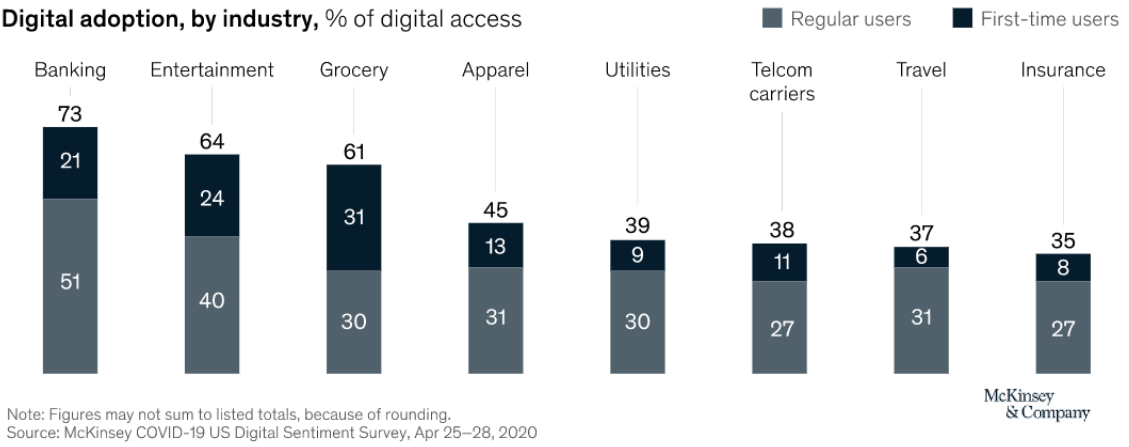


The digital adoption has been boosted by the pandemic across all industries and across all global regions. Nonetheless, not all industries are capturing the same share of a larger pie. While COVID-19 has evened out digital adoption rates across the globe, the same is not true by industry.

In the case, U.S. consumers are accelerating adoption of digital channels after the COVID-19 crisis, a trend seen across global regions. According to McKinsey & Company[35], the Grocery industry saw the biggest growth with up to 31% of new first-time users of digital channels. Banking and Entertainment hold the biggest t share of the digital adoption pie with a 73% and 64% of digital access respectively.

[35] The COVID-19 recovery will be digital: A plan for the first 90 days. By Aamer Baig, Bryce Hall, Paul Jenkins, Eric Lamarre, and Brian McCarthy. May 14, 2020 | Article. Available from: https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/the-covid-19-recovery-will-be-digital-a-plan-for-the-first-90-days

Figure 19 | U.S. Digital Adoption, by Industry, % of Digital Access

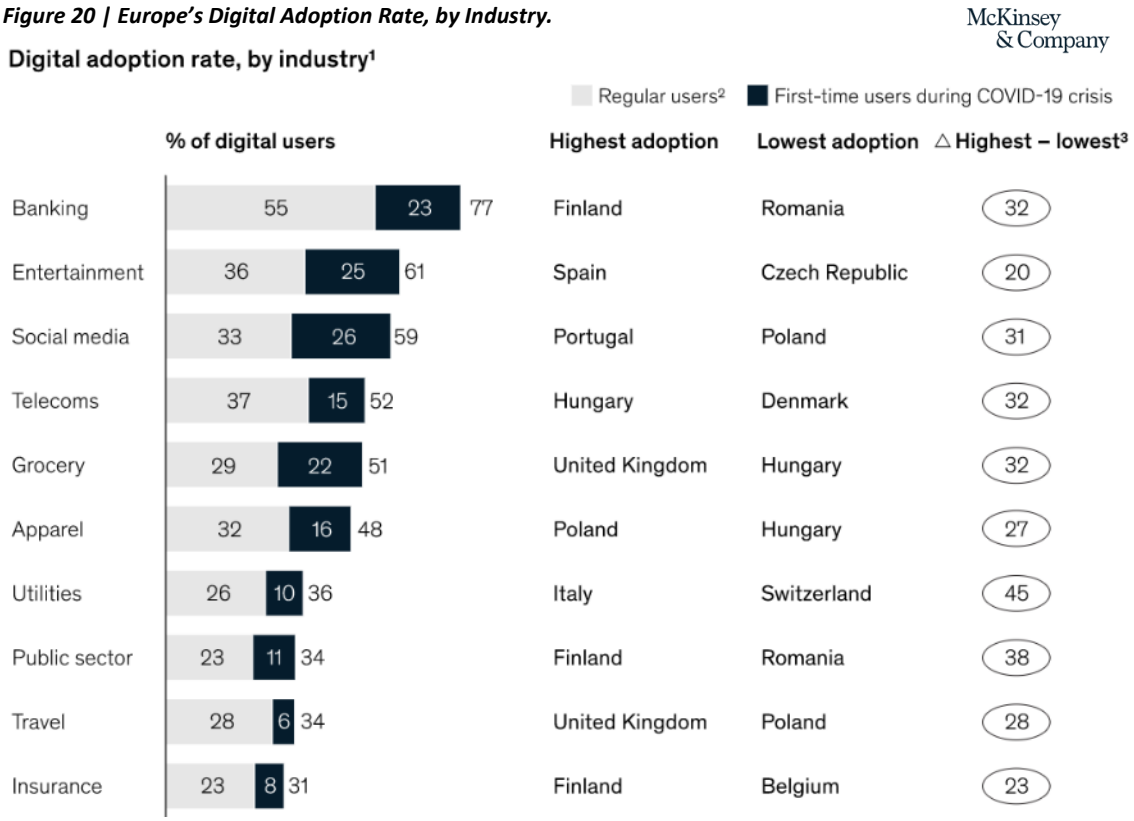


Note: Figures may not sum to listed totals, because of rounding.
Source: McKinsey COVID-19 US Digital Sentiment Survey, Apr 25–28, 2020

Europe, like much of the world, has "gone digital" as a result of the lockdowns and social-distancing measures imposed to deal with the COVID-19 pandemic. To glimpse the COVID-19 dramatic shift on digital-customer behaviour and technology consumption the New York-based consultancy firm McKinsey & Company[36], conducted a survey of more than 20,000 European consumers from April 28 to May 20, 2020.

According to such source, Europe's digital migration during COVID-19 has been led by social media and entertainment industries which saw the most growth in terms of first-time users. In absolute numbers, that is regular users and first-time users during COVID-19 crisis, Banking, Entertainment and Social media industries are the uncontested leading sectors.

Figure 20 | Europe's Digital Adoption Rate, by Industry.



[36] McKinsey & Company, 2020. Europe's Digital Migration During COVID-19: Getting Past the Broad Trends and Averages. By Santiago Fernandez, Paul Jenkins and Benjamin Viera. June24, 2020 | Article. Available from: https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Europes%20digital%20migration%20during%20COVID%2019/Europes-digital-migration-during-COVID-19.pdf

On the other hand, low growth in the travel industry during the pandemic is the result of the generalised travel bans. Also, the Insurance industry had the lowest digital penetration of all industries before the pandemic and experienced the second-lowest growth of all after the epidemiologic crisis.

In fact, the European average **digital adoption rate has jumped from 81 percent to 94 percent** during the pandemic – a rise that according to McKinsey & Company would have taken two to three years in most industries at pre-pandemic growth rates.

This average mask wide geographic differences, however, driven both by the severity of restrictions imposed in different markets on people's movement and business operations and by the digital maturity of those markets. Nordic countries top the list while, quite surprisingly, two out of the four EU-4 countries (Germany, France, Spain, Italy) sit at the bottom of the list together with the United Kingdom.

Noticeable too, is the extent to which the pandemic has shrunk the gaps that exists between European countries in terms of online activity. Figure X maps average adoption rates and the average number of industries accessed online by users in each country before the pandemic and at the end of May. The difference between the countries with the highest and lowest digital adoption rates fell from 32 percentage points to just ten.

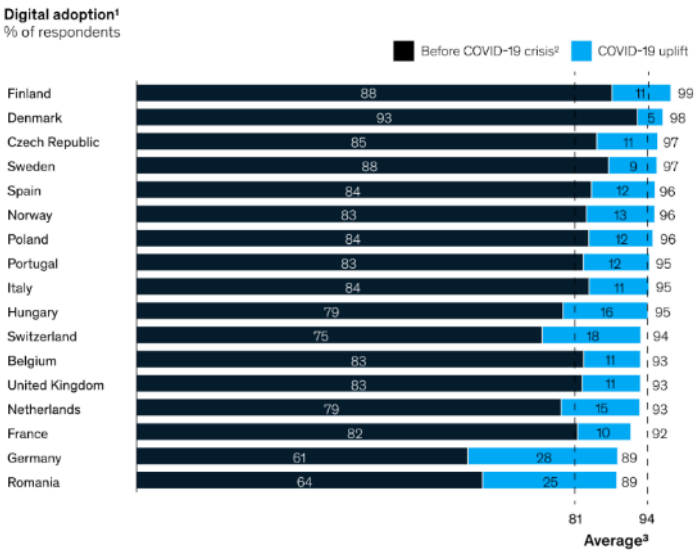


Figure 22 |Europe's Average Digital Adoption Before and After COVID-19 Crisis, % of Respondents.

Q: Which of these digital channels have you used in the past 6 months? Of these, which did you start using for the first time during COVID-19?

[1] Percentage of respondents using at least 1 digital service in at least 1 of 10 industries in the 6 months ending May 2020. Industries include: banking, insurance, grocery, apparel, entertainment, social media, travel, telecommunications, utilities and public sector. Note that figures may not sum to their totals, because of rounding.

[2] Percentage of respondents using at least 1 digital service in at least 1 of 10 industries in the 6 months ending May 2020, excluding those who used digital services for the first time during the COVID-19 crisis.

[3] Equal weight for all countries.

McKinsey & Company

Figure 21 |Europe Digital Gap – Number of Industries Accessed Digitally Before and After COVID-19 Crisis.

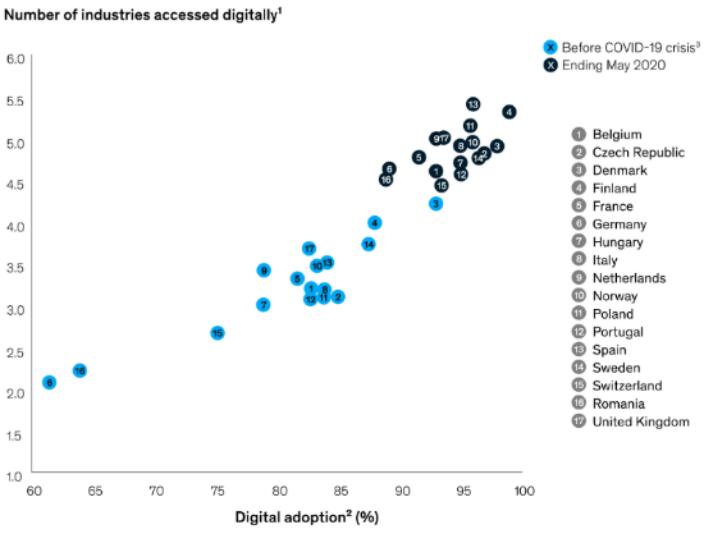
[1] Average number of industries accessed digitally by respondents, from a choice of 10, in the 6 months ending May 2020. Industries include: banking, insurance, grocery, apparel, entertainment, social media, travel, telecommunications, utilities and public sector.

[2] Percentage of respondents using at least 1 digital service in at least 1 of 10 industries in the 6 months ending May 2020.

[3] Average number of industries accessed digitally by respondents in the 6 months ending May 2020, excluding those accessed for the first time during the COVID-19 crisis; percentage of respondents using at least 1 digital service in at least 1 of 10 industries in the 6 months ending May 2020, excluding those who used digital services for the first time during the COVID-19 crisis.

Source: McKinsey & Company COVID-19 digital sentiment insights survey

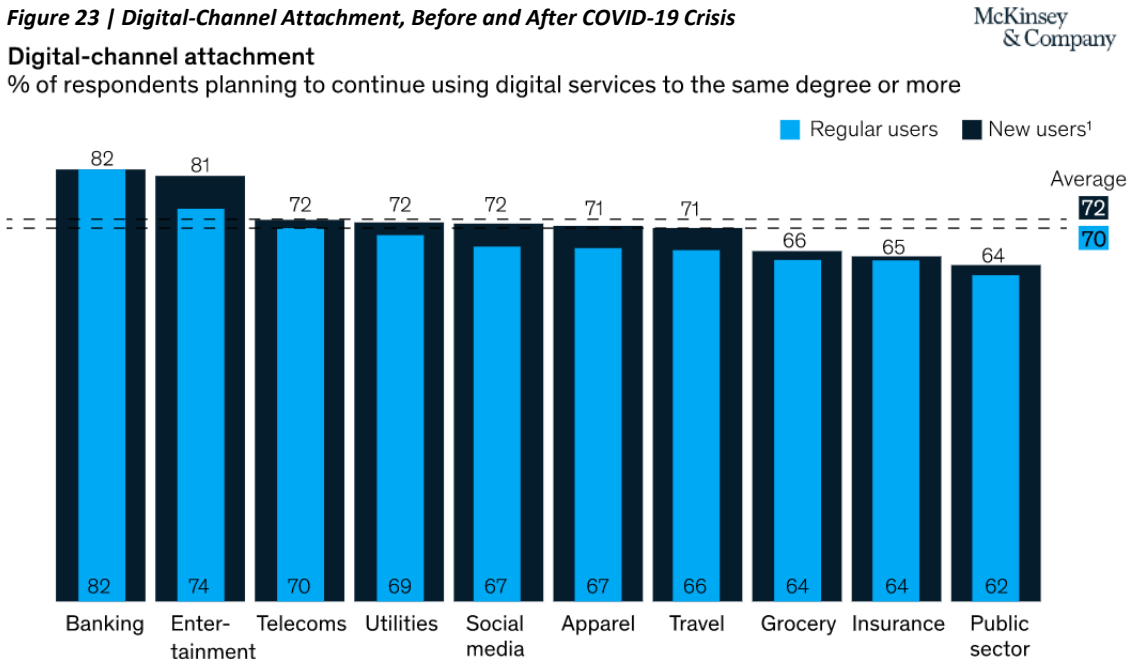
McKinsey & Company



The recently published survey by McKinsey & Company makes clear that the surge in the digital adoption is no temporary phenomena: over 70% of respondents stated they expect to continue using digital channels as they do now or even more often. However, it is worth noting the fact that important differences across industries exist here too.

From top to bottom, Banking has the most engaged users as measured by future intentions: 82 percent of those surveyed say they will continue using online banking services to the same degree or more. On the other hand, insurance, the public sector, and grocery are perceived as the most vulnerable in both regular recurrent and first-time users. This means that respondents don't expect to keep using digital channels in this market segments after the COVID-19 crisis stabilises or ends once a vaccine or efficient treatment is released.

Figure 23 | Digital-Channel Attachment, Before and After COVID-19 Crisis



Q: *Which of these digital services do you plan to continue using after the COVID-19 crisis?* Possible answers: banking, insurance, grocery, apparel, entertainment, social media, travel, telecommunications, utilities, public sector, and none.
¹Respondents who used digital services for the first time during the COVID-19 crisis.
Source: McKinsey & Company COVID-19 digital sentiment insights survey

COVID-19 PANDEMIC COULD LEAD TO HIGHER VR/AR ADOPTION

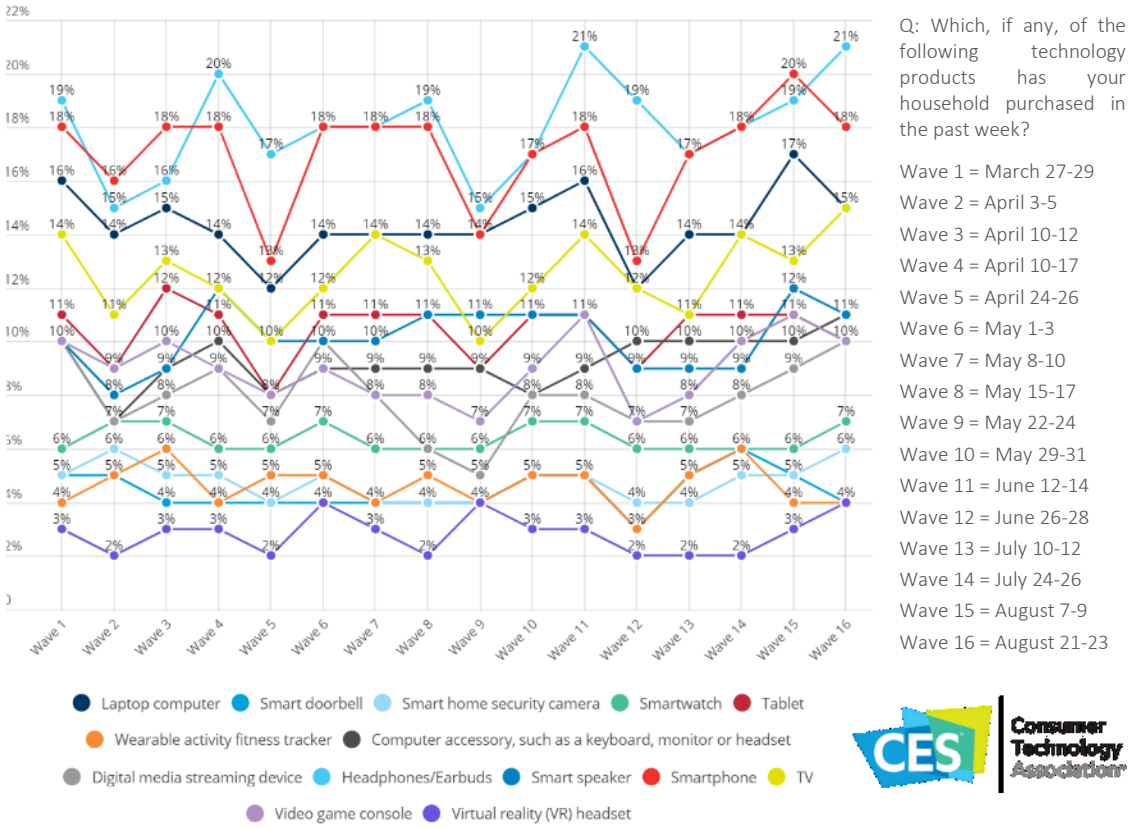
Such broader behavioural change in terms of digital adoption and given its long-lasting effect may also provide a boost for AR/VR. In fact, as the world went into lockdown, there was a big uptick in demand for VR applications. According to the Consumer Technology Association (CTA)[37]

These technologies are affordable and readily available. Though people cannot satiate their social instincts in person with them, they can fulfil them virtually. The COVID-19 pandemic has likely given rise to a new phenomenon wherein many more will become reliant on tools like AR, VR, and mixed reality to work, shop and socialise.

Even after the lockdown ends, the behavioural change it instigated will last considerably longer if not forever. People will remain socially distant but using technologies and extended reality they will be virtually close. These platforms and technologies will allow businesses to run and grow irrespective of the challenges posed by social distancing.

In fact, there's no end to the possible use cases for VR and AR during the current pandemic. In healthcare, doctors and surgeons use VR to view detailed scans of a patient's anatomy without the patient being present. In the education field, classes and labs are increasingly being conducted at a distance, as if the entire class is in the same room. And think of the travel industry, which can offer virtual tours of almost any site or attraction on earth.

Figure 24 | Impact of the novel coronavirus (COVID-19) on purchasing tech products in the United States in March-August 2020.



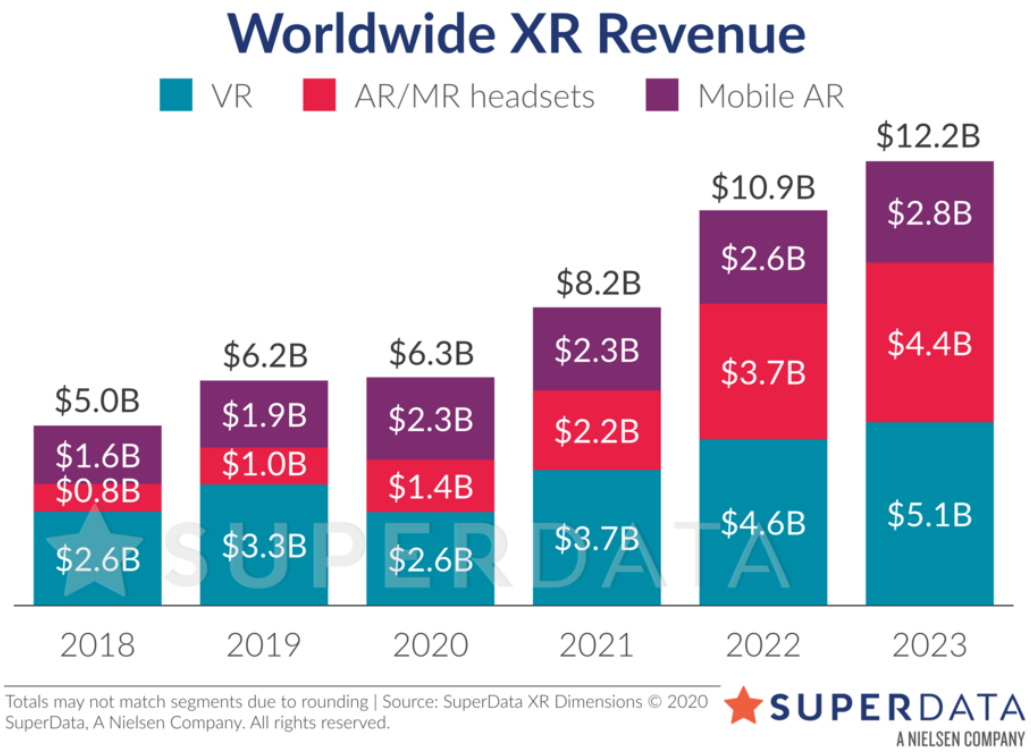
Q: Which, if any, of the following technology products has your household purchased in the past week?

Wave 1 = March 27-29
Wave 2 = April 3-5
Wave 3 = April 10-12
Wave 4 = April 10-17
Wave 5 = April 24-26
Wave 6 = May 1-3
Wave 7 = May 8-10
Wave 8 = May 15-17
Wave 9 = May 22-24
Wave 10 = May 29-31
Wave 11 = June 12-14
Wave 12 = June 26-28
Wave 13 = July 10-12
Wave 14 = July 24-26
Wave 15 = August 7-9
Wave 16 = August 21-23

CES Consumer Technology Association

[37] Consumer Technology Association™, 2020. Biweekly CTA Tech Use and Purchase Tracker: COVID-19 Impact. Wave 16, August 26. Available from: https://www.cta.tech/Resources/Research-and-Forecasts/CTA-Tech-Use-and-Purchase-Tracker

Figure 25 | Worldwide Extended Reality (VR, AR & MR) Revenue, 2018-2023 Forecast.



As a result, despite COVID-19 pandemic, the VR/AR market is still expected to expand at a significant rate of CAGR +24.64% for the upcoming 2020-2023 period according to the VR/AR industry leading market research company SuperData. In fact, since failing sales are due to lack of supply, not demand, shipments of many headsets are expected to quickly rebound as supply chains return to normal.

In addition, as strict lockdown measures increase the demand for further immersive technology solutions, the VR/AR market is expected to drastically rebound, especially in the light of the huge adoption and upsurge of social networks, e-work and e-health platforms.

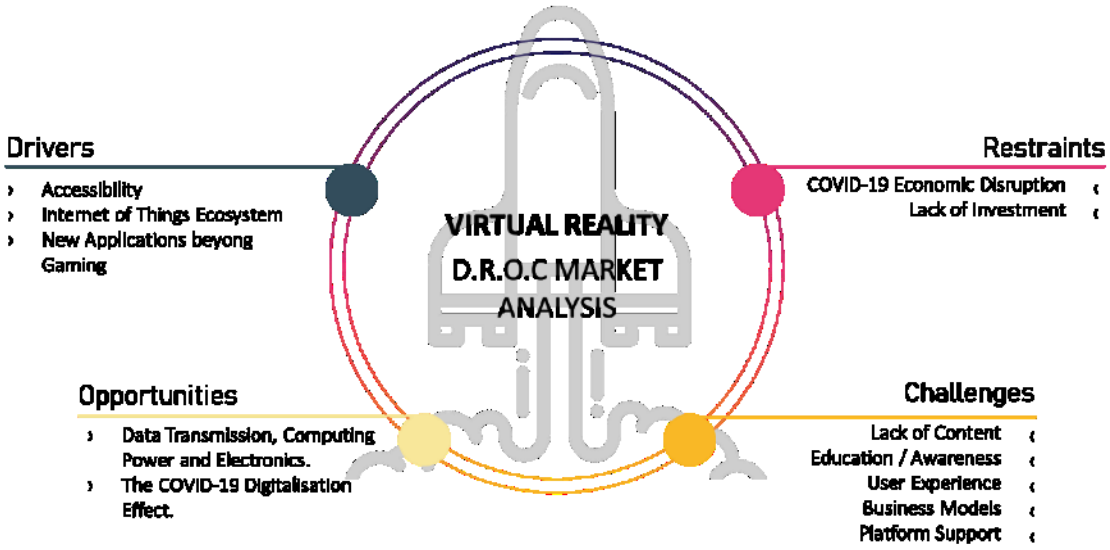
The bottom line is that **digitization is no longer optional**. As society continually changes with new realities like quarantining, social distancing, e-work, e-health and many other examples only the most innovative businesses are surviving. It's crucial to think of ways to bring customers to products, even if the customer never leaves their home. It's also important to think of new ways to virtually bring employees to work, conferences, and events not to mention the pressing need to keep quality education digitally.

But how will AR/VR help the market in the long run? According to the Media Bulletin[38], the answer is through Mergers and Acquisitions (M&A). As previously mentioned in section 2.2, despite AR/VR investment volume (number of deals) declined significantly in the last 2 quarters due to the pandemic, a significant rebound is expected in the light of the new reality which involves digitalisation of the society. The main aim behind these acquisitions is to strengthen their R&D capabilities and position in the market. Such strategies also help in expanding vendors' businesses, which accelerate technological advances in the field. Thus, during the pandemic, such acquisitions will positively impact market growth in the long run.

[38] Oishee Mukherjee, 2020. Increasing Demand for AR and VR Technology to Boost Market Growth During Covid-19. The Media Bulletin, August 2020. Available from: https://www.themediabulletin.com/increasing-demand-for-ar-and-vr-technology-to-boost-market-growth-during-covid-19/

2.4.4. DROC ANALYSIS

Figure 26 | Virtual Reality DROC Analysis



2.4.5. DRIVERS – THE FORCES ENABLING THE NEW WAVE OF VR/AR EXPERIENCE

Plummeting hardware and software costs, increasingly impactful applications outside of entertainment, and the ubiquity of mobile devices are contributing to the rise of immersive XR technologies[39]. This is the primary conclusion of Perkins Coie fourth Annual Augmented and Virtual Reality Survey, conducted in early 2020 in collaboration with XR Assoaciadion and industry venture capital firm Boost VC. The survey, taken before global markets were roiled by the coronavirus outbreak, found growing momentum for nearly every area of immersive technology's use and, importantly, expanding avenues for monetization.

As such, there are multiple factors that are supporting the growth in terms of adoption of VR/AR technologies across the society and businesses:

a) Accessibility

As any new technological paradigm, when a new product or experience category is launched to the market it is usually expensive due to the small addressable market and volumes, resulting in high-cost adoption rates. This has been the case of VR/AR over the last decades but now accessibility

The cost of acquisition and development of both hardware and software used to access VR and AR technologies and content has become affordable for nearly all pockets. This coupled with the wide-spread adoption of smartphones and the ever-increasing mobile device computing power and battery life at an all-time high is driving the wide-spread adoption.

An example of such accessibility force is the fact that Google has developed a DIY entry-level carboard set for experiencing a VR mobile apps[40], meaning the cost has become

[39] Perkins Coie LLP, 2020. 2020 Augmented and Virtual Reality Survey Report. March 2020. Volume 4. Available from: https://www.perkinscoie.com/images/content/2/3/v4/231654/2020-AR-VR-Survey-v3.pdf
[40] Google Cardboard, 2020. Available from: https://arvr.google.com/cardboard/

absolutely minor for HMDs. In the field of software, the San Francisco-based Unity Technologies[41] has developed the most popular cross-platform VR engine. The software development tool is free to access for aspiring non-commercial VR/AR developers and designers.

b) Internet of Things (IoT) Ecosystem

As the world becomes more and more digitalised, the connected ecosystem of smartphones, cameras, network data and beacons enable VR/AR developers and users to expand beyond on-site applications and opens the door to taking the technology into a multi-layered consumer environment. This will allow for new applications, experiences and audiencias, as well as enabling new business models.

In fact, by bridging both the digital and physical worlds using VR/AR and IoT is set to become the so-called Real-World Web (RWW)[42] in which any object or physical environment can be blended with the digital. It can also be regarded as a dual system in which VR/AR technologies function as the human interface with the digital world and the IoT acting as the world's nervous system.

c) New Applications

While some still see augmented reality (AR) and virtual reality (VR) as technologies reserved for gamers and niche entertainment purposes, many have taken notice of the considerable potential for each across a variety of industries.

As hardware developers make AR and VR headsets more affordable and user-friendly, startups are developing new solution enabling use cases far beyond gaming, applying the technologies to everything from marketing to healthcare to space exploration, and more. Outside of gaming and entertainment, the most disruption from immersive technologies is expected in healthcare and medical devices over the next 12 months. According to Perkins Coei Survey, 38% of respondents pointed to healthcare and medical devices as ripe sectors for disruption, and education followed closely at 28%.

Industry leaders are noticing tangible and significant advances in the adoption of VR, AR and MR across sectors, such as healthcare, education, workforce training, manufacturing and retial, to name a few. As mentioned by Elizabeth Hyman, CEO of XR Association, "the industry is at the precipice of an integration of XR – a category that includes all VR, AR and MR - technology that will transform business and society for the better".

What is more, Perkins Coie survey indicates boom times ahead for the industry with nearly 200 professionals representing startups, enterprise technology firms, and investors showing strong optimism. Immersive gaming is set to continue growing, but other, broader uses are too — meaning there can be no doubt that the market for XR technologies is **growing and maturing at a rapid pace**.

[41] Unity Technologies, 2020. Virtual Reality. Available from: https://unity.com/unity/features/vr

[42] Xperiel, 2018. The Real World Web: the Link Between AR, VR and the IoT. By Alex & Philipp Hertel, Ph.D. Available from: https://medium.com/xperiel/the-real-world-web-the-link-between-ar-vr-and-the-iot-ce02b39e61d8

2.4.6. RESTRAINTS - FACTORS HOLDING BACK VR/AR ADOPTION

a) COVID-19 Economic Disruption

COVID-19 has quickly emerged as the number one risk to global and regional economic activity. In the short-term the VR/AR market is forecast to be impacted by COVID-19 related factors including – but not limted to – lockdowns, brick-and-mortar retail closures, supply chain disruption at all levels (supplier, manufacturer, distribution, wholesale, retail) and economic recession/depression impact.

The crisis has been devastating for physical retail and location-based entertainment venues, bringing the sector to a standstill and accelerating some long-term trends by years. As for supply chains, while the U.S.-China trade war had already begun to have an impact on global supply chains, the pandemic crises has been far more significant. This is as true for VR/AR as for any other industry.

Last, he swift and massive shock of the coronavirus pandemic and shutdown measures to contain it have plunged the global economy into a severe contraction. According to World Bank forecasts, the global economy will shrink by 5.2% this year[43]. The blow is hitting hardest in countries where the pandemic has been the most severe and where there is heavy reliance on global trade, tourism, commodity exports, and external financing. As for any other industry and market segment such contraction will also impact the VR/AR industry in the short-term.

However, a dichotomy prevails. As it has already been reviewed, the pandemic may in fact changed the fate of VR/AR. For the past several years, VR has remained a niche industry. However, the current crisis may be the necessary spark for new technologies that allow people to collaborate more deeply. Be that as it may, the COVID-19 crisis probably will affect the fortunes of AR and VR in the short term, but inexpensive headsets and better software coupled with the pandemic-related massive behavioural change towards digitalisation could change the game.

b) Lack of Investment

As reviewed, investment in the technology has slowed dramatically, heavily impacted by the pandemic crisis which has brought investment back to 2013 levels. It is too early to tell whether the peaks of AR and VR investment from recent years might return after the coronavirus crisis has reached a resolution.

Additionally, AR/VR has seen relatively low M&A volume (i.e. number of deals) compared to other tech sectors due to the early stage of the market. In the current augmented and virtual reality market, startups might be most focused on short term revenue generation and managing burn rates through 2020/2021. Leveraging Venture Capital to accelerate growth is challenging in normal time, but these are not normal times. Public investment and support are needed more than ever before to help VR/AR startups consolidate and help find a way through the pandemic context.

[43] The World Bank, 2020. COVID-19 to Plunge Global Economy into Worst Recession since World War II. Washington, June, 2020. Available from: https://www.jabil.com/blog/human-factors-impacting-augmented-reality-and-virtual-reality-adoption.html

2.4.7. OPPORTUNITIES – POISED FOR SUCCESS

a) Data Transmission, Computing Power and Electronics.

While mobile devices are still the go-to device for AR/VR immersion, new forms of hardware enable tactile, multi-sensory experiences at home or allow remote real-time use of the technology.

Creating an VR/AR experience is no easy task and does not come without technical challenges. Combining and synchronizing the real world and the motioning of the user with a digital world requires a massive amount of graphical rendering processes. Because the graphics require heavy rendering, on-device processes are augmented by splitting workloads between the AR/VR device and the edge cloud. Graphics rendering on the edge cloud augment latency-sensitive on-device head tracking, controller tracking, hand tracking and motion tracking to photon processing. This concept is called split rendering. But when the rendering is done in the cloud, and not on a mobile device, you also need a fast and reliable 5G connection to deliver the final experience to the user.

Both AR and VR use cases require stringent network requirements such as low latency, high reliability and high bandwidth. With the market launch and adoption of novel technologies such as 5G, Depth Cameras (e.g. new Iphone 12 pro LiDAR system) Edge Computing and the improved computing power of smartphones and standalone headsets a new landscape of growth opportunities is revealed in the VR/AR field.

b) The COVID-19 Digitalisation Effect

The COVID-19 pandemic is expected to further support the growth of the VR market. Given the current context of the pandemic, there is a great opportunity to promote the use of VR and AR in different industries and to spark interest among business and end-users.

Considering that digitalization in certain industries is being forced and driven by the current context of pandemic, the incorporation of new technologies such as VR/AR can help brands and companies solve process and business opportunity issues. Most importantly, this helps companies adapt to a new scenario where the virtual world has become predominant. Such opportunity ranges from workflow and collaboration tools, marketing and advertising, healthcare and medical devices to education or even real state.

Such a trend also represents an opportunity for reaching the large audience of potential consumers since real-time socialising platforms are on the rise, especially in the context of quarantines are mobility restrictions.

2.4.8. CHALLENGES – UNLEASHING THE POTENTIAL OF VR

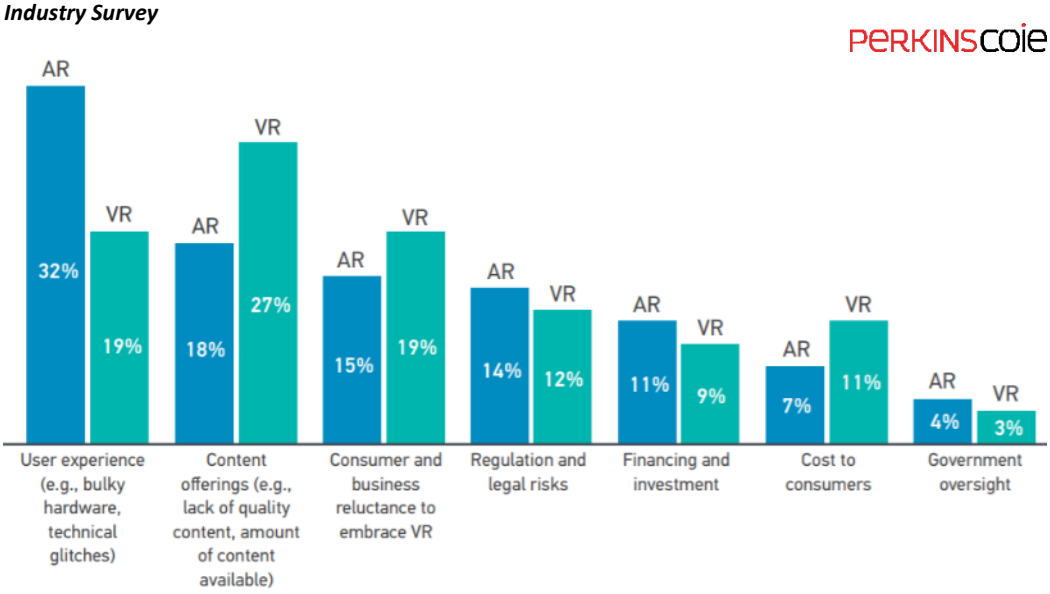
There are four main challenges facing mainstream adoption of VR/AR technology:

a) Lack of Content

Frustrations with a lack of content threatens to undermine the momentum in the growth of the VR market being an urgent challenge to be successfully overcome. A new survey by a joint effort by Boost VC, XR Association and Perkins Coie[44], sought to find out how the fledgling VR scene felt about its own chances of achieving significant success.

Most respondents did not claim that the high prices of hardware or the still niche-nature of the VR market as their chief concern for the consumer adoption of VR. Instead, according to the survey, 27% of respondents stated content offerings was the biggest obstacle to mass adoption of VR (18% in the case of AR).

Figure 27 | What is the biggest obstacle to mass adoption of AR and VR technologies? Perkins Coie 2020 Industry Survey



Thus, it can be concluded that there is a lack of quality content that limits consumer interest which hinders the business case for more VR/AR content development, generating a vicious cycle of events. Interestingly, according to a survey conducted by Google[45], sky-high quality content does not necessarily mean the production needs to have crisp graphics, but rather focus on the impressiveness and to be compelling.

b) Education / Awareness

AR and VR content can come in many forms, and this could be a cause for confusion. Few members of the general public have an accurate understanding of the technology due to a lack of first-hand experience. This results in lack of consumer interests due to lack of information and knowledge about the technology's potential and applications is causing VR mass-adoption to stall.

[44] Perkins Coie, 2020. Indsutry Insight into the Future of Immersive Technology. BoostVC, Perkins Coie and XR Association. Available from: https://www.perkinscoie.com/images/content/2/3/v4/231654/2020-AR-VR-Survey-v3.pdf

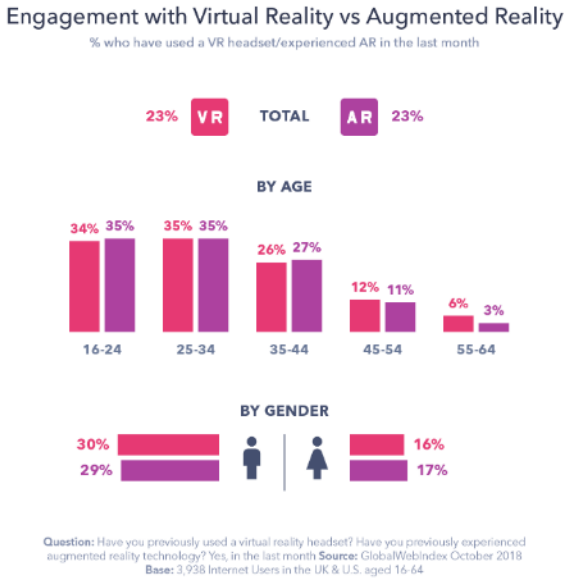
[45] Think with Google, 2017. 3 Best Practices for Creating Engaging VR Content. Alexis Cox. Available from: https://www.thinkwithgoogle.com/marketing-strategies/video/vr-content-audience-engagement-best-practices/

According to a Global Web Index survey conducted in the U.S. and in the UK, over 90% of consumers in these markets were aware of VR whereas only 65% were aware of what AR is. However, an important dichotomy exists by age.

Awareness of VR/AR ranges between 70-75% in the 16-44 age group but drops dramatically among the 45-54s (56%) and 55-64s (44%). By gender, males (71%) display notably higher level of awareness compared to women.

Notably, only 23% of those surveyed by Global Web Index used a VR headset/experienced AR in the last month noting there is an important bridge between awareness and usage.

Figure 28 | Global Web Index 2018 Survey on VR vs. AR Engagement.



Source: Global Web Index, 2018.

Getting audiences to engage with a new technology is challenging. One way to bypass such situation and encourage the public to take this step is by participating in events or congresses, advertising the technology and collaborating with key technological firms.

Another proven strategy is by leveraging an existing brand (brand licensing). This provides a hook to draw the audiences through a known and exciting name. The 2016 hit application, Pokémon GO, is an example of where AR technology was targeted at an appropriate market and become a global phenomenon. Aside from the power of leveraging a popular brand, the application ran on handheld AR devices – effectively smartphones and tablets, which are ubiquitous in the world today.

c) User Experience

From both a software and hardware perspective, setting up and running high-end VR/AR systems and experiences is not a simple task. Most of the nowadays popular VR experiences include the combination of three form factors to provide the experience: an HMD, a computing device and headphone. The user experience of managing all the different devices is complex and takes away the potential of VR.

In addition, for a virtual environment system to be compatible with their users, it is vital for designers to understand design constraints imposed by human sensory and motor physiology. The physiological and perceptual issues that directly impact the design of virtual environment systems are visual perception, auditory perception, and haptic and kinesthetic perception. If all these factors are not considered or fully understood, the user experience is negatively impacted resulting in lack of immersiveness. It could even generate the opposite effect, the so-called cyber sickness due to spatial distortions and illusions.

d) Business Models

A company's business model is central to the success of any VR. One of the most pressing challenges for the VR/AR industry is the lack of sustainable business models. Despite being a cutting-edge technology, it is yet unclear how it can translate to a robust business case. This is due to market adoption: VR/AR has not yet penetrated the consumer market to a large enough extent to make most business cases viable. For internal businesses applications, this is less of a concern as adoption can be artificially developed through company policy.

e) Platform Neutrality

As VR technology quickly progresses, it is important to be able to develop and run applications on different systems and receive a similar user experience. Some of the challenges associated with cross platform VR development are dissimilarity between the hardware devices and a lack of software support. Being able to overcome these challenges will allow for organizations to develop applications which fit the available VR hardware. This not only will result in reduced costs and time but ultimately will result in increased market growth of the technology across all market categories and applications. Such challenge is already being addressed by developers of cross-platform VR systems and engines such as Unity Technologies or Youtube VR[46].

[46] Youtube VR, 2020. VR is going places. Come find out where. Available from: https://vr.youtube.com./

3. THE EUROPEAN VR / AR ECOSYSTEM

3.1. SIZE AND GROWTH OF THE EUROPEAN VR/AR INDUSTRY

Virtual and Augmented reality technologies are booming in Europe and are expected to create up to 480.000 jobs and will increase in value up to 34 billion € by 2020, according to the latest and most optimistic market estimations conducted by the consultancy firm Ecorys.

The study, which analysed both the VR and AR industries in Europe for the 2016-2017 period, took into account a range of different market studies as well as the specific idiosyncrasies of the European landscape to determine the impact of the growing VR/AR demand on Europe economy.

On this premise, the production value of the European VR and AR industry, as of 2015, accounted for almost €700 million, roughly one quarter of the global value at that time (€3 billion). However, Ecorys market projections estimate the **market value to increase between €15 billion and $34 billion by 2020**. That is an impressive CAGR of **84.59%-117.41%** for the 2015-2020 period.

Like GoldmanSachs global VR/AR market size estimations (see Figure 17), Ecorys considered two scenarios:

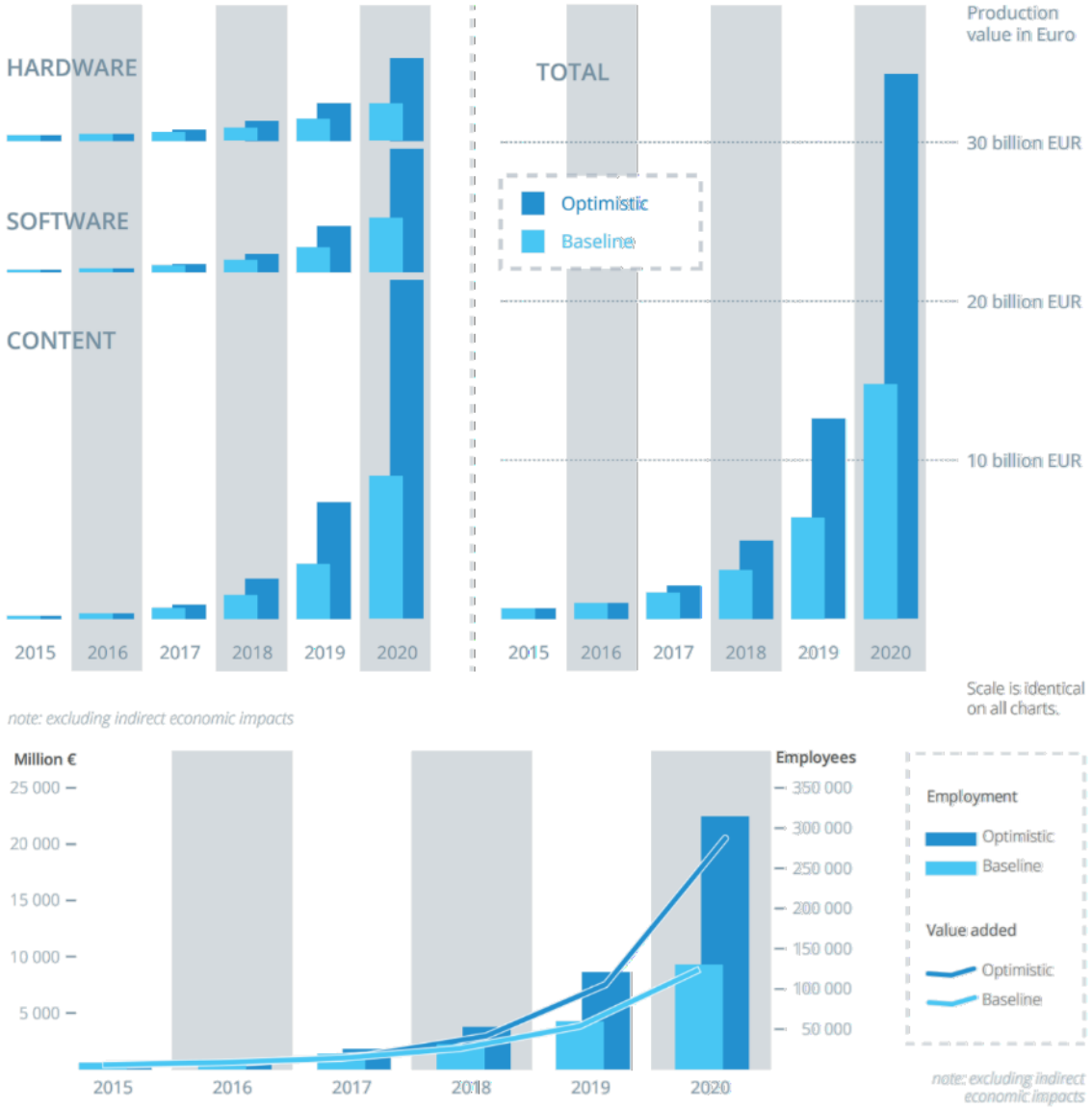
a. The **baseline scenario** contemplates a steady growth of VR applications for professional uses, but a rather moderate growth for mass adoption consumer applications.

b. In contrast, the **optimistic scenario** expected optimal conditions for mass-adoption of end-use applications. This includes more user-friendly and comfortable hardware in combination with price reductions, software optimisation to allow minimal motion sickness and breakthrough consumer applications (like social VR) and new content.

In these scenarios, by 2020 the European production value is expected to increase to between €15 billion and €34 billion, representing a gross value added of between €9 billion and €21 billion and directly creating employment for some 140,000-300,000 people. Also, wider supply chain impacts are expected to indirectly increase the production value with between €5.5 billion and €12.5 billion and generate an additional 85,000-180,000 jobs.

According to Ecorys, this will bring the overall economic impact of the VR and AR industry for Europe at a **total production value of between €24 billion and €54.5 billion, a gross value added of between €14.4 billion and €33.6 billion and 225,000-480,000 jobs.**

Figure 29 |Market Size and Growth of the European VR / AR Industry



Source: Ecorys, 2018.

NOTE | *More information regarding the quantitative market development estimates available at https://ec.europa.eu/futurium/en/system/files/ged/vr_ecosystem_eu_report_0.pdf. (Annex B: Quantitative assessment of the AR/VR market).*

At a granular level, the **Content Sector** is poised to reach between the 14.770-21.313 million EUR level, concentrating a 61%-62% of the overall market share depending on the scenario. The **Software** sector will concentrate the 23% of the market with a size ranging between the 3.425-7.775 million EUR. Finally, the **Hardware** will account for the least market share, roughly 15-16%, and the least market size – 2.346-5.185 million EUR – according to each scenario respectively.

In the context of a Global VR/AR market, Ecorys expects the European market to represent the **29.63%-33.56% of the global industry**. That is a 8.80%-16.27% of the global VR Software market, 34.43%-41.68% of the global VR Hardware sector; and 45.80-55.93% of the global VR content sector.

Table 2 | Ecorys European VR/AR Industry Growth Prediction

EUROPE - BASELINE SCENARIO							
Growth rates	Sector / Year	2015	2016	2017	2018	2019	2020
	HW	N/A	1,2	1,3	1,45	1,7	1,7
	SW	N/A	1,6	1,8	1,9	2	2,2
	Content	N/A	2	2	2,2	2,3	2,6
Proportion of sectors	Sector / Year	2015	2016	2017	2018	2019	2020
	HW	53,00 %	43,00 %	34,00 %	26,00 %	22,00 %	16,00 %
	SW	21,00 %	23,00 %	25,00 %	25,00 %	24,00 %	23,00 %
	Content	25,00 %	34,00 %	41,00 %	49,00 %	54,00 %	61,00 %
Market size in million EUR	Sector / Year	2015	2016	2017	2018	2019	2020
	HW	359	431	560	812	1.380	2.346
	SW	142	228	410	779	1.557	3.425
	Content	171	342	684	1.505	3.461	8.999
	Total	672	1.000	1.654	3.095	6.398	14.770

EUROPE - OPTIMISTIC SCENARIO							
Growth rates	Sector / Year	2015	2016	2017	2018	2019	2020
	HW	N/A	1,2	1,6	1,8	1,9	2,2
	SW	N/A	1,6	2,2	2,3	2,5	2,7
	Content	N/A	2	2,6	2,85	2,9	2,9
Proportion of sectors	Sector / Year	2015	2016	2017	2018	2019	2020
	HW	53,00 %	43,00 %	33,00 %	25,00 %	19,00 %	15,00 %
	SW	21,00 %	23,00 %	24,00 %	23,00 %	23,00 %	23,00 %
	Content	25,00 %	34,00 %	43,00 %	51,00 %	58,00 %	62,00 %
Market size in million EUR	Sector / Year	2015	2016	2017	2018	2019	2020
	HW	359	431	689	1.240	2.357	5.185
	SW	142	228	501	1.152	2.880	7.775
	Content	171	342	889	2.534	7.349	21.313
	Total	672	1.000	2.079	4.926	12.586	34.273

Source: Ecorys, 2018.

NOTE | *More information regarding the quantitative market development estimates available at https://ec.europa.eu/futurium/en/system/files/ged/vr_ecosystem_eu_report_0.pdf. (Annex B: Quantitative assessment of the AR/VR market).*

Interestingly, such figures clearly outline the fact that Europe is especially strong within the Content creation and software sectors, in alignment with European strong academic and high-precision technologies background and its immense cultural diversity (see section 2.2.1). In stark contrast, other regions such as Asia-Pacific is more intensive in Hardware production and North America has a balanced distribution among all sectors.

Despite it could be arguable whether these figures stand far from the 2020 reality, especially on the current environment of global sanitary and economic crisis as previously reviewed (see section 2.3.2), the upward trend is further corroborated by other relevant sources.

In a study by ResearchAndMarkets and as published in PR Newswire and Statista[47,48], the European VR/AR market was valued at $4.57 billion in 2018 and will grow up to the $50.55 billion by 2026, at a CAGR of 35.04% for the 2018-2026 period. When extrapolating (linear) the 2020 figure from those estimations, for comparison purposes, the market size is of €8,33 billion, standing far behind even the most pessimistic scenario developed by Ecorys. This is indicative of

[47] PR Newswire, 2019. Europe Augmented Reality and Virtual Reality Market to 2026 by Technology, Component, Device Type, Industry Vertical, End-user, and Country. CISION. Dec 05, 2019, 10:30 ET.Available from: https://www.prnewswire.com/news-releases/europe-augmented-reality-and-virtual-reality-market-to-2026-by-technology-component-device-type-industry-vertical-end-user-and-country-300969982.html

[48] Statista, 2020. Size of the augmented & virtual reality (AR/VR) market in Europe 2018-2026. Published by Thomas Alsop, Jun 12, 2020. Available from: https://www.statista.com/statistics/1121370/european-augmented-virtual-reality-market-size/

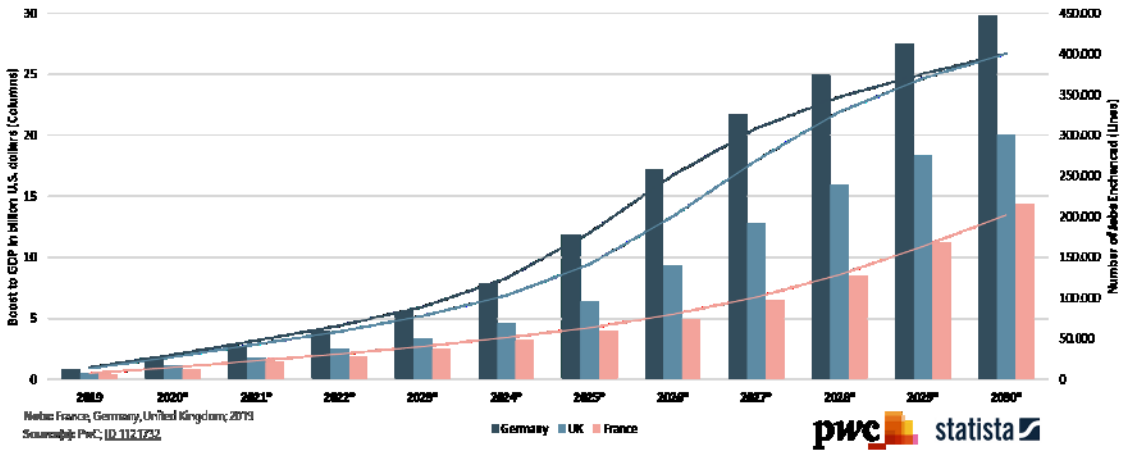
a delayed market uptake of the technology, although all forecasts consulted align with the fact that the upward trend is only going to grow in the upcoming years.

Price Waterhouse Coopers (PwC)[49], expects VR/AR to boost gross domestic product (GDP) by $13.3 billion within three of the most prominent European Markets, Germany ($6.3 billion), France ($3.2 billion) and UK ($4.1 billion). These figures, if extrapolated to the rest of the European Union context match with those predicted by Ecorys.

What is more, PwC forecasts VR/AR will boost GDP by 103.6 billion U.S. dollars in Germany by 2030, whilst in the UK, GDP is forecast to receive a 69.3 billion U.S. dollars boost as a result of VR and AR technologies. France is forecasted to receive a boost of up to 3.2 billion US. dollars in GDP for the same year.

In a similar trend, as of the PwC 2019 report, it is forecast that over 400 thousand jobs will be enhanced by virtual reality (VR) and augmented reality (AR) technologies in both Germany and the UK by 2030, an increase from the 10 to 15 thousand jobs that were enhanced by VR and AR in each of these countries in 2019. In the third case, France, the number of jobs enhanced by 2030 will be as of 202.000, a 0.73% of the total by the country.

Figure 30 | Boost to GDP from virtual reality (VR) in Europe's leading economies 2019-2030 (Columns); Number of jobs enhanced by virtual reality (VR) and augmented reality (AR) in Europe's leading economies from 2019 to 2030 (Lines).



Overall, such estimations demonstrate that Europe is in a strong competitive position to seize new emerging opportunities in these industries. Europe's successful VR track record has been sustained by VR companies creating content, application and technologies, all of which have been supported by a strong focus on R&D across the continent. Thus, we can conclude that despite all the R&D conducted and available content, the valorisation of exploitation of such results is barely just beginning.

In fact, as previously mentioned, the simultaneous fostering of VR companies, as well as continued research, has not only allowed Europe to become an important industry stakeholder, but has also prompted international teams to relocate to Europe to benefit from the highly skilled workforce and facilities.

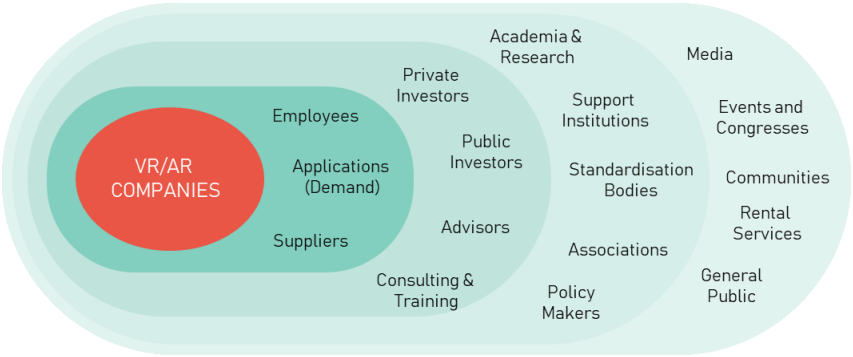
[49] PwC, 2019. Seeing is Believing: How AR and VR will transform business in the economy. Report 2019. Available from: https://www.pwc.com/gx/en/industries/technology/publications/economic-impact-of-vr-ar.html

3.2. THE EUROPEAN VR/AR ECOSYSTEM

For the VR/AR industry to progress, there needs to be acknowledgment that VR/AR companies are not the only stakeholders involved and that they cannot operate independently. The public govern and public institutions, academic institutions, and others all have varying degrees of influence over the future of the industry.

The VR & AR ecosystem consists of various actors who are all interrelated. In the centre of VR and AR ecosystem are naturally companies creating technical solutions, software and applications. Nevertheless, the ecosystem is reliant also on other players.

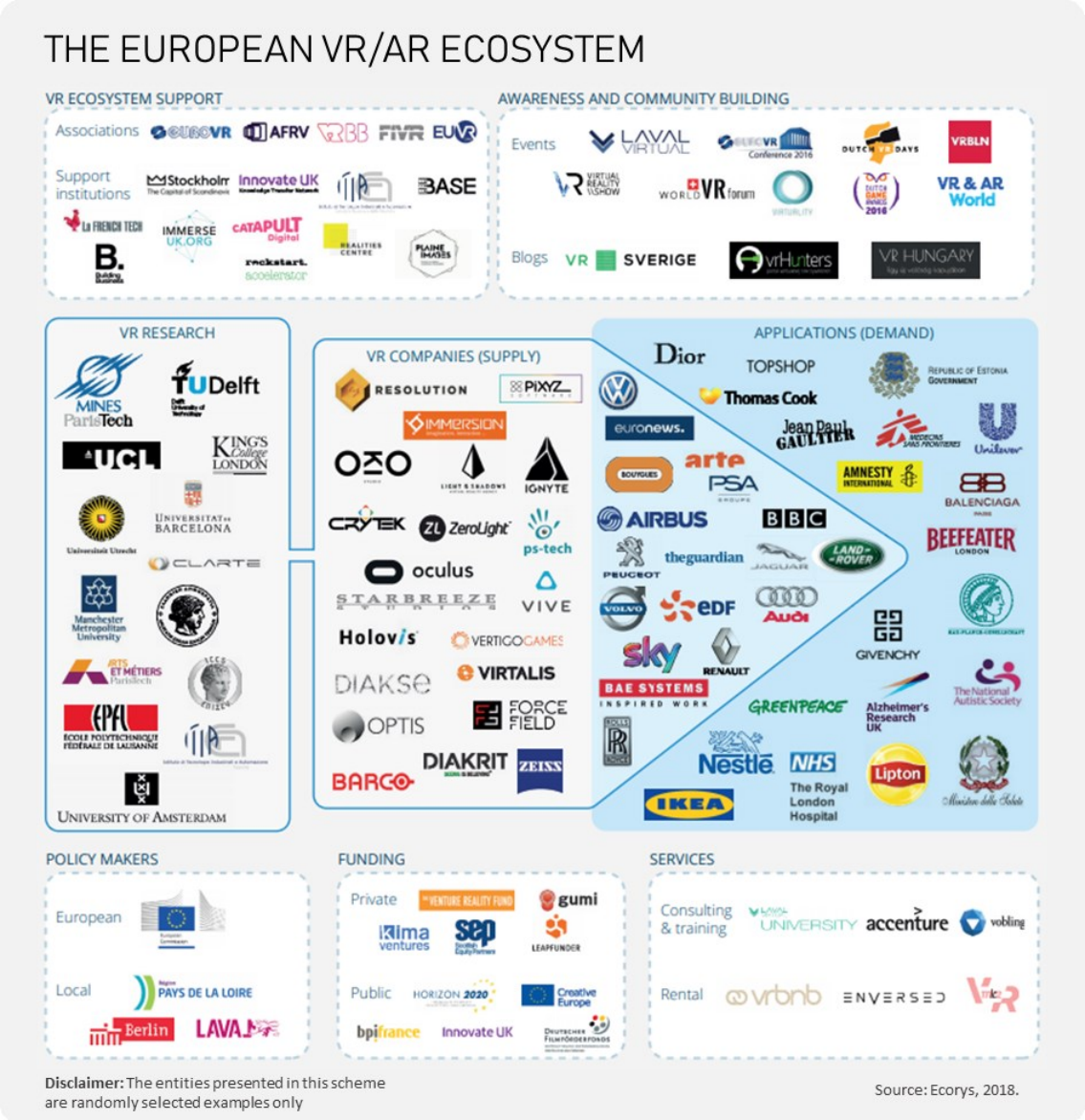
Table 3 | Stakeholder of the VR/AR Ecosystem



STAKEHOLDER	DESCRIPTION	RECOMMENDATION TO VR/AR COMPANIES
Government	All European and Nation government entities with potential influence on VR/AR companies (e.g. European Commission,	Keep updated on upcoming legislation and funding opportunities, engage with industry networking groups, and look to join lobby groups where possible to influence decision making
Customers	Individual purchasers of VR/AR technology and content.	Establish a continuous feedback loop with customers about products and services, both existing and upcoming.
Advisers	Organizations involved in providing legal, tax, consulting, or funding advice to the VR/AR industry. Includes industry analysts.	Identify the company's requirements in its current and near-term future state and seek out individuals/ companies for legal, tax, consulting, or funding advice as appropriate.
Investors	Non-governmental organizations and individuals who could provide funding to a VR/AR company.	Practice elevator pitches, attend investor events, and build individual connections with investors.
Media	Journalists, digital and print news outlets	Seek out opportunities for commentary on the industry or product and be prepared to handle difficult questions during challenging times
Public	Members of the public who are not consumers of VR/AR technology.	Where the opportunity arises, educate the public and correct false perceptions through first-hand demonstrations of the technology.
Employees	Staff members of VR/AR companies.	Promote a culture of equality, diversity and autonomy, keep utilization of employees balanced, and motivate with meaningful work.
Suppliers	Suppliers of key technologies (e.g. headsets) to VR/AR companies.	Consider new product announcements and their place in the strategic roadmap.
Academia	Universities and other mainly research-oriented organizations.	Keep updated on upcoming research papers and studies and offer input if helpful.

In fact, the VR & AR ecosystem is made of intricate and interrelated relationships established between the different industry actors. Those actors can be divided into six different blocks depending on their role within the market. Based on a typology map elaborated by the economic and strategy consulting firm Ecorys, the following map provides a general typology of all actors and illustrates how this relate and connect to each other.

Figure 31 | The European VR & AR Ecosystem



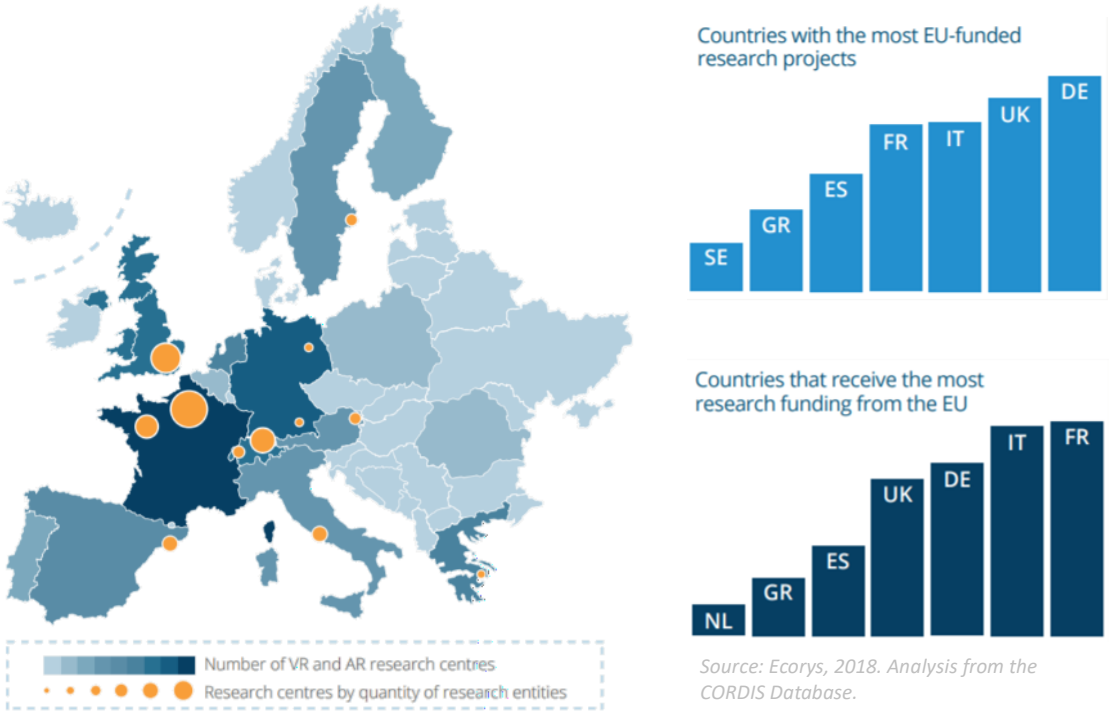
3.2.1. VR Research

The European VR Research Landscape

VR research is represented by universities, schools and research centres around Europe and their activity closely relates to that of VR/AR companies (supply of technology solutions). Their key importance for the ecosystem is twofold. On the one hand they run VR research projects in technical and creative fields and help advance VR technology and applications; on the other hand, they also supply qualified workers to companies and other entities.

The European research scene is concentrated in France (especially in Paris and Laval), the UK (London and Manchester universities), and Germany (Berlin and Munich). Spain (Barcelona), Sweden (Stockholm), Austria, Italy and Greece are also engaged in virtual research. R&D is focused on health care, industrial use of VR or general advancement of VR and AR technology. European universities ºare used to working together and also cooperate on large-scale international projects funded by European research funds.

Figure 32 | VR & AR Research Landscape in Europe, 2018.



Source: Ecorys, 2018. Analysis from the CORDIS Database.

VR research, especially in the areas of industrial design and mechanical engineering, has a long-standing tradition within universities such as **ParisTech (FR)** or **Technical University of Munich (DE).**

Technical universities often cooperate well with manufacturing industries – for example Paris Tech has a long-standing partnership with SNCF (the French Railroad Company) or French car manufacturers. In the engineering sector, the cooperation between academia and the private sector seems to work well even though not all inventions get applied in the end.

For example, the technological resources centre **CLARTE (FR),** specialised in VR/AR, has established multiple partnerships with industry leading companies such as Renault, Saint Gobain, or Vinci Constructions.

In fact, the research centre invented a high-tech VR conferencing system back in 2018 that allows collaboration on the industrial design process and without the use of headsets. However,

the top R&D centre has not yet been able to commercialise the invention and instead has shifted its focus towards training applications.

Also, the Warwick Manufacturing Group (WMG), an academic department of the **University of Warwick (UK)**, signed a 100 million partnership with Jaguar-Land Rover for research in the engineering and electronic field, including Virtual Reality.

Another area where European universities are active and successful is neuroscience, psychology and psychiatry. Among them **King's College (UK)** has been researching for years on VR possibilities in treatment of phobias and deformed body image. The university is currently discovering opportunities to use their methods in the wider psychology practice. Other universities active in the field of psychology are the **University of Barcelona (ES), University College of London (UCL), University of Oxford (UK), University of Milan (IT), Groningen University (NL) and VU Amsterdam (NL)[50],** among many other.

For instance, a particularly relevant example is the **École Polytechnique Fédérale de Lausanne (CH)[51],** active in the neurology applications field of VR. The research made lead to the spin-off of a global leader in medical VR **MindMaze (CH)[52].** The Swiss company, became well known after it raised funds at $1.1 billion valuation back in 2016[53], being a successful example of technology transfer from research to market.

Other examples include the work of **Amsterdam UMC (NL)[54],** leading the research on using VR for obsessive-compulsive disorder assessment and treatment. Or the work of the **Max-Planck-Institute for the Study of Crime, Security and Law (DE)[55,56]** for using VR in crime research.

The field of **VR in education** is also very active in terms of research within Europe. In education we sometimes find subjects and concepts that are difficult to teach using conventional teaching methods. These may for example be difficult to imagine, while others may be too dangerous or too expensive to study in real life. These subjects can benefit from teaching modules that use VR and/or AR as the way to communicate these subjects.

For instance, the **University of Amsterdam (NL)[57]** has been long researching on using VR/AR for its use in teaching biology, anatomy chemistry or programming subjects to students. The **University of Dublin (IRE)** is also active in the field, for all education, health and creative industries.

The last category, **creative industries**, such as creative schools and arts centres is also a relevant category of research. They are active in content creation in VR and teach how to capture images or create 360-degree movies. For example, **University of Paris 8 (FR)** in cooperation with a **Athens School of Fine Arts (GR)**, teaches a degree connecting art and VR technology. This results in an art project involving a haptic device where the visitor moves around in a virtual space. Practical schools of gaming such as **Futuregames (SE)** help to advance computer graphics and software development, while movie making centres such as **Bayerisches Filmzentrum (DE)** help to advance cinematic production and also actively cooperate with local universities to find new technical solutions for a truly immersive VR experience. Also, the **University of Barcelona (ES)** is

[50] VY Amsterdam, 2020. Prof. Dr. Tilo Hartmann. Available from: https://research.vu.nl/en/persons/tilo-hartmann
[51] EPFL, 2020. MindMaze. Available from: https://epfl-innovationpark.ch/success-stories/mindmaze/
[52] MindMaze, 2020. https://www.mindmaze.com/
[53] Bloomberg, 2016. VR Startup MindMaze Raises Funds at $1.1 Billion Valuation. Technology. Jing Cao, Februry, 17, 13:30 CET. Available from: https://www.bloomberg.com/news/articles/2016-02-17/vr-startup-mindmaze-raises-funds-at-1-1-billion-valuation
[54] A Virtual Reality Game to Assess Obsessive-Compulsive Disorder. *Martine J. van Bennekom, M. Soemiati Kasanmoentalib, Pelle P. de Koning, and Damiaan Denys.* Cyberpsychology, Behavior, and Social Networking 2017 20:11, 718-722
[55] Max-Planck-Gesellschaft, 2020. Prof. Jean-Louis van Gelder, Ph.D.. Available from: https://www.mpg.de/13777765/strafrecht-van-gelder
[56] VRDays, 2020. VR:Tool for Research. November 6-6, 2020. Available from: https://vrdays.co/program/vr-tool-for-research/
[57] University of Amsterdam, 2020. Computation Science Lab – Informatics Institute – Faculty of Science. Robert Belleman. Available from: https://staff.fnwi.uva.nl/r.g.belleman/

also actively researching on the field of art and culture, by collaborating with Thyseen-Bornemisza group, proprietary of multiple world-renowned art museums. Another example is the **NEMO Science Museum**[58] in Amsterdam with its MonA project in which investigates the use of VR/AR for museopedagogy purposes. In both cases, partners of the VRTogether consortium are also closely collaborating with such cultural institutions, as it is the case of TheMo with the Thyseen-Bornemisza group and CWI with NEMO Museum.

In general, European universities' prime focus is on fundamental research. Their main goal is to improve scientific theories and to better understand phenomena in a scientific domain with findings published by credible academic articles. Next to fundamental research, **applied research** projects, attempting to solve issues brought by a private sector partner, are relevant to many universities (two-thirds of universities are actively in touch with businesses). Also, universities across Europe are well connected and they actively work together – in fact, some EU research funding requires such international collaboration. Funding comes mostly from national public funds, however more than half of the universities and research bodies are benefiting from European research funds and one-third also receive private funding.

Top Areas of VR Research

The recent technological advances and the decreasing costs of the VR technologies is attracting the attention of users, researchers and businesses, suggesting it may be the next largest steppingstone and technological. However, the history of VR technology is longer than it may seem: the concept of VR was formulated in the 1960s and the first commercial VR tools appeared in the late 1980s.

For this reason, during the last 20 years, hundreds of researchers, universities and technological centres extensively explored and did research on the technology, processes, impacts and applications of VR/AR generating thousands of scientific articles building a robust research foundation. By analysing the R&D trends it is possible to identify which areas are of the most interest and extrapolate which will be the most promising applications of the technology in the foreseeable future. It is therefore key to analyse the outcome of this significant research work.

In this regard several scientific reviews[59,60] have explored the main areas of VR research as well as the main trends of the past, present and future of VR technologies. According to the studies, the subject category statistics from the Web of Science, indicated that the leading category of VR research is computer science, followed by engineering, which, together account for over 15.000 articles or 71% of the total production of the past 20 years in this field. However, when considering the last 5 years a shift is identified given that this subjects only reach about 55% if the total output with un upscale in other subject categories such as neurosciences (11,1%),

Table 4 | Category Statistics from the WoS regarding VR research comprising the last 20 years and the last 5

%	Frequency	Subject category (for all the period)
42,15	9131	Computer Science, 1990–2016
28,66	6210	Engineering, 1990–2016
8,21	1779	Psychology, 1990–2016
7,15	1548	Neurosciences and Neurology, 1992–2016
6,55	1418	Surgery, 1992–2016
5,85	1267	Automation and Control Systems, 1993–2016
4,80	1040	Neurosciences, 1992–2016
4,74	1027	Imaging Science and Photographic Technology, 1992–2016
4,30	931	Education and Educational Research, 1993–2016
3,92	849	Robotics, 1992–2016
%	**Frequency**	**Subject category (for the last 5 years)**
29,80	2311	Computer Science, 2011–2016
25,44	1973	Engineering, 2011–2016
11,10	861	Neurosciences and Neurology, 2011–2016
9,32	723	Psychology, 2011–2016
7,70	597	Surgery, 2011–2016
7,53	584	Neurosciences, 2011–2016
6,02	467	Education and Educational Research, 2011–2016
5,54	430	Rehabilitation, 2011–2016
4,42	343	Clinical Neurology, 2011–2016
3,92	304	Materials Science, 2011–2016

Source: Cipresso P., *et al.* 2018.

[58] NEMO Science Museum, 2020. MonA – Museopedagogy and Augmented Reality. Available from: https://www.nemosciencemuseum.nl/en/about-nemo/organization/nemo/international-projects/mona-museopedagogy/

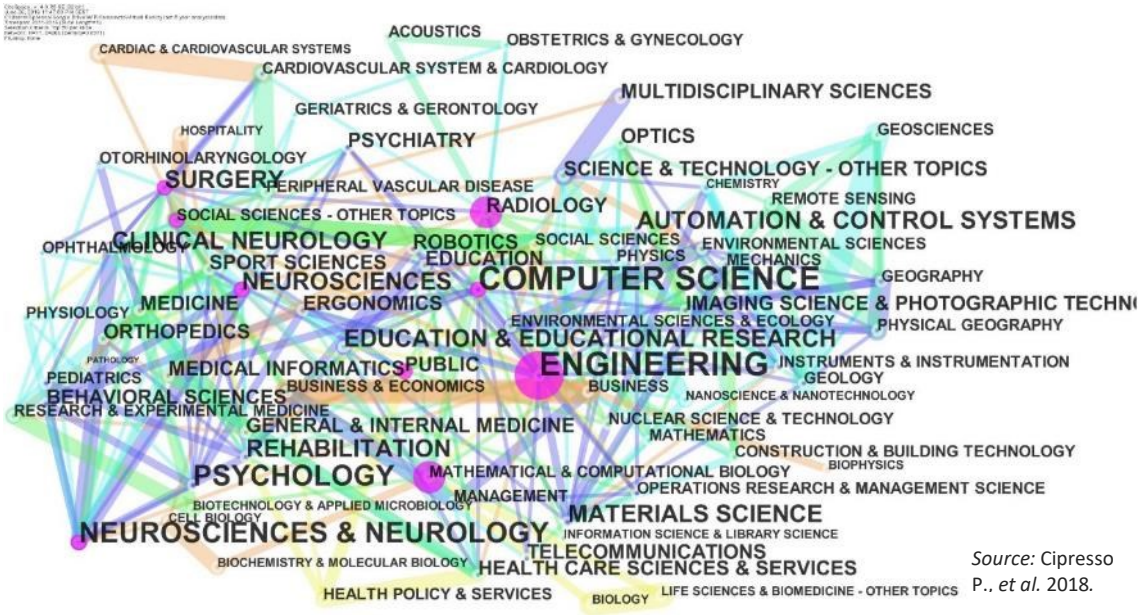
[59] Amditis A., Karaseitanidis I., Mantzouranis I. (2008) Virtual Reality Research in Europe: Towards Structuring the European Research Area. In: Talaba D., Amditis A. (eds) Product Engineering. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-8200-9_1

[60] Cipresso P, Giglioli IAC, Raya MA and Riva G (2018) The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature. Front. Psychol. 9:2086. doi: 10.3389/fpsyg.2018.02086

psychology (9,32%), Surgery (7,70%) and Education (6,02%) among others.

As reported by Cipresso P. *et al* 2018, the evidence highlights that VR technologies are in good health driving a lot of interests from academia and research centres in both hardware and software components. However, with respect to the past, we are witnessing in the last 5 years an increasing number and polarization of applications, especially in the medical and educational areas. In fact, historic areas, such as automation and control systems, imaging science and photographic technology, and robotics, which had accounted for about 14.5% of the total articles ever produced were not even in the top 10 for the last 5 years, with each one accounting for less than 4%.

Figure 33 | Category of VR Research from the WoS; network for the last 5 years.



Source: Cipresso P., *et al.* 2018.

Not surprisingly, the most active regions and countries involved in research within Virtual Reality have been the United States on first place, followed by China, England and Germany. Despite, the situation remains the same if we look at the articles published over the last 5 years there is an increasing number of contributions from all over the globe with Japan, Canada, Italy, France, Spain, South Kore and Netherlands taking positions of prominence.

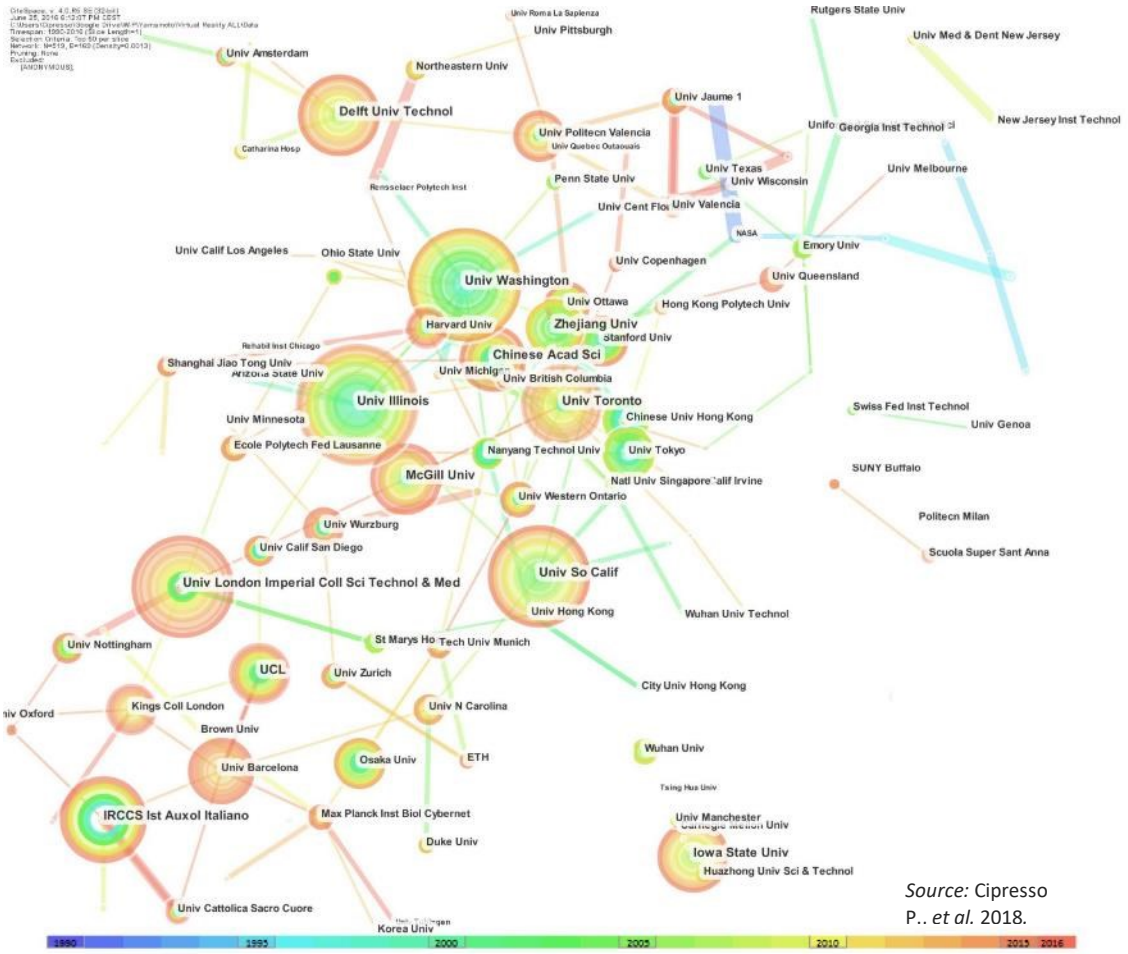
In fact, when aggregating the country data for those belonging to the **European Union** (including the UK) **accounts for 53,37% of all the VR research output for the last 20 years**. This is an indicative statistic of the relevance of Europe for the global VR industry and is also indicative of the potential market expectations that could derive from the technology in this region.

In regard to the most active academic and research institutions researching on the field of VR, the United States leads the rank capitalizing the top-three positions: University of Illinois, University of South California and the University of Washington.

Other countries in the top-ten list were The Netherlands, with the Delft University of Technology ranked fourth with 129 articles; Italy, with IRCCS Instituto Auxologico Italiano, ranked sixth. Great-Britain, ranked seventh with 125 articles from the University of London's Imperial College of Science, Technology, and Medicine; and China with 104 publications, with the Chinese Academy of Science, ranked ninth.

Other remarkable institutions in Europe were the University of Barcelona (ES), University of Valencia (ES), the University of Copenhagen (DK), the Max Planck Institute (DE), University of Zurich (CH), ETH Zurich (CH), École Polytechnique Fédérale Lausanne (FR), and the University of Manchester (UK), among other.

Figure 34 | Network of VR Research active Institutions.



Source: Cipresso P.. *et al.* 2018.

In the light of the data presented, and as concluded by Cipresso, P. *et. al* 2018, two important implications can be identified. First, there seems to be an evolution and development of VR and AR research, moving from essential technological research (hardware) to a more applied and application-directed purposes (software).

Industrial development in VR and AR changed a lot in the last 10 years. In the past, the development involved mainly hardware solutions while nowadays, the main efforts pertain to the software when developing virtual solutions. Hardware became a commodity that is often available at low cost. On the other hand, software needs to be customized each time for each application or end-use and this requires huge efforts in terms of development.

Secondly, the clinical dimensions of VR are consolidating being one of the most investigated fields ever, hand in hand with other areas of research such as computer science, engineering and allied sciences. VR and AR developments in this new clinical era rely on computer science and vice versa.

Future of VR Research

Be that as it may, the future of VR and AR is becoming more technological than before, and each day, new solutions and products are coming to the market. Both from software and hardware perspectives, the future of AR and VR depends on huge innovations in all fields. The first 30 years of VR and AR consisted of a continuous research on better resolution and improved perception. Now, researchers already achieved a great resolution and need to focus on making the VR as realistic as possible, which is not simple. In fact, a real experience implies a realistic interaction and not just great resolution, something VRTogether (https://vrtogether.eu/) is planning to address in this project.

Next years are expected to be catalyst for VR evolution in multiple fields. Corona virus pandemic surely will spur growth in VR hardware and software. Research will be stimulated by the market trends as they arise by this new reality.

VR research is needed to cover market demand for applications that go beyond leisure or tourism and are more affordable for users. Virtual interfaces also need to be improved to minimise the effects that VR produces in people such as motion sickness and dizziness induced by the mismatch between the movement of the body and what is being seen in the virtual world. This is one of the main research areas that has occupied scientists in the past and will do it also in the future.

Moreover, research on the latest 5G standard will also provide very interesting scenarios for the evolution of VR. This standard will allow more devices and large user communities to be connected making it possible for consumers to send, transmit and receive rich volumetric images and data in real time.

The future of VR research is also dedicated to health industry. Providing a safe environment for experiments, tracking physiological data, treatment for mental and physical disorders, building sensibilization and empathy are only a small part of the possible research applications expected to grow in the next years.

Last but not least, the haptic technology that allows feeling digital objects and interacting with them in a natural way is one of the most interesting research directions in the VR ecosystem. In order to develop immersive and interactive VR systems, haptic feedback is an indispensable component. With the development of the computing platforms in the past 30 years, the paradigm of haptics interaction has shifted through three stages, namely desktop haptics, surface haptics and wearable haptics. To meet the goal of "ultimate display", more powerful haptic devices will need to be developed. Cross-disciplinary endeavours will need to be made for innovative solutions to high fidelity haptic devices, where novel sensors and actuators using advanced and smart functional materials will find a place. The goal of research in this field should be to provide multimodal haptic stimuli to accommodate with the marvellous perceptual capabilities of human.

3.2.2. VR Companies

Europe's virtual reality ecosystem continues to grow with more and more companies entering the sector every year[61]. In terms of European VR and AR businesses **France, Germany, the United Kingdom and the Netherlands are clear frontrunners**, with growing VR and AR activity to be observed in the Nordic Countries (Sweden and Finland), Switzerland, Spain, Italy and to a more limited extent Eastern Europe (Poland and the Czech Republic). Specific "hot spots" of VR activity can be found in Paris, Laval, London, Amsterdam, Berlin, Munich, Stockholm, Zurich and Barcelona.

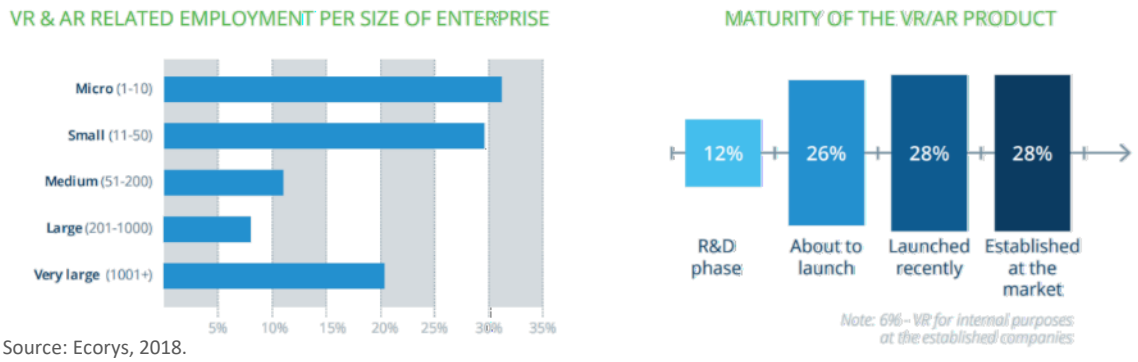
According to the world-leading database for company insights from early-stage start-ups to the Fortune 1000, known as Crunchbase[62], as of November 2020 a lump sum of **1.283 companies made up the Europe Virtual Reality Companies** Landscape. In 2020, the total funding amount has been of $1.3 billion with 748 successful funding rounds. Only 4% of the companies have been acquired in 2020, a total of 77 acquisitions, with a total acquired price of $299.4 million (average transaction of $3.8 million).

Such numbers, if compared to 2016 numbers when, according to The Venture Reality Fund and LucidWeb, there were roughly 300 companies in the European industry. This represents an increase of more than 900 companies, translating into an impressive **CAGR of 44.28%** over the course of 4 years.

Of this, **800 companies make up the number of VR organizations in the EU**[63]. As could be expected, the majority of VR companies concentrate in Western European Countries with over 70.6% of the share (535 companies) while Eastern European companies concentrate the remaining 29.3% (235 companies)[64].

European companies in the European VR & AR ecosystem are mostly small and medium-sized enterprises. Together they employ over half of the total number of employees. The large companies are often established fi rms that come from manufacturing industries and deploy VR solutions for engineering. About half of these companies are at initial phases of product development, meaning that they are either in an R&D phase or at the very early stage of product launch, and they are not making any profits yet. The rest of the companies are already generating profits and/or have already launched their products.

Figure 35 | European VR & AR Companies in Numbers (Part I)



Source: Ecorys, 2018.

[61] Tech.Eu, 2017. Europe's VR ecosystem continues to flourish with more and more companies. By Jonathan Keane, August 1st, 2017. Available from: https://tech.eu/brief/europe-vr-ecosystem-2/

[62] Crunchbase, 2020. Europe Virtual Reality Companies. Available from: https://www.crunchbase.com/hub/europe-virtual-reality-companies

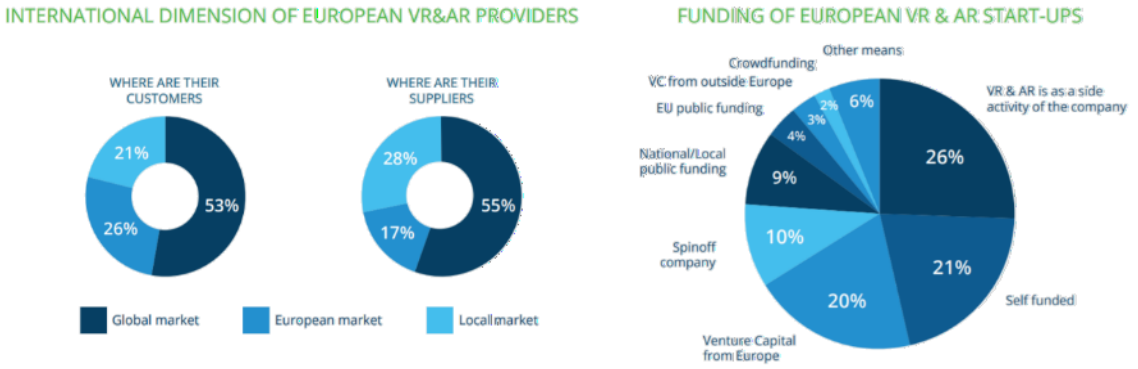
[63] Crunchbase, 2020. European Union (EU) Virtual Reality Companies. Available from: https://www.crunchbase.com/hub/european-union-virtual-reality-companies

[64] Clutch, 2020. Top VR Companies & AR Companoes in Eastern Europe. List of the Top Eastern AR & VR Developers. Available from: https://clutch.co/developers/virtual-reality/eastern-europe

Results from Ecorys 2018 indicate that the European ecosystem is to a great extent part of a global value chain. VR & AR companies are split between those that choose their suppliers from around the world and target customers globally and those that choose their suppliers from Europe and focus mainly on the European market.

Access to finance is a major challenge for European companies as many of them had to be creative to make it to the market. Most companies are either self-funded, or are financed as part of the larger company to which they belong(ed). Less than a quarter of European companies found access to venture capital to start their business.

Figure 36 | European VR & AR Companies in Numbers (Part II)



VR companies are involved in three main core activities – **R&D, manufacturing and content creation**. European VR companies produce three main types of products: **hardware, software and content**. Many companies provide more than one of these product types at the same time.

Given the fact that these core activities and the produced outputs are often confused given the multiple overlaps that exist. First, **R&D activities** consists in the development of new processes and technical solutions within the VR field, consisting of all hardware, software and conent product categories. As opposed to the other to main activities, R&D activities do not undertake commercial activities although, its impact exceeds that of basic research given that most companies take advantage of the VR research infrastructure and the skilled workers it produces to unveil new opportunities for capitalising the market.

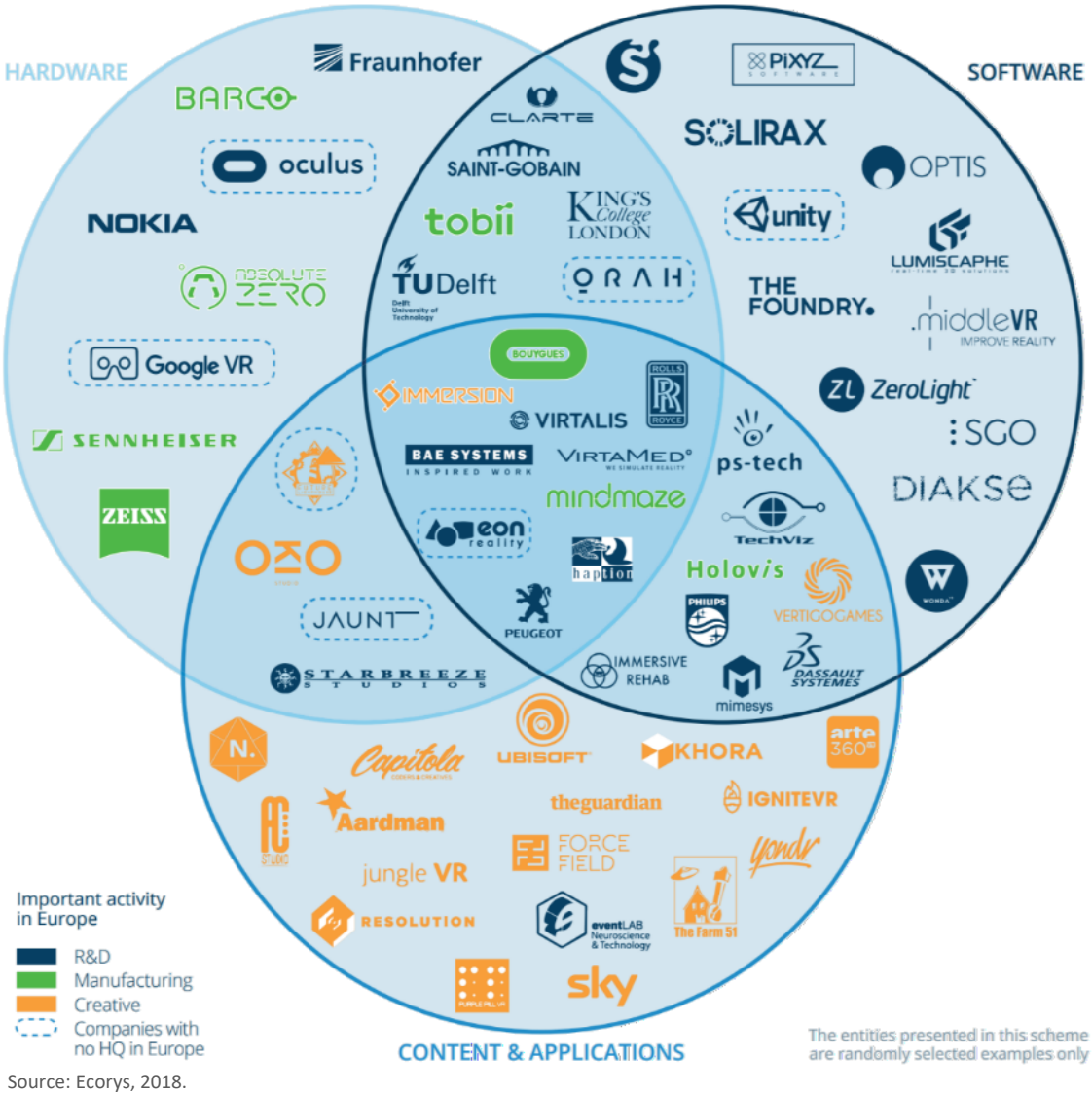
Secondly, **manufacturing** commonly refers to hardware production such as of that of HMDs, recording and capturing systems, data transmission technologies or processing systems. Nevertheless, software tools for non-content related purposes, such as management systems, SDKs (software development kits), game engines, modelling, coding and executing software, among others, are also included within this category.

Last, **content creation** refers to those activities related to either audio-visual recording (p.e. 360-degree immersive video or point-cloud recording) and/or 3D animation or construction of real environments or, by contrast, completely imaginary worlds, and encompass once more hardware, software and content & applications.

Europe is a centre of R&D for both software and hardware and specialised applications. Interestingly, even non-European companies such as **Jaunt (USA)**, **Oculus (USA)** or **EON (USA)** often locate their R&D departments in Europe to benefit from the presence of high-skilled workforce. Some successful software and hi-tech companies such as **Unity (USA–DK)** or **Metaio (USA–DE)** kept their R&D in Europe but either relocated their business development and official headquarters to the USA or were acquired by big global brands such as Apple.

Some specialised applications are R&D intensive and require content creation, but also need software expertise to coordinate virtual images with real-time movement. These are for example healthcare companies such as **Medical Realities (UK), Psious (ES),** or industry companies like **Jungle VR (FR)** and **Light & Shadows (FR).**

Figure 37 | European Companies Landscape, by activity and output.



Source: Ecorys, 2018.

By type of product or output, **hardware manufacturing**, in the case of European companies**, is mostly high-precision and niche technology**. This in stark contrast to other regions, such as the United States and specially China, whom mostly manufacture mass-market HMDs, sensors, PCs or other input/output devices.

As an illustration, the company **Tobii (SE)** is involved in advanced eye tracking and manufactures all its products in its home country. The same applies to **Zeiss (DE)** that specialises in optics, or **Fraunhofer (DE)** that has been running its VR Solutions Centre since 2001 and in addition to other VR products provides globally renowned audio solutions. **MindMaze (CH)** is making its own neuro-treatment devices backed by hi-tech research. In the European context, companies involved in manufacturing also perform their own R&D activities, often in cooperation with European universities and research centres. When it comes to hardware for mass production, R&D is often done in Europe while the actual products are manufactured elsewhere.

As previously mentioned, content that can be either **360-degree videos or computer-generated images (CGI)** is mostly associated with the creative processes of making video games, VR experiences and movies. Europe is strong in creative processes, with studios such as **Okio (FR)** providing independent movies and VR experiences. European broadcasters including the **BBC (UK)** and **ARTE (DE/FR)** are also involved in the VR content creation process. Some content studios would also build their own cameras to fi t their needs.

3.2.3. Other Actors in the European Ecosystem

An important part in the European VR ecosystem is played by actors beyond the demand and supply. These actors hold the ecosystem together, enable exchange of information and know-how, and facilitate business and research activities. These actors are:

a. **Associations think tanks and other support institutions** that gather VR and Related companies and represent their interests. Some of these actors work on the European level ((EuroVR) connects researchers from universities and research oriented companies from around Europe, EUVR.org is more business-focused and targets start-ups, the European Broadcasting Union (EBU) gathers broadcasters), and others work on the local level (Finnish Virtual Reality Association (FIVR), UniVR (FR) – a VR think tank that connects actors across industries and specialisations).

"Support institutions" are often (semi-)public bodies and their goal is to provide support **for innovation in general or VR in particular. Examples include Realities Centre (UK) or** Invest Stockholm (SE) which have their activities aimed specifically at the local VR communities. VRBase (NL/DE) is a venture capital-funded initiative which is an example of a multi-country VR-specialised institution. It works as a city hub for VR companies and is currently placed in Amsterdam and Berlin, but expanding to Paris and Barcelona. Startup campuses such as Station F (FR) enable the sharing of knowledge and experiences between innovative entrepreneurs from different sectors.

b. **Awareness and community building actors** include events and VR blogs. Events help the VR and AR community to periodically meet up and exchange the latest information across the border. Europe hosts some events of global importance such as Laval Virtual (FR), currently the biggest VR & AR fair in Europe dedicated mostly to professional uses of VR. Other important events include World VR Forum (CH) and VR Days (NL) focused on content production or the EuroVR annual conference dedicated to VR & AR researchers. Local meet-ups and smaller informal events happen almost daily at VR hub cities such as London or Berlin. Blogs run by VR enthusiasts, such as vrsverige.se (SE), or operated by companies further support flow of information and knowledge sharing.

c. **Funding from both private and public sources** enables development of VR technologies and paves the way from research to VR products. It also supports content creation. Venture capital funds that provide finance to new innovative businesses are less typical for Europe. However, some of the largest global VCs, such as Gumi (JP) or Venture Realities (USA) are active in Europe as well. National funds provide research grants to support development of technology and relatively large amounts are provided via EU schemes, such as Horizon 2020. Centre national du cinéma et de l'image animée – CNC (FR) or German Federal Film Fund – DFFF (DE) provide grants for independent VR content creation.

d. **Policy makers at the European and local level** help to form favourable business and research environment. The European Commission (EC) provides a European policy framework for Internet networks, research investment or business rules. EU institutions have the power to ensure coordinated action at the European level and set up rules for the internal market. Policy makers at the national level, as well as those at the regional and city level can provide more targeted support to industries and can create VR communities. A great example is the administration of the city of Laval (FR) that started providing incentives for the growth of the VR community already 20 years ago.

e. **Gradually there is a growing need for VR and AR services** that support the demand side in particular. Specialised training and consulting services help companies to understand what VR and AR are and how to benefit from them. Rental services allow companies to borrow high-end VR & AR equipment either to create VR content or to use them for example for VR trainings or promotional activities.

3.2.4. Europe Specific VR Challenges to Facilitate Growth

The European Commission supports European researchers and entrepreneurs to help scale up the ICT innovation ecosystem in Europe by reinforcing actions for ICT innovation through Horizon 2020 (the EU Research and Innovation programme) with nearly €80 billion of funding available for the time period 2014–2020. Horizon 2020 also supports SMEs through a new dedicated €2.8 billion SME Instrument, which is targeting innovative SMEs. Open Disruptive Innovation is a scheme under this SME Instrument, which aims to support fast growing, innovative SMEs with close-to-market ideas bearing high disruptive potential. Additionally, other SME support initiatives are available through the European Commission.

In 2017 the EC introduced a new instrument in cooperation with the European Investment Fund (EIF). The market-driven Pan-European Venture Capital Funds-of-Funds has been designed to boost levels of investment in new generations of highly innovative European firms. VR companies focusing on content creation can also benefit from the Media Programme.

Broadband Europe and Wireless Europe are other initiatives which feed into the wider Digital Single Market strategy of the Commission and strive to ensure progress in internet access and connectivity. Important aims include offering gigabit connectivity in key economic nodes, the introduction of 5G networks, and internet access of at least 100 Mbps for all European households by 2025.

Next to a focus on strengthening the Digital Single Market, the European Commission initiated its Creative Europe programme in 2014, with a budget of €1.5 billion. The programme aims to support Europe's cultural and creative sectors to seize the opportunities of the digital age and globalisation.

Despite the many strengths of the VR and AR industry in Europe, there are certain issues that will need to be addressed in order for Europe to become a powerful player in the global VR and AR industry. Various challenges have been identified that have **an impact on the growth of the European VR landscape.** These include:

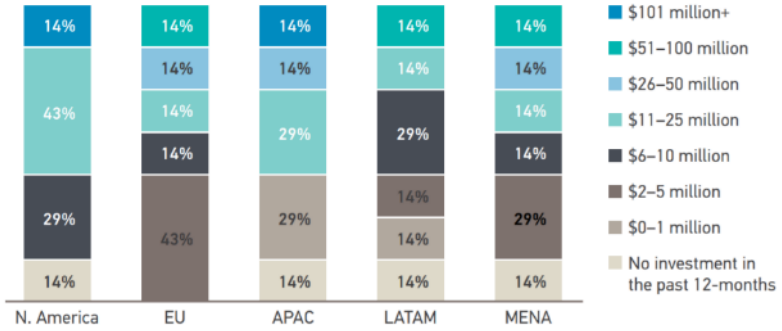
a. **A lack of risk funding as well as a pro-risk and experimentation mentality in general**

   Despite the availability of public research funding in general, research and development support for individual (start-up) companies rather than research consortia is not always equally accessible. Where it is available it is often highly result-oriented, allowing for little experimentation and failure on part of the start-up. As a result, start-ups tend to either become absorbed by larger, often foreign, companies, or they seek funding outside of Europe.

   This is in fact corroborated by several sources. For instance, Perkins Coie's 2020 Survey[65] highlights the fact the EU region, as opposed to N. America or APAC, mainly accounts for small-scale investments in VR/AR in 43% of the cases. This mainly consists of EU-funded programs the majority of which are represented by consortia consisting of investments between de 2-5 million €. Risk-investment is much less common than in other regions, with few big deals.

[65] Perkins Coie, 2019. Augmented and Virtual Reality Survey Report – Industry Insights into the Future of Immersive Technology. March, 2019. Volume 3. Available from: https://www.perkinscoie.com/images/content/2/1/v4/218679/2019-VR-AR-Survey-Digital-v1.pdf

Figure 38 | VR & AR Investment in the last 12 months by size and region, 2019.



In another Survey by Ecorys, most of the companies were found to be either self-funded (21%) or were able to undertake them as part of other activities within the company (32%). This translates into the fact that up to 53% of the companies active in the digital reality field lacked venture investment, with few room for experimentation in the technologies. In fact, according to the European consultancy firm, only 25% of the companies indicated to have benefitted from Venture Capital opportunities from within Europe.

b. Weak links between research and the market

A considerable amount of public money goes into research institutions and universities across Europe, which are developing incredible technologies. These, however, often do not make it to the market. Only 29% of the companies surveyed by Ecorys actively cooperate with universities and research centres, while 61% of the companies carry out R&D internally, indicating a real need to improve the links between research and the market. Moreover, there is much more pronounced focus on fundamental than applied research across universities and research centres, and research outcomes often do not make it past the prototype stage.

c. Lack of cooperation across the different countries in Europe.

Despite the high levels of cooperation observed within the various hubs and countries in Europe, cross-border collaboration could be improved further. Most supplier/ customer relations are also either national or global, further hinting at limited European networks. Market fragmentation and the fast-paced environment of the VR landscape is one of the main factors hindering the cooperation between companies, which often spend too much time simply building their networks. In fact, as reported by Ecorys and Perkins Coie, approximately one third of the companies surveyed indicated a need for more networking opportunities.

Apart from collaboration across Europe, further collaboration should be encouraged between the three VR/AR global 'bubbles': of Europe, Silicon Valley and Asia. Also, the potential impact of Brexit also needs to be monitored given that London is one of the biggest channels of transatlantic collaboration within the industry.

d. Current and expected needs for adequate infrastructure and resources.

An adequate infrastructure can strongly facilitate the uptake of VR, along with the spread of VR hardware among consumers and businesses. Furthermore, the education of technicians, designers and developers fluent in VR/AR technologies is essential for the future growth of the industry, with up to 24% of the companies saying they would greatly benefit from workers with the necessary technical skills, according to Perkins Coie.

3.3. Europe's VR/AR Leading Countries

3.3.1. Germany

Germany has its VR and AR centres spread out across the country. Its most vibrant centre of VR is definitely Berlin with its animated informal meet-up scene and creative industries giving rise to creative start-ups. VR in the south of Germany is rather focused on the manufacturing industry base with large car makers, but also large film making and animation studios. VR in Germany is benefiting from the presence of Europe's biggest industrial manufacturers and thus business opportunities in design, training or production. It also offers numerous creative centres for start-ups and freelancers.

Berlin is often mentioned as the German VR hub and also the upcoming VR centre in Europe. Its cultural scene has a blooming start-up environment and attracts creative minds and developers. The Berlin VR meet-up scene is one of the largest in Europe and this well-working informal networking structure fosters collaboration in Berlin's VR star-ups. Besides the main VR meet-up that has around 200,000 participants, there have been other specialised VR meet-ups, such as for psychology, "room-scale" VR developers, filmmaking, creative, science and mixed reality – these themes nicely illustrate the current focus of Berlin start-ups.

The VR research in Germany is concentrated around car producers such as VW or BMW. For example, the Technical University of Munich works on VR for industrial design. Fundamental research is also taking advantage of VR technologies – for example the NeuroCure cluster at Humboldt University of Berlin or Max-Planck Centre Munich uses VR for neuroscience and research on the human brain.

3.3.2. France

Counting already a couple of decades of VR activity, Paris and Laval are the pioneer hubs that stand out as centres of excellence in the French and European VR landscape. Industrial VR applications dominate the French landscape, varying from 3D modelling and industrial design to highly specialised training applications. Many companies with a strong focus on VR film, art and new media content production are located in Paris, as well as companies working in social VR and VR teleconferencing. The second largest VR cluster in France is located in Laval – a city of less than half a million inhabitants which since 1999 has hosted one of the most important VR events in Europe - Laval Virtual, thanks to its connection with the Univ. of Rennes. A lot of VR activity also occurs in Lille, as an outcome of the established high-tech cluster in 3D imaging, and Bordeaux, as a well-established regional industrial ecosystem.

France benefits significantly from the early adopting industries (e.g. automotive, fashion) and public broadcasters (e.g. TF1, ARTE) that created an early demand for VR. Collaboration with innovative start-ups and bigger players brings mutual benefits and takes place throughout the country.

The strong research tradition and the high quality of educational programs of French universities contribute to the VR industry by being a source of highly qualified developers and VR professionals, and by partnering up with companies that provide solutions to real problems. MINES ParisTech University has 25 years of research on using VR in industry and strong links with companies such as SNCF (France's national state-owned railway company). It also runs a programme for the creation of research spin-off start-ups. Similarly, Arts et Metiers ParisTech

University and CLARTE research institute cooperate closely with most of Laval's VR ecosystem as well as other French and international companies and universities.

Policies promoting high tech innovation and funding opportunities are well established in France and VR & AR also benefit from them. Bpifrance, Les pôles de Compétitivité and the French National Research Agency (ANR) are the main public bodies that fund VR companies and research institutes. The French-tech label identifies 13 metropolitan areas of high innovation, offering to the companies in these areas premium access to public services and support opportunities for conducting research in the US or participating in international events. Tax incentives exist for promoting cooperation between companies and universities or for non-French companies that produce creative content in France.

3.3.3. Spain

Following the economic crisis in 2008, Spain has been putting a lot of effort into attracting foreign investors to support the growth of its businesses. Despite a struggle to win investment over countries such as France or Sweden, the Spanish VR scene has been developing, building upon the creativity and skills of the local professionals as well as on the competitively priced workforce. The creative scene is characterised by small companies keen on experimenting and centred around Barcelona, while VR and AR for industrial purposes grow around Madrid.

In terms of the business scene, Barcelona is leading in attracting small creative VR startups focused on content creation. Its VR scene is often described as similar to the one in Berlin, with creatives and designers, hip environment and vibrant VR community.

In terms of the business scene, Barcelona is leading in attracting small creative VR startups focused on content creation. Its VR scene is often described as similar to the one in Berlin, with creatives and designers, hip environment and vibrant VR community.

Madrid's VR industrial scene, on the other hand, is more formalised and concentrated around branches of big European companies. The industry-focused companies are small to medium-sized with a focus on software and training applications.

VR research is centred around engineering schools in Madrid such as the Technical University of Madrid and around the University of Barcelona and its Event Lab with experimental virtual environments for neuroscience. The research here is focused on body perception and ownership. Both Spanish universities and research-oriented companies are well used to European funding and take advantage of it.

3.3.4. The Netherlands

The film and gaming industries dominate the VR field in the Netherlands and a dedication to deliver quality content. For instance Amsterdam and Eindhoven, and their respective surrounding areas are vibrant and international, and they attract people from all over the world.

The level of venture capital opportunities for start-ups in the Netherlands lags behind that in the UK, Germany and Scandinavia. As a direct consequence start-up growth and development in the Netherlands tends to be rather cautious and slow. This is also due to having access to few available projects as the size of the national market is quite small. The VR start-up scene in the Netherlands is nevertheless very dynamic and the third most prominent in Europe, after London and Berlin.

Much like elsewhere in Europe, Dutch VR start-ups often find funding in big brands, who are looking to up their advertising game. Once they consider their business model to be a viable one, they generally do well focusing on steady growth. Some successful examples of VR start-ups that have made it big within their field include the VR studios **Force Field XR**[66] and **Vertigo Games**[67]; haptics and tactile solutions for immersive experiences **Manus VR**[68] or **SenseGlove**[69]. Also, spin-offs from research institutes also generate important market leads such is the case of **PS-Tech**[70], for optical tracking systems and **TiledMedia**[71], a world-class streaming software for high-quality VR. Once established within the Netherlands, however, and having reached the confines of the Dutch market, some companies then choose to move to the US in order to be part of a wider VR and AR ecosystem and to grow further.

There are therefore a number of ongoing efforts to connect the players within the VR/AR industry across Europe. There are also many meetups across the Netherlands, bringing together actors from all over Europe, such as **VRDays**[72], an annual event since 2015. Across the country, networks of collaboration are already well in place, including between companies and universities. They produce an abundance of highly skilled people.

Much like in the UK, the Netherlands have made tech and innovation a funding priority, although the focus rests somewhat more heavily on research. There is a favourable tax code, and innovation credits and grants are made available for developing innovative products.

3.3.5. United Kingdom

A buzzing hub of VR/AR activity, London boasts a healthy start-up environment, benefitting from good access to finance as well as a substantial amount of governmental investment into technology and innovation. The latter serves to support the development of VR/AR companies not just in London but all over the UK, in particular along the East Coast and in Greater Manchester (where much of the BBC's activities take place). While the VR/AR community in London shares close ties with communities in other VR/AR hubs across Europe, such as Amsterdam and Berlin, the strongest channel of collaboration runs between London and Palo Alto (USA), not least because of the common language and similar business mindset. Even as the UK prepares to leave the EU, it continues to build, strengthen and/or solidify its relationships with the other hubs across Europe (particularly the engineering camp in the Netherlands and the research base in France)

As one of the world's largest financial centres, the opportunities for venture capital in London are more numerous, hence attracting VR/AR entrepreneurs and developers from all over the continent. London is a global media and post-production hub, as well as the home to many large businesses with departments active in VR & AR. Many of the main players within the UK's creative and media industries have their own dedicated R&D departments for VR/AR (e.g. the BBC).

[66] ForceFieldXR, NL. https://forcefieldxr.com/
[67] Vertigo Games, NL. https://vertigo-games.com/
[68] ManusVR, NL. https://manus-vr.com/
[69] SenseGlove, NL. https://www.senseglove.com/
[70] PS-Tech, NL. https://www.ps-tech.com/
[71] TiledMedia, NL. https://www.tiledmedia.com/
[72] VRDys Europe, 2020. https://vrdays.co/

Start-ups within the VR/AR industry in the UK are able to develop and grow into companies of considerable size and stature, as exemplified by VR companies like Holovis, The Foundry, Virtalis, and Happy Finish, that have established a strong global presence.

There is an established collaboration within the creative industry as well as among various industrial sectors that are well supported by multiple VR and AR-dedicated events, such as VR & AR World[73] or VR UK[74]. The sheer number of events on VR and AR in the city of London is immense. These connect industry and academia and they seem to work better for VR/AR than for other industries in the UK. This is probably because the pool of VR talent is as yet rather restricted and the community is well networked, supportive, and with established working relationships. Many universities all over the UK have VR/AR labs, (UCL, MMU and King's College) or a good number of immersive studios, and a growing number of accelerators (Realities Centre).

London also benefits from a positive attitude of the public authorities towards VR & AR, which is making available investment for tech and innovation.

The UK government supports the sector by allocating funding to innovation through the government agency Innovate UK. For the year 2016/2017, this funding amounts to £561 million, £86 million of which is dedicated to "emerging and enabling technologies", one of five priority areas. Innovate UK works closely with networks and accelerators, such as Knowledge Transfer Network (KTN) or Digital Catapult, to help develop the industry. Together they have recently set up Immerse UK, which shall focus on connecting businesses and research organisations across all parts of the UK that are active and interested in VR/AR. What is more, start-ups in the UK enjoy some appealing tax breaks, such as R&D tax credits and the Enterprise Investment Scheme, that is incentivising angel investors.

[73] VR & AR World, 2020. https://tmt.knect365.com/ar-vr-world/
[74] VR World (VR UK), 2020. https://www.vrworldevent.com/

4. VR AND AR APPLICATIONS AND USE CASES

VR and AR are powerful technologies that have the potential to impact our everyday working and personal lives. Although, VR/AR is typically covered by the media from an entertainment perspective, in recent years, a variety of other applications have emerged as business began exploring the potential of using VR technology to capitalise on cost-saving opportunities.

VR, however, has several other uses that extend far beyond entertaining customers. As a matter of fact, the potential for VR/AR across multiple sectors is huge and the full potential of many of them has yet to be untapped.

Be that as it may, so far VR/AR has proved that it is creating changes in various application areas, from industry to healthcare, from training and education to retail and e-commerce. Continuously new application areas are arising making use of the advantages and strengths of VR and AR technologies.

Technological advancement by technological providers (hardware and software) both private companies and universities, enable and inspire practical application of VR. In turn the need of novel application of VR drive further technology advancement, by expressing their need for a better more immersive customer experience and for concrete practical solutions.

Such feedback loop is further promoted when coupled with the plunging costs of the VR technology driving the development of comfortable and more advanced hardware as well as more powerful software to allow for fast image processing for a realistic real-time immersive experience.

4.1. VERTICAL APPLICATIONS VS. HORIZONTAL USE CASES

This section further elaborates on the major current application and end uses domain. However, it is preceded by an important distinction between potential applications and use cases. The distinction is non-negligible as the future of VR/AR is not necessarily driven by a unique market vertical but instead by horizontally enabled use cases. This creates a class of multi-vertical (or industry) matching market with a strong lattice structure enabled by a common transferable technology use case. For such reason, it is important to analyse and describe the VR/AR market from both perspectives, vertical market applications and horizontal use cases, given their own unique multiple advantages as well as disadvantages.

A **vertical market** is a market encompassing a group of companies and customers that are interconnected around a specific niche or industry. Companies in a vertical market are attuned to that market's specialized needs and generally do not serve a broader market. As such, vertical markets are usually **industry-specific or demographic-specific** with their own idiosyncrasies.

Operating in a vertical market may provide a **comparative advantage** given that as the market grows the level of expertise of the operator also grows in terms of specialist knowledge and understanding (p.e. market trends, terminology, regulations and compliance) all leading to an increased level of competitiveness. Also, some of the most considerable advantages for vertical market businesses come in the savings from marketing expenses. Vertical market business has the benefit of targeting a narrower customer base. This narrow focus can lead to more streamlined and focused commercial and marketing campaigns which are less costly than those seeking to reach a wider mass-audience.

Overall, a company that specializes in a vertical can provide targeted insight and specialized services to clients, becoming an integral component of their business over the long term. With specialized products and services, a vertical company can justify charging higher rates that can result in higher profits from a narrowed market focus.

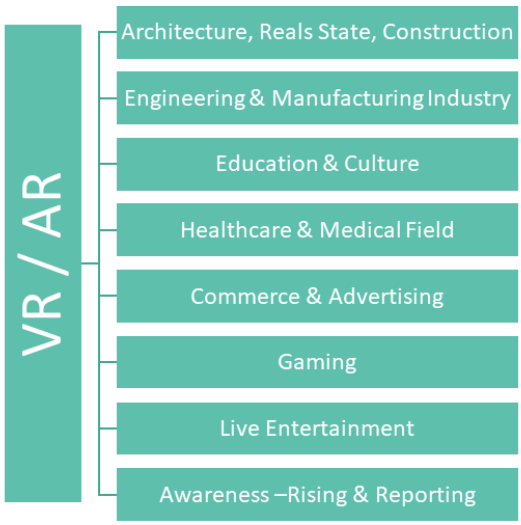
On the other hand, a **horizontal market** is diversified so that the products created are able to meet the needs of more than one industry. A horizontal market is one in which the output good or service is widely used and in wide demand, thus the producers bear little risk in demand for their output, however, will typically face a great amount of competition within the industry.

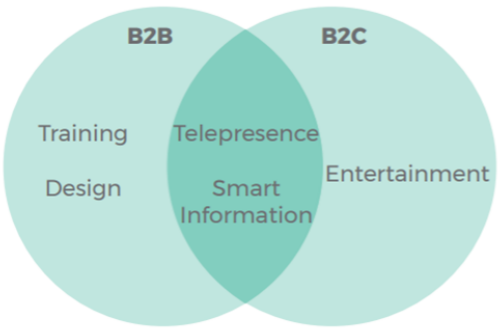
The profitability for companies producing goods in a horizontal market is determined more by internal, rather than external, factors, as their products are commonly used. Also, horizontal market business seeks to appeal to a wide demographic that is not niche, the opposite of niche-specific vertical markets.

In the context of VR/AR, vertical market applications refer to industry-specific use cases such as for example engineering & manufacturing industry, education and culture or healthcare. On the flip side, the VR/AR horizontal market does not focus on a specific industry or demographic but on a specific use case that is common to all. For instance, this is the case of training use case in which both healthcare and engineering industries need to train the staff to perform operations and maintain machinery. Or telepresence, especially in the context of COVID-19 pandemic, a common need across all industries and demographics.

Table 5 | Differences Between VR/AR Vertical vs. Horizontal Market

VERTICAL MARKET	HORIZONTAL MARKET
Defined by a group of businesses that share the same industry.	Defined by a common feature (demographic, use case, etc.) that applies to different kinds of market segments, industries and businesses.
Always specific (niche) and cannot cross industries.	Broader than Vertical Markets
Often competing against each other within the market vertical.	Cooperative and Seeking Joint Opportunities
An Opportunity to a Market to a Specific Audience	An Opportunity to a Market to a General Audience





4.2. VR/AR APPLICATIONS FIELD

4.2.1. VR/AR TECHNOLOGY PROVIDERS

Sitting at the centre of the VR/AR application field sit the technology providers. Many European innovative start-ups, companies and also universities, are working on the development of general VR technologies and software that enable the use of VR in different application areas.

In terms of **hardware** it is worth mentioning a few technology providers that are leading the way in Europe and are paving the future of the market. One of such companies is the Finnish **Varjo (FI)**[75], one of the world leading companies in the VR/XR HMDs field. Varjo makes human-eye resolution (known as **foveated rendering**) virtual and mixed reality products that help professionals in the most demanding industries pushing the limits of VR applications. Their latest X-3 headset includes Automatic IPD, 200 Hz Eye tracking, Hand tracking, LiDAR + RGB fusion, Horizontal 115° FOV, 2880 x 2720 px per eye + 27°x27° focus area with 1920 x 1920 px per eye. An absolute world-class HMD.

Other top-notch VR technological companies, often targeting niche audiences, are **CReal (CH)**[76]**,** which is developing a light-field MR glasses which it hopes to bring to VR headsets and eventually AR glasses. Recently the swiss company secured a 7.2 million investment lead by Swisscon Ventures, raising the total funding mark in 15.5 million. Also, **Sensiks (NL)**[77]**,** a company focusing within the Sensory Reality landscape is pioneering in the field of sensorics pods in which the user can experience hyper-realistic multisensory simulations. In the field of 360º video hardware, **Video-Stitch (FR)**[78] with its Orah 4i live spherical VR camera or **Spherie (DE)**[79] with its world's first 360-video VR recording drone.

Regarding the **user input hardware**, several companies are leading the way in hand motion capture as **ManoMotion (SE)**[80], **Manus VR (NL)**[81] **or SenseGlove (NL)**[82]**,** with its force-feedback gloves. Also, companies such as **Cyberith (AT)**[83], **3DRudder (FR)**[84], **3DiVi (RU)**[85], and **Criffin (EE)**[86], among others, develop a wide range of hardware solutions for body locomotion and tracking.

Haption (FR/DE)[87] is the world leader in synchronising movement in the virtual world with physical response in the real world. Others such as **Ultraleap (UK)**[88], **Generic Robotics (UK)**[89], or **Actronika (FR)**[90] also play withing the haptic technology field. **Inisghtness (CH)**[91] is one of the leading companies in the Vision Positioning Systems (VPS) segment providing spatial awareness for mobile devices and platforms. A similar eye tracking technology has been developed by **Tobii VR (SE)**[92] aiming to reduce GPU resources due to rendering thank to providing positional tracking inputs to the system.

[75] Varjo Technologies, 2020. Web content. Available from: https://www.varjo.com
[76] CREAL, 2020. Web Content. Available from: https://www.creal.com/
[77] Sensiks, 2020. Web Content. Available from: https://www.sensiks.com/
[78] Video-Stitch, 2020. Web Content. Available from: https://www.video-stitch.com/
[79] Spherie UG, 2020. Web Content. Available from: https://www.spherie.com/
[80] ManoMotion AB, 2020. Web Content. Available from: https://www.manomotion.com/
[81] Manus Machina, 2020. Web Content. Available from: https://manus-vr.com/
[82] SenseGlove, NL. 2020. Web Content. Available from: https://www.senseglove.com/
[83] Cybertih GmbH, 2020. Web Content. Available from: https://www.cyberith.com/
[84] 3DRudder SAS, 2020. Web Content. Available from: https://www.3drudder.com/
[85] 3divi, Inc., 2020. Web Content. Available from: https://www.3divi.com/
[86] Criffin Inc., 2020. Web Content. Available from: https://criffin.com/
[87] Haption, 2020. Web Content. Available from: https://www.haption.com/
[88] Ultraleap, Ltd., 2020. Web Content. Available from: https://www.ultraleap.com/
[89] Generic Robotics, Ltd., 2020. Web Content. Available from: https://genericrobotics.com/
[90] Actronika SAS, 2020. Web Content. Available from: https://www.actronika.com/
[91] Insightness AG, 2020. Web Content. Available from: https://www.insightness.com/
[92] Tobii AB (publ), 2020. Web Content. Available from: https://www.vr.tobii.com/

Brand new technologies made in Europe attempt to make virtual world even more immersive as **Mindmaze (CH)**[93] with its **MindLeap** by fusing VR with motion capture and electroencephalographic scans to create hand-tracking, mind-reading virtual reality environments for healthcare purposes. Also, by enabling VR visitors to walk around it as provided by the treadmill ROVR from **WizDish (UK)**[94] or smell their surroundings as proved by **Olorama (ES)**[95] or even improve the sight of patients with untreatable sight loss patients using clinically validated medical device VR by **GiveVision (UK)**[96]. Also, **Univrses (SE)**[97] offers capturing hardware for leveraging meaningful data for building the autonomous smart city future.

On the other hand, **software** is usually developed for a particular area of use and is then taken and optimized for other sectors. This is for example the case of **Unity 3D (DK/US)**[98], **The Foundry (UK)** [99] or **Crytek (DE)**[100], that were principally developed as processing engines for gaming and entertainment, but currently generate VR content in the medical field, industrial design and training, among others. **Pixyz (FR)**[101] or **Lumiscaphe (FR)**[102] initially focused on industrial design and are now finding their way to marketing and commerce. Also, **Monado from Collabora (UK)**[103] is a great example of an open source OpenXR platform.

Other interesting software producing companies include **Improbable (UK)**[104], producing SpatialOS which offers a new way of building virtual worlds. Improbable has been also experimenting with AI and developed powerful technologies that can simulate entire game worlds, but also predict the development of natural disasters. Another example of a VR & AI company is **Blippar (UK)**[105], which provides powerful object and face recognition software – this technology is key for realistic interactions with 3D virtual spaces. **Wonda (FR)**[106], which offers a more user-friendly and simpler alternative to Unity especially for movie makers, **Solirax (CZ)**[107], with its VR environment builder for everyone, and **SGO (ES)**[108] an ultra-fast VR post-production software.

Basic research also benefits from the progress on hardware and software. For example, neuroscience basic research, taking place for example at **Max Plank Institute (DE)**[109] or **Humboldt University of Berlin (DE)** uses powerful game engines and technology solutions for VR headsets to advance their exploration of the brain. New VR solutions, enabled by general technology advancement allow to perform complicated brain exploration on mice instead of monkeys, and activate specific parts of the brain. Basic research spin-off companies such as **Winterlab (DE)**[110] work on a further advancement of the technology to perform safe brain exploration on humans.

[93] Mindmaze Holding SA, 2020. Web Content. Available from: https://www.mindmaze.com
[94] WizDish Ltd., 2020. Web Content. Available from: https://wizdish.com/
[95] Olorama Technology, S.L., 2020. Web Content. Available from: https://www.olorama.es/product/pack-realidad-virtual/
[96] GiveVision, Ltd., 2020. Web Content. Available from: https://give.vision.net/en/
[97] Univrses AB, 2020. Web content. Available from: https://univrses.com/
[98] Unity Technologies, 2020. Virtual Reality. Available from: https://unity.com/unity/features/vr
[99] Foundry Visionmongers Limited, 2020. Web Content. Available from: https://www.foundry.com/
[100] Crytek GmbH, 2020. Web Content. Available from: https://www.cryengine.com/
[101] Pixyz Software SAS., 2020. Web Content. Available from: https://www.pixyz-software.com/
[102] Lumiscaphe, 2020. Web Content. Available from: https://www.lumiscaphe.com/en/home/
[103] Monado, 2020. Web Content. Available from: https://monado.dev/
[104] Improbable Worlds Limited, 2020. Web Content. Available from: https://improbable.io/
[105] Blippar, 2020. Web Content. Available from: https://www.blippar.com/
[106] Wonda VR, 2020. Web Content. Available from: https://www.wondavr.com/
[107] Solirax Ltd., 2020. Web Content. Available from: https://solirax.com/
[108] SGO, S.L., 2020. Web Content. Available from: https://www.sgo.es/
[109] Max Planck Institute for Human Development, 2020. Virtual Reality Lab. Available from: https://www.mpib-berlin.mpg.de/598330/institute-labs-vrhttps://www.mpib-berlin.mpg.de/598330/institute-labs-vr
[110] Winterlab, 2020. Virtual Reality Servo Ball. Available from: https://www.winterlab.org/virtual-reality/virtual-reality-servo-ball/

4.2.2. IDENTIFIED AREAS OF VR/AR APPLICATION BY VERTICAL

Several different classifications of vertical applications for VR exists but all seem to converge around **10 industry-specific categories**[111,112,113]. These include (1) Education & Culture, (2) Healthcare, (3) Awareness Rising & Reporting, (4) Communication & Social Interaction, (5) Art & Storytelling, (6) Commerce & Advertising, (7) Gaming, (8) Live Entertainment & Experiences, (9) Engineering & Manufacturing Industry and (10) Architecture, Real State & Construction.

Figure 39 | VR/AR Ecosystem Map by Application Areas and Technology Providers

Similarly, the Perkins Coie 2020 VR Survey Report pinpointed the most promising VR market vertical segments. One of the key takeaways from the survey is that, while AR applications may be lighting up consumer smartphones, there is still a wide range of immersive technology application coming online for enterprise use across a variety of sectors, including healthcare, education, manufacturing and retail.

[111] Bezegová, E. *et al.*, 2017. Virtual Reality and Its Potential for Europe. Ecorys International B.V. Holland. Available from: https://ec.europa.eu/futurium/en/system/files/ged/vr_ecosystem_eu_report_0.pdf

[112] PwC, 2017. An Introduction to Enterprise Virtual Reality. May 2017. Available from: https://www.pwc.com.au/consulting/assets/technology/virtual-reality-may17.pdf

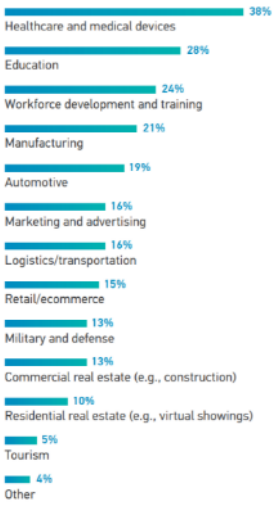
[113] Deloitte, 2016. Tech Trends 2016: Innovating in the Digital Era – Augmented and Virtual Reality got to Work. Available from: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/technology/deloitte-uk-tech-trends-2016-augmented-and-virtual-reality.pdf

Healthcare specifically is a sector that is attracting the most attention in both terms, investment and adoption interest, mainly due to the short-term expected **Return on Investment (ROI) and payback period** in the new pandemic context, especially for those eHealth use cases. Up to **38% of respondents ranked healthcare** the most disruptive market segments beyond of entertainment (namely gaming) in the next 12 months, only followed by **education (28%)**, **workforce development (24%)** – this being a horizontal market - and **manufacturing (21%)**.

However, an important warning must be made. The current context of containment and treatment of the novel coronavirus has brought into light how valuable these technologies can be in the healthcare setup. Nonetheless, there may be a potential bias of the technology's potential in such segment due to the same reason.

Figure 40 | Perkin Coie's 2020 AR/VR Survey Report - Sectors with Most Disruption by Immersive Technologies in the Next 12 Months.

Q: In which sectors do you expect to see the most disruption by immersive technologies in the next 12 months? (Outside of the gaming and entertainment space)

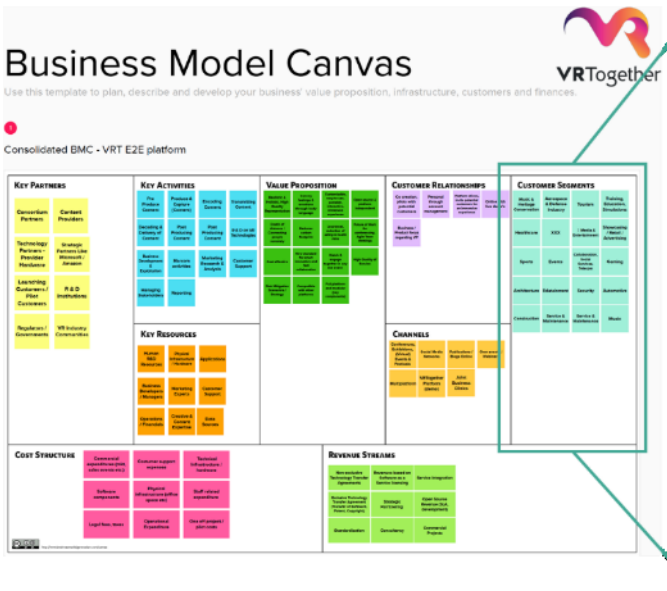


PERKINS COIE
boostVC
XRA XR ASSOCIATION

And what is more, such classification is further corroborated by the first VRTogether Joint Business Clinics held the 9th of July in Barcelona, Spain. A total of 33 industry leaders participated in a set of workshops one of which consisted in identifying the sectors which the most disruption by immersive technologies in the next year is expected in the form of a Business Model Canvas.

Below, the consolidated form of the BMC is presented and a correlation with the industry-specific market verticals is provided. It is important to note that those horizontal market verticals have been here excluded such as the case for Training & Simulations and Communication & Collaboration segments.

Table 6 | First Joint Business Clinics Consolidated Business Model Canvas - Identification of Most Promising Customer Segments for the VR/AR Market for the next 12 months.



IDENTIFIED CUSTOMER SEGMENTS	
JBC CUSTOMER SEGMENTS	CONSOLIDATED INDUSTRY SEGMENT
Music & Heritage Conservation	Art & Storytelling
Aerospace & Defence Industry	Other (Defence)
Tourism	Other (Travel)
Education	Education & Culture
Healthcare	Helathcare
Adult Industry	Other (Adult Industry)
Media	Awareness rising & Reporting
Retail & Showcasing	Commerce & Advertising
Sports & Live-Events	Live Entertainment & Experiences
Gaming	Gaming
Architecture & Construction	Architecture, Real State & Construction
Security	Other (Defence)
Automotive	Engineering & Manufacturing Industry

Before diving into the specific industries, we note that VR and AR have the potential to not only create new markets but also disrupt existing one across all the verticals. From the identified verticals for VR/AR technologies, Goldman Sachs[114] expects that by 2020, the largest segment will be video games. The healthcare and engineering segments are also expected to experience high levels of growth in the coming years, further exhibiting the wide range of possible uses for the technology. Such figures are based on the Goldman Sachs base case scenario (see section 2.3.2 - Mid-term VR/AR market forecasts) for both 2020 and 2025 forecasts.

Another important key takeaway is the fact that only 3 out of the 9 use cases are entirely driven by the end-consumer (videogames, live-events and video entertainment), making up the 60% of the total VR/AR revenue assumptions for 2025. The remaining 40% is driven by enterprise and public sector spend with the largest revenue generating industries in engineering, healthcare and real state.

Also, Goldman Sach's expects that 75% of the 2025 VR/AR Market will be made of VR specific use cases ($26 billion in revenue) while AR applications will represent 25% ($9 billion in revenue).

Figure 42| Forecast size of the augmented and virtual reality (VR/AR) market worldwide in 2020 and 2025, by segment (in billion U.S. Dollars)

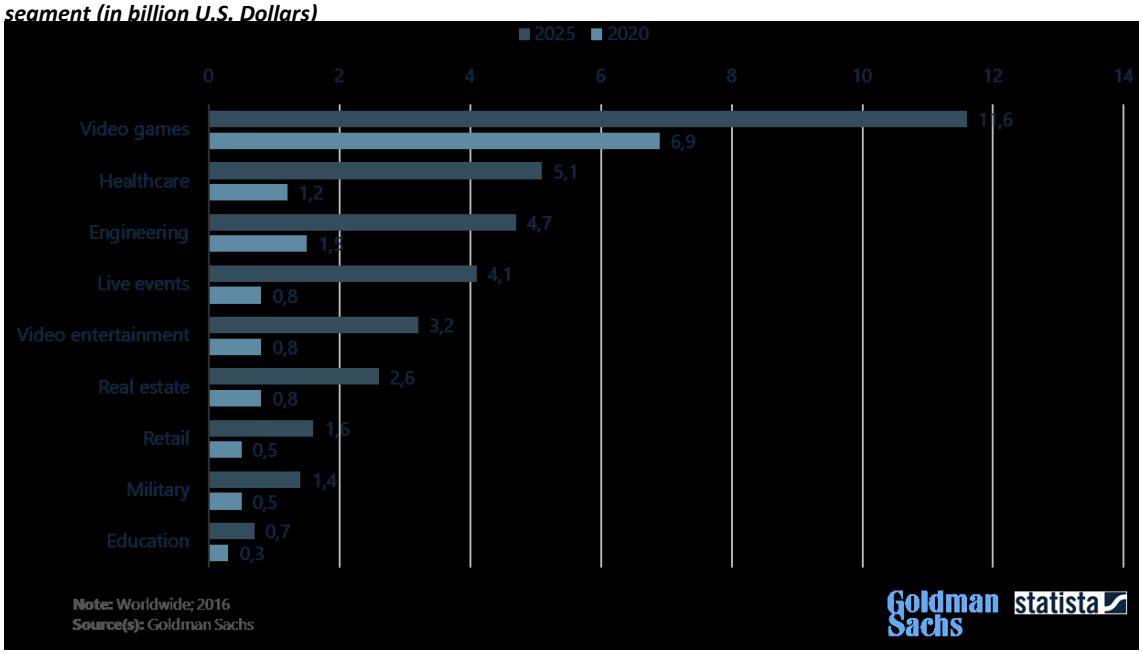
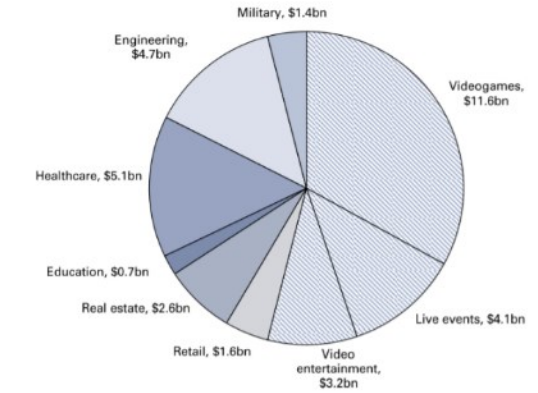
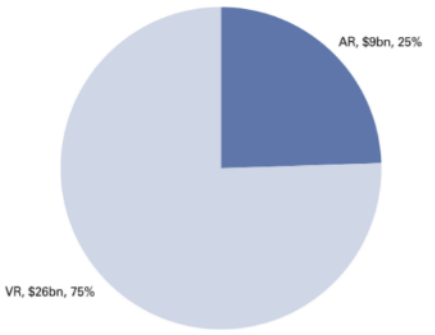


Figure 42 | Goldman Sach's 202 VR/AR estimates by use case (Left); and 2025 Software estimates by VR and AR (Right)



Source: Goldman Sachs Global Investment Research.



Source: Goldman Sachs Global Investment Research.

[114] Goldman Sachs, 2016. Goldman Sach's Virtual & Augmented Reality – Understanding the Race for the Next Computing Platform. As published on Statista. Available from: https://www.statista.com/statistics/610112/worldwide-forecast-augmented-and-mixed-reality-software-market-by-segment/

4.3. VR/AR INDUSTRY-SPECIFIC MARKET ANALYSIS, BY VERTICAL

In the present deliverable we will analyse the current market situation of the most prominent and growing VR verticals. Serving that purpose, we have pre-selected those market verticals that, to our knowledge are of the most interest for VRTogether. These consist of (1) Education & Culture; (2) Healthcare; (3) Engineering & Manufacturing; (4) Awareness Rising & Reporting; (5) Commerce & Advertising; (6) Live Entertainment & Experiences.

Regarding Art & Storytelling, it has been included within the Culture market vertical. Also, despite gaming currently represents one of the most profitable market verticals within the VR scene, it falls clearly out of the scope of VRTogether, which aims to explore new social applications of the immersive technology beyond the classical gaming experiences.

4.3.1. Education & Culture[115]

4.3.1.1. Education

Education is the base for a thriving society, and the transfer of knowledge has been a top priority for civilizations since the very beginning. People are constantly looking for ways to make knowledge transfer more easily, more quickly, and more effectively. In the era of digital devices, we have an opportunity to enable better learning with technology. Virtual Reality (VR) seems to be the natural next step for the evolution of education.

Before diving into the details of how VR in education will help improve the learning process, it's important to understand why we need to improve the quality of education in the first place. Historically, most technologies and tools designed to aid learning have been aimed at enabling access to information — facts and observations about the world. Before computers, we had a powerful tool that helped us retain facts: **books**.

In the era of digital technologies, books are being turned into eBooks. Modern search engines make fact-finding really easy with just a few clicks you can discover answers to many questions. While knowledge has become more easily available for more people, the current approach to education hast two significant problems:

a. **It is based on the same old-fashioned format – Fact Retention.**

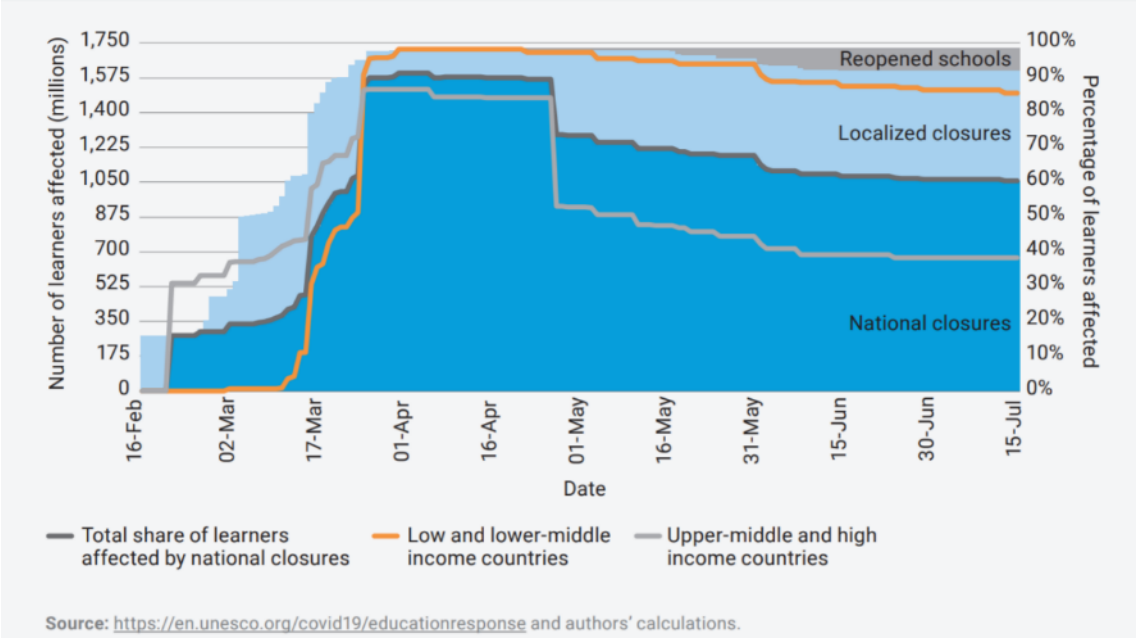
   Teaching methods are focused on providing facts; however, having access to and consuming a lot of information it is not learning but being informed. Instead, it is more and more common to apply new methodologies which involve **learning by doing**. By involving the students in the process, engagement increases through the process, learning accelerates, and retention improves. Also, the personal nature of experiential learning engages student's emotions as well as enhancing their knowledge and skills. This is in fact a social process in which VR can really provide a new platform to do so.

b. **A lot of students have difficulties comprehending and processing complex information.**

   Too much information received in a short period of time can easily overwhelm students. As a result, they become bored, disengaged, and usually not sure why they are learning about a topic in the first place.

[115] **Disclaimer**: Culture, in relation to VR market, refers to any use of the technology related to bridging the gap between cultural exhibitions, interpretations and society. In refers to the use of VR for virtually assisting or experiencing culture. Despite the fine line, this needs to be clearly distinguished from the concept of VR Art or content creation, which is the use of the technology to explore and create art exhibitions, here considered a different market vertical.

Figure 43 | UNESCO - Number of Children Affected By School Closures Globally Due To COVID-19 Pandemic



Be that as it may, another major problem has disrupted educational systems worldwide – the COVID-19 pandemic. According to a recent **United Nations**[116] report, COVID-19 has created the largest disruption of education systems in history, affecting 1.6 billion learners in more than 190 countries in all continents. Quarantines and lockdowns have resulted in schools and universities closures having impacted 94% of the worlds student population. A problem that has been further exacerbated in low and lower-middle countries with up to 99% disruption.

According to **UNESCO**, the disruptions caused by COVID-19 to everyday life meant that as many as **40 million children worldwide** have missed out on early childhood education in their critical pre-school year. They thus missed a stimulating and enriching environment, learning opportunities, social interaction and in some cases adequate nutrition.

In technical and vocational education and training systems, vulnerabilities **including low levels of digitalisation** and long-lasting structural weaknesses, have been brought to light by the crisis. In the higher education sub-sector, while **online learning** has generally taken place through recorded lectures and online platforms, some universities have postponed learning and teaching until further notice, due to the lack of information technology (IT) infrastructure for both students and teachers

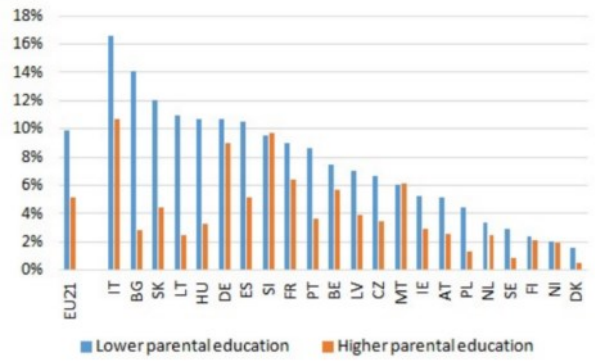
Not surprisingly, the most vulnerable learners are also among those who have poor digital skills and the least access to the hardware and connectivity required for distance learning solutions implemented during school closures. According to the European Commission (EC)[117], in half of 21 European countries examined, Grade 4 students from lower socio-economic backgrounds were half as likely to have access to internet as their more advantaged peers.

[116] United Nations, 2020. Policy Brief: Education during COVID-19 and beyond. August 2020 United Nations for Education, Science and Culture (UNESCO) – Educations Response. Available from: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/08/sg_policy_brief_covid-19_and_education_august_2020.pdf

[117] European Commission, 2020. Educational inequalities in Europe and physical school closures during Covid-19. Available at https://ec.europa.eu/jrc/sites/jrcsh/files/fairness_pb2020_wave04_covid_education_jrc_i1_19jun2020.pdf

In addition to the learning loss, the economic impact on households is likely to widen the inequities in education achievement. Should millions be pushed into poverty, evidence shows that children from households in the poorest segments are significantly less likely to complete primary and lower secondary education than those in the richest segment.

Figure 44 | Percentage (%) of 4th Graders without internet access at home, by parental education and country, 2016.

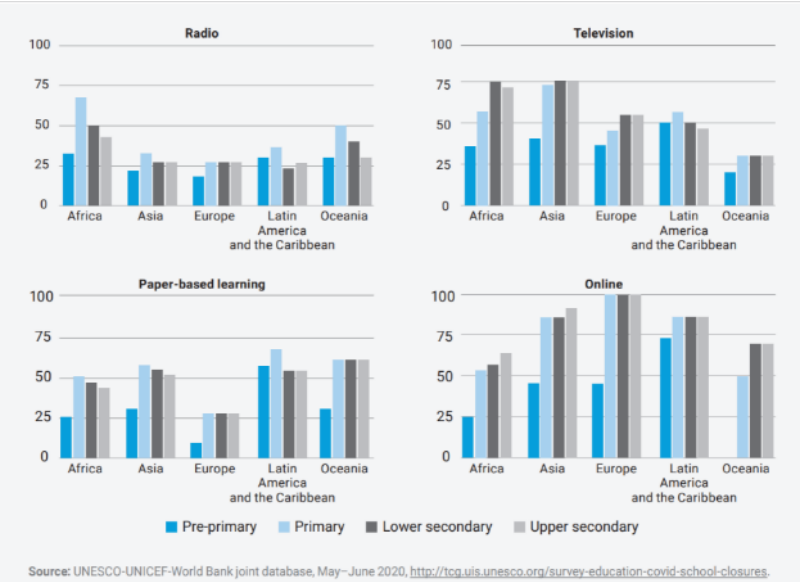


On the other hand, the crisis has **stimulated innovation within the education sector**. As the health crisis unfolded, causing massive socio-economic disruptions, education systems around the world were prone to react and adapt.

Ensuring learning continuity during the time of school and other educational institutions closures became a priority for governments, many of which turned to Information and Communications Technologies (ICT), requiring teachers and students to move to **online learning tools an novel technology.**

According to a joint UNESCO-UNICEF and World Bank database[118], online modalities have been used the most across the world during pandemic times. The **European Union (EU) region has been the pioneer in implementing online learning modalities** being the preferred system (100%) in all primary, lower secondary and upper secondary education levels. This is in turn, a reflection of the great connectivity levels of the EU after years of incentivising policies.

Figure 45 | Country Choice of Distance Learning during School Closures was Influenced by Education Level and Region (%).



[118] World Bank Group, UNESCO-UNICEF, 2020. Survey on National Education Responses to COVID-19 School Closures. Technocal Cooperation Group on the Indicators for SDG 4. Available from: http://tcg.uis.unesco.org/survey-education-covid-school-closures/

As a result, local governments and private educational institutions need a way to deliver learning in the safety of student's homes, trying to match the level of immersiveness they would experience in a classroom setting.

In this context, **EdTech (Education Technology),** the practice of introducing ICT tools into the classroom to create more engaging, inclusive and individualised learning experience, is quickly rising as an alternative. One of such EdTech alternatives is **Virtual and Augmented reality**, which could be both a very useful tool in this regard given thanks to its ability to simulate any learning environment.

For instance, VR-based immersive and experiential learning has the potential to create a deeper level of engagement with target topics, in a distraction free environment. Such an environment creates chances for focus and attention on a topic or idea, which should positively affect retention rates of the subject matter.

One of the possible advantages of VR is the opportunity to gain real-life experience in certain areas, which can be difficult to achieve, dangerous, or just plain expensive. VR can connect students with those experiences, from the most specialized skill-set training, such as welding practice, to performing simple lab experiments. With a look-see-do mode of learning, students are encouraged to choose, explore, manipulate, and comprehend subjects in a different way.

Also, VR/AR tools may provide a toll for empowering both teachers and students, but only if paired with the right content. Regardless of the medium, **quality content** is crucial for effective learning.

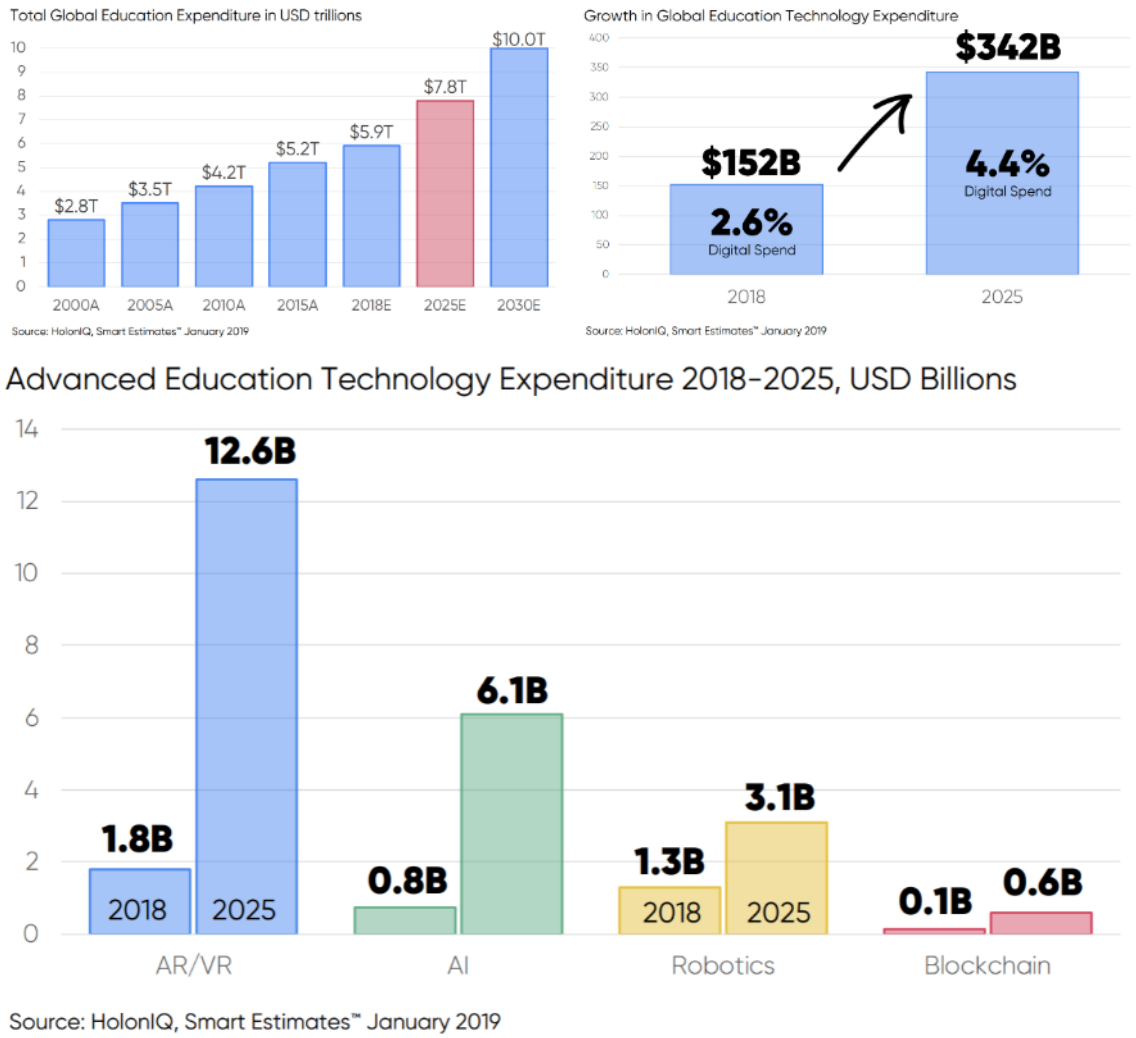
Table 7 | How VR in Education Will Change How We Learn and Teach

How VR In Education Will Change How We Learn And Teach	
BENEFITS OF VR IN EDUCATION	CONSOLIDATED INDUSTRY SEGMENT
Better Sense of Place	When students read about something, they often want to experience it. With VR, they aren't limited to word descriptions or book illustrations; they can explore the topic and see how things are put together. Thanks to the feeling of presence VR provides, students can learn about a subject by living it. It's easy to forget that VR experiences aren't real — a body actually believes it's in a new place. This feeling engages the mind in a way that is remarkable.
Scale Learning Experiences	Technologies such as science labs are amazing — they allow students to understand how things work based on practical experience. But such technologies are expensive and almost impossible to scale. They are also limited in the number of things they can do.
Learning by Doing	It's a well-known fact that people learn best by doing; however, if you inspect modern education, you'll see how little learning actually happens by doing. Students are focused on reading instructions rather than using them in practice. VR in education provides an experience anchor to the instruction. With VR education, learners are inspired to discover for themselves. Students have an opportunity to learn by doing rather than passively reading.
Emotional Reaction	Visceral reactions to what we are experiencing are fundamental to forming memories. VR in education makes it easy to engage students the whole time, making experiences memorable.
Developing Creativity	Having virtual reality in education is useful not only for content consumption, but it's also great for content creation. By giving students powerful tools you help them boost their creativity.
Visual Learning	A lot of people are visual learners — VR is really helpful for this group of learners. Instead of reading about things, students actually see the things they're learning about. Being able to visualize complex functions or mechanisms makes them easier to comprehend.

And what is more, **users are ready to embrace the technology, even before the COVID-19 disruption**. According to Business Insider and Greenlight VR[119], desire and interest for education use of VR outweighs interest for gaming content (63.9% for education versus 61% for gaming). A similar survey conducted by Loup Ventures[120] also highlight that Education is the second interest application in VR second only to entertainment.

As a result, this is generating a prosperous environment for the growth of the EdTech market, and more specifically for the VR/AR technology within this. According to the world-renowned global education market intelligence company **Holon IQ[121],** the total global education expenditure was of **$5.9 trillions in 2018** and is expected to reach a whopping **$7.8 trillion mark by 2025**. Within the education market the global EdTech expenditure represents an approximately 3% of the total, namely **a $152 billion market in 2018** (2.6% of total). However, such market is predicted to increase up to a 4.4% concentrating a $342 billion by 2025 in size at a CAGR of +12.28%.

Figure 46 | EdTech Market Size and Forecast, 2018-2025.



[119] Greenlight Insights, 2016. 2016 Virtual Reality Consumer Report. Greenlight VR. June 21, 2016. Available from: https://greenlightinsights.com/consumer-interest-in-virtual-reality-goes-far-beyond-gaming/

[120] Loup Ventures, 2017. VR Excitement Index: 10.2. Andrew Murphy. Jan 3, 2017. Available from: https://loupventures.com/vr-excitement-index-10-2/

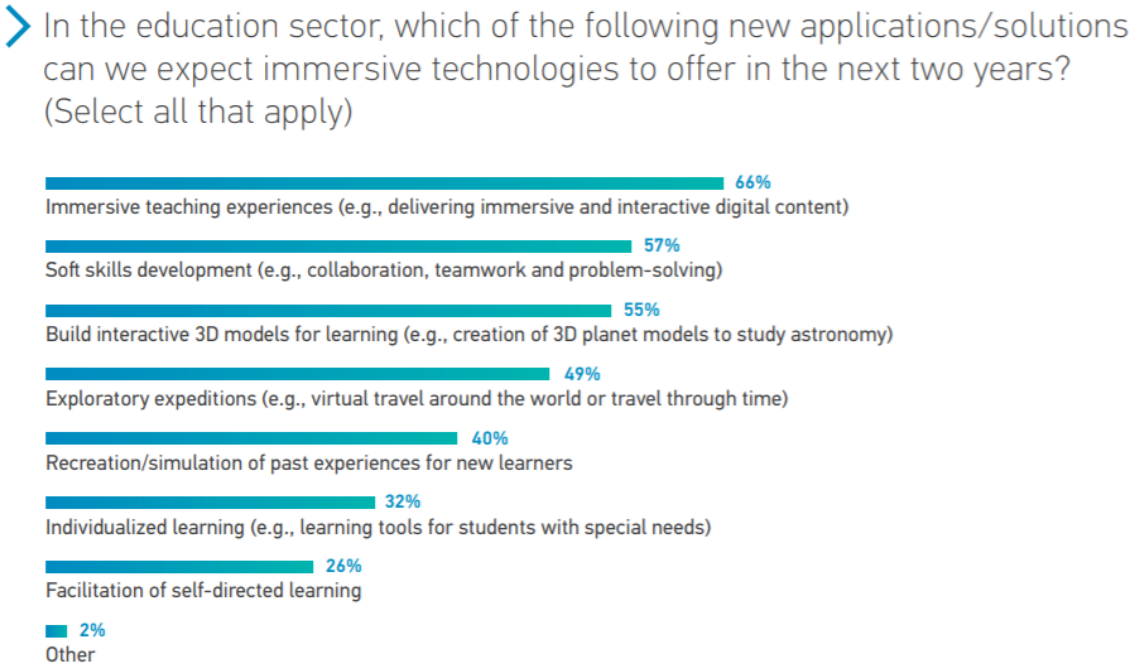
[121] Holon IQ, 2019. Global Education Market in 10 Charts. February 2019. Available from: https://www.holoniq.com/wp-content/uploads/2019/02/HolonIQ-2019-Global-Outlook-Deck.pdf

By technology category, **VR/AR concentrates most of the EdTech market** with a total **$1.8 billion spend in 2018**. Interestingly, it estimated to reach **$12.6 billion by 2025** representing a an impressive **CAGR +32.05%** for the forecasted period.

Applications of the VR technology within the Education field include immersive teaching experiences, soft skill development (e.g. collaboration, teamwork and problem-solving), building interactive 3D models for learning, exploratory expeditions or individualized learning inter alia.

Among all, and according to the consultancy firm Perkins Coie and its 2020 annual Survey of the VR Industry[122], immersive teaching is regarded as the big VR application/solution within the Education sector to expect in the next two years (66% of respondents). Soft skill development and interactive 3D models for learning are second and third in position with 57% and 55% of responses.

Figure 47 | New Immersive Technologies Applications/solutions in the education sector expected in the next two year.



The prosperous forecasted market is attracting venture capital investment. In 2014, investment in EdTech was valued in 1.8 billion and only after 4 years the such figure quadrupled up to the 8.2 billion mark. In this regard, China and the United States are the leading market regions in terms of investment with $5.2 bn and 1.6 bn invested respectively in 2018. The European Union comes 4th, only after India, with a 0.5 bn investment in EdTech in 2018.

This trend is further confirmed by 2019 Brighteye Venture[123] report which concludes that EdTech is in fact consolidating in the market with ever growing number of investments deals in both number and in size. According to the source, European EdTech VC investment broke another record in 2019 with 187 deals and more than $1.2 billion invested. n 2015, the 5 most funded

[122] Perkins Coie, 2019. Augmented and Virtual Reality Survey Report – Industry Insights into the Future of Immersive Technology. March, 2019. Volume 3. Available from: https://www.perkinscoie.com/images/content/2/1/v4/218679/2019-VR-AR-Survey-Digital-v1.pdf

[123] Brighteye Ventures, 2020. The European EdTech Funding Report 2020. Jan 28, 2020. Available from: https://www.brighteyevc.com/post/european-edtech-funding-report-2020

EdTech companies received between $6M and $30M, compared to $37M and $60M in 2019. The bar is rising as EdTech companies are able to raise much more money than before, especially in the UK and France, the strongest EdTech nations in Europe.

Figure 49 | Global Education Venture Capital Investment, 2014-2018 USD Billions. (Top – Holon IQ; Bottom - Brighteye Ventures).

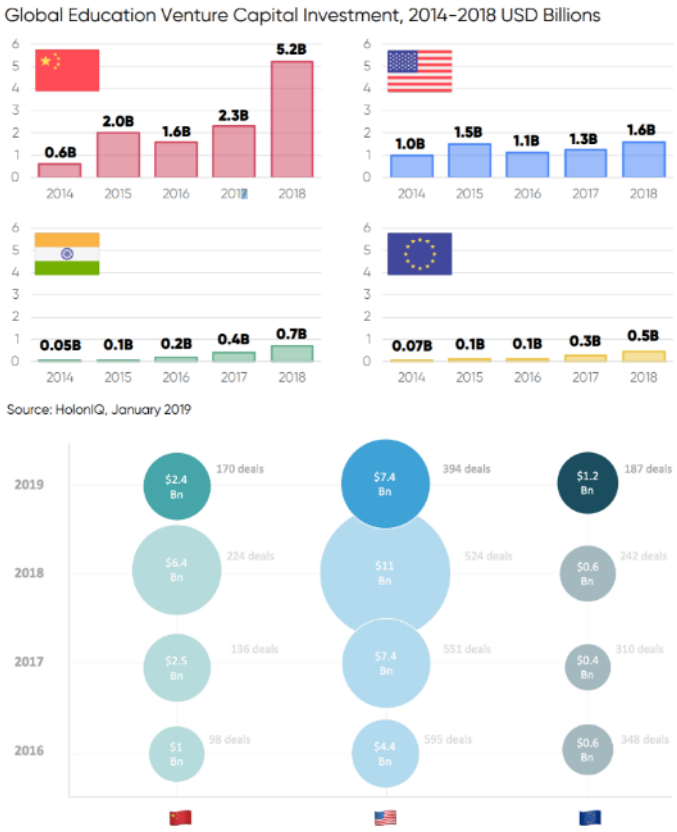
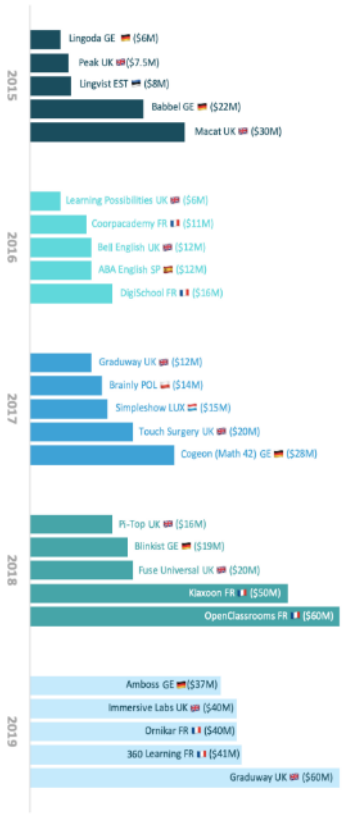


Figure 48 | Top 5-EU EdTech Investment Deals, 2015-2019.



Source: Brighteye Ventures, 2020.

Examples of VR in Education

One of the leading companies in the VR Education field at a global scale is **zSpace (USA)**[124]. Founded in 2006 in San Jose, zSpace for Education allows users to manipulate an array of virtual, 3D objects including building circuitry and experimenting with gravity. zSpace offers its client classrooms more than 250 STEAM (science, technology, art and math) lesson plans aligned to the Common core, Next Generation Science Standards (NGSS) and other state standards for K-12 education. zSpace enables 3D printing and also partnered with Google to combine zSpace's AR technology with the Google Expeditions Pioneer Program.

A recent survey of teachers using zSpace with their students demonstrated their belief in the power of AR/VR to transform learning. Nearly 100 percent of teachers surveyed said that using AR/VR allows them to expose their students to things that would otherwise be impossible.

Through its *zSpace as a Service (ZaaS)* business model[125], a term-based program that provides educational institution with a lab set-up of VR hardware units with the zSpace platform (software, installation, professional training, updates and support) offered to educational

[124] zSpace, USA. https://zspace.com/

[125] zSpace, 2020. zSpace Service Solution (ZaaS). Available from: https://cdn.zspace.com/downloads/documentation/legal/ZaaS_Services_Agreement_05242018.pdf

institutions customers, the company has generated over $14 million in revenue and is serving over 1 million student users. In addition, it has raised over $76 million in funding over the last decade.

Based in Waterford, Ireland, **Immersive VR Education (IRE)**[126] uses virtual reality to transform education and corporate training through virtual reality. Its online virtual social learning and presentation platform, ENGAGE, provides a platform for creating, sharing and delivering proprietary and third-party VR content for educational and corporate training purposes. ENGAGE allows any virtual environment to be created – for example a replication of a real-world workspace or a place in which it would be impossible, dangerous or cost prohibitive to visit in real life – like the bottom of the ocean, the surface of Mars, a disaster zone, ancient Rome, an architectural model, an artist's 3D painting or even a journey into the human body. Founded in 2014, the startup has raised €1 million to date.

Another great example within the EdTech field is the Waterford City-based, **Engage (IRE)**[127]**.** Engage is an advance virtual reality and education platform aiming to facilitate collaboration, creativity and learning in VR. It empowers educators and companies to host meetings, presentations, classes and events with people across the world. Using the platform, virtual reality training and experiences can be created in minutes. The system allows for up to 50 remote users and to visualize more than +1200 3D objects as well as more than 21 virtual locations. In addition, aiming to facilitate collaboration among students the platform includes quizzes and forms as well as the possibility to create presentations and media streaming.

For children's and teenagers, educational apps in VR are already coming up, like for example learning experiences provided by **WeMakeVR (NL)**[128]. The Amsterdam-based EdTech company offers a wide range of learning experiences such as traffic rules for teenagers or short films about historical events, climate change among other educational immersive experiences.

School and universities have been experimenting with adding VR as a teaching tool or makingVR lectures a part of the curricula. Companies such as **Labster (DK)**[129], which created virtual labs for experiments, as the abovementioned **Immersive Education (IRE)** and **Lifeliqe (CZ)**[130] take the concept of VR education even further by providing a whole new interface for learning and exploring. In fact, Lifeliqe claims a **86% improvement on students test scores, 97% students got more engaged in lessons, 98% understood more difficult topic better and 97% felt more excited about learning.**

[126] Immersive VR Educations, IRl. https://immersivevreducation.com/
[127] Engage VR, IRL. https://engagevr.io/
[128] WEmAKEvr, nl. http://wemakevr.com/
[129] Labster, DK. https://www.labster.com/
[130] Lifeliqe, CZ. https://www.lifeliqe.com/

4.3.1.2. Culture

Culture is a notoriously difficult term to define. According to UNESCO[131], **culture** can be defined as "the set of distinctive spiritual, material, intellectual and emotional features of society or social group, that encompasses, not only art and literature, but lifestyles, ways of living together, value systems, traditions and beliefs".

Whereas it is not always possible to measure such beliefs and values directly, it is possible to measure associated behaviours and practices. As such, **cultural activities** correspond to those activities whether ending in themselves or contributing to the production of cultural goods and services, which embody or convey cultural expressions, irrespective of the commercial value they may have.

In the context of the present VR market report, this needs to be dissociated from the concept of **art or cultural content creation**, which would be included in a different market vertical (Art & Story-telling) and, as such, only focuses on **cultural and heritage services, education, and distribution or sharing**.

These correspond to those industries that embrace or use culture as an input and have a culture as a dimension, namely: Heritage, Archives and Libraries including museums, historic buildings, archaeology and conservation or art/photography galleries; Performing arts which include theatre and musical theatre, magic, spoken word or circus arts; Cultural Education and other cultural sectors such as Cultural Tourism or Auctioning.

However, beyond the classical Cultural and Creative sectors, the artistic content created has an impact on a wide range of industries that depend on the creative output. These include,

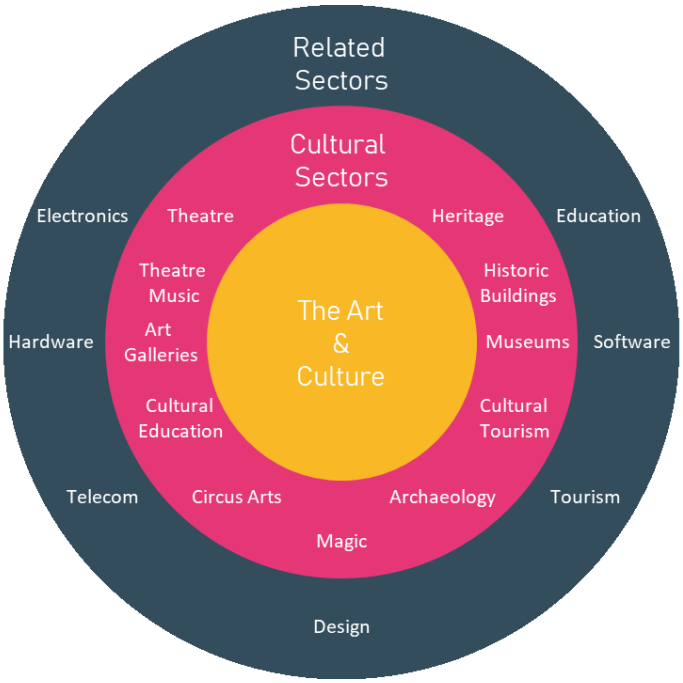


Figure 50 | The Cultural Industry Ecosystem

* The Cultural Ecosystem includes but is not limited to the sub-sectors here represented.

[131] UNESCO, 2001. Universal Declaration on Cultural Diversity. Adopted by the 31st Session of the General Conference of UNESCO. Paris, 2 November 2001. Available from: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CLT/pdf/5_Cultural_Diversity_EN.pdf

consumer electronics (e.g. TV, Tuners, DVD content); Telecom services, Industrial Design, Tourism, Software and Education.

A recent market analysis report of the cultural and creative sectors in Europe, co-developed between European Investment Fund (EIF) and the European Commission[132], highlights the European Cultural sector represent a key market for the EU in terms of size, employment and value added.

In 2016, according to Eurostat, the Cultural Sector represented more than 6.7 million employees in the EU, accounting for **2.45 million companies and generating a value-added amount of $290 bn**. In the most recent 2019 report[133], nearly **9 million people in the EU worked in the field of culture; this is a 3.8% of the total employment**. For comparison, the value added of the cultural sector within the EU-28 was slightly higher than that for the motor trades sector and was almost equal to that for food manufacturing. The **cultural sector's turnover** (the total value of market sales of goods and services) was **€466 billion**, which represented 1.7 % of the total turnover generated within the EU-28's non-financial business economy.

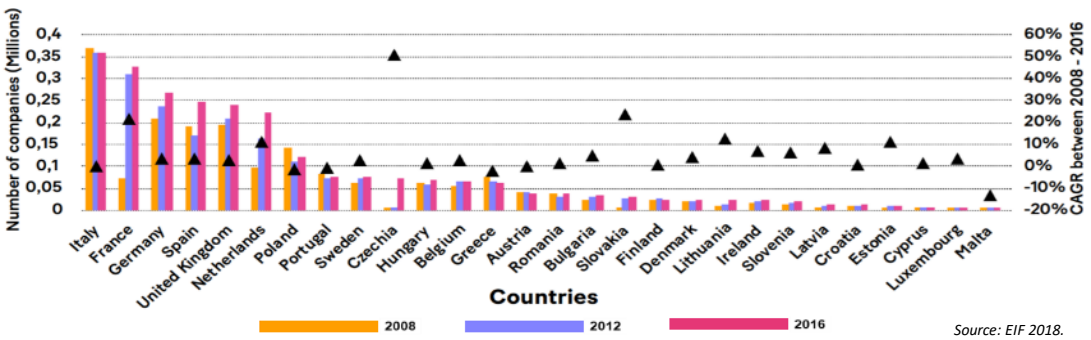
Figure 51 | Cultura ***Sector Share of Employment Out of Total Employment (Left);***

Criteria	ICT	Accommodation and food services	Cultural Sector
Percentage of EU GDP[2015]	4%[2015]	4%[2015]	4.2%[2014]
Value added	EUR 570 billion[2016]	EUR 252.9 billion[2016]	EUR 290 billion[2016]
Employment	6.3 million[2015]	11.1 million[2015]	6.7 million[2016]
Number of companies	1.1 million[2015]	1.9 million[2015]	2.45 million[2016]
Average company size (Employment /Number of companies)	5.73 employees per company[2016]	5.84 employees per company[2016]	2.7 employees per company[2016]

Source: Eurostat 2015; EIF 2018.

In fact, the Cultural Sectors has been on the rise over the last years, with an ever-increasing positive growth in terms of number of companies in most EU countries. Overall, the number of cultural sector companies has steadily increased over the period 2008-2016, with a CAGR of 4%. Regarding CAGR, the Netherlands, Slovakia, Lithuania and Estonia are the top performing countries with over 10% growth. In the EU, 22 countries experienced growth and only 6 countries saw a reduction in the number of companies. In 2016, the countries counting the most CCS companies were Italy (355,836), France (324,579), Germany (267,118), Spain (244,762), the United Kingdom (239,062) and the Netherlands (221,031).

Figure 52 | Evolution of Cultural Sector Companies per Country and Growth Rate between 2008-2016.



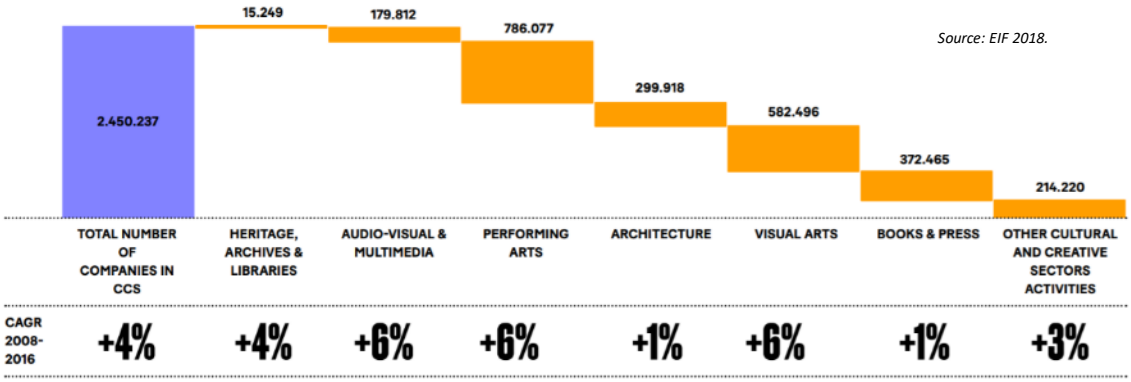
Source: EIF 2018.

[132] EIF & EC, 2019. Market Analysis of the Cultural and Creative Sectors in Europe – A Sector to Invest In. Available from: https://www.eif.org/what_we_do/guarantees/cultural_creative_sectors_guarantee_facility/ccs-market-analysis-europe.pdf

[133] Eurostat, 2020. Culture Statistics – 2019 Edition. ISBM 978-92-76-09702-0. Available from: https://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-01-19-712

When distributed by sub-sectors, the Cultural Market companies have seen an increase in the number of companies in the past years across all categories. As of 2016, the largest sub-sectors in terms of companies were Preforming Arts, Visual Arts, Books & Press and Architecture and the strongest growth rates were experienced by the Cultural related Audi-Visual & Multimedia sector, Performing Arts and Visual Arts.

Figure 53 | Distribution of Companies by Cultural Sub-sector in 2016.

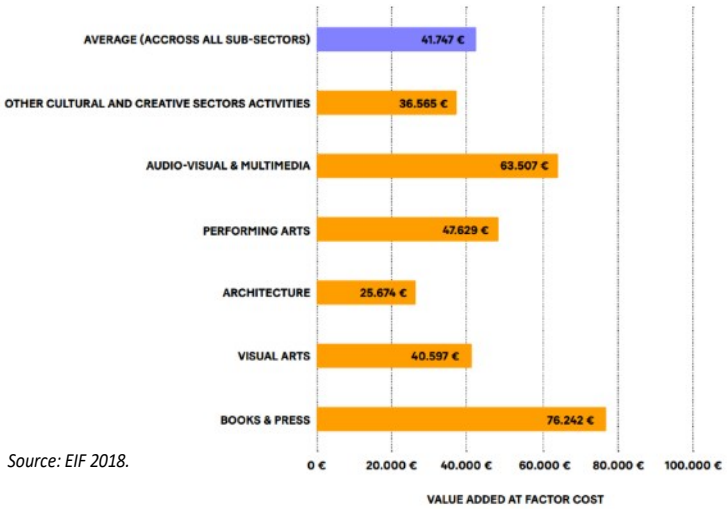


In terms of market size by sub-sector, the Cultural Sector has seen constant growth in the past years reaching the €290.2 bn burden in 2016, according to EIF. Over the reference period (2008-2016) the gross value added has consistently grown with a CAGR of more than 2%. This refers to the **total gross value added at factor cost**, corresponding to the gross income from operating activities after adjusting for operating subsidies and indirect taxes.

On average, the value added across Cultural Sub-sectors amounted to €41.7 billion. Out of the 6 CCS sub-sectors for which data on gross value added was available, 5 have seen an increase in the gross value added over the reference period. The only sector that has experienced a moderate decline in gross value added is Books & Press.

The sub-sectors Books & Press and Audio-visual & Multimedia achieve the highest gross value added. Furthermore Audio-visual & Multimedia achieves the highest compound average growth rate over the reference period in gross value added.

Figure 54 | Value Added at Factor Cost* 2016 (million €).



Source: EIF 2018.

***VALUE ADDED AT FACTOR COST**

The gross income from operating activities after adjusting for operating subsidies and indirect taxes. It can be calculated as the total sum of items to be added (+) or subtracted (-):

- turnover (+);
- capitalized production (+);
- other operating income (+);
- increases (+) or decreases (-) of stocks;
- purchases of goods and services (-);
- other taxes on products which are linked to turnover but not deductible (-);
- duties and taxes linked to production (-).

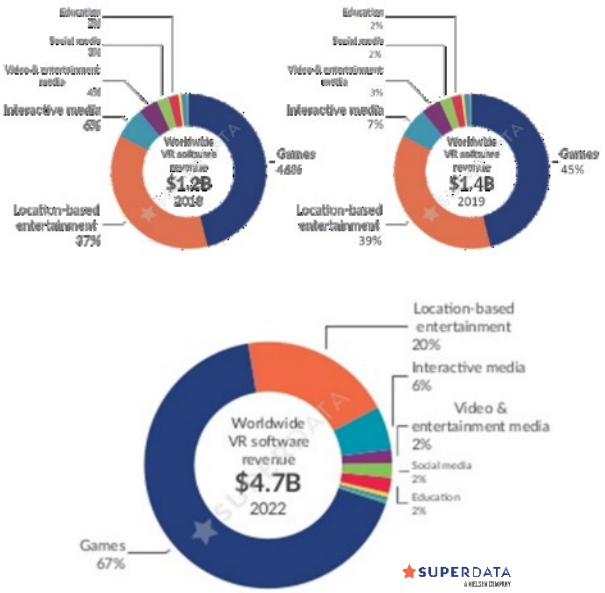
Alternatively, it can be calculated from the gross operating surplus by adding personnel costs.

The use of virtual reality within culture permeates each and every single of the above-mentioned sub-sectors, a trend that has been growing over the past few years. Often referred to as **venue-based cultural sectors** (such as museums, performing arts, live music, festivals, cinema, etc.) have already been embracing digital technologies, such as VR/AR, for exploring new ways of engaging with the audience and driving cultural participation.

As of 2019, SuperData[134] estimated **location-based software to represent 39% of the $1.4 bn total VR software market, roughly $546 million**. By 2022, the VR revenue from venue-based software is estimated to comprise the 20% of the global VR software revenue, up to the $940 million burden at a CAGR of 19.85%.

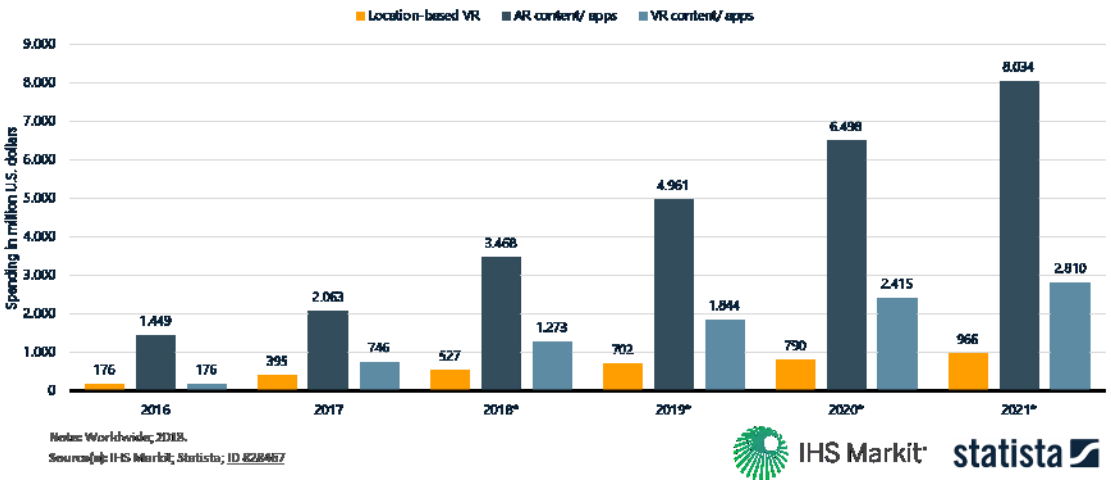
Also, consumer spending on augmented and virtual reality content and applications worldwide from 2016 to 2021 showed location-based VR/AR has been on the rise over the last years.

Figure 55 | Share of Global Virtual Reality Software Revenue in 2018, 2018 and 2022, by Category.



According to HIS Market and Statista Estimates[135], location-based VR, including venue-based cultural applications, grew from the $176 million consumer spending in 2016 to $702 million in 2019, at a staggering 58.59% CAGR. What is more, IHS Markit 2018 forecast estimated location-based consumer spending reach the $966 million by 2021, confirming the fact that this is a growing and fructiferous market.

Figure 56 | Consumer Spending on augmented and virtual reality (AR/VR) content and apps worldwide from 2016 to 2021 (in million U.S. dollars)



[134] Superdata, 2019. XR by the Numbers: What the Data Tells Us. AWE USA 2019. Published in SlideShare. Available from: https://www.slideshare.net/AugmentedWorldExpo/stephanie-llamas-superdata-xr-by-the-numbers-what-the-data-tells-us

[135] HIS Markit; Statista Estimates, 2018. Consumer spending on augmented and virtual reality (AR/VR) content and apps worldwide from 2016 to 2021. April 2018. Available from: https://www.statista.com/statistics/828467/world-ar-vr-consumer-spending-content-apps/

Be that as it may, it is important to mention that SuperData's and IHS Markit's forecasts may include within the Location-based VR Segment, other applications related to entertainment (arcades, theme parks, etc.) that may result in a distortion or misrepresentation of the actual and specific cultural venue-based market segment. However, providing a more in-depth level of detail regarding the individual cultural market segment of VR/AR has proved to be a difficult task, given that is often included within other market sectors due to the multiple cross-links and the fact cultural infiltrates into many social, economic and scientific sectors.

Since the emergence of COVID-19 and as a result of quarantines, lockdowns and other visitor-capacity restrictions, the disruption of the cultural sector has been unprecedented meaning any previous estimation are now obsolete.

The most recent update by SuperData[136], as of July 2020, suggests that location-based applications have been revised downwards due to the ongoing COVID-19 impact. 2020 spending is estimated to be roughly one-quarter of 2019 spending ($146M vs. $597M), but the long-term impact of COVID-19 on the economy and entertainment venues means it is now expected 2023 spending ($422M) will still be 29% lower than the total in 2019.

In fact, **the venue-based cultural sectors might have been the hardest hit among all by social distancing measures**. According to the Organisation for Economic Co-operation and Development (OECD)[137], the abrupt drop in revenues puts venue-based cultural sectors financial sustainability a risk and has resulted in reduced wage earnings and lay-offs with repercussions for the value chain of their suppliers.

Furthermore, the international economic organisation expects the effects of the crisis on distribution channels and the drop in investment by the sector to affect the production of cultural goods and services and their diversity in the months, if not years, to come. Over the medium term, the anticipated lower levels of international and domestic tourism, drop in purchasing power, and reductions of public and private funding for arts and culture, especially at the local level, could amplify this negative trend even further.

At the present moment, it is difficult to assess the overall economic impact on the CCS value chain and its sub-sectors; nevertheless, some estimates provide an essential snapshot of the seriousness of damage suffered by the industry.

Spending on recreation and culture in the G7 economies has decreased significantly: for instance, -10% UK, -7% Germany, -6% France and -5% Italy[138]. According to UNESCO at the beginning of June 2020 50% of world heritage sites were still closed.

The result? Thousands of museums, cultural institutions, festivals and global happenings have temporarily shuttered operations, leaving behind empty streets and a restless public. In a sector that thrives on in-person connection, the loss of an audience is disastrous, yet resilient performers, institutions, galleries, even entire art fairs, are moving to the **digital arena**.

[136] SuperData, 2020. SuperData XR Q2 2020 Update. July 27, 2020. Press Release. Available from: https://www.superdataresearch.com/blog/superdata-xr-update/

[137] OECD, 2020. Culture shock: COVID-19 and the cultural and creative sectors. OECD Policy Responses to Coronavirus (COVID-19). September 7, 2020. Available from: https://www.oecd.org/coronavirus/policy-responses/culture-shock-covid-19-and-the-cultural-and-creative-sectors-08da9e0e/#section-d1e1459

[138] OECD, 2020. Evaluating the Initial Impacto of COVID-19 containment measures on economic activity. June 10, 2020. Available from: https://read.oecd-ilibrary.org/view/?ref=126_126496-evgsi2gmqj&title=Evaluating_the_initial_impact_of_COVID-19_containment_measures_on_economic_activity#page=5

Now, with social distancing, the **VR/AR technology is experiencing something of a renaissance in the cultural field** since **venue-based cultural sectors** have been forced **to explore alternative digital spaces.** The wide-spread digitalisation coupled with emerging technologies is ushering **new** innovative **forms of cultural experience, dissemination and new business models with market potential.**

Examples of VR in Culture

Another place where education takes place are **museums and galleries, as well as other cultural experiences and events.** A great example of how VR technology can offer alternative ways of experiencing art and culture is **VIVE Arts**[139]. VIVE arts is a program that combines HTC's virtual reality software and expertise with artists and cultural institutions. By creating unique experiences, VIVE arts wants to enable and preserve cultural heritage for the world, and to democratize creation with digital innovation in the arts. In doing so, VIVE arts mission addresses a diverse, global audience and contributes to the knowledge and enjoyment of cultural heritage, both in museums and in the home.

In October 2019, **Paris' Louvre** together with VIVE Arts launched 'Mona Lisa: Beyond the Glass', a VR experience that explores the Renaissance painting as part of its Leonardo da Vinci blockbuster exhibition. Through interactive design, sound and animated images, users discover details about the painting, such as its wood panel texture and how the passage of time has changed the way it looks. Available in five languages, the experience can be enjoyed for four months by booking directly at the Louvre and is downloadable on VR app store VIVEPORT, iOS, and Android.

In the UK, London's **Tate Modern** has been embracing the VR trend too. Alongside their Modigliani retrospective in 2017/18, they created a fascinating VR exhibit. Visitors were able to experience complete immersion in a 3D model of the artist's Paris studio. The exhibit used the actual studio space as a template. The room itself still exists but is not as it was then. After painstaking research, the museum created a faithful recreation of the artist's final studio as it would have been 100 years ago.

Also, **The Virtual Dutch Men (NL)**[140] create fictional virtual museums and other art exhibitions gathering masterpieces from all over the world. The company has more than twenty years of 3D expertise and more than five years of virtual reality experience and has established collaborations with Samsung, HTC and Oculus. For instance, an example of their work was to offer more interesting and challenging experiences to the audience of the National Archive in The Hague, the depository of Cultural Heritage in the Netherlands. Also, they developed the Europe's first VR-museum, the EUseum, for the Europeana Foundation gathering heritage and art pieces from all over the world and which could be explored using a simple HMD.

In Spain, **Thyssen-Bornemisza Meseum (ES)** "Entrar en el Cuadro"[141] expostition led more than 15.000 people to enter inside various paintings visiting a three-dimensional space in first-person. Thanks to the immersion googles the audience was able to walk through Auver's Meadows painted by Van Gogh, visit the streets of New York that inspired Mondrian, or

[139] VIVE arts, US. https://arts.vive.com/us/
[140] The Virtual Dutch Men, NL. https://thevirtualdutchmen.com/
[141] Thyssen.Bornemisza National Museum, 2020. Entrar en el cuadro. Realidad virtual. Itinerancia de la actividad por España 2019 – 2020. Available from: https://www.museothyssen.org/apoyo/apoyo-empresarial/entrar-cuadro-realidad-virtual-itinerancia

immerse themselves in the flowers and insects of a Dutch still life. This unique sensory experience, was developed by **The Modern Cultural Productions (ES)**[142] in IED Innovation Lab.

Another Spanish example is **Carabanchel Creativa VR Experience (ES)**[143]. One of the most risky projects carried out by IED Madrid for the City of Madrid with the Collaboration of our Virtual Reality Laboratory for the visualization of urban interventions.It is a project of non-intervention, urban development and enhancement of the citizenship of specific areas of the Carabanchel neighborhood in Madrid. For the first time, virtual reality was used to visualize the interventions obtained in the neighborhood meetings and with the work of citizens, architects, urban planners and experts in the field such as the City Lab.

Other galleries such as **Serpentine Galleries (UK)**[144] and **Zabludowicz Collection (UK)**[145] are also active in the field of cultural immersive experiencies by offering exhibitions in which the audience can explore artists VR work. **Art Graphique & Patrimoine (FR)**[146] also specialises in digitalisation of artwork and creation of VR experiences for the Louvre, Musée d'Orsay, and other museums and landmarks (Notre-Dame, Mont-Saint-Michel, etc.) in France and abroad.

Software such as **VR-All-Art (CH)**[147] allows anyone to explore and create virtual reality exhibitions and a marketplace for artists, galleries, museums and the general public to exhibit, explore and acquire art in the virtual world.

[142] TheMo, ES. http://www.themodernculturalproduction.com/
[143] IED Madrid, ES. https://iedinnovationlab.com/project/acora-city
[144] Serpentine Galleries, UK. Serpentine Augmented Architecture. Available from: https://www.serpentinegalleries.org/whats-on/serpentine-augmented-architecture%20/
[145] Zubledowickz Collection, UK. 360: Virtual Reality Room. Available from: https://www.zabludowiczcollection.com/exhibitions/view/360-virtual-reality-room
[146] Art Graphique & Patrimoine, FR. Virtual Visits, Immersive and VR Systems. Available from: https://www.artgp.fr/-immersive-system-and-virtual-reality-.html?lang=en#art156
[147] VR-All-Art, Switzerland. https://vrallart.com/

4.3.2. Healthcare - The role of VR/AR in the future of care

The healthcare industry is facing an aging population, an increase of chronic diseases and a higher demand for cost-effective ways to provide qualitative care. In this context, technological innovations are accelerating disruption in the wellness and healthcare fields. Today's biggest trends in the healthcare industry are dominated by the concept of preventive and personalized care, with an increasing number of sector stakeholders aiming to deliver this through **smart and digital technologies** (such as AI, machine learning, VR, AR, advanced data processing, blockchain, etc.) and patient-centred solutions.

Digital health[148] is the convergence or intersection of digital technologies (information and communication technologies or ICT) with healthcare. It aims to improve the quality of life of patients through effective, sustainable and personalized healthcare delivery.

Technology applications provide us the ability to store, share and analyse health related information and improve quality of life of patients in ways that could not have been imagined a decade ago. Technology can play an important part in reducing costs, facilitating patient access to their health data and improving care in general. It makes healthcare more intelligent, scalable and fast. The role of these technologies has evolved tremendously over the last 20 years and will continue to disrupt healthcare in conjunction with our societal technological advancements.

Figure 57 | Understanding Digital Health: The Facets and Technologies

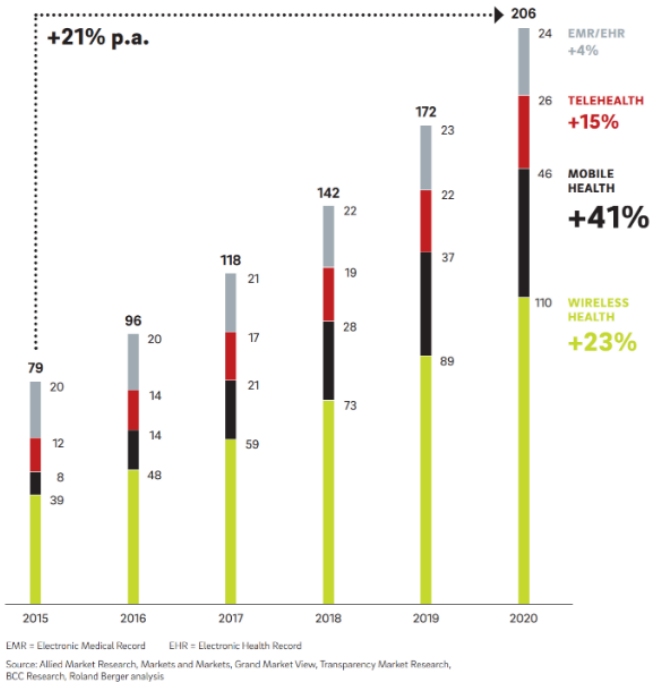
Source: Capgemini, 2018.

[148] There are many definitions of digital health: this definition reflects the general scope of the digital health sector.

In this scenario, the **Digital Health Market is expected to expand from $140 billion in 2018 to $380 billion in 2024[149],** according to the most recent analysis conducted by Dalal, K. et al. 2017 and as published on the world-renowned The Lancet journal. The study analysed the health spending in 184 countries providing the most detailed health expenditure analysis conducted until date.

The Digital Health market is already a mature and fructiferous market. According to Capgemini and Statista[150,151], as of 2020, the market has already reached the impressive $206 billion value threshold and has persistently been growing at a CAGR of +21% since 2015. By sectors, wireless health, which often also includes Mobile Health, with a value of $110 billion and $41 billion respectively. Telehealth and Electronic Health Record (EHR) complete the list with $26 and $24 billion market value respectively.

Figure 58 | Global Digital Market Size 2015-2020.



In more Detail:

› mHealth

Despite to date no standardized definition of mHealth has been established, the Global Observatory for eHealth (GOe)[1] – a subdivision of the World Health Organization (WHO) - defines mHealth as medical and public health practice supported by mobile devices, such as mobile phones, patients monitoring devices, personal digital assistant and other wireless devices.

› Telehealth

As defined by WHO is the delivery of health care services, where patients and providers are separated by distance. Telehealth uses ICT for the exchange of information for the diagnosis and treatment of diseases and injuries, research and evaluation, and for the continuing education of health professionals. Telehealth can contribute to achieving universal health coverage by improving access for patients to quality, cost-effective, health services wherever they may be. It is particularly valuable for those in remote areas, vulnerable groups and ageing populations.

Digital health has experienced strong investment trends with the potential for immense financial gains in the coming future. Its financial growth has been just as remarkable as the technological advancements that drive it. This growth is driven by both established firms and start-ups with the latter raising more than $8.1 billion in funding in 2018 alone and more than half of all deals were made for seed and series A rounds.[152] If these trends continue, digital health will have more than quintupled in size by 2025, with even more diverse offerings for consumers and providers.

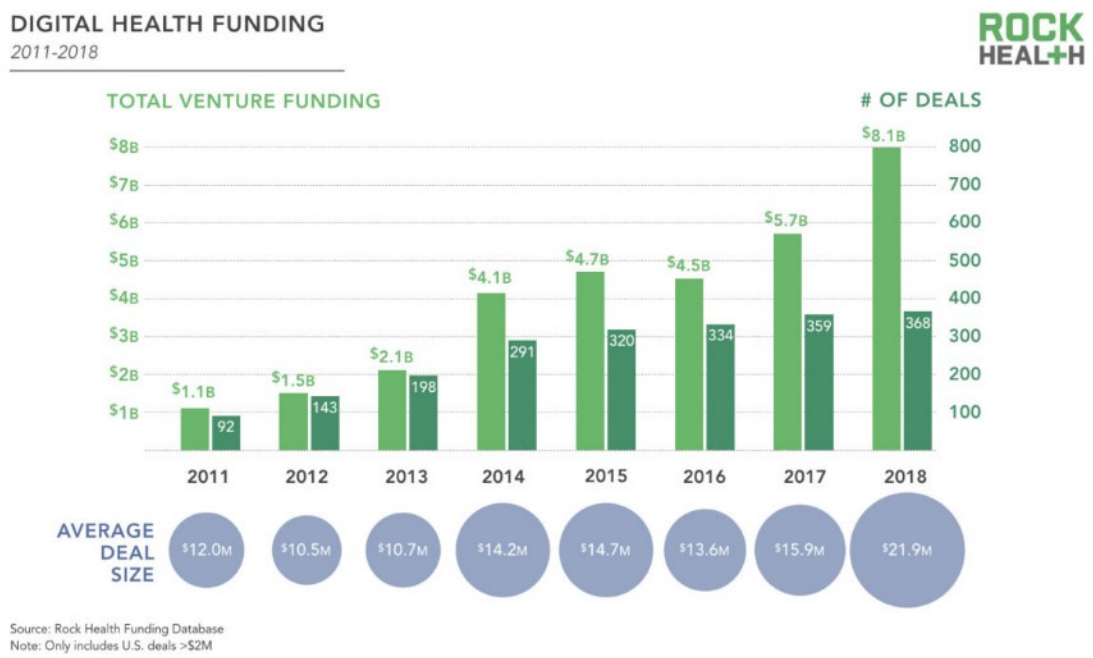
[149] Dalal, K. (2017). Future and potential spending on health 2015-40: development assistance for health, and government, prepaid private, and out-of-pocket health spending in 184 countries. The Lancet.

[150] Capgemini; MarketsandMarkets; Expert(s) (R. Sankrityayan). Global digital health market size between 2015 and 2025, by major segment. As published in Statista, 2018. Available from: https://www.statista.com/statistics/387867/value-of-worldwide-digital-health-market-forecast-by-segment/

[151] Capgemini, 2018. Digital Health – Transforming Healthcare. Available from: https://www.capgemini.com/be-en/wp-content/uploads/sites/17/2018/10/Digital-health-final-paper-22.10.pdf

[152] Rock Health, 2019. 2018 Year End Funding Report: Is digital health in a bubble? Available from: https://rockhealth.com/reports/2018-year-end-funding-report-is-digital-health-in-a-bubble/#:~:text=Across%202018%2C%20investors%20poured%20nearly,shot%20up%20to%20%2421.9M.

Figure 59 | Digital Health Funding 2011-2018.



There is no doubt Digital technologies are transforming healthcare. From clinical research to clinical practice, there has been an explosion of new technologies revealing endless possibilities. This is also the case for immersive technologies. Virtual Reality and Augmented Reality present themselves as interesting tools for the digital health industry[153,154].

As with many prior technology waves, AR and VR technology got an early boost from entertainment uses and are graduating to new roles, also in the digital health. In healthcare, AR appears to be more directly applicable to providing clinical utility at the point of care, because by definition it maintains the ability to keep the real-world patient in view at all times. VR can be leveraged in training medical students and residents on procedures for a more truly immersive experience before engaging with real patients.

Developers are beginning to hear and answer the call for applications designed specifically for clinical, research, educational, and business uses across the industry. The evolution from niche technology to commonplace widespread tool; and from pilot/demo to uses that stakeholders in health care rely on every day, is leading to a day when VR and AR will be more widely used.

Each new study and application points to the possibility of wider adoption of these immersive technologies, but a lot of consideration first needs to go into the context and the clinical setting for VR-AR, followed by clinical test cases, in order for that to occur. And getting this right requires extensive collaboration between a host of stakeholders: clinicians, data scientists, interaction designers, and other experts, and obviously a deep understanding of clinical care.

[153] CES, 2020. Digital Health Trend for CES 2020. Available from: https://cdn2.hubspot.net/hubfs/636866/EN-CES2020%20Digital%20Health%20Trends/Digital-Health-Trends-for-CES-2020-by-Digimind.pdf

[154] Deloitte, 2018. Digital Reality in Life Sciences and Healthcare. Tech Trend 2018 | A Life Sciences and Health Care Perspective. Available from: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/life-sciences-health-care/us-lshc-tech-trends-digital-reality.pdf

Among healthcare providers, the use of VR/AR is currently focused in a number of discrete areas. For **patient**, these technologies can speed **education about conditions or treatment plans**. The technology can also be used as therapies themselves when used in visualization and relaxation exercises for certain conditions. Applications in opioid addiction therapy, phantom limb treatment, phobia therapies, cancer therapy planning, peri-operative planning, posttraumatic stress disorder, palliative care and general pain management are some established examples.

In the **clinical setting**, AR and VR can **help physicians and care teams at the point of care**. For example, surgeons can use a heads-up display to provide a data overlay on the patient's body during surgery, or to visualize the entire procedure during pre-surgical planning. This heads-up display allows the user to see both real and projected objects or data at the same time. Combined with medical imaging, AR is beginning to provide clinicians with the ability to project medical images, such as CT scans, directly onto the patient and in alignment with the patient's body.

What is more, **VR/AR is also intersecting with the parallel trend in telehealth and home-based care.** Rather than a 2D video visit for a patient, the technology can help create a 3D environment resulting in an improved patient engagement, a better view of the patient's condition and an improved overall experience for patient and caregiver.

This technology can even enhance the quality and thoroughness of a routine check-up or add detail and immediacy to the way people communicate about more acute needs. XR tools can also enhance the collection of everyday data such as fitness activities, vital signs monitoring, treatment adherence, and unsafe events – especially as AR and VR devices evolve from plug-ins to standalones that can access the Internet without being tethered to a PC. In fact, in the light of the current COVID-19 pandemic the uptake of VR/AR in the healthcare is clearly poised to continue, if not accelerate.

In addition, many treatment plans include exercise or therapy programs that a patient carries out under the guidance of a medical professional. Through the use of VR tools, many of these **therapies could become at-home sessions** instead of requiring trips to a remote clinic or other care facility. In some cases, live connections may bring care providers into direct contact with patients while they undergo the therapy.

Therefore, VR can provide life sciences companies new opportunities in patient services and support, especially in the management of rare diseases or chronic conditions, the so call **remote patient-monitoring market**. By using these technologies, life sciences companies can empower patients, their families, and their caregivers with educational materials to help them manage their disease states which would translate to increased life quality to patients and reduced healthcare expenditure.

What is more, when combined with artificial intelligence and natural language processing, AR and VR technology may also be able to contribute to clinical trial data collection by enhancing the ability to monitor patients remotely.

Companies are also assessing how these technologies can support Standard Operating Procedures or Good Manufacturing Practices (SOPs or GMPs). Life sciences organizations have hundreds, and in some cases, thousands of SOPs.

AR and VR can help enhance training and drive compliance. On the manufacturing side, companies are investigating how to use AR and VR to improve line efficiencies and decrease down time associated with maintenance and training

Health insurers have made large investments in the shift from cure to prevention, and wellness and preventive health features of health plans are already in widespread adoption. In encouraging people to live well and stay healthy, part of the challenge is to help them visualize how small changes can add up to large differences – how a healthier diet and regular exercise can benefit them in the long run.

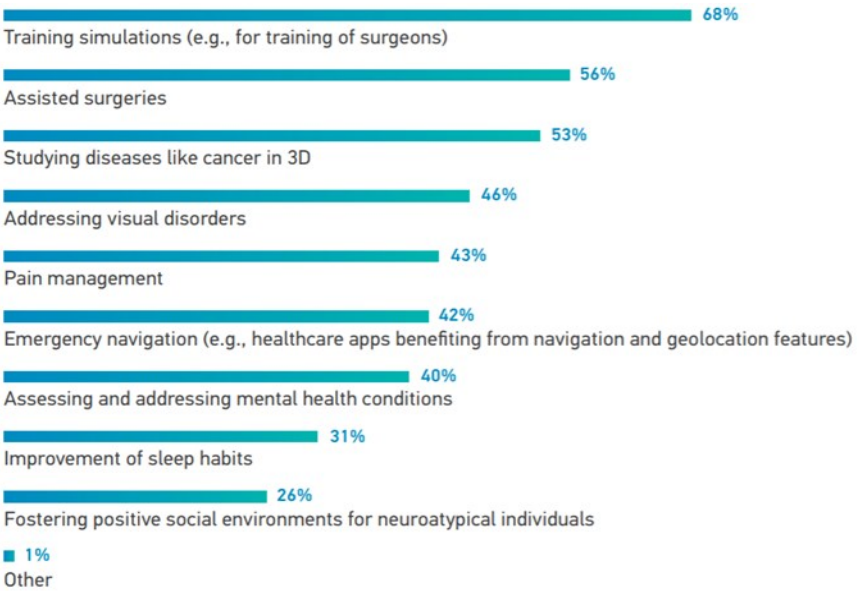
Also, **gamification in healthcare is gaining momentum,** with attempts to apply gaming principles to improve patient clinical outcomes. Introducing fun and games to healthcare apps can motivate patients and collect essential data. After all, it helps to make informed decisions on daily activities that contribute to one's health. AR and VR have significant potential in these areas as well.

There are far more instances of virtual and augmented reality to be explored. Their application in digital healthcare will be disruptive, allowing healthcare professionals to provide more effective and risk-free care and empower patients in the new era of personalised and home-based medicine.

However, those applications more likely to be offered to patients in the short-term (next wo years) are training simulations (e.g., for training surgeons or other healthcare professionals), assisted surgeries, 3D representation and study of diseases at the molecular level, treating visual disorders and pain management procedures, according to the latest VR Industry Survey conducted by Perkins Coie.[155]

Notably, the top three VR uses in the medical field do not involve diagnostics or treatment procedures, given the fact that these applications would need to fulfil minimum clinical outcomes and undergo thorough clinical trials, as is the case of addressing visual or mental disorders or pain management.

Figure 60 | In the healthcare sector, which of the following new applications/solutions?

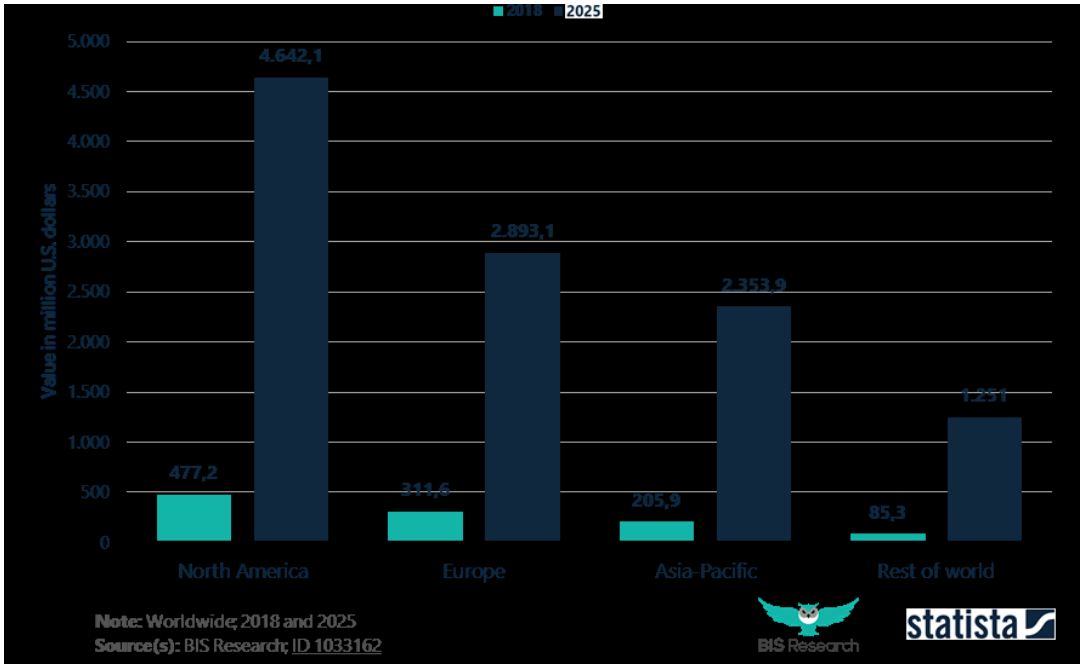


[155] [155] Perkins Coie LLP., 2019. 2019 Augmented Reality and Virtual Reality Survey Report. March 2019. Available from: https://www.perkinscoie.com/images/content/2/1/v4/218679/2019-VR-AR-Survey-Digital-v1.pdf

Such potential of VR and AR technologies applied to Digital Health is also reflected on the current market value and expected forecasts. According to estimates firm BIS Research[156,157] the **global AR/VR market in the healthcare industry is expected to grow to nearly $11.1 billion by 2025**, at a **CAGR of more than 36% for the 2018-2025 period**.

Such impressive projections are partly driven by an increasingly large array of immersive technology applications that are being recognized, including physician training, patients' treatments and hospital management.

Figure 61 | Global healthcare AR and VR market in 2018 and 2025, by region (in million U.S. dollars)



By region, North America concentrates the biggest market share, valued at $477.2 million in 2018 and is expected to reach the $4.64 billion by 2025, representing a 57.62% CAGR growth for the period. Second in place is Europe with an estimated market size of $311.6 million in 2018 and a forecasted value of $2.89 billion by 2025, an equally impressive 56.15% CAGR for the period. Next, Asia-Pacific region is third with a market size of 205.9 million as of 2018 and an expected value of 2.35 billion by 2025, registering the highest across all regions of 62.79% for the 5-year period. Last, the rest of the world market value was of 85.3 million in 2018 and is expected to register a CAGR of % for the 2018-2025 period, until reaching the $1.25 billion market size in 2025, according to BIS Research.

Such figures are further corroborated by Verified Market Research[158], who expects the **Virtual Reality healthcare market to reach the $33.27 billion by 2027, growing at a CAGR of 41.2% from 2020 to 2027** boosted by the **increased uptake of digitalisation among societies in part due to the COVID-19 pandemic collateral effects.**

[156] BIS Research, 2019. Global Augmented Reality and Virtual Reality Market in Healthcare; Focus on Component Type (Hardware, Software and Services) and Application Areas (Surgical Training, Rehabilitation, and Pain Management). Available from: https://bisresearch.com/industry-report/augmented-reality-virtual-reality-healthcare.html?utm_source=Statista

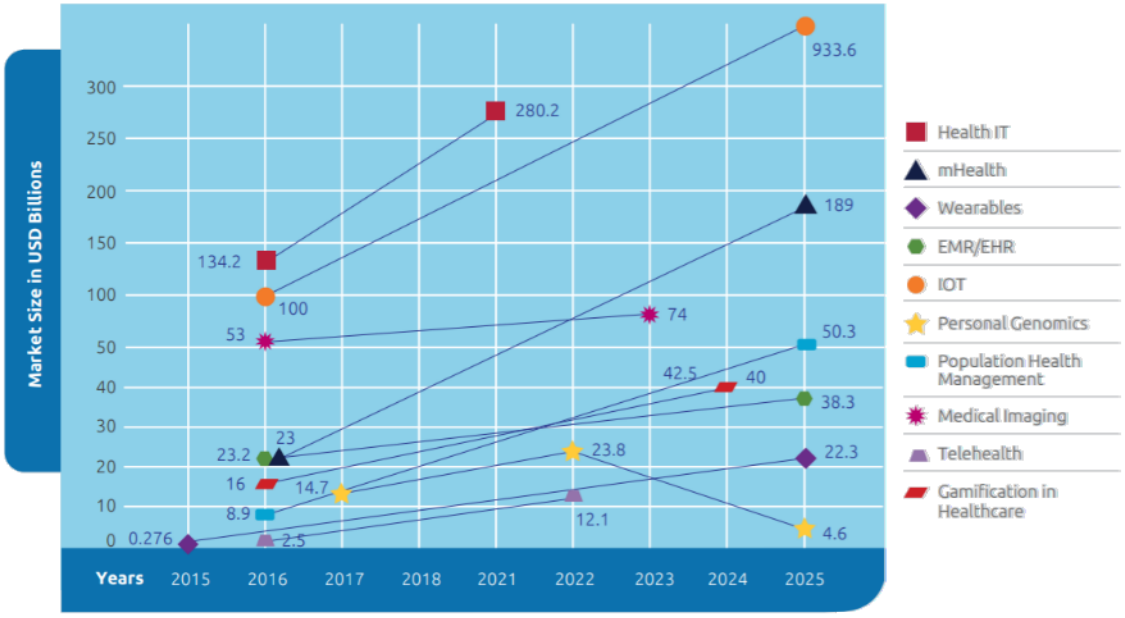
[157] Statista, 2020. Global healthcare AR and VR market forecast in 2018 and 2025, by region. Published by Matej Mikulic, Oct 22, 2020. Available from: https://www.statista.com/statistics/1033162/healthcare-ar-and-vr-market-forecast-worldwide-by-region/

[158] Verified Market Research, 2020. Virtual Reality in Healthcare Market by Component, by Application, by geography Scope and Forecast. Jul 2020. Available from: https://www.verifiedmarketresearch.com/product/virtual-reality-in-healthcare-market/

The occurrence of pain management due to chronic pain after surgery and delay in recovery is a substantial factor for the rise in market growth. Also, the rise in investments of organizations by Research and Development in VR in Healthcare is a significant aspect, which will reduce the healthcare cost and will drive market.

The role that digital health can play has come under the spotlight during the COVID-19 pandemic. Recent global events related to the containment and treatment of the novel coronavirus are a testament to just how valuable these technologies can be and how they are being used on the ground today.

Figure 62 | Evaluation of the Healthcare Market by technological category and application.



Source: Capgemini, 2018.

Key Challenges and Risks to Adoption of VR/AR in Digital Health[159,160]

The continuing refinement of the technology that powers Digital Health, such as VR and AR is clearly poised to continue, if not accelerate. As with many new disruptive technologies, the development and deployment need to overcome multiple challenges and risk before widespread adoption can occur.

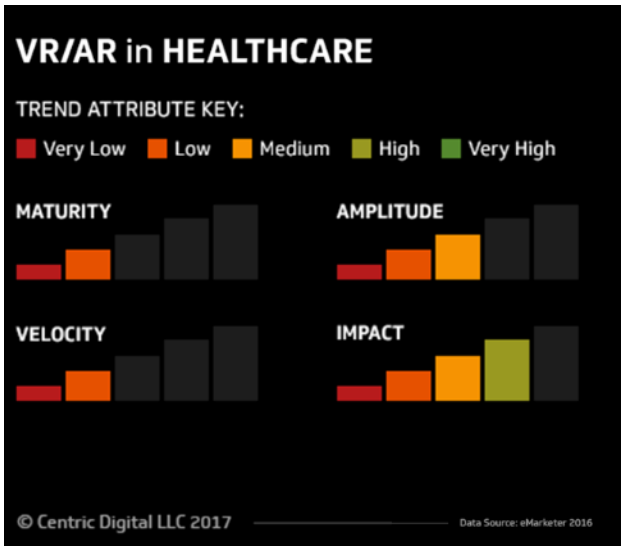
This is especially true for healthcare and wellness applications given their unique nature and the strict compliance and regulatory requirements, to ensure not only efficacy but also patient security and safety, especially as uses move from small-scale and pilot stages to more widespread adoption.

[159] Baniasadi T, Ayyoubzadeh SM, Mohammadzadeh N. Challenges and Practical Considerations in Applying Virtual Reality in Medical Education and Treatment. *Oman Med J*. 2020;35(3):e125. Published 2020 May 18. doi:10.5001/omj.2020.43

[160] Katin, P. and Lane, H., 2017. Key Challenges to Adoption of VR/AR for Healthcare. The VR/AR Association, 2017. Available from: https://www.thevrara.com/blog2/2017/6/10/key-challenges-to-adoption-of-vrar-for-healthcare

VR in healthcare is still on its early life. According to eMarketer and Centric Digital[161], the maturity of the VR technology in healthcare is still low. In terms of amplitude and market impact the trend is different suggesting that this may become one the most interesting markets in the field. However, the development and adoption velocity are low, in part due to the inherent challenges and risks of any solution within the healthcare industry.

Figure 63 | VR/AR in Healthcare - Maturity Status



In this bold new world, both VR companies and health institutions are still learning how to provide effective user interfaces that blend voice, body and object positioning to improve patient diagnosis, treatment and, ultimately, quality of life. While the cost and complexity of devices to create the experience and the supporting technology are dropping, there are still hurdles to overcome[162]:

› CYBERSECURITY, DATA INTEGRITY AND DATA PROTECTION

Currently, the healthcare and life science industries, like any other sector, are facing the threat of cybercrime. With Digital Health and VR changing how people interact with data, the environment, and with each other, the cyber-risk implications of technology systems become even more complex, being especially true in this field in which **sensible private medical data needs to be shared securely**.

In this context, technology developers will have to deal with a higher demand of securing and managing sensible patient data. n such a scenario, the key stakeholders are shifting their focus towards secure, cloud-based platforms. Such platforms will not only help to maintain confidentiality, but also will support compliance with HIPAA and CAPA regulations and improve overall efficiency. The regulators are already working on this important challenge, to ensure the safety of both the patients and their data by imposing rigorous standards on medical developers.

The **EU has the eHealth action plan[163]**, aligned with the **Europe 2020** strategy to outline the vision and actions to implement digital health projects. Targeted initiatives like **General Data Protection Regulation (GDPR)** are being launched to keep in step with the digital technologies. GDPR is an initiative from the EU that provides EU citizens protection and security of their personal data that can be exported outside the EU or between the EU member states.

Similarly, the US **Food and Drug Administration (FDA)** has recently introduced the **21st Century Cures Act[164]** that will be used to regulate medical software in addition to the traditional regulations like HIPAA and CAPA.

[161] Centric Digitial, 2017. Could Virtual Reality Minimize the Costs of Healthcare? April 25, 2017. By Centric Digitial. Available from: https://centricdigital.com/blog/virtual-reality/could-virtual-reality-minimize-the-costs-of-healthcare/

[162] Baniasadi, Tayebeh et al. "Challenges and Practical Considerations in Applying Virtual Reality in Medical Education and Treatment." Oman medical journal vol. 35,3 e125. 18 May. 2020, doi:10.5001/omj.2020.43

[163] European Commission, 2020. eHealth Action Plan 2012-2020: Innovative healthcare for the 21st century. 7 December 2021. Available from: https://ec.europa.eu/digital-single-market/en/news/ehealth-action-plan-2012-2020-innovative-healthcare-21st-century

[164] U.S. Food & Drug Administration, 2020. 2st Century Cures Act. Content Current as of 01/31/2020. Available from: https://www.fda.gov/regulatory-information/selected-amendments-fdc-act/21st-century-cures-act

› VALIDATION OF VR APPLICATIONS

Evidence showed that VR can be considered a useful tool for medical education, diagnosis, and treatment. However, this technique is still at an early stage, and it is necessary to perform controlled trials before it can be used routinely. Collaboration between clinical and IT experts is necessary to design VR-based training packages. This collaboration may lead to the extraction of requirements such as information structures, technical and technological components, and suitable standards. The mere assertion that programs are efficient by companies cannot be accepted and must have empirical support.

› SAFETY CONSIDERATIONS

Like any other type of treatment, VR should only be used when it is prescribed by the appropriate clinical expert. Using services such as VR rehabilitation or any type of emerging technology such as telepsychology and online therapy, according to the patients' opinion (self-diagnosis, self-help, and self-treatment) can place patients at potential risks.

In addition, VR can cause problems in the cognitive organizations, human experiences, memories, judgments, beliefs, and distinguishing between themselves and the environment. Having multiple virtual experiences over the years can make real judgment and self-identity difficult. Therefore, managing the health and safety implications of VR are important things to be considered.

Examples of VR in Healthcare

OxfordVR (UK)[165] is startup that is revolutionising therapy using virtual reality, building psychological treatments using state-of-the-art immersive technology. The startup's focus is on developing VR-based, clinically validated, and cost-effective cognitive treatments for clinical conditions that will have a significant impact on patients, the health system and wider economy. Using VR and a cognitive-behavioral therapy approach, patients can go into the situations they find difficult and practise more helpful ways of thinking and behaving – something impossible to do in face-to-face therapy. The treatments are automated and delivered by a virtual coach, with simulations adapted to each condition. Founded in 2016, Oxford VR raised £3.2 million in September 2018.

Founded in 2016, **HypnoVR (FR)**[166] just began marketing its medical hypnosis virtual reality solution to improve the management of patient pain, stress and anxiety. Using virtual reality headsets like Oculus Rift or Samsung Gear, HypnoVR's solution places the patient into an intense multisensory three-dimensional immersion experience. The technology is currently being used in applications for paediatric surgery, gastroenterology, gynaecology and dental surgery. The startup, based in Strasbourg, has raised €700k to date.

Within the wellness field, **Icaros (DE)**[167] takes virtual reality to the gym. The Icaros VR system recreates typical action environments like racing and interacts with standard off-the-shelf VR headsets and smartphones for basic control. The fitness component is a full-body workout machine uniquely designed to rotate on three axes, shifting the user's body weight to different muscle groups while synchronizing the user's physical movement VR simulations like flying and diving. The base price for a home model is €2,000, with pro models available for installation in

[165] Oxford VR, UK. https://ovrhealth.com/
[166] HypnoVR, FR. https://hypnovr.io/
[167] Icaros, DE. https://www.icaros.com/

gyms. Whether in the gym or online, Icaros also offers multi-user VR experiences and games. Based in Martinsried, Germany, and founded in 2015, the startup has raised $3.5 million to date.

4.3.3. Engineering & Manufacturing Industry

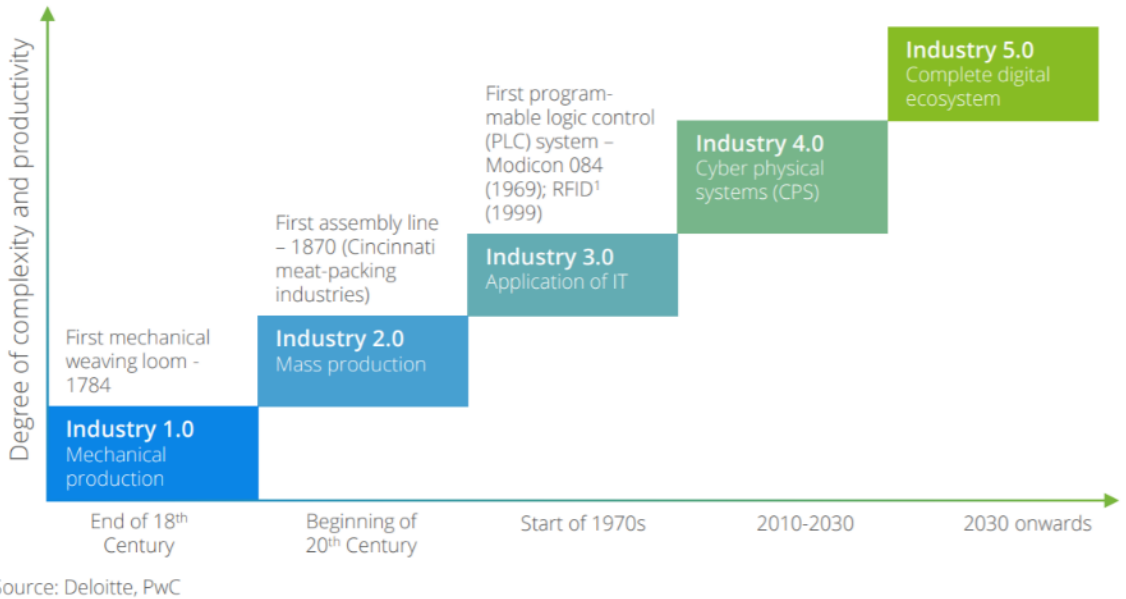
Industry 4.0 or the fourth industrial revolution is quite simply the use of digital technologies in the manufacturing process to produce higher-quality goods at reduced costs[168,169]. Even though developments in electronics and information technology have resulted in the automation of manufacturing processes since the early 1970s, it is only the recent advances in digital technologies that are beginning to extend the scope of disruption.

Companies are now experiencing major benefits in terms of lower costs, improved efficiencies, increased yield, mass customization, and most importantly new revenue and business models. Digital technologies are disrupting all elements of the value chain including product design, supply chain, manufacturing, and customer experience, while creating new business models.

The last decade has witnessed rapid advancements in technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, mobile, cloud computing, big data analytics, additive manufacturing (3D printing), and **virtual and augmented reality**. These technologies, woven together by the massive proliferation of big data generated mostly by connected devices (IoT), are blurring the lines between the physical, digital, and biological aspects of global production systems.

Companies are now experiencing major benefits in terms of **lower costs, improved efficiencies, increased yield, mass customization, and most importantly new revenue and business models.** For example, in addition to physical objects, companies are now selling data and services, while technologies such as IoT have added connectivity to industrial processes.

Figure 64 | Industrial evolution timeline: from industry 1.0 to industry 4.0 and beyond.



Source: Deloitte, PwC

[168] PwC, 2014. Industry 4.0 – Opportunities and Challenges of the Industrial Internet. Available from: https://www.pwc.nl/en/assets/documents/pwc-industrie-4-0.pdf

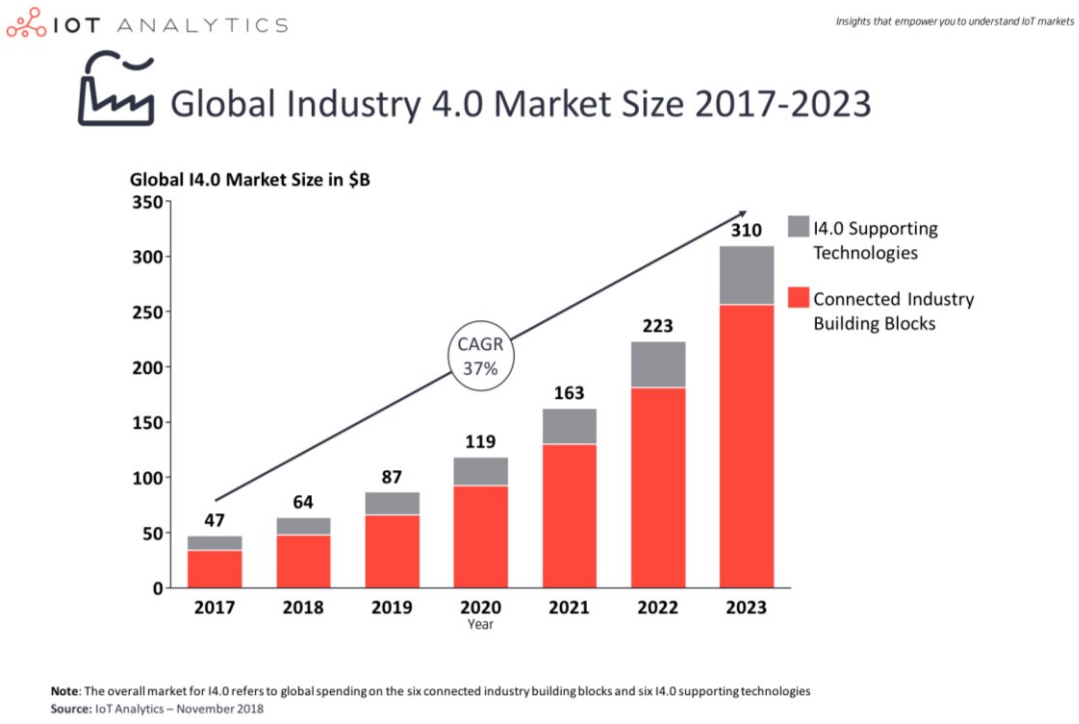
[169] Deloitte, 2014. Industry 4.0 – Challenges and solutions for the digital transformation and use of exponential technologies. Available from: https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf

Even though the digitization of the manufacturing process involves various technologies such as artificial intelligence, robotics, IoT, Virtual Reality and others. With each one of them contributing substantially, it is only their coming together that can create new capabilities never witnessed before. More importantly, the application of these technologies is not limited only to manufacturing or the supply chain but extends to business operations and ultimately revenue growth.

In terms of market size, the global industry 4.0 is predicted to grow from the $**47 billion in 2017 to more than $310 billion by 2023**, at a sustained **CAGR of 37%** over the 2017-2023 period, according to IoT Analytics[170].

The connected industry building blocks – namely hardware, connectivity, cloud platform & analytics, applications, cybersecurity and system integration – will account for over 80% of the market. However, there is an upward trend for **Industry 4.0 supporting technologies** to capitalise a bigger proportion of the Industry 4-0 Market, of which **3D Printing and VR/AR** stand-out.

Figure 65 | Global Industry 4.0 Market Size 2017-2023 (in billion U.S. Dollars)



In this context, the Washington D.C.-based Portulans Institute evaluates evert three years the technology competitiveness and innovation readiness related to Industry 4.0 by country[171].

[170] IOT Analytics, 2018. Industry 4.0 & Smart Manufacturing 2018-2023. November 2018. Available from: https://iot-analytics.com/product/industry-4-0-smart-manufacturing-market-report-2018-2023/

[171] Portulans Institute, 2019. The Newtork Readiness Index 2019: Towards a Future-Ready Society. Portulans Institute (2019): Network Readiness Index 2019, Washington D.C., USA. Available from: https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf

Serving that purpose, the non-profit firm has developed the Network Readiness Index based on different criteria analysis of four pillars: technology, people, governance and impact.

The Network Readiness Index (NRI) 2019 ranks a total of 121 economies. The top performer in 2019 index is Sweden, which is just ahead of Singapore in 2nd place and the Netherlands in 3rd. there is not much separating the leading countries in the NRI, as reflected in their overall scores. For instance, the top 5 countries (which also include Norway, 4th, and Switzerland, 5th) are all within a couple of points of each other. Similarly, the other countries that make up the top 10—Denmark, Finland, the United States, Germany, and the United Kingdom—are less than 5 points away from Sweden's top score.

Figure 66 | Network Readiness Index of Leading Countries for Industry 4.0 in 2019

Rank	Country/Economy	Score	Income group	Region
1	Sweden	82.65	High income	Europe
2	Singapore	82.13	High income	Asia & Pacific
3	Netherlands	81.78	High income	Europe
4	Norway	81.30	High income	Europe
5	Switzerland	81.08	High income	Europe
6	Denmark	81.08	High income	Europe
7	Finland	80.34	High income	Europe
8	United States	80.32	High income	The Americas
9	Germany	78.23	High income	Europe
10	United Kingdom	77.73	High income	Europe
11	Luxembourg	77.46	High income	Europe
12	Japan	76.17	High income	Asia & Pacific
13	Australia	74.80	High income	Asia & Pacific
14	Canada	74.72	High income	The Americas
15	Austria	74.36	High income	Europe
16	New Zealand	73.97	High income	Asia & Pacific
17	Korea (Republic of)	73.84	High income	Asia & Pacific
18	France	73.42	High income	Europe
19	Ireland	73.29	High income	Europe
20	Belgium	72.62	High income	Europe
21	Iceland	71.94	High income	Europe
22	Israel	70.86	High income	Europe
23	Estonia	69.30	High income	Europe
24	Hong Kong (China)	68.14	High income	Asia & Pacific
25	Spain	68.01	High income	Europe
26	Malta	66.94	High income	Europe
27	Slovenia	66.89	High income	Europe
28	Portugal	65.56	High income	Europe
29	United Arab Emirates	65.45	High income	Arab States
30	Czech Republic	65.09	High income	Europe
31	Lithuania	64.13	High income	Europe
32	Malaysia	63.76	Upper-middle income	Asia & Pacific
33	Qatar	63.73	High income	Arab States
34	Italy	63.21	High income	Europe
35	Slovakia	61.95	High income	Europe
36	Cyprus	61.57	High income	Europe
37	Poland	61.46	High income	Europe
38	Hungary	59.95	High income	Europe
39	Latvia	59.31	High income	Europe
40	Bahrain	58.73	High income	Arab States
41	China	57.63	Upper-middle income	Asia & Pacific
42	Chile	57.38	High income	The Americas
43	Greece	57.07	High income	Europe
44	Croatia	56.75	High income	Europe
45	Saudi Arabia	56.49	High income	Arab States
46	Uruguay	56.04	High income	The Americas
47	Romania	55.47	Upper-middle income	Europe
48	Russian Federation	54.98	Upper-middle income	CIS
49	Bulgaria	54.77	Upper-middle income	Europe
50	Costa Rica	54.59	Upper-middle income	The Americas
51	Turkey	53.75	Upper-middle income	Europe
52	Serbia	53.65	Upper-middle income	Europe
53	Mauritius	53.40	Upper-middle income	Africa
54	Kuwait	53.39	High income	Arab States
55	Oman	52.87	High income	Arab States
56	Thailand	51.54	Upper-middle income	Asia & Pacific
57	Mexico	51.44	Upper-middle income	The Americas
58	Argentina	51.27	Upper-middle income	The Americas
59	Brazil	51.07	Upper-middle income	The Americas
60	Kazakhstan	50.68	Upper-middle income	CIS
61	Belarus	50.34	Upper-middle income	CIS
62	Armenia	49.84	Upper-middle income	CIS
63	Viet Nam	49.57	Lower-middle income	Asia & Pacific
64	Trinidad and Tobago	49.29	High income	The Americas

Source: Portulans Institute, 2019.

PORTULANS INSTITUTE

Caused by the current highly competitive business and manufacturing environment, the **manufacturing industry is embracing this technology with the aim of implementing integrated VR systems that could enhance manufacturing processes**, as well as **product and process development**, leading to **shorter lead-time, reduced cost, increased flexibility and improved quality and safety.**

But how are manufacturers and engineers using VR? In every possible way, given the huge possibilities of the technology in the field:

- Assembly

  The modern manufacturing process involves the precise assembly of hundreds or even thousands of components in the shortest possible time, depending on the complexity of the product. Traditionally, the work instructions for this process have been delivered in the form of PDFs that can be difficult to work through. AR/VR makes these instructions available in an easy-to-use format which is often hands-free and voice controlled.

- Supply Chain Management

  Before the advent of AR/VR, workers juggled through inventory by picking the correct item using RFID or barcode scanners, a process that was cumbersome and time-consuming. Technologies such as smart glasses not only help the employees keep the picking lists in their view at all times, but also show them the best route through the warehouse. This helps in reducing errors, decreasing the time spent on the job and a reduction in on-the-job training.

  Additionally, it is nowadays being used for **factory planning** – where to place machines, tools and operators-, to design production flows or to analyse workers and robots performing tasks, which are crucial factors for productivity. As engineering changes in existing manufacturing plants or a new one need testing and trials, VR becomes very useful because enables instant alterations without increasing the cost.

- Maintenance, Quality Control and Inspection

  The visualisation of 3D models, CADs and other content in VR applications give the possibility for different **people to access them from any location**, to analyse and interact with them in a virtual environment. This can improve the manufacturing process, firstly during the conception phase for the design and development of components or the final product, and secondly for the creation of **prototypes, quality control and inspection** once the final product has been developed. Both applications are radically reducing meeting costs and possible errors, as distant communication can be just as efficient as meetings in person.

- Training

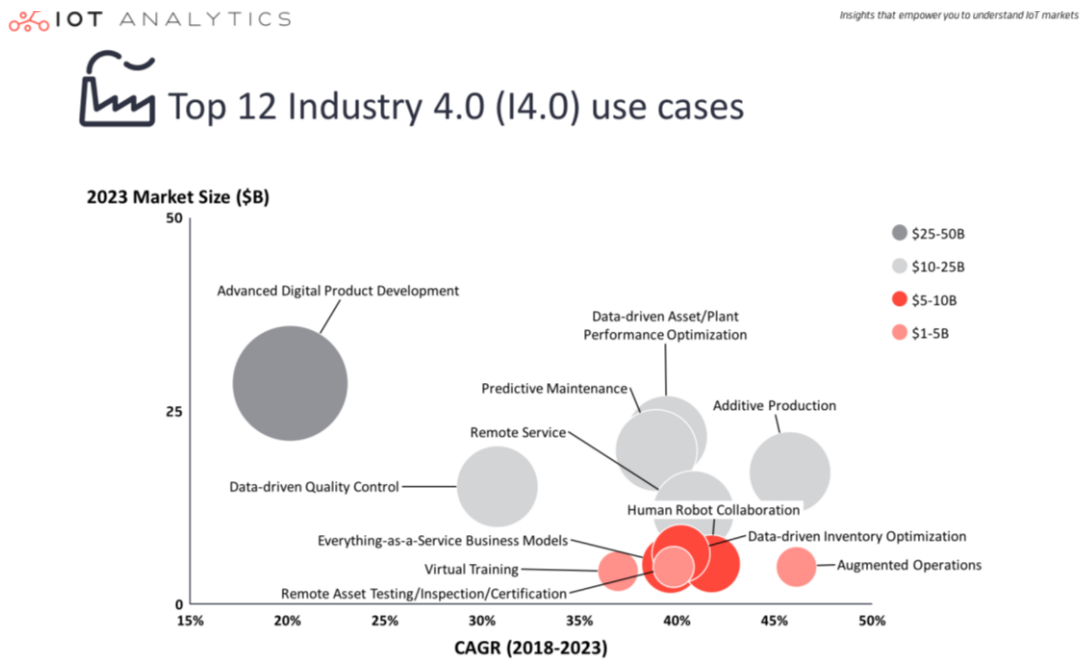
  With global industries currently facing a labour shortage especially in semi-skilled positions, AR/VR technologies have the potential to alleviate some of these concerns. They can enable newly hired employees to receive more tailored and relevant training while on the job in the form of training prompts.

- Design

  In the area of **product design**, VR can change the way in which engineers develop products, by enabling companies to digitalize the product-design process in order to accelerate design workflow, generate ideas, embodying concepts, enhance quality and producing the information necessary for cost-effective manufacturing. Virtual prototyping technique has been studied and implemented in recent years in engineering design. In mechanical engineering, VR prototyping is going to replace physical mock-ups, as it is less expensive and more flexible.

  In addition, VR prototypes help improve the understanding of the final product between colleagues from different disciplines, enables clients to have more realistic expectations and investigate alternative options (different colours, sizes or material).

Figure 67 | Top 12 Industry 4.0 Use Cases



In terms of market size and growth, IoT Analytics expects Virtual Reality in Manufacturing and Engineering Industry to reach the $**10-15 billion by 2023**, when aggregating the estimated market size of each use-case where VR can apply to. Interestingly, those use case to experience the biggest growth are Augmented Operations with up to a 45% CAGR for the 18-23 period and Virtual Training with up to A 37% CAGR for the same period, emphasizing the huge potential of the technology within the field in the short -term.

Similarly, Absolut Reports[172], estimated that VR in manufacturing industry market size was valued at **$924.7 million in 2019, and will reach the $14.8 billion by 2026, with a CAGR of 39.2%,** consistent with the previously mentioned estimations.

[172] Absolute Reports, 2019. Virtual Reality in Manufacturing Industry Market Size, Share, Growth | Global Industry Research Report, 2019-2026. Available from: https://www.absolutereports.com/enquiry/request-sample/15633454

In terms of technology adoption in the field, according to PwC[173], more than one-third of manufacturers we surveyed either already use VR technology or plan to do so in the next three years, with adoption plans for AR technology roughly the same. Meanwhile, another one-third of manufacturers have no plans in place to adopt the technologies.

In fact, according to a PwC and Zpryme survey and analysis, the most popular application of AR and AR was product design and development (38%), followed by safety and manufacturing skills training (28%), maintenance, repair or equipment operations (19%) and remote collaboration (19%).

Take a look at the future, Perkins Coie's survey respondents claim that the offering real-time remote assistance, instructions and feedback to employees will become the most prevalent application of immersive technologies within manufacturing and engineering in the next two years, with 75% of responses. Second, the horizontal training with up to 48% of the responses and third reduction of assembly errors (quality control) with 45% of the responses; the same percentage as improvement of supply chain management in fourth place.

Figure 69 | Most popular VR/AR Applications among Manufacturers

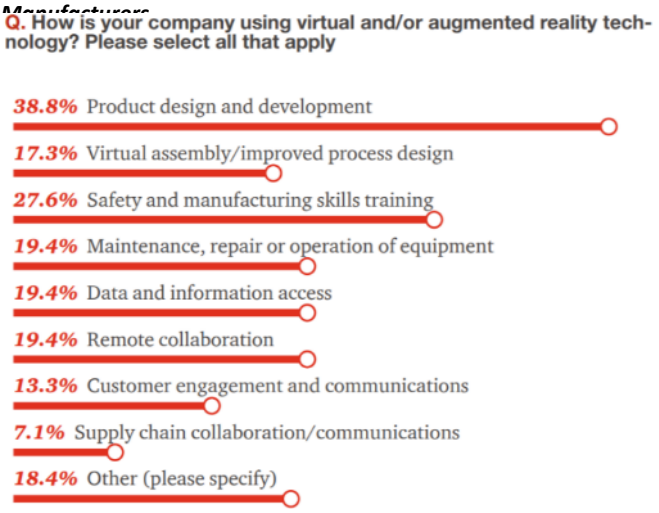
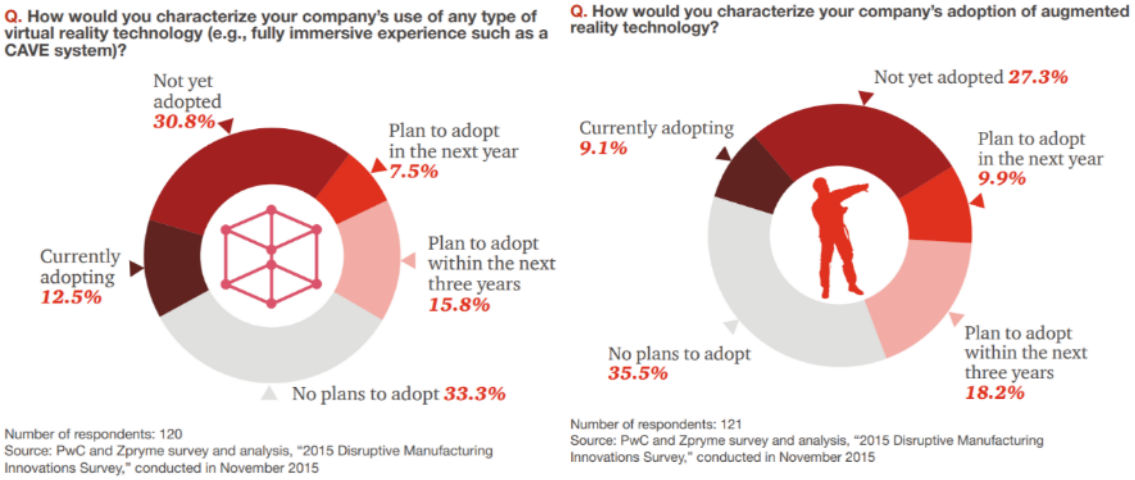


Figure 70 |n the manufacturing sector, which of the following new applications/solutiins can we expect immersive technologies to offer in the next two years?

Figure 68 | VR & AR Adoption in Manufacturing and Engineering.



[173] PwC, 2016. How Virtual Reality and augmented reality technologies are reimagining America's factory floors.. Available from: https://www.pwc.com/us/en/industrial-products/publications/assets/augmented-virtual-reality-next-manufacturing-pwc.pdf

Examples of VR in Manufacturing and Engineering

VR applications can be used for industrial purposes to improve product development processes, train staff and enhance communication. Driven by the needs of major European industries, VR applications are either developed in-house or are outsourced to VR/AR dedicated companies. Early adopting companies that already use VR solutions come from: the automotive industry (**Groupe PSA (FR), Renault (FR), Jaguar Land Rover (UK), BMW (DE), Volkswagen (DE)**) the aeronautical industry (**Dassault aviation (FR), Airbus (FR)**) the transport sector in general (**SNCF (FR), Alstom (FR)**) the energy industry (**EDF (FR)**), and other industries where industrial design is expensive and elaborate (**Bosch (DE), Siemens (DE)**). The large list of companies that have integrated VR solutions in their design and production processes is continuously expanding as new companies want to benefit from this new technology.

One of the most relevant companies and successful examples in the manufacturing and engineering at the start-up level is **Varjo (FL)[174].** Varjo produces an industrial-grade VR / XR headset that allows professionals in sectors from aerospace to architecture to work in human eye-resolution quality virtual or mixed reality when designing new products. The headset can be integrated with the world's most popular 3D engines and software tools. Unlike devices such as Magic Leap, HoloLens, and HTC Vive Pro, Varjo's product can be used in fields where extreme precision and visual accuracy are necessary, and the startup is already collaborating with major companies such as Airbus, Audi, Lilium, Saab, Sellen, Volkswagen, and Volvo Cars to optimise the headset for their respective business sectors and needs. Founded in 2016 and based in Helsinki, the startup raised $31 million in Series B funding in October 2018.

The Finnish company has just release, as of November 2020, a **new HMD named the XR-3[175]**. The XR.3 delivers one of the most immersive mixed realities experiences in the market featuring photorealistic visual fidelity across one of the widest fields of view of any XR HMD. The XR-3 is capable of automatic interpupillary distance (IPD), 200 Hz Eye tracking, Hand tracking, LiDAR sensor, Red-Green-Blue (RGB) fusion, Horizontal 115° Field of View (FOV), 2880 x 2720 px per eye and a 27x27 focus area with 1920 x 1920 px per eye. The system is compatible with the 3D applications and graphics engines available such as Unity, Unreal Engine or Autodesk VRED.

The technology packed XR-3 is arguably one of the most if not the most advanced headset in the market, with a listing price of 1.495€ positioning Varjo as one of the most innovative and prolific VR companies in Europe.

[174] Varjo, FL. https://varjo.com/
[175] Varjo, 2020. XR-3 Headset. Available from: https://varjo.com/products/xr-3/

Founded at the end of 2017, Zurich-based proptech startup **HEGIAS (CH)**[176] has developed a browser-based, virtual reality CMS solution with applications for architects, construction companies, homeowners, brokers, and interior designers. Currently, the startup is focusing on the construction industry, where it is used to prevent building errors, as well as in real estate, but plans to be applicable for any VR content in the near future. HEGIAS has recently surpassed €900k in funding, after raising €450k in August 2018 in an ongoing Series A round from a range of investors, in which it expects to raise a total of €2.1 million by March 2019.

Figure 71 | Varjo XR-3 High-End HMD

[176] Hegias, CH. https://hegias.com/

4.3.4. Awareness Rising & Reporting

Many **broadcasters** and companies active in **news and journalism**, as well as organisations engaged in and/or furthering humanitarian efforts, are tapping into the unique potential of VR/AR technologies, in particular the empathy-inducing capabilities of VR. These can effectively educate and raise awareness about certain issues, and even elicit response and action among viewers. VR/AR can act as powerful tools for increasing compassion and influencing behaviour, tackling serious issues ranging from racism to climate change.

Examples of the using VR within reporting are growing. For instance, **BBC (UK)[177],** has been ad the forefront of developing the future of broadcasting technology. The BBC is currently collaborating with the industry on a selection of VR and 360-degree video projects, through it own dedicated R&D department. Among other projects the BBC has developed Documentaries in collaboration with **Crossover Labs (UK)[178]** and **VRTOV (AUS)[179]** a ground-breaking new form of history documentary making, exploring how VR might create a completely new way for people to engage with the past – by living through a protagonist's memories and perceiving events from their perspective.

Other examples include the fairy tale created in partnership with VRTOV "Turning Forest", to be used with Oculus Rift VR headsets or the "We Wait" a real story of refugees developed in collaboration with the Oscar-winning **Aardman Studios (UK)[180]** helping to give audiences a sense of presence by placing them at the heart of the story, and with technology allowing interactive eye-contact between them and the characters.

In a similar fashion, **Sky News (UK)[181]** collaborated with **Jaunt (UK),** now acquired by Verizon US**,** to create the VR experience "Migrant Crisis", where one can experience first-hand the struggle of refugees. Also, Sky News Arabia has launched a virtual reality studio in Abu Dhabi, to broadcast a daily love sport show and documentaries using immersive technologies.

Euronews (FR), aims to become the first European newsroom to fully adopt VR journalism and regularly publish 360-degree news videos.

Organisations furthering humanitarian eff orts and/ or engaged in public services are making use of these technologies for similar reasons and in similar ways. Charities seeking to incite empathy among the public have been among the early adopters, including the **National Autistic Society (UK)**, that in 2016 created in collaboration with **Happy Finish (UK)** a film showing people what it was like to live with autism.

Similarly, **Alzheimer's Research (UK)** created the VR experience "A Walk Through Dementia", which put viewers in the shoes of someone with the condition. **Nokia (FI) and Humanitarian Cooperative (UK)** made a VR film about Syrian child refugee and **Amnesty International (UK)** created a VR experience showing the devastation in Syria, in order to incite humanitarian relief response and charitable contributions for the cause.

VR/AR technologies are also used to educate and spur action from viewers concerning issues that can feel far-removed yet have a direct impact on humanity. This is the case of **Sweden[182] Virtual Reality (SE)**, who organises an international VR contest to boost and showcase the enormous potential of VR while contributing to awareness-rising purposes given that the theme has to be based on one of the United Nations seventeen Sustainable Development Goals.

Commerce & Advertising (Marketing)

[177] BBC, 2016. The BBC and Virtual Reality. Available from: https://www.bbc.co.uk/rd/blog/2016-06-the-bbc-and-virtual-reality
[178] Crossover Labs, UK. https://xolabs.co.uk/
[179] VRTOV, AUS. https://vrtov.com/
[180] Aardaman Studios, UK. https://www.aardman.com/
[181] Sky News, UK. https://news.sky.com/#
[182] Sweden VR, SE. https://www.swedenvirtualreality.com/

VR in retail is still in its very early stages, but it is becoming better, more affordable, more ubiquitous, and customers are increasingly interested in it. While the initial success has been with immersive brand experiences, continued growth has moved from 'view only' to 'interactive', where better and more technology has meant increased touchpoints. Future growth will integrate other parts of the customer lifecycle with existing data tools to unlock new possibilities.

Smart retailers are looking to where their customers are looking, in an effort to provide the best possible experience for them. It is well known that the omni-channel customer journey begins a long time before customers enter the store and extends way beyond the purchase experience. While the decision to purchase a product is often made before the customer even enters the store, the moments of truth within the customer journey are becoming more frequent, subtle and often go undiscovered by marketers, retailers and sales staff alike. Immersive technologies have the potential to transform these 'blind spots' into meaningful interactions, targeted conversations and data-driven decision making. In particular AR/VR can tap into:

- Acquisition: experiential immersive brand experiences, product trials, customised offers, in-store navigation, product history, brand differentiation.
- Conversion: remote expert consultations, immersive virtual stores experiences, personalised experiences, in-store engagement.
- Retention: AR/VR support, behavioural nudges and special offers, remote expert advice.

As AR/VR technology rapidly improves, analysts from Bloomberg predict the retail industry may be one of the biggest beneficiaries[183]. Brands are seeking to use VR and AR both for direct sales opportunities and to enrich the consumer's experience of the brand.

Technology is dramatically changing the retail landscape, but one thing remains the same: retail is about providing high-quality, engaging experiences for customers. Retailers can experiment with new technology, while still maximising the long-standing priority of connecting with customers. So, the most successful adopters of VR and AR will be retailers which use the technology to enhance their relationship with customers, rather than replace it.

According to ABI Research and Statista Estimates[184], the forecast size of the retail and marketing virtual reality market is of **$605 million in 2020** (including software, services and other but excluding hardware), and it is predicted that the market will be worth **$1.79 billion by 2022, growing at an impressive CAGR of 72.01%** for the forecasted period.

Similarly, according to Goldman Sachs[185], the market for AR and VR in retail will reach **$1.6 billion by 2025.** Statistics show that two-thirds of internet users would be interested in virtual reality, and 63% said such technologies would change the way they shop.

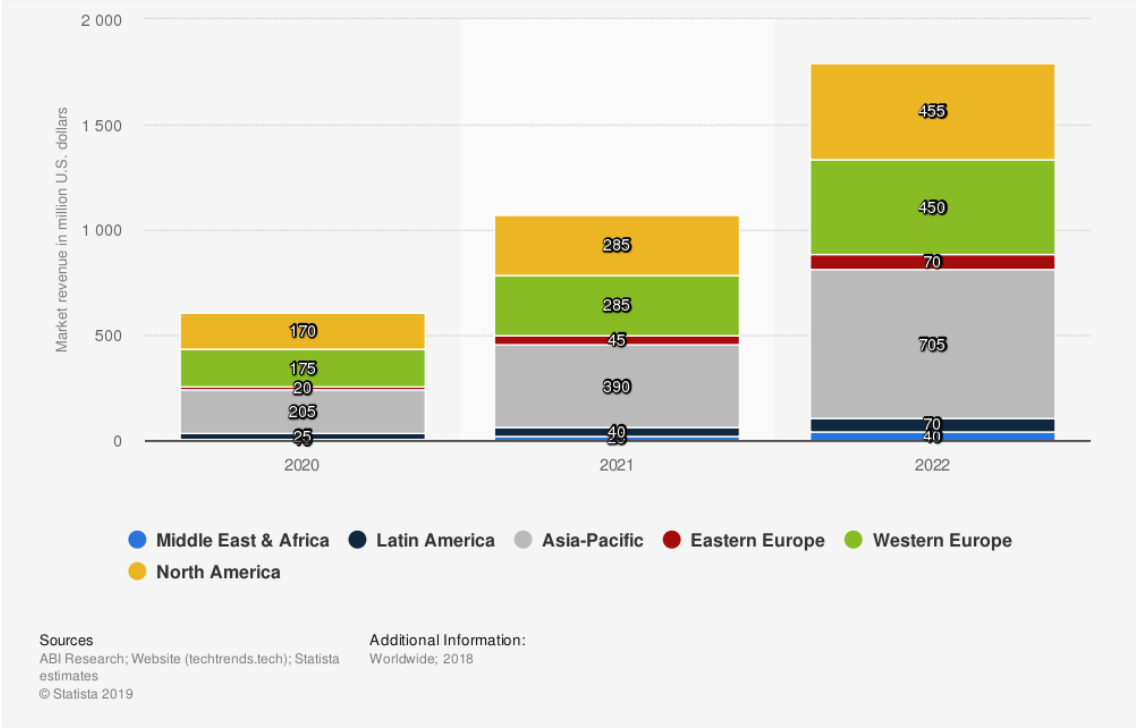
[183] Bloomberg, 2017. Google Moves Into Augmented Reality Shopping With BMW and Gap. Available from: https://www.bloomberg.com/news/articles/2017-01-04/google-moves-into-augmented-reality-shopping-with-bmw-gap

[184] ABI Research, 2018. Forecast size of the retail and marketing virtual reality (VR) market worldwide from 2020 to 2022, by region (in million U.S. dollars)*. May 2018. Available from: https://www.statista.com/statistics/969418/worldwide-forecast-virtual-reality-market-by-segment/

[185] Goldman Sachs, 2016. Virtual & Augmented Reality: The Next Big Computing Platform? 09 Feb, 2016. Available from: https://www.goldmansachs.com/insights/pages/virtual-and-augmented-reality-report.html

By region, **Asia-Pacific is leading the market with a valued size of $205 million in 2020 and a forecasted worth of over $705 million by 2022**. This is no surprise, given that chine is undoubtedly at the forefront of progress in emerging technologies and retail, especially luxury goods, are skyrocketing. The combined influence of other countries in Asia and the governmental support is also propelling VR growth in Japan and Korea, which accounts for half of the worldwide retail VR market. In second place, **North America and Western Europe are valued, in 2020, at $170 and $175 million respectively.**

Figure 72 | Forecast size of the retail and marketing virtual reality (VR) market worldwide from 2020 to 2022, by region (in million U.S. dollars)*



Needless to say, the possibilities and potential uses of VR/AR in retail are huge:

- Pre-plan shopping trips

  AR and VR allow customers to make more informed purchases as they visit stores, increasing the buyer conversion rate.

- Brand Differentiation

  Gamification can be used to enhance a physical product, which can increase consumer engagement and incentive to purchase.

- Information Delivery

  Customers can receive a myriad of information, from virtual coupons to nutritional information, about products while shopping.

- In-store engagement

  AR and VR can be used to assist customers to navigate a store, find or receive product information in-store and gain store incentives or rewards as they move through the store.

- Product customisation

Clients and potential customers are able to customise product features and designs using AR and VR technologies, allowing them to visualise what the product might look like in different scenarios.

› Experiential campaigns

AR/VR can add an emotionally immersive component to any product activation through gaming, storytelling and branded experiences.

› Low-cost visualisation of high-cost assets

High-cost assets often carry a high cost sales cycle because of customers' hesitation in purchasing something they can't properly visualise. Using VR, models of high-cost assets can be developed at a much lower cost, increasing accessibility.

Examples of VR use in retail include **DIAKSE (FR)**[186]**,** a start-up active in e-commerce, believes that incorporating VR/AR technologies into the online shopping experience is currently the only way to remain competitive against big players in the industry. The start-up creates virtual environments within which a customer can walk around, and which, thanks to Big Data technologies, reconfigure themselves for each individual so as to allow them to experience a unique and tailored visit.

Pre-packaged foods retailer **Kraft (US)** has partnered with **Walmart (US)** and the VR/AR developing company **Blippar (UK)**[187] to deliver, through AR, digital recipes, other assets and a points loyalty system for customers.

Similarly **Savvy (UK)**[188], a retail and shopper marketing agency that has produced immersive content and campaigns for the likes of **Grolsch (NL)**[189] and **Lipton (UK)**[190], is currently exploring how VR could transform and boost e-commerce for their clients, be it in grocery retail, travel, or fashion.

L'Oréal's (FR) Makeup Genius app allows users to virtually apply L'Oréal makeup products such as lipstick and eyeliner to their face, with their smartphone camera acting as a virtual mirror. Makeup Genius has already piqued a lot of consumer interest, having been downloaded more than 16 million times worldwide.

The **Dulux Colour (FR)** app uses AR technology in its 'ColourView' feature, which enables users to visualise through their smartphone camera what a certain colour of Dulux paint will look like on the ceilings, walls and furniture of their home. Users can browse through 4,000 different Dulux colours and get an accurate projection of what the finished product will look like in their chosen space.

IKEA's (SE) catalogue app uses AR to allow customers to virtually place IKEA products in their home and get a realistic idea of whether a piece of furniture will fit in their living room or

[186] Diakse, FR. https://home.diakse.com/
[187] Blippar UK. https://www.blippar.com/
[188] Savvy, UK. https://www.getsavvy.com/vr-ar
[189] Grolsch, NL. As seen on BierNet. Available from: https://www.biernet.nl/nieuws/grolsch-komt-met-proefbrouwerij-in-virtual-reality
[190] Lipton, UK. As seen on VR Focus. Available from: https://www.vrfocus.com/2016/12/life-in-360-three-six-tea/

bedroom. This saves the customer time in measuring the dimensions of a piece of furniture and calculating the amount of space it could potentially take up.

Fashion brands such as **Topshop (UK), Balenciaga (FR), Tommy Hilfiger (NL) and (Dior (FR),** are already very active in the field, showing in-store customers their latest collections by offering them headsets with which to view 360-degree videos of their runway shows, live-streaming their fashion shows in virtual reality, or creating their own VR headset.

For instance, Topshop partnered up with ground-breaking technology retail and marketing agency **Inition (UK)**[191] to create a virtual reality world of the London Fashion Week. Similarly, luxury fashion brand Balenciaga have unveiled their new Autumn/Winter 2021 collection through an immersive online video game. Tommy Hilfiger became the first major retailer to make virtual reality a fixture in its stores back in 2016, offering its shoppers a virtual trip, via a Samsung GearVR headset.

Automobile manufacturers, such as **Jaguar Land Rover (UK)**[192], are also making use of VR/AR technologies directly in their showrooms, believing this to be particularly valuable as it allows visitors to experience the interiors and view various colour combinations on the spot.

Numerous big brands are also investing a lot into marketing and advertising campaigns incorporating VR/AR, and are therefore important contributors to the development of VR/AR.

For example, fashion brands like **Givenchy (FR) and Jean-Paul Gaultier (FR),** consumer brands like **Nestlé (CH)** and **J&B Whisky (UK)**, and automobile brands such as Peugeot (FR) and **Renault (FR)**, have collaborated with production house **OKIO-STUDIO (FR)**[193] in order to expand the reach of their brands through elaborate immersive advertisements promoting their companies.

Some other examples of VR studios producing promotional content for established brands across Europe include **Scopic (NL)**[194]**, Ignyte (DE)**[195]**, Gardner Creative (UK)**[196] **or Polar Effect (NL)**[197]**.**

4.3.5. Live Entertainment & Broadcasting

VR/AR technologies are creating new experiences and ways of entertainment that are immersive and in real time. This means being able to experience sport matches, concerts and theatrical performances remotely, an end-use that is gaining momentum as a result of confinement and lockdowns due to COVID-19 pandemic.

However, live streaming events has certain requirements that VR has yet to fully meet. Modern smart TVs and even smartphones (through dedicated broadcasting apps) provides high definitions very good coverage of live events, with high definition, the possibility to pause, rewind and replay. None of those qualities are currently available with VR. The value of VR in

[191] Inition, UK. https://www.inition.co.uk/products/virtual-reality/
[192] Jaguar Land Rover, UK. https://www.jaguarlandrover.com/news/2017/01/jaguar-land-rover-customers-immerse-themselves-virtual-vehicles
[193] OKIO Studio, FR. http://www.okio-studio.com/
[194] Scopic, NL. https://scopic.nl/
[195] Ignyte, DE. http://ignite-vr.com/
[196] Gardner Creative, UK. https://www.gardnercreative.co.uk/
[197] Polar Effect NL. https://polareffect.com/

this context lies in its immersiveness, putting the viewer at the centre of the action and creating a 360 experience that mimics that off the actual live event.

Secondly, VR also creates mounds of data, making live streaming with current broadband capacities difficult. In this context, 5G will therefore be very important to overcome such hurdle and provide not only fast but also stable connection to enable real-time VR streaming.

Likewise, the telecommunications and TV giant **Orange (FR)**[198] is pioneering in the field of VR broadcasting. It has launched several initiatives in the field virtual reality related to e-sports for example and is exploring the use of 5G to deliver quality VR experiences to smartphones. This year during **Rolland-Garros event**[199]**,** Orange unveils new video technology with on-site 5G network and showcased various uses cases from 3D images, 8K content, and 360° video to virtual, augmented and mixed reality. On the other side of the Channel, BT Sport, a group of pay television sports channels and EE (formerly known as Everything Everywhere) a British mobile phone network operator released **Match Day Experience** [200] an application to bring 360 degree viewing, AR graphics and Dolby Atmos to BT Sport on iPhone.

[198] Orange, FR. https://www.orange.com/en/orange-content-overview/new-horizons-virtual-reality-and-esports

[199] https://hellofuture.orange.com/en/at-roland-garros-the-future-is-now-orange-unveils-new-video-technology-with-5g/

[200] Match Day Experience https://www.givemesport.com/1608304-ee-and-bt-sport-launch-gamechanging-match-day-experience-for-football-fans

4.4. VR/AR INDUSTRY-SPECIFIC MARKET ANALYSIS, BY HORIZONTAL

4.4.1. Social Interaction and Work Collaboration

VR has the potential to change the way we communicate and interact with each other. The added value of VR in comparison to other distance-based communication tools, is the interactivity and visualisation possibilities (data, documents, 3D models). In this respect, VR can offer new opportunities for efficient distant business meetings as well as fun social interactions.

By using VR technologies, it enables people to achieve multi-dimensional interaction without meeting each other physically. It is an **emerging social and work collaboration method**. Compared with traditional social methods, communications and interaction with VR has three new features: high immersion, diverse interactive modes and contextualized social content[201].

At the present time, **VR social products** on the market can be divided into **VR social games** and **VR social tools** according to what the focus. The VR social game aims to create a multiplayer online game experience. It emphasizes on social attributes, but the degree of VR interaction is light. VR social tools can be classified according to the ways of only socializing with friends or collaborating with work colleagues (private) and strangers (public).

The later, VR for social interaction and work collaboration is what is consider in this report as the horizontal application for VR. Not to mention that represents **the core attributes of the VRTogether project mission**. In deliverable 5.2, the market for Social VR was already reviewed in depth, emphasizing not only technological components necessary for that purpose but also providing an in-depth review of the main companies and, by extension potential competitors.

VR social interaction (Private Residential Users)

However, since the submission of D5.2 we have been able to gain more perspective on not only the Social and Work Collaboration VR, but also to understand better how the market dynamics may have changed as a result of the COVID-19 pandemic, promoting the rapid digitalisation of societies and enterprises. It is therefore important to re-evaluate such market.

Inherently, social VR encompasses multiple applications, end-users and potential VR experiences given its cross-sectional and horizontal nature. It is important then, in a market-wise manner, to analyse the current status of Social VR, the available platforms and solutions. Being able to have a panoramic overview of the market, together with the developed technology will enable to pinpoint the enabled market uses and end-users to target.

Serving that purpose, a first good comparison of 16 social VR platforms was provided in D5.2 extracted from Ryan Schultz blog[202]. Below we present an updated version of such table:

[201] Minhan Wang 2020. Social VR: A New Form of Social Communication in the Future or a Beautiful Illusion? J. Phys.: Conf. Ser. 1518 012032

[202] Ryan Schulktz, 2019. An Updated Comparison Chart of Sixteen Social VR Platforms (Updated and Expanded Draft, November 2019). Available from: https://ryanschultz.com/2019/11/12/an-updated-comparison-chart-of-sixteen-social-vr-platforms-first-draft-november-2019/

Table 8 | Comparision of most prominent Social VR Platforms

Company	Purpose of Platform	Desktop (Non-VR) OS Support	VR Headset Support	Motion	Character Representation	Architecture/ Game Engine	Open Source?
AltspaceVR (Microsoft Company)[203]	General Purpose - Live events / Education / Social VR	Windows	Oculus Rift, Quest, Go, HTC Vive, Valve Index, Windows MR, Gear VR, Google Daydream Mobile:Android	Yes	Cartoon-Like Avatars	Unity	Closed Source
Anyland[204]	General Purpose /	None	Oculus Rift, HTC Valve, Valve Index, WIndows MR No mobile support	Yes	A Pair of Hands (You Build Your Own Avatar)	Unity	Closed Source
Bigscreen, Inc.[205]	Media (Video, TV, Movies)	Windows	Oculus Rift, Quest, Go HTC Vive, Valve Index, Windows MR, Gear VR No mobile support	Yes / No	Cartoon-Like Avatars	Unity	Closed Source
Cryptovoxels[206] (Nolan Consulting Ltd.)	General Purpose / Culture & Art	Windows, MacOS, Linux (Web Based)	Any that support WebVR: Oculus Rift, Quest, Go HTC Vive, Valve Index, Windows MR, Gear VR, Google Daydream Mobile: iOS and Android	Yes	Artist Mannequin Avatar (Not Changeable)	BabylonJS	Closed Source
Engage VR Education Holdings PLC	Education	Windows	Oculus Rift, Oculus Quest (via SideQuest), HTC VIve, Valve Index, Windows MR No mobile support	Yes	Human Avatars	Unity	Closed Source
High Fidelity[207]	General Purpose (Remote Work collab.)	Windows, MacOS	Oculus Rift, HTC Vive, Valve Index, Windows MR Mobile : Android support	Yes	Artist Mannequin Avatar	QT-C++	Open Source
Mozilla Hubs VR[208]	General Purpose	Windows, MacOS, Linux (Web Based)	Any that support WebVR: Oculus Rift, Oculus Go, HTC Vive, Valve Index, Windows MR, Gear VR, Google Daydream Mobile: iOS and Android	Yes	Cartoon-Like Avatars	ThreeJS + Aframe (AmmoJS for Physics)	Open Source

[203] AltspaceVR, CA, USA. https://altvr.com/
[204] Anyland, Germany. http://anyland.com/
[205] Bigscreen Inc., CA, USA. https://www.bigscreenvr.com/
[206] Cryptovoxels, New Zeland. https://www.cryptovoxels.com/
[207] High Fidelity, CA, USA. https://www.highfidelity.com/
[208] Mozilla Hubs, USA. https://hubs.mozilla.com/

NeosVR Solirax Ltd[209]	Entertainment / Games	None	Oculus Rift, HTC Vive, Valve Index, Windows MR (Oculus Quest and Oculus Go in beta test for Patreon supporters only) Mobile: Android (beta for Patreon supporters only)	Yes	Cartoon or Human Avatars	Unity	Closed Source
Rec Room Inc.[210]	Entertainment / Games	Windows	Oculus Rift, Oculus Quest, HTC Vive, Vale Index, Windows MR, PSVR Mobile : IOS	Yes	Cartoon-Like Avatars	Unity	Closed Source
Sansar[211] Linden Lab	General Purpose (New Focus on Live Events)	Windows	Oculus Rift, HTC Vive, Windows MR (unofficial)	Yes	Human Avatars	Custom, Proprietary	Closed Source
Sinespace Sine Wave Entr.[212]	Entertainment / Games	Windows, MacOS, Linux (also a Web Client)	Oculus Rift, HTC Vive Mobile: iOS and Android	Yes	Human Avatars	Unity	Closed Source
Somnium Space[213]	General Purpose (Entertainment Open World	Windows	Oculus Rift, HTC Vive, Valve Index, Windows MR, Gear VR, Google Daydream	Yes	Head-and-Shoulders Avatars (Full-Body Avatars are Planned)	Unity	Closed Source
VRChat VRChat Inc.[214]	General Purpose (Entertainment Open World	Windows	Oculus Rift, Oculus Quest, HTC Vive, Valve Index, Windows MR	Yes	Cartoon or Human Avatars (You Can Select a New Avatar In-World or Create a Custom Avatar Using the Tafi Beta App)	Unity	Closed Source
vTime XR[215] vTime Limited	General Purpose (Entertainment Open World	Windows	Oculus Rift, Go, Windows MR, Gear VR, Google Daydream Mobile: iOS and Android	No, Locked to Seat	Human Avatars		Closed Source
Wave WaveXR[216]	Music Performance	Windows	Oculus Rift, HTC Vive, Valve Index, Windows MR	Yes	Cartoon-Like Avatars	Unity	Closed Source

[209] Neos, a Solirax LTD. Company, CZE. https://neos.com/
[210] Rec Room Inc., WA, USA. https://recroom.com/
[211] Sansar, CA, USA. https://www.sansar.com/
[212] Sinespace, UK. https://sine.space/
[213] Somnium Space, CZE. https://somniumspace.com/
[214] VRChat Inc., CA, USA. https://hello.vrchat.com/
[215] vTime XR, UK. https://vtime.net/
[216] Wave XR, CA, USA. https://wavexr.com/

VR for Work Collaboration (Private Corporate Users)

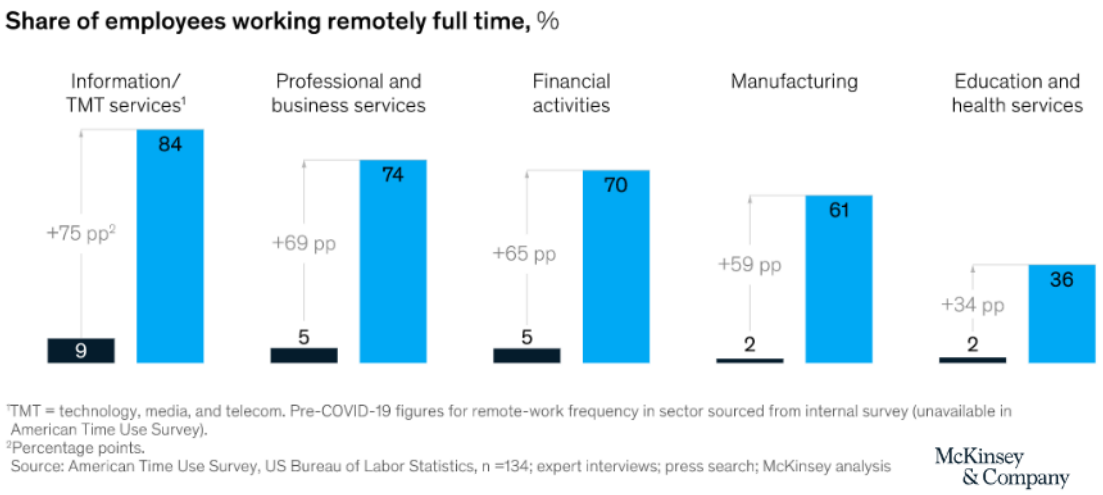
As more organizations develop remote-work policies, virtual reality is emerging as a tool whose collaborative capabilities extend far beyond the offerings of video chatrooms and onscreen meetings. VR-powered organizations may see benefits beyond the collaboration that immersive, 3D experiences can unlock. When geographically disparate teams can be in the same "room," organizations save on travel expenses as well as environmental costs. Meetings can have far smaller carbon footprints.

Since the global disruption caused by the pandemic in the first quarter of 2020, the levels of remote working have skyrocketed and are likely to remain higher than pre-crisis levels for some time. This is the conclusion derived from McKinsey extensive 2020 survey[217]. This is a trend observed across all industry categories, from ICT and Business Services to Manufacturing or even Education and Health Services.

In fact, there has been up to **75 percentage points increase in the share of employees working remotely full time**. For instance, in the ICT and Technology, Media and Telecom sector 84% of the employees are working remotely nowadays, compared to only 9% in the same period 2019.

Interestingly, those sectors in which physical contact is unavoidable, such as health services or education eWork has also experienced an impressive growth, from 2% in 2019 to more than 36% in 2020.

Figure SEQ Figure * ARABIC 73| The COVID -19 Impact on Remote Work - Share of Employees Working Remotely



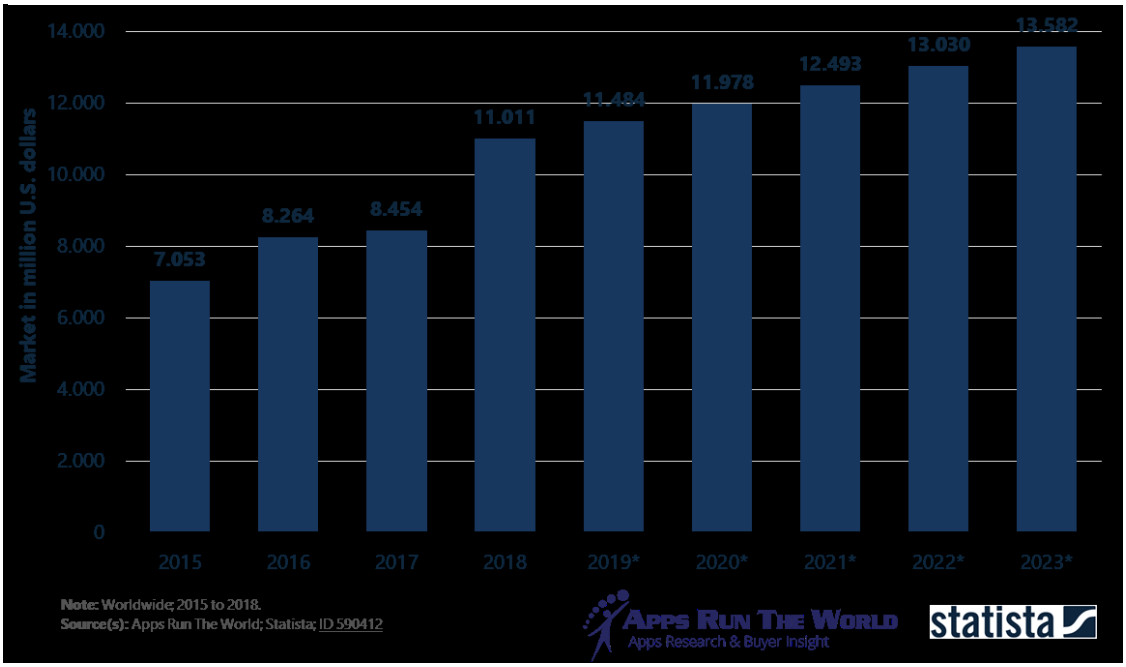
In fact, the work collaboration software market is a huge and dynamic business, even before the COVID-19. According to Apps Run the World[218], the Collaboration applications market size is expected to reach $13.6 billion by 2024, compared with $12.4 billion in 2019 at a compound annual growth rate of 1.8%.

Collaboration applications include Cloud tools for Web conferencing, team collaboration, social business platform, event management, eSignature, and sharing of online community resources. Collaboration applications also include conventional tools for email, group calendaring and scheduling and threaded discussion.

[217] Boland, B., De Smet, A., Palter, R., Sanghvi, A., 2020. Reimagining the office and work life after COVID-19. Mc. Kinsey, 2020. Available from: https://www.mckinsey.com/business-functions/organization/our-insights/reimagining-the-postpandemic-workforce

[218] Apps Run the World, 2020. Top 10 Collaboration Software Vendors, Market Size and Market Forecast 2019-2024. Updated in November 2020. https://www.appsruntheworld.com/top-10-collaboration-software-vendors-and-market-forecast/

Figure 73 | Collaboration Software Marker revenues from 2015 to 2023 (in million U.S. dollars)



Estimates by Apps Run the World could even run short according to the latest Fortune Business Insight[219] report on Team Collaboration Software, in which is estimated the market to reach **$35.71 billion by 2027 from the $13.44 billion of 2019, exhibiting a CAGR of 13.2% during the forecast period.** The market is set to gain impetus from the increasing trend of bring-your-own-device in various small and medium-sized enterprises. It helps in lowering the initial infrastructure costs that tend to limit early development.

Importantly, this only refers to the software market but it is a very useful estimation to also predict the knock-on effect on the corresponding hardware market, in this case HMDs and any other supportive hardware (Capture Systems, 3D Sensors, Data Transmission, etc.) in the potential application of VR as a work collaboration tool.

In the dystopian present, communicating has become more pressing than ever, and high speed, super reliable, hyper realistic communications have become quintessential to the execution of ordinary operations in each and every sector. From real estate to manufacturing industries, from health facilities to higher education institutions, several businesses are turning to AR, VR and 3D tech to improve their improvised home-office arrangements. Here is a list of the most prominent ones:

[219] Fortune Business Insights, 2020. Team Collaboration Software Market Size, Share & Covid-19 impact Analysis, 2020-2027. October, 2020. Available from: https://www.fortunebusinessinsights.com/industry-reports/team-collaboration-software-market-101327

Table 9 | Most Relevant Work Collaboration VR Platforms

Platform / Company	Description
Glue Collaboration (FL) [220]	**Glue Collaboration (FL)** is a Helsinki-based company developing remote collaboration tools for AR/VR. The company mission is to enable people thousands of miles apart to collaborate effectively in virtual environments, just as they might in a real physical setting. In just a few years, Glue, has already achieved tremendous results and amassed an impressive amount in funding, €3.5 million.
Proximie (UK)[221].	Another great example of novel companies that are providing work collaborations amid the COVID-19 lockdowns and quarantines is **Proximie (UK)**. The London-based startup is a secure surgical collaboration platform, that enables doctors to connect and interact anywhere in the world. The medical platform is stepping up in these times of emergency. Proximie is, in fact, committed to enable self-isolating clinicians to remotely support colleagues on the front line, so that every clinician can connect and collaborate off site during Covid-19. At this very moment, Proximie is being used to provide remote ITU expertise to frontline clinicians, ensuring every patient has access to the best possible care.
Meeting Room (IRE)[222]	**meetingRoom** is yet another business-oriented social VR platform, by an Irish company, with support for Windows, Mac, iOS, and Android devices, as well as Oculus Rift, HTC Vive, and Windows Mixed Reality (WMR) headsets. The company sells its VR platform under the business model known as **Space-as-a-Service** for virtual Teams. It allows each user to create their own avatar and collaborate in a well-known meeting room environment with acess to whiteboards, for example.
Spatial. Io (USA)[223]	Based in New York, **Spatial.Io** provides a virtual space where groups of people can collaborate on projects working on Microsoft HoloLens, Magic Leap One and Oculus Quest VR. You create an avatar by uploading a single photo of your face, and then machine learning turns it into a digital, 3D version of you. The avatars represent you from the waist up, so you can move your arms and make gestures, thanks to hand-tracking technology in the Oculus headset. Spatial also uses AI to animate the avatar's faces based on what you're saying. This is in fact one of the key characteristics of Spatial.Io that sets apart from the competition, since it offers to create a photorealistic avatar of the person. Once you've created an avatar, you can join rooms, kind of like you would in Zoom, and you can interact with the avatars of your friends or coworkers. You can talk to them and see versions of their real faces, as well as move around the room, watch videos together, and give high-fives. Spatial has raised a total of $22.3M in funding over 5 rounds. Their latest funding was raised on Jan 30, 2020 from a Series A round.
InsiteVR (ResolveBIM), (USA)[224]	**InsiteVR** is a social VR platform that is intended to work with designs created in software such as BIM 360, Navisworks, Revit, Sketchup, and other programs that create three-dimensional models. Planners and designers can meet up in a virtual space to explore and

[220] Glue, FL. https://glue.work/
[221] Proximie, UK. https://proximie.com/
[222] MeetingRoom, IRE. https://meetingroom.io/
[223] Spatial.io, NY, USA. https://spatial.io/
[224] ResolveBIM an InsiteVR Company, NY, USA. https://www.resolvebim.com/

	"walk through" their 3D models. InsiteVR supports The Oculus Rift, Oculus Quest, Oculus Go, HTC Vive, and Windows Mixed Reality headsets, as well as desktop users.
MeetinVR, (DK)[225]	**MeetinVR** is another social VR app targeting the business market, created by a Danish company. MeetinVR combines the flexibility of online meetings with the interactivity of in-person meetings, enabling companies to collaborate inside virtual work-spaces designed to promote engagement and productivity. Industrial VR headset maker **Varjo** unveiled a collaboration with MeetinVR at the online-only Augmented World Expo. COVID-19 has boosted the interest in MeetinVR's solution, and the company worked hard to put out the beta version. The company recently raised $500,000 from a list of Nordic angel investors and Vækstfonden (the Danish Growth Fund), bringing its total investment to date to $1.5 million. And the company is also getting ready for a new funding round soon.
Future Visual, Vision XR (UK)	**VISIONxR** is an immersive platform allowing multiple users, in multiple locations, on multiple devices (VR, AR, desktop and mobile) to collaborate, communicate and learn together. It removes the barrier of geography, reduces time and travel costs and speeds up the process of learning and collaboration. VISIONxR™ is a response to the changing world of work and learning where real-time collaboration and knowledge share empower and enhance performance.
WorldViz (USA)[226]	WorldViz develops and provides VR software and platform that offers three-dimensional visualization solutions for businesses and enterprises. Since 2012, the company has been recognized for their expertise in VR solutions, they were providing guidance to researchers, trainers, teachers, government leaders, and business teams all around the globe. More recently they have focused on creating VR creation and collaboration tools that are accessible to non-technical users.

[225] MeetinVR, DK. https://www.meetinvr.com/
[226] WordlViz, CA, USA. https://www.worldviz.com/

4.4.2. Training

With the Industry 4.0 revolution and the uptake of digitalisation within societies and economies, including fields such as artificial intelligence and machine learning, robotics, nanotechnology, 3-D printing and genetics and biotechnology, it is expected a widespread disruption not only to business models but also to labour markets over the next years. This will represent a shift in skill sets and requirements for the future workforce.

Thus, to fill the new and reconfigured jobs of the intelligent and digitalised enterprise, companies will need new approaches to training. However, even though **almost 50% of business leaders** surveyed by Accenture **identify skill shortages as a key future challenge, but only 3% state their organisation plans to increase investment in training programs** significantly in the next three years[227].

What is more, up to **85% of people believe they need new skill to stay relevant at work**, according to an online survey of 10.527 workers across skill levels and generations in Australia, Brazil, France, Germany, India, Italy, Japan, Turkey, the U.K. and the U.S. in 2016 by Accenture[228].

Considering such numbers it is clear that new technologies will enable companies can achieve more with less, but only if they are willing to innovate their training methods. In fact, research from World Economic Forum[229] estimates that by 2020, nearly 35% of the top skills needed across all job families will change. In terms of overall impact, up to 7.1 million jobs could be lost through redundancy, automation or disintermediation.

It is therefore pivotal for many companies to embrace new skilling programs, which must be rapid, flexible, tailored and large-scale to maximize the value humans and machines can create together.

According to the Training Industry in 2019[230,231], companies spend an estimated **$370.3 billion on corporate training initiatives worldwide**. North America sits at the forefront of corporate training expenditure with $169.4 billion while the rest of the world accounted for $200.9 billion.

Looking at previous years, this numbers represents a sustained compound annual growth rate (CAGR) of **4.54% for the period 2009-2019**, although Year-over-Year (YoY) growth peaks have reached the 10% burden.

From such training expenditure, in 2019, Training Industry estimates that companies spend an average of 39% of their training budget on external (outsourced) suppliers, while approximately 61% of their budgets is spent on internal resources.

[227] Accenture Strategy, 2018. Reworking the Revolution – Are you ready to compete as intelligent technology meets human ingenuity to create the future workforce?. By Ellyn Shook and Mark Kickrehm. Jan, 2018. Available from: https://www.accenture.com/_acnmedia/pdf-69/accenture-reworking-the-revolution-jan-2018-pov.pdf

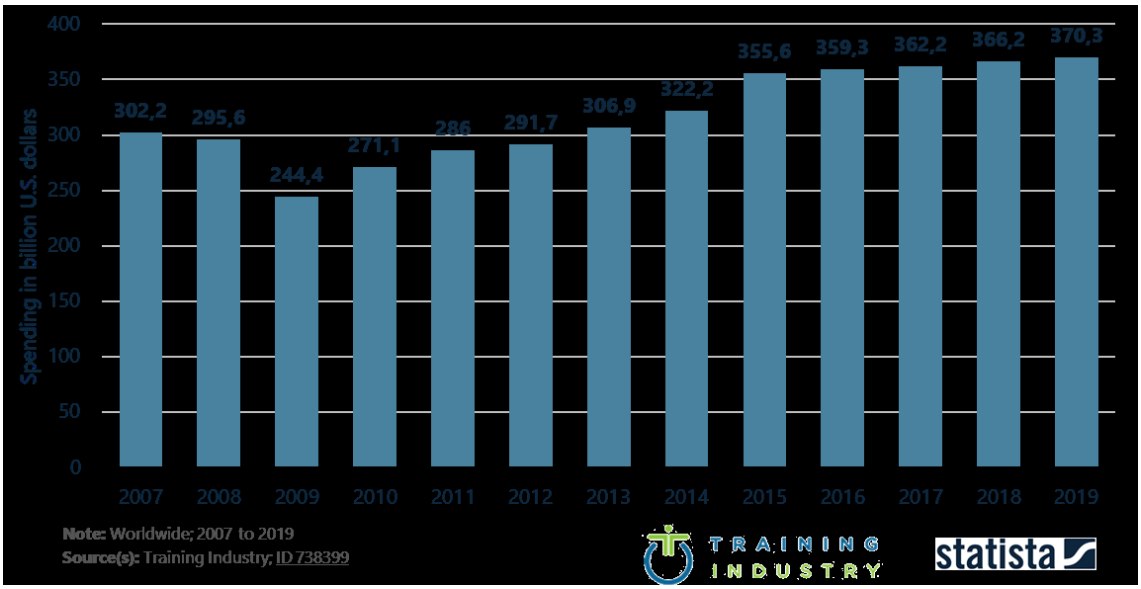
[228] Accenture, 2016. Harnessing Revolution – Creating the Future Workforce. By Ellyn Shook and Mark Kickrehm. 2016. Available from: https://www.accenture.com/_acnmedia/pdf-40/accenture-strategy-harnessing-revolution-pov.pdf

[229] World Economic Forum, 2016. Five Million Jobs by 2020: the Real Challenge of the Fourth Industrial Revolution. 18 Jan, 2016. Available from: https://www.weforum.org/press/2016/01/five-million-jobs-by-2020-the-real-challenge-of-the-fourth-industrial-revolution/

[230] Training Industry, 2020. Size of the Training Industry. Updated April 1, 2020. Available from: https://trainingindustry.com/wiki/outsourcing/size-of-training-industry/

[231] Statista, 2020. Market size of the global workplace training industry from 2007 to 2019(in billion U.S. dollars). April, 2020. Available from: https://www.statista.com/statistics/738399/size-of-the-global-workplace-training-market/

Figure 74 | Market Size of the Global Workplace Training Industry frim 2007 to 2019 (in billion U.S. dollars)



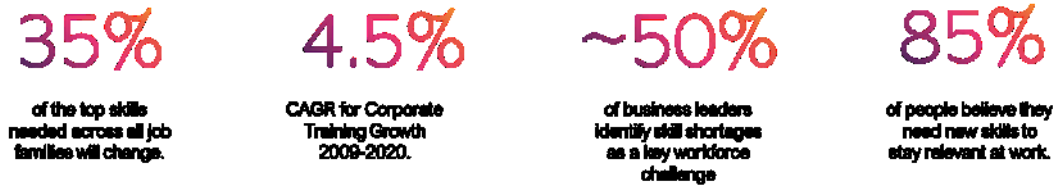
However, despite the huge training expenditure and growth, these sessions are still delivered in traditional formats like classroom-based seminars or online training modules. While passive learning and memorization has been the past model, today's workforce requires a more active and ongoing approach to training in which employees learn through practical experience.

In addition, it is important for companies to create a realistic version of dangerous scenarios to test safety and compliance protocols. In those scenarios experimental learning has been long argued as the most effective way to learn and train. In fact, studies have shown that learning by doing or experimental learning increases the quality and improves learning retention by up to 75%[232].

In this context **Extended Reality (XR),** which refers to all real and virtual combined environments and human-machine interactions generated by computer technology and wearables comprising both VR and AR, can be an effective mechanism for experiential learning to address today's learning needs.

Research from Stanford University and Technical University Denmark found learners recall more when using virtual teaching methods than with traditional methods, resulting in a **76% increase in learning effectiveness[233,234].**

Fiaure 75 | The demand for and investment in learnina is increasina.



[232] Eagle's Flight, 2017. The experiential Learning Spectrum. January 6, 2017. Available from:https://www.eaglesflight.com/blog/the-experiential-learning-spectrum#:~:text=Simply%20telling%20an%20individual%20how,and%20at%20every%20career%20level.

[233] Bonde, M., Makransky, G., Wandall, J., Larsen, M. V., Morsing, M., Jarmer, H. Ø., & Sommer, M. (2014). Improving biotech education through gamified laboratory simulations. Nature Biotechnology, 32(7), 694-697. https://doi.org/10.1038/nbt.2955

[234] Markowitz DM, Laha R, Perone BP, Pea RD and Bailenson JN (2018) Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change. Front. Psychol. 9:2364. doi: 10.3389/fpsyg.2018.02364

Looking across industries, the use of immersive tools in workforce training is flourishing right now. According to IDC[235], spending on AR/VR training will grow at a **compound annual growth rate of 46% between 2018 and 2023, reaching over US$8 billion by 2023**. In addition, such figures are corroborated by ABI Research, which estimated the enterprise VR training market to have generated **$216 million in 2018 and grow to $6.3 billion in 2022[236]**.

VR is especially well-suited to acquiring behavioural and social skills by immersing the learner in an environment and simulating critical scenarios. This is invaluable for preparing workers for stressful or hazardous circumstances.

AR, in contrast, is better suited to building technical skills on the job. The combination of physical and digital visual information allows an engineer or surgeon, for example, to perform a procedure while receiving complementary information, without having to look away.

Regardless of the immersive technology, the benefits of immersive training and learning are huge:

- MIRROR REAL-LIFE SITUATIONS

  Immersive learning is effective in emphasizing things through visualization. By providing environments that more closely mimic real-life situations, employees can reach greater levels of expertise in less time.

- END OF DISTANCE

  Through immersive experiences, businesses can tap expertise in thousands of skills from anywhere in the world. XR can also provide remote guided tours and remote collaboration.

- REDUCED OPERATIONAL COSTS

  Organizations that adopt immersive learning can cut costs on employee travel and transporting equipment to training locations and even save space on real estate. The trainers themselves can also be part of the XR programming so companies can reduce faculty costs.

- LEARNING THROUGH MISTAKES

  One of the most compelling advantages of immersive learning is people do not have to worry about making mistakes, which can be costly in the real— both in terms of machinery and safety. Training for hazardous environments, as well as simulations that allow individuals to practice presentations, reduce behaviors that do not support inclusion or that could negatively impact a client deal can all be achieved through XR.

- INCREASED ENGAGEMENT

  With the ability to build-in gamification, immersive learning can be fun. When trainees are engaged and interested, it leads to better retention.

- BETTER ANALYTICS

  XR captures enriched user data—behavioral, eye tracking, heat maps and gesture tracking. Management can review immersive learning experiences and test results through automated reports that help position employees for future growth.

[235] International Data Corporation (IDC), 2019. Worldwide Semiannual Augmented and Virtual Reality Spending Guide. May, 2019. https://www.idc.com/tracker/showproductinfo.jsp?prod_ id=1381

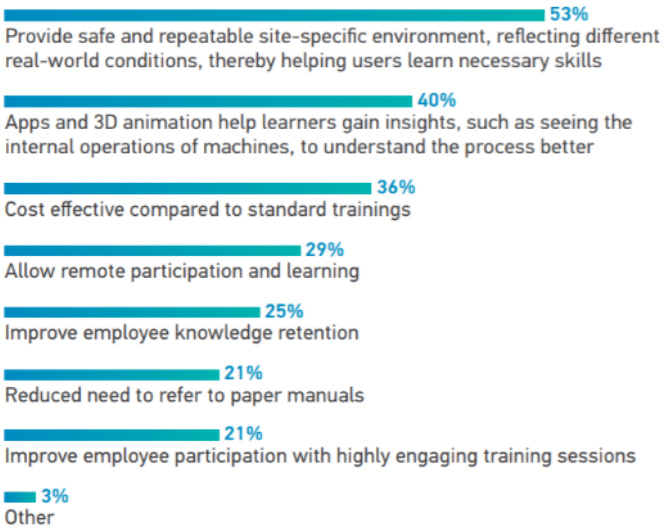
[236] ABI Research, 2017. Enterprise Virtual Reality Training Services to Generate US$6.3 billion in 2022. Oyster Bay, New York – 21 Nov 2017. Available from: https://www.abiresearch.com/press/enterprise-virtual-reality-training-services-gener/

Among these, Perkins Coie's 2019 Survey[237] involving over 191 professionals within the VR industry, highlights the which are considered to be those challenges within corporate and safety training that can be addressed by VR technologies.

Respondents found that **providing safe and repeatable real-world conditions** as well as apps and **3D animation to help learners gain insights** to be the top ways immersive technologies can be used to effectively address challenges, in 53% and 40% of the cases respectively.

In second position, **40%** of respondents considered VR most effective to **help learners gain insights** of machines or complex industrial processes through 3D animation.

Figure 76| Perkins Coie's 2019 Survey - How do you believe AR/VR technologies can most effectively address challenges in safety training situations?



Up to **36%** of survey respondents says that VR is a **cost-effective solution compared to other classical standard trainings**, given the low amount of resources and personnel needed. Interestingly, remote participation and learning is also an important potential use of VR within training, emphasizing the need for robust real-time and remote VR solutions.

To evaluate the impact of VR/AR training on work productivity and safety, the strategic consultancy firm Accenture[238] carried out a study in which workforce date for 432 occupations across 14 industries in 14 G-20 countries was analysed to assess the opportunities for workers to perform specific tasks with XR tools.

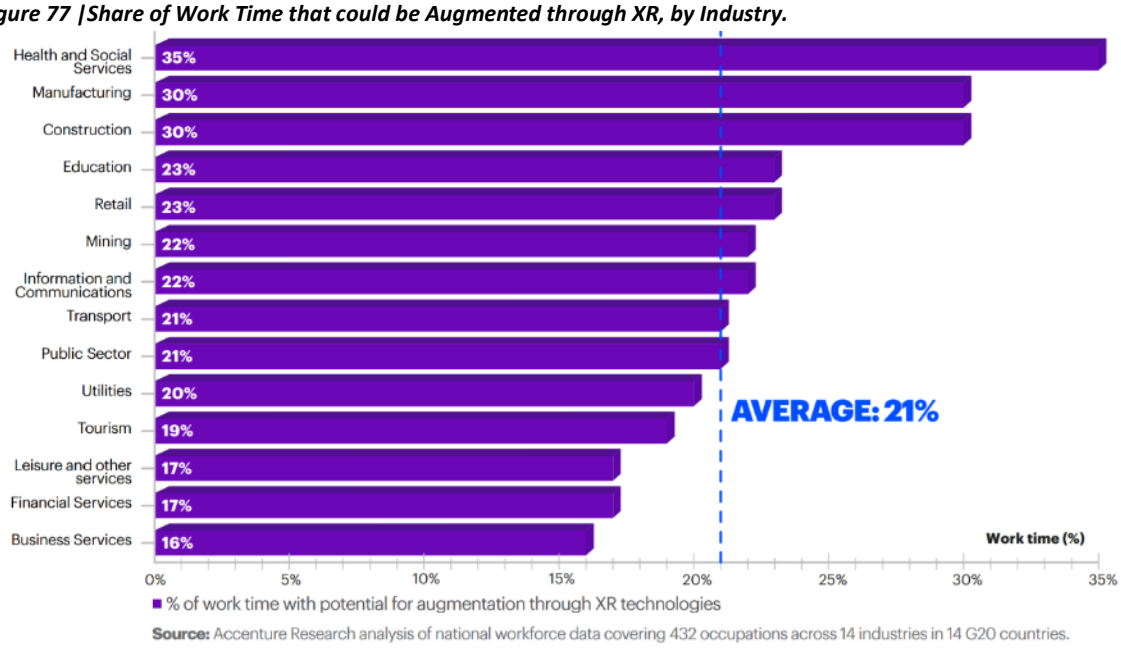
By doing so, Accenture was able to determine the **proportion of work time that could potentially be augmented** by working with XR technologies such as VR. Augmentation refers to the improved productivity that comes from performing a task with the XR tool. Strong XR-driven productivity gains are available across all industries, but it is fascinating to see the array of industries that stand to benefit most, ranging from healthcare and education to manufacturing and mining.

In 2019, it was found that **35% of work time in the health and social services** industry could be augmented through the use of extended reality (XR) technology. In comparison, just 16% of work time in the business services industry could be augmented, falling below the 21% average taken from across all of the industries studied. Workers across all industries could improve their productivity through the use of XR, with the opportunities most likely to be felt in the **healthcare and social services, manufacturing, construction and education industries.**

[237] Perkins Coie LLP., 2019. 2019 Augmented Reality and Virtual Reality Survey Report. March 2019. Available from: https://www.perkinscoie.com/images/content/2/1/v4/218679/2019-VR-AR-Survey-Digital-v1.pdf

[238] Accenture, 2019. Waking up to a New Reality – Building a responsible future for immersive technologies. As published in Statista, 2020. Available: https://www.statista.com/statistics/1096873/augmentation-of-work-time-using-xr-technology-by-industry-2019/

Figure 77 |Share of Work Time that could be Augmented through XR, by Industry.

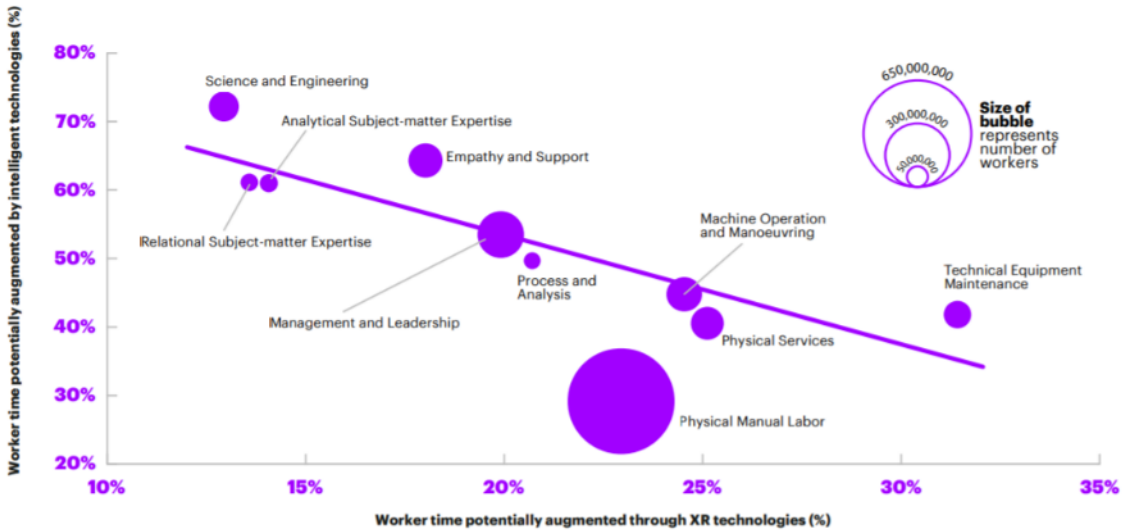


At this point is important to mention that, as opposed to other technologies such as automation or robotics, XR technologies boost productivity instead of replacing humans at the workplace which often do not have clear economic benefits.

At the macro level, firms need to understand how new tech tools are best suited for different purposes, and how they can complement each other. For instance, those roles that have the most opportunities to be augmented through VR/AR are those that have the least opportunities for augmentation through intelligent technologies such as artificial intelligence, machine learning and smart robotics. Ultimately, understanding such complementary strengths will improve overall tech investment decisions.

Workers who spend a significant amount of their time performing routine or repetitive tasks are at risk of losing their job to automation. Yet, many of these same roles involve activities and tasks that could be augmented through XR, making them more valuable to the workforce.

Figure 78| Intelligent and Immersive Technologies Complementary Strengths.



Source: Accenture Research analysis of national workforce data covering 432 occupations across 14 industries in 14 G20 countries. Note: See Appendix for full methodology

Industries with high-risk working environments such as energy, industrial, manufacturing or construction are already experiencing the benefits of immersive learning. Now other industries are exploring the space, highlighting the horizontal or cross-industrial applications of VR in training, including:

- Healthcare Training

  Virtual reality technology is becoming an increasingly popular training surgical training tool, both for medical students as well as veteran surgeons learning to use new medical devices. The most obvious benefits of VR training for surgical procedures is the wider range of anatomical viewing angles compared to studying a two-dimensional textbook image, and the ability to repeat a VR training simulation countless times, unlike the cadaver training method.

  Surgeons and other medical staff often lack adequate opportunities to consistently practice skills they're learning, especially skills related to new medical technologies. When training on a new device, surgeons often travel to a one- to two-day training workshop with the medical device company. This one-time training generally does not offer avenues for surgeons to continue reinforcing their skills.

  Virtual-reality-based training systems offer an intriguing solution to several aspects of these challenges. These platforms directly address the skills gap by providing immersive, hands-on training that closely simulates an operating room environment. VR platforms offer portable, on-demand training being and accessible technology worldwide.

  What is more, these VR-based tools incorporate objective and personalized assessment and feedback, allowing for a highly granular picture of what physicians are doing correctly and identifying areas for improvement.

  Hospitals and universities around the world have successfully embraced VR-based training for years. In fact, Satava[239] first proposed training surgical skills in VR back in 1993. Since that time, may VR-based healthcare training simulators and trainers have been developed and deployed.

  As an example, **Oxford Medical Simulation (OMS)[240]** has developed a Virtual Reality healthcare training simulator for medical and nursing simulation. The technology is being used for both medical students (Hull York Medical School, The University of Edinburgh, Imperial College London, Middlesex University, Rory Meyers School of Nursing, University of Northampton) as well as for medical staff training across several NHS hospitals (UK), the Government of Jersey (NJ, USA) and Boston's Children Hospital (MA, USA). OMS delivers real-life scenarios, with standardized clinical training to physicians, nurses and all other healthcare professionals, all in a highly-realistic simulation. This provides optimal leaning for professionals, given the repeatability of the scenarios, its accessibility and cost-effectiveness.

[239] Satava RM. Virtual reality surgical simulator. The first steps. Surg Endosc. 1993 May-Jun;7(3):203-5. doi: 10.1007/BF00594110. PMID: 8503081.

[240] Oxford Medical Simulation, 2020. Helping you transform healthcare training. Available from: https://oxfordmedicalsimulation.com/

Similarly, **ORama VR (CH)[241],** founded in 2016 as a spin-off company of the Foundation for Research and Technology-Hellas (FORTH), offers proprietary VR clinical simulation tools, and psychomotor and gamified multi-user VR software platforms for training simulations for more than 8 medical and surgical procedures as well as emergency trauma scenarios training.

Within this field it is also important to mention **OssoVR (CA, USA)[242],** one of the most advanced and well-known VR training platforms for surgeons. This is a surgical training platform focused on teaching medical procedures in a highly realistic virtual and immersive environment. Osso VR currently has around 30 customers, 12 of which are in the medical device space. The company uses Oculus Quest headsets and is deployed in 20 teaching hospitals across 20 different countries.

In a recent validation study conducted by UCLA, surgeons training with Osso VR showed a **230% improvement in overall surgical performance and up to a 20% faster[243,244]**. This has resulted in a $14 million round of financing making it one of the leading companies within the field.

Intersecting with other market verticals such as education and training, **Fundamental VR (UK)**[245], is tackling a very particular niche, surgery training. Fundamental VR has created a surgery simulation experience that lets junior surgeons practice various procedures, like hip replacements or spinal operations. It also provides "tactile feedback" (haptics), for mor realistics simulations of touch and sensitivity. The startup's tech is already in use in various clinics and universities including Mayo Clinic, Sana Kliniken and University of California, Los Angeles (UCLA). Earlier this year it raised a $5.7m Series A led by Downing Ventures.

The benefit of VR medical training has been extensively studied and reviewed[246,247,248,249,250], with up to 40%-87% fewer mistakes and accuracy than physicians who are conventionally trained, and up to 74% improved learning by medical students.

[241] ORamaVR, 2020. Transform Virtual Learning, Reform Real Medicine. Available from: https://oramavr.com/

[242] OssoVR, 2020. The Leading Virtual Reality surgical training and Assessment Platform. Available from: https://ossovr.com/

[243] Orland, Mark D. BS *et al.* 2020. Does Virtual Reality Improve Procedural Completion and Accuracy in an Intramedullary Tibial Nail Procedure? A Randomized Control Trial, Clinical Orthopaedics and Related Research: September 2020 - Volume 478 - Issue 9 - p 2170-2177 doi: 10.1097/CORR.0000000000001362

[244] Harvard Business Review, 2019. Research: How Virtual Reality Can Help Train Surgeons. October 16, 2019. Available from: https://hbr.org/2019/10/research-how-virtual-reality-can-help-train-surgeons

[245] Fundamental VR, UK. https://www.fundamentalvr.com/

[246] Samadbeik M, Yaaghobi D, Bastani P, Abhari S, Rezaee R, Garavand A. The Applications of Virtual Reality Technology in Medical Groups Teaching. J Adv Med Educ Prof. 2018;6(3):123-129.

[247] Hooper J *et. al* 2019. Virtual Reality Consortium. Virtual Reality Simulation Facilitates Resident Training in Total Hip Arthroplasty: A Randomized Controlled Trial. J Arthroplasty. 2019 Oct;34(10):2278-2283. doi: 10.1016/j.arth.2019.04.002. Epub 2019 Apr 8. PMID: 31056442.

[248] Pottle J. Virtual reality and the transformation of medical education. *Future Healthc J*. 2019;6(3):181-185. doi:10.7861/fhj.2019-0036

[249] Sattar MU, Palaniappan S, Lokman A, Hassan A, Shah N, Riaz Z. Effects of Virtual Reality training on medical students' learning motivation and competency. Pak J Med Sci. 2019;35(3):852-857. doi:10.12669/pjms.35.3.44

[250] Kyaw BM, Saxena N, Posadzki P, et al. Virtual Reality for Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration. J Med Internet Res. 2019;21(1):e12959. Published 2019 Jan 22. doi:10.2196/12959

› Retail Training

When a retail company hires a new employee, they may need that person on the sales floor as soon as possible. One way to achieve a quick onboarding experience is through the use of virtual reality (VR). This technology creates realistic workplace experiences, which allows employees to train without disrupting the workflow or customer interactions.

Companies that utilize VR for their employee education sessions save both time and resources in their retail training process. Instead of relying on senior individuals to leave the floor or spend time with new hires, businesses can place new hires into virtual environments. Aside from these benefits, other contributions of VR include:

- **Building a team**: Situations, where collaboration is necessary between employees, can be created using VR technology. These scenarios can either be high stress or time-sensitive to allow team members to experience and practice for these instances.
- **Shortening Onboarding**: Retail employees can have a high turnover rate, especially during the holiday season. For stores that require short team employees or quick training sessions, VR provides these businesses with a chance to teach these individuals without using less resources and time.
- **Sharing information**: Top-performing employees cannot always be pulled from the floor to train new hires. However, AI or virtual trainers can perform these duties. Virtual trainers can share information easily with trainees as well as documenting their exact actions or how well they performed a task.
- **Testing changes to current practices**: VR lets employees try out new processes in a safe environment without involving real-life customers in the retail training process. The interactive aspect of VR builds engaging experiences for employees and possibly the chance to create empathy in tricky situations.
- **Preparing for the worst**: Robberies, natural disasters, and angry customers are not situations that usually happen during an employee's training. VR, however, can help prepare individuals for these scenarios without placing them into dangerous situations. The knowledge and practice will be useful should any of these incidents occur.

The leading adopter of VR for employee training was **Walmart (US)[251].** The company uses VR to replicate different situation that might not usually happen when a person is training on the floor, for instance Black Friday. In 2017, the company used their VR headsets to let new hires learn how to deal with difficult situations such as crowd control and confrontations, **reducing up to 80% in training time[252]**.

Another example is IKEA, which implemented VR training for the Human Resources team, especially for exploring the integration of VR in their Talent development approach in collaboration with **Virsabi (DK)[253]**. Also, the technology is being used for the onboarding process of ne IKEA co-workers.

[251] VIAR 360, 2020. Companies Using Virtual Reality for Employee Training. Available from: https://www.viar360.com/companies-using-virtual-reality-employee-training/

[252] Business Insider, 2017. Enterprise Virtual Reality Training Services to Generate US$6.3 billion in 2022. Market Insider. Nov, 21, 2017. Available from: https://markets.businessinsider.com/news/stocks/enterprise-virtual-reality-training-services-to-generate-us-6-3-billion-in-2022-1008940801

[253] Virsabi, 2020. https://virsabi.com/

The VR-experience was delivered in 18 different languages. It met cultural differences and different learning methods and at the same time, it sought to unite the co-workers to feel as a part of a big global family that is keen on helping each co-worker in reaching the next level. From a business perspective IKEA also wished to use VR technologies to develop their co-worker's capabilities in an efficient and cost-effective manner.

› Other Applications of Immersive Training technologies

British Petroleum, BP, (UK)[254] uses virtual reality to train their employees in start-up and emergency exit procedures at its oil refinery in Hull, England. Employees were able to learn from mistakes in the virtual world and thus reduce the probability of making the same error in the real world, an error that could ultimately cost someone's life.

The wales-based Igloo Vision (UK)[255] was commissioned to recreate the actual working environment in great detail, in order to inform the employees about all the possible threats in the facility without the actual danger. A rigorous training beforehand in a virtual environment could save lives at the actual refinery.

Similarly, **ExxonMobil (USA)**[256] is using VR for safety training. Immersive simulations can transport VR users onto the loading dock of a liquefied natural gas tanker, where they spend a day on the job assessing and reacting to different scenarios. The experiences allow employees to hone their instincts, catch their mistakes, and make instant decisions so that they're better equipped to work smarter and safer.

Serving this purpose **EON Reality (US-SE)**[257]**,** develops and commercialises immersive solutions for training across several industries such as energy, transportation, construction or medical field.

Another example is the case of **United Parcel Service (UPS)**[258]. Recently, the company announced the expansion of its driver training to include virtual reality (VR) headsets at its UPS Integrad training facilities in Cologne, Germany, and Burton upon Trent, UK. The VR headsets simulate the experience of driving on German and UK city streets while teaching a typical road hazards.

Other examples of VR safety training and prevention applications include **airplane traffic control training** as the EU-Funded **Retina**[259] **or AD4**[260] projects.

Virtual Reality has also been used for the health and safety management within the architecture, engineering and construction industry, which is often unstructured, disconnected and complicated. For instance, **3D Repo (UK)**[261] in collaboration with Innovate UK has developed the SafetiBase platform for making construction sites safer by immersing workers in dangerous situations and teaching them how to avoid and mitigate such risks.

[254] British Petroleum, 2020. Perfecting skills before we use them. Available from: https://www.bp.com/en_us/united-states/home/who-we-are/our-commitment/safety/perfecting-skills-before-we-use-them.html
[255] Igloo Vision, 2020. https://www.igloovision.com/
[256] Exxon Mobile, 2020. Safety Training Gets a Dose of Virtual Reality. Enegy Factor by ExxonMobil. Apr. 30, 2019. Available from: https://energyfactor.exxonmobil.com/science-technology/digital-garage-safety-training/
[257] EON Reality, 2020. https://eonreality.com/
[258] UPS, 2019. UPS Enhances Driver Safety Training With Virtual Reality Available from: https://www.pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1560261872163-765
[259] RETINA, 2020. Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provison. Available from: http://www.retina-atm.eu/
[260] Cordis, 2020. AD4: 4D Virtual Airspace Management System. Available from: https://cordis.europa.eu/project/id/12328/es
[261] 3DRepo, 2020. https://3drepo.com/

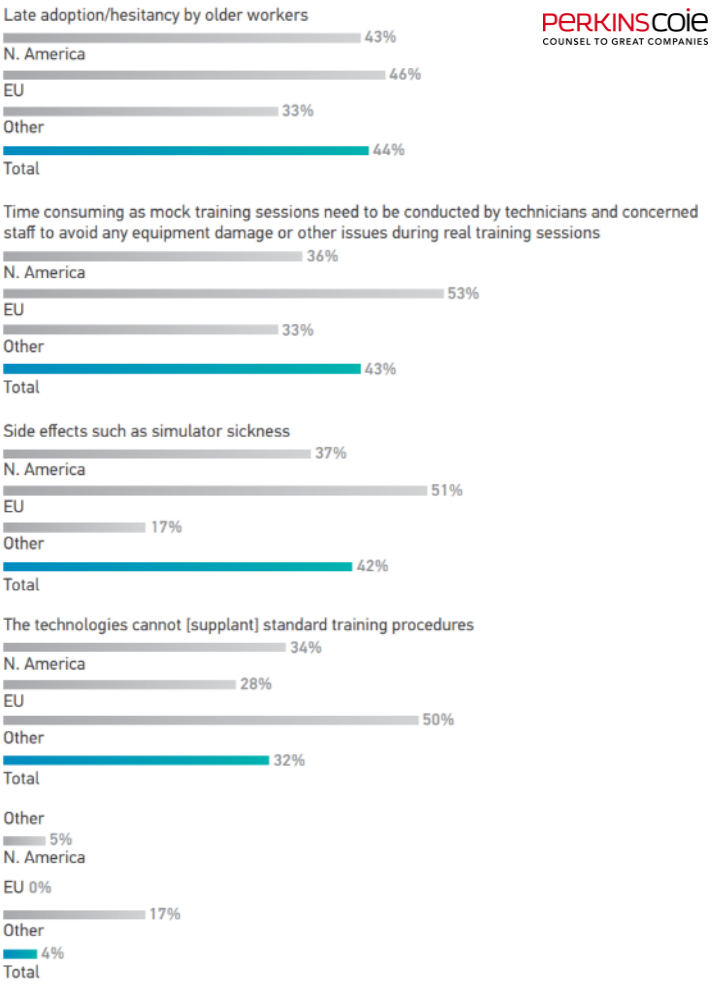
As with any other sector, the use of VR in safety and corporate training face several challenges that need to be successfully addressed in the forthcoming years in order to ensure viable adoption of the technology.

In this regard, there are three equally relevant challenges to beware off according to industry experts surveyed by Perkins Coie's 2020 Industry report; 1) Late adoption or hesitancy by older workers to embrace VR in training; 2) ; the need for technicians to conduct such trainings and the associated resources in terms of time and cost; and 3) the potential side effects derived from VR prolonged use such as motion or simulator sickness.

Also is important to mention that there is a 32% of respondents that state VR training cannot supplant standard training procedures.

Interestingly, the European region is the more reluctant in this concern with up to 50% of industry experts questioning whether VR may be a more cost-effective training method.

Figure 79 | Which of the Following challenges do users of VR/AR technologies face relating to safety training situations? - Perkins Coie's 2019 Survey

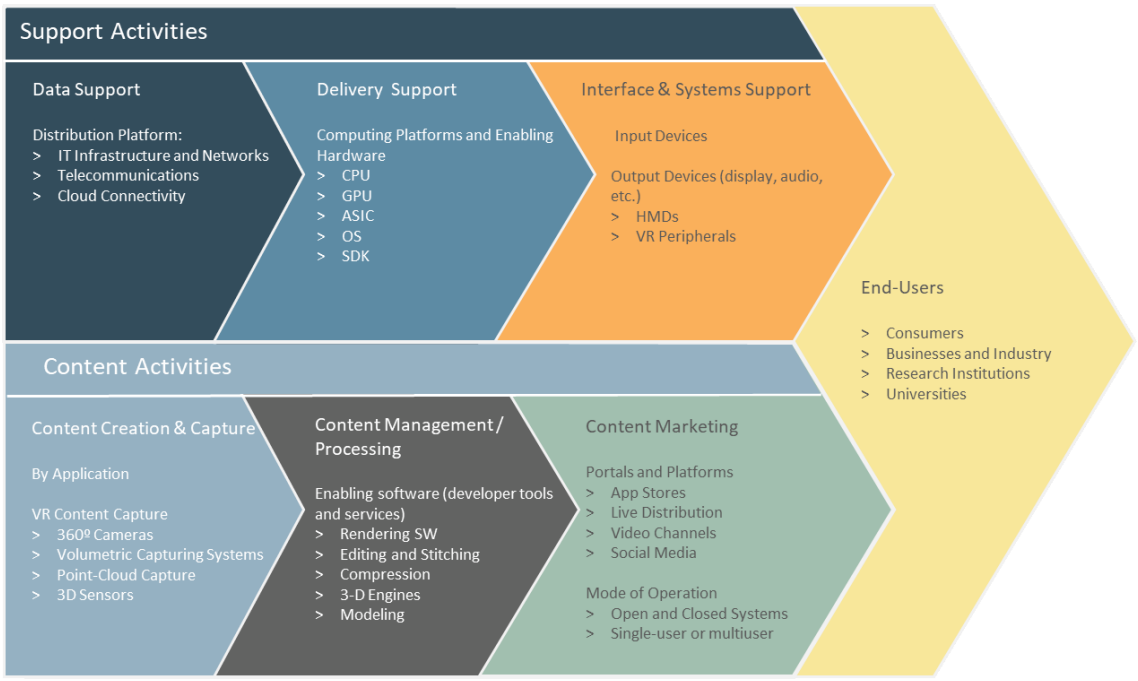


5. AR/VR VALUE CHAIN AND BUSINESS MODELS

5.1. The AR/VR Value Chain

The VR/AR industry is incredibly complex and diverse. It is obvious that developers of such technology, content and headset manufacturers would be included within the industry, but businesses should also be mindful of adjacent products and services. Given the dynamic and fast-paced nature of the VR/AR industry, with constant innovations and technological advances, **the VR ecosystem itself is still in flux**. Therefore, the value activities that are pursued by different actors carrying out these roles may evolve as new possibilities emerge. Additionally, owing in part to ever-increasing globalization, the activities that comprise the VR value chain frequently depend on complex networks of individual actors on a global scale.

Several value chains have been defined.[262,263] At a high level, VR/AR value chain is comprised of six core processes that can be divided into two main areas: **(1) Content Activities**, which should be considered primary activities, and **(2) Support Activities**, which refer to digital infrastructures and hardware.



Adapted from: de Regt, A. et al. 2020.

Figure 80 | The VR/AR Value Chain

technologies that add value in providing VR experiences to the end user.

› **Content Activities**

As defined by Kings Collage Value Chain model developed by de Regt, A. *et al.* 2020, the content segment consists of three core processes: content creation and capture, content management and processing and content marketing. Those content activities necessarily run in parallel to the support activities, given that these two forms a feedback loop and are needed to generate value to the end user. Each of these processes are described next:

[262] L.E.K Consulting, 2019. Capitalizing on the Opportunities in VR/AR. Executive Insights, Volume XXI, Issue 8. Available from: https://www.lek.com/sites/default/files/insights/pdf-attachments/2108-English_Capitalizing-Opportunities-VR-AR_1.pdf

[263] de Regt, A., Barnes, S. and Plangger, K., 2020. The virtual reality value chain. *Business Horizons*, 63(6), pp.737-748.

a. Content Creation and Capture

Firms pursuing these processes add value through generating original VR content through two complementary techniques: **creation and capture**. **Content creation** encompasses the digital production of VR materials by making use of programming and animation techniques to develop the content. **Content capture** relates to recording real-life photo or video content.

I. Content Capture

To capture VR content, various technologies and techniques are implemented most of which rely on **volumetric video capturing**, a technique that captures three-dimensional space. Different volumetric capturing systems exist such as 360-video Recording, real-time 4D-Cameras, etc. An in-depth analysis of capture systems is available in section 3.2 of Deliverable 5.2.

The volumetric video market is expected to grow from $578.3 million in 2018 to $2.78 billion by 2023[264]. A recent 2020 report by Research and Markets[265] not only confirms this trend but also expects to grow at a faster pace, from the $1.4 billion market size of 2020 to the $5.8 billion by 2025, at CAGR of +32.8% for the forecasted period.

Different workflows or techniques to generate volumetric video are currently available. These are not mutually exclusive and are used effectively in combination[266].

First, the **Mesh-based** approach is a geometric data structure that allows the representation of surface subdivisions by a set of polygons. Meshes are particularly used in computer graphics, to represent surfaces, or in modelling, to discretize a continuous or implicit surface. A mesh is made up of vertices (or vertex), connected by edges making faces (or facets) of a polygonal shape. When all faces are triangles, we speak of triangular meshing. These are the most common in Reality Capture workflows.

On the other hand, **Point-based (also known as Point-Clouds)** refers to a set of data points in a three-dimensional coordinate system, which often represent the envelope of an object. **3D-Sensors** devices obtain the external surface in its three dimensions to generate the point cloud.

These are often obtained through photogrammetry, LiDAR, depth sensing and more recently deep learning. Each technique holds several specificities influencing the quality and completeness of the data. Regardless of the technique point-cloud provide simple yet efficient 3D data representations, highlighting its **fast rendering and exact representations** which make of Point-Cloud based solutions particularly **optimal for real-time volumetric VR applications.**

[264] Volumetric Video Market by Volumetric Capture, Application , & Content Delivery and Region - Global Forecast to 2025, Markets And Markets: https://www.marketsandmarkets.com/Market-Reports/volumetric-video-market-259585041.html
[265] Research and Markets, 2020. Volumetric Video Market – Global Forecasts to 2025. February 2020.
[266] Poux, F., 2020. How to represent 3D Data?. Towards Data Science. May 11. Available from: https://towardsdatascience.com/how-to-represent-3d-data-66a0f6376afb

However, this results in higher requirements regarding storage space, making them too large to stream directly over bandwidth limited networks, and requires compression and encoding (see section 3.3 from Deliverable 5.2).

II. Content Creation

Regardless of the techniques implemented, developing VR content is fundamentally different from editing linear narratives, especially for room-scale VR. In a VR context, the user is in charge and, as in real life, can view the setting from different vantage points that are constantly changing. This enhanced level of user participation requires developers to design an experience while keeping in mind reaction speed, speed of movement, and scale relative to the user's size.

Two distinct groups are involved in the production of VR content: professional and amateur providers. Professional providers are companies such as studios or developers mainly geared to providing quality content for healthcare, engineering, training, education, entertainment or gaming purposes. On the other hand, amateur providers are comprised of consumers who gather to create VR content. Enhanced accessibility to and affordability of capturing devices has made it easier for amateurs to contribute to the VR content base. Traditionally, amateur content has focused on gaming and entertainment applications of the technology.

Overall, content creation and capture provide active business in the field with a broad range of opportunities, especially as VR adoption widens across both businesses and particular consumers.

b. Content Management and Processing

Software that enables the conversion of digital content and raw 360º footage into usable formats is crucial to ready the content for distribution and mainstream usage. Companies provide value by reconfiguring and performing post-production editing of the VR content.

Depending on the tasks performed and the technological tools and services used, these processes can be divided into a few subclassifications. Content rendering, content stitching and editing, content compression and encoding all pertain to the visual content.

- **Rendering** refers to the process of generating photorealistic images by means of computing power based on either 2-D images or 3-D images. Additionally, **3D engines** and other modelling software provide the architecture or frameworks for creating computer-generated imagery. Currently, Unity and Unreal Engine are the most common engines for immersive VR.

  Given the immersive nature of VR, one of the greatest challenges is to reduce rendering workload. Dynamic Foveated rendering (e.g. Tobii (SE)[267] or SmartEye (SE)[268]), which reduces image quality outside the peripheral vision based on eye-

[267] Tobii Technologies, 2020. https://www.tobii.com/
[268] SmartEye, SE. https://smarteye.se/

tracking, is perhaps the latest solution to accomplish that purpose[269]. This is effectively, the ability to only render a portion of the scene that a user is looking at.

- **Stitching** and editing software enable developers to edit raw 360º video and to stitch together footage from multiple cameras. Example of VR editing, and stitching software include Veer VR (China)[270] or VideoStitch (FR)[271].
- **Compression** is also key for VR content since it enables to reduce the file sizes. This most helpful in the case of real-time VR and even more relevant in the case of Social VR, with streaming of high-quality VR content. For instance, as previously mentioned, real-time point-cloud based capturing is great for photorealistic capturing of images or people, but the volumetric files are too big to be streamed between the different users of the room (see section 3.3.1 from Deliverable 5.2 for more information).

c. Content Marketing

Firms involved in this step of the value chain act as market makers by providing user access through downloading or streaming services. Their primary tasks are to host, market, sell, and distribute VR content through various portals and platforms. Hence, VR companies, publishers and developers generate value by taking on the role of vendor in either the B2B or B2C (or other B2B2C or B2G) VR market channel.

As defined by de Regt, A. et al. 2020, the different mobile, console, or PC portals and platforms can be classified as either open or closed systems. In open systems, users have unrestricted access to applications and content, whereas in closed systems the service provider restricts such access.

Within the VR market, platforms can be classified across three dimensions: **(1) hardware, (2) content, and (3) price**. With regards to **hardware**, platforms can be classified whether they can be accessed by various VR systems (open) at the one-end, and closed VR ecosystems that are tied to specific headsets (e.g. Oculus). Regarding **content**, platforms permitting user-generated content are regarded as open platforms, whereas platforms providing only premium content generated by studios and developers are considered closed platforms. Hybrid platforms also exists in which there is open and closed content. In regard to **price**, there are free-to-access platforms being considered as open, or, by the contrary, pay-per-content or fee-based platforms.

The market can also be divided into single-user and multiuser experiences. Currently, the majority of VR experiences are created by professional designers and are intended largely for single users. However, there is a going trend for Social VR platforms which enable for multiuser connections.

› Support Activities

In looking at VR support activities, digital infrastructures and services are of critical importance. The main reasons for this are that many VR features require a fast internet

[269] Forbes, 2020. How The Measurement Of Dynamic Foveated Rendering Can Benefit VR And AR. Anshel Sag, Jun 23, 2020. Available from: https://www.forbes.com/sites/moorinsights/2020/06/23/how-the-measurement-of-dynamic-foveated-rendering-can-benefit-vr-and-ar/?sh=4afad7c12785

[270] Veer VR, China. https://veer.tv/

[271] VideoStitch, FR. https://www.video-stitch.com/

connection to work, both in terms of large bandwidth and speed, given the vast majority of the content is offered digitally and needs to be either downloaded or streamed. The support activities of the value chain can be further divided into three categories: data, delivery and interface and systems support.

a. Data Support

Firms engaged in data support add value by providing the processing power and network infrastructure necessary to distribute VR content to end users. Content distribution networks are a crucial layer on the internet as a whole and play a similarly important role in the VR ecosystem.

Data support includes network technologies for distribution of data designed to transport large volumes of VR datasets while overcoming issues related to latency, quality and fidelity and reach. This not only reduces to large bandwidth networks but also to embracing new technologies such as 5G that enable bidirectional communication, interoperability, and widespread adoption of the technology.

The major benefits of 5G to VR, as well as other industries, is that connectivity will be more secure and stable. At present, VR and AR apps can be interrupted by network performance, which massively affects the experience. 5G would mean that networks can operate with, as well as process many more devices at the same time.

Additionally, such investments in 5G and high-speed networks support real-time rendering of VR content streamed from cloud computing services. Altogether, will not only result in better experiences but also will enable multiuser real-time VR experiences, such as Social VR or Work collaboration applications.

b. Delivery Support

Companies that provide delivery support systems facilitate user interaction with digital content and enable the VR experience to run smoothly. Regardless of the end-use, VR technologies require important, dedicated, and specialized hardware components, that meets the minimal requirements such as enough RAM, the central processing unit (CPU) and the graphics processing unit (GPU), all vital for delivering good VR performance.

Among of all, the most important and critical is Central Processing Unit – CPU. As with most computing systems, the CPU performs the basic operations. For VR, this means processing data regarding the simulated world and data from user input. The CPU frequency is especially important for VR development.

An important difference exists between tethered or standalone VR devices and even smartphone AR, and that is where the CPU is located. In the case of tethered VR solutions, the VR processing is run on a PC. On the other hand, standalone VR devices need to run all the digital processing within the headset. Needless to say, important differences exist in terms of space, heat reduction, etc. between the two and, as a result, specifically designed and optimised CPU can be found on the market for each solution.

For tethered solutions which require a PC to run the VR experience, we have identified two important stakeholders: Intel and Advanced Micro Devices (AMD). The tech giant AMD has recently released a set of VR ready processors and VR graphics card to power the demanding VR workloads. This is the case of AMD Ryzen 7 1800x CPU, high-quality

processor designed for high-performance video encoding, content streaming and gaming at 4k resolution.

On the other hand, the world-renowned Intel also offers multiple CPU that are VR ready. The top-notch Intel Core i9-9980XE leads the way being the fastest high-end desktop processor available on the market.

Regarding standalone VR Devices CPU, Qualcomm stands-out as one of the most important stakeholders, if not, currently the most important one. Qualcomm is a big stakeholder in the HMD market; they are not only headsets manufacturers but also provide the main chipset to run them.

The newest chip, Snapdragon XR2[272], features a lot: 5G-enabled extended reality system, which should allow for experiences that rely on low latency, super-fast data connections. The Snapdragon XR2 offers double the CPU and GPU performance of its predecessors allowing for 8K, 360-degree video playback and supporting display panels as pixel-dense as 3K by 3K per eye running at 90 frames per second.

The GPU is specialized to perform display functions and renders the images, animations, and video displayed in the VR context. While the CPU and GPU can perform various functions, application-specific integrated circuits (ASIC) chips are designed to perform specific repeated functions effectively, with the best performance and lowest energy consumption. With regard to VR, ASIC implementations can range from custom rendering of images to sound conversion.

And in addition to hardware, VR operating systems (i.e., the platforms that serve as foundations on which VR applications run) are growing more important as means to gain a competitive advantage.

c. Interface and Systems Support

Companies working in interfaces and systems support develop the technological components of VR delivery systems that enable users to interact with digital content. VR systems can be broadly classified as either **non-immersive** (e.g. desktop VR) or **immersive** (e.g. HMDs systems). Non-immersive systems generally only present monoscopic VR content.

Technologically, the devices used in the virtual environments play an important role in the creation of successful virtual experiences. According to the literature, can be distinguished **input and output devices[273,274]**.

Input devices are the ones that allow the user to communicate with the virtual environment, which can range from a simple joystick or keyboard to a glove allowing capturing finger movements or a tracker able to capture postures. More in detail, keyboard, mouse, trackball, and joystick represent the desktop input devices easy to use, which allow the user to launch continuous and discrete commands or movements to the environment. Other input devices can be represented by tracking devices as bend-

[272] Qualcomm, 2020. https://www.qualcomm.com/products/snapdragon-xr2-5g-platform
[273] Burdea, G., Richard, P., and Coiffet, P. (1996). Multimodal virtual reality: input-output devices, system integration, and human factors. *Int. J. Hum. Compu. Interact.* 8, 5–24. doi: 10.1080/10447319609526138
[274] Burdea, G. C., and Coiffet, P. (2003). *Virtual Reality Technology*, Vol. 1, Hoboken, NJ: John Wiley & Sons.

sensing gloves that capture hand movements, postures and gestures, or pinch gloves that detect the fingers movements, and trackers able to follow the user's movements in the physical world and translate them in the virtual environment (e.g., as shownd in the CWI/SenseGlove awarded demo "a social VR clinic for knee arthritis patients with haptics" in June 2020[275]).

On the contrary, the **output devices** allow the user to see, hear, smell, or touch everything that happens in the virtual environment. As mentioned above, among the visual devices can be found a wide range of possibilities, from the simplest or least immersive (monitor of a computer) to the most immersive one such as VR glasses or helmets or HMD or CAVE systems.

Furthermore, auditory, speakers, as well as haptic output devices are able to stimulate body senses providing a more real virtual experience. For example, haptic devices can stimulate the touch feeling and force models in the user.

› Users

The wide range of applications of VR technology across different global market sectors and industries is contributing to a broad spectrum of end users. To help differentiate between the uses of VR technology, we identify four distinct end-user segments: **(1) consumers, (2) companies and industry, (3) research institutions and universities, and other stakeholders.**

a. Consumers

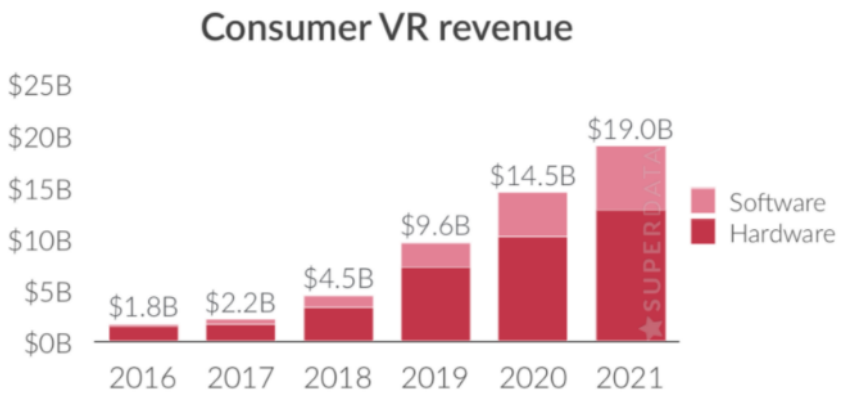
Most of the revenue in the consumer VR market is generated through hardware sales. Although this will likely remain the case for several years, eventually consumer VR software revenue should surpass hardware revenue as the installed base of headsets expands. Since consumers mainly use VR technology for leisure and entertainment, gaming and video entertainment are at the forefront of this revolution. Two main catalysts could encourage broader consumer adoption of VR hardware: the decreasing price of premium consumer headsets and the increasing availability of high-quality VR content.

SuperData[276] predicts that hardware will represent, in 2020, for approximately one third of the total $14.4 billion consumer VR Market. However, it is expected that software/services will grow at a faster pace than software in the forthcoming years slowly concentrating an increasing share of the market.

[275] https://www.youtube.com/watch?v=c89E98SQRqk

[276] SuperData, 2018. State of the XR Market. February 2018. As published in: GameIndustry.biz by Haydn Taylor. Availabel from: https://www.gamesindustry.biz/articles/2018-05-25-revenue-expected-to-double-this-year-for-augmented-and-mixed-reality

Figure 81 |Consumer VR Revenue by type, 2016-2021.



b. Businesses and Industry

While business adoption of new technologies sometimes lags behind consumer demand, for the VR market they appear to be moving at a similar pace, as a steadily increasing number of firms are expressing interest in commercial VR implementations. As it has been described in previous sections, many businesses are finding VR helpful in the manufacturing process, in product design and prototyping, and for employee training or work collaboration.

c. Research Institutions and Universities

Although at present a relatively small number of research labs use VR technology, VR technology will likely become a standard lab tool within the next 5 years[277].

Within some government research institutions, VR is a key application in the display of complex 3-D structures and the visualization of large data sets. Visualization of information in a 360º context can make it easier to detect hidden patterns and correlations, and it could thus help scientists, researchers, and analysts spot meaningful data that machines cannot.

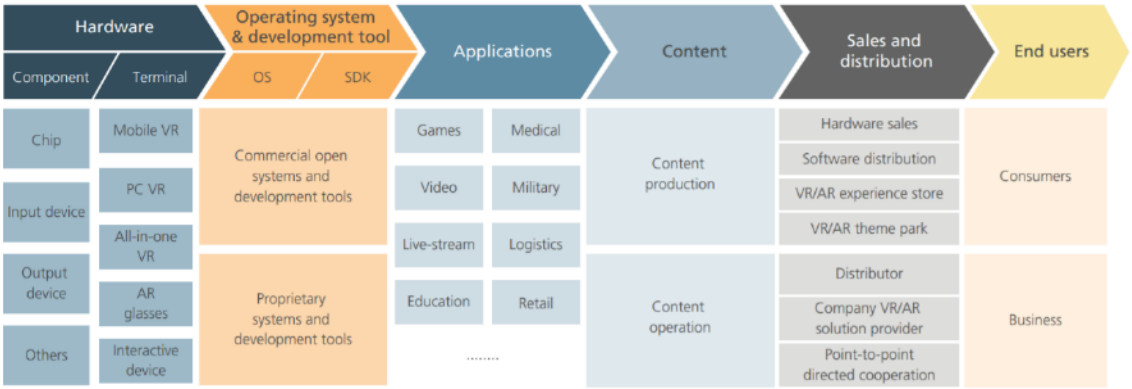
While the consumer, retail, and manufacturing sectors are spearheading investment in VR technology, VR is expected to transform colleges and universities by improving student and staff engagement and enhancing the efficacy of learning. This transformation will result in short-term, and potentially long-term, business opportunities because the majority of these institutions will outsource this work owing to a lack of expertise.

In conclusion, VR value chain is well defined and stablished in which two clearly separate streams have been identified, content activities and support activities. However, this parallel model of the value chain can be transformed in a more traditional streamlined value chain as the example provided by L.E.K[278].

[277] Nature, 2018. Virtual-reality applications give science a new dimension. David Matthews. Available from: https://www.nature.com/articles/d41586-018-04997-2

[278] L.E.K Consulting, 2019. Capitalizing on the Opportunities in VR/AR. Executive Insights, Volume XXI, Issue 8. Available from: https://www.lek.com/sites/default/files/insights/pdf-attachments/2108-English_Capitalizing-Opportunities-VR-AR_1.pdf

Figure 82 |Linear VR Value Chain

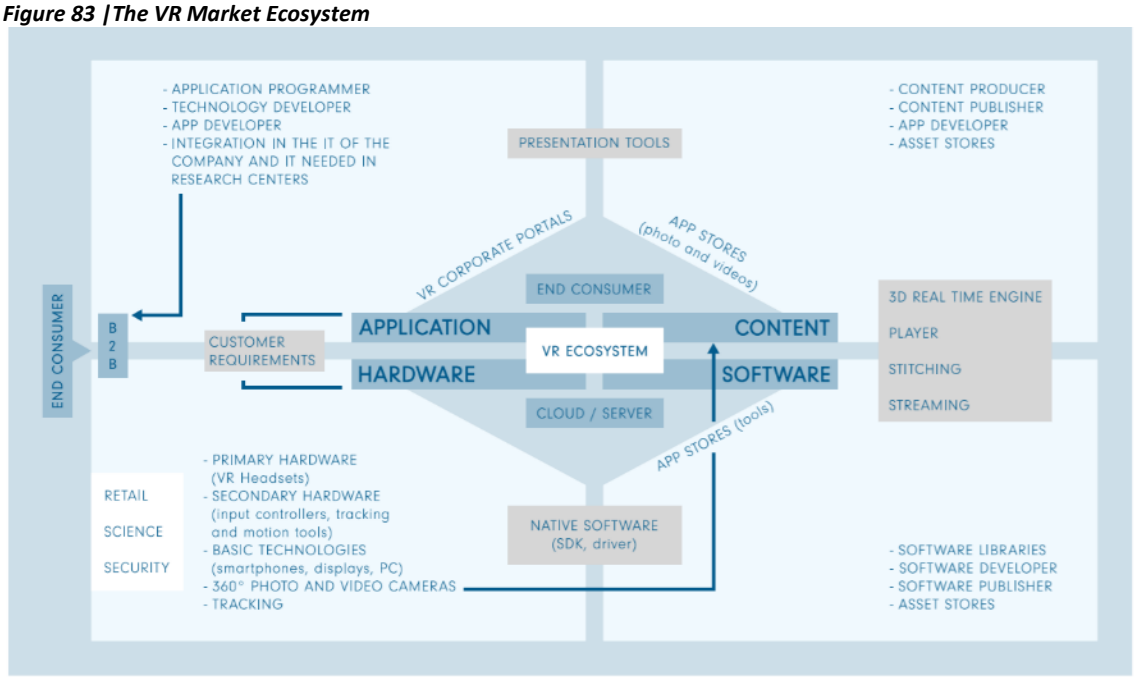


Adapted from: L.E.K. Consutling, 2019.

In the case of the linear VR value chain the same value chain segments can be identified but in this case are organized separately. Hardware components stand at the base of the value chain as necessary components for any VR content to be either produced or experienced. Following the necessary hardware, the operating systems and development tools for content creation and capture are found, which are necessary for designing and generating VR content for any given application. Such generated content will then need to be sold and distributed to the end users either if it is software or hardware (e.g., HMDs).

However, the reality of the VR ecosystem main not resemble that of the parallel value chain suggested by de Regt, A. et al. 2020 nor L.E.K Consulting. Instead, the VR ecosystem forms a complex network of interactions between all the different key stakeholders along the value chain and the end-users resembling that of an interconnected loop.

Figure 83 |The VR Market Ecosystem



5.2. VRTogether Added Value

VRTogether's **value proposition** is to offer a **modular end-to-end photorealistic holographic VR pipeline for social interactions and joint consumption of different media contents to be experienced simultaneously, in real-time by multiple users represented in 4 dimensions.**

VRTogether aims at being the new reference in terms of realistic VR conferencing software in domestic and business market by providing photorealistic rendering of end- users. The first step is to develop and integrate cost-effective production and delivery techniques to provide photorealistic experiences.

One of the key innovations targeted by the project is that the Native VRTogether Platform allows **real time** capturing of **volumetric video**. The VRTogether solution has been designed in a way that different set ups can be used to deliver social VR experiences enabling real time user representation:

- On one side, a **single camera solution** has been developed which significantly reduce costs of depth capturing hardware and volumetric data handling.
- On the other side, **more complex capture setups** have been developed managing to achieve the expected quality while keeping the infrastructure investment under acceptable costs.

As defined in **Deliverable D5.6**, the Minimum Viable Product (MVP) of VRTogether can be considered as a **simple, modular end-to-end VR pipeline for social interactions and joint consumption of different media contents in real-time where users and the environment are represented in 3D.**

Considering the strict Minimum Viable Product, the Native VRTogether Platform is characterized by the following key features:

- ✓ **Social connection and remote interaction** of users
- ✓ **Photorealism** – The Native VRTogether Platform delivers 3D photorealistic human digitization and rendering thus replacing virtual avatars used by existing social VR platforms on the market. Further developments are needed the pass from a currently recognizable-realistic state to a high-quality 3D representation of users.
- ✓ **Real-time** – The Native VRT Platform is the first dynamic Point Cloud pipeline for real-time use cases (i.e. enabling real-time communication amongst users).
- ✓ **Standardised, modular and extensible system** – The system is standardised (e.g. DASH, Point Cloud codec) and has been designed for the easy replacement or extension of modules (e.g. change of the capturing system or the delivery technology). It is also future proof as new embedded one-single camera system that is easy to use install and to use.
- ✓ **Seamless distribution of different media contents in a VR environment**
- ✓ **Adaptability** – The system has been designed for allowing for optimisation of the experience depending on the ongoing conditions (e.g. the codec allows for different levels of details or different parts of the Point **Cloud can be chosen depending on the viewport of the viewer)45.**

This positions VRTogether in a unique advantage situation given that the MVP here considered covers a **diverse and vertical approach** of all the VR value chain, from support to content activities, which lowers its dependence on third parties and clearly differentiates the technology from other competitors.

5.3. Identified Business Models

As with any other new big technological paradigm, business models for VR/AR solutions are difficult to identify and classify. In fact, given that VR/AR is considered as one of the fourth major platform shifts (after PC, web, and mobile) business models are still evolving with new ways to monetize the technology. Regardless of the formula, all business models come down to installed bases, use cases and unit economics.

To start with, one of the most important classifications of business models refers to whether the solution/platform will be used **by consumers** or, by contrast, **enterprise and professional users**.

› CONSUMERS

VR for consumers is mainly referring to applications such as games, travel experiences, short movies or adult entertainment. Upcoming products include medical and training applications or educational application. Consumers also purchase hardware such as head-mounted displays (HMD), HMDs for smartphones, 360-degree cameras etc. or specific software (for example Tilt Brush).

The different distribution channels and business models adopted to reach out to consumers can be divided according to the type of VR product:

Table 9 |Consumer VR Business Models, by product

Hardware	Direct sales	Direct sale of consumer hardware via a website	HMD, cameras
	Intermediary	Using an online or physical retailer	HMD, cameras
	"Free gift"	Offer to a phone subscription or other services	Mobile HMD
Content, apps	Direct sale	Single purchase of an app/content	Travelt, gaming
	Subscription	By paying a period fee, consumer can access an online library	Travel, education
	Freemium/demo	Basic content for free, more advanced content for a fee	Travel, gaming
	"Free"	Promotion purposes, consumer pays with attention or data	Advertising
VR experience	Pay for time	Pay for time spent enjoying experience	Cinema, arcades, VR café
	Rental	Rent VR gear with content for a period of time	VR rental
	"Free"	Promotion purposes, at fairs and public spaces	Advertising

a. Hardware

Hardware sales represent one of the most lucrative VR business models. Ignoring hardware is not an option for established leaders and new insurgents in the market. Hardware sales could be the one business model to rule them all in AR/VR, and early investment is redeemed to develop into early smart revenue.

According to Digi-Capital AR/VR Business models by 2020, hardware sales accounts for over 40% of the total revenue generated. This comes as no surprise given that for any VR content to be experienced hardware is needed for its creation (3D Cameras, Depth cameras, transmission systems, etc.) or for the consumption of the content (HMDs, PC, GPUs, etc.).

Within the consumer segment of the market hardware business models are mainly going to refer to content consumption hardware, the main market channels for which can be direct sales (B2C) or by means of an intermediary or distributor (indirect B2B2C). Despite not as common, other companies engage with customers through offering hardware components through a "free gift" offer to another service or the purchase of a smartphone, a typical model used in mobile HMDs segments.

b. Content, apps.

VR content and VR apps can also be distributed by means of direct sales in which the consumer acquires a VR app or service with a unique direct payment (e.g. VR videogame). However, it is becoming more prevalent the use of third-party app stores (e.g. Google Play, Steam, App Store, etc.) in which a small commission is charged by the owner and for in-app purchases of the digital content, known as Paymium.

On the other, in the Subscription-based business models users pay a monthly fee to access VR content and apps, and, in return, are offered new content and incentivizing features on an ongoing basis. This has become the most prevalent business models over the last couple years within the VR content ecosystem. In fact, is the preferred model of VR content related to training, education, healthcare, manufacturing, gaming, etc.

A small variation of such model is the Freemium Model, in which users pay nothing to download or access the VR content and are offered optional in-app purchases for premium features, additional content, or digital goods. The path to monetization is through engagement, and when users are given time to enjoy an app, they may be more inclined to invest in paid features.

Last, but not least, the open-access business model is also common within the industry. In this case, the VR content is offered as a completely free of charge experience but is often associated to promotional purposes or to gather data from the users, thus being very common within the commerce & advertising verticals of the market.

c. VR Experience

VR experiences, such as using VR for events fairs, location-based entertainment or for cultural purposes is usually associated to Pay-for-Time (or pay-per-use) business models in which the customer is metered or charged for a specific usage of the service. Also, given that not all end-users have the necessary equipment to experience VR in its full performance, rental of VR gear with content for a period is a common business case among the consumer segment. Also, there is the possibility that the VR Experience is offered for free at a trade fair or event, mostly for promotions purposes.

› Business or Professional VR Uses

VR for professional users includes applications and content, software, hardware, or a combination of these. As opposed to consumer, these are often niche applications in which top technological equipment is used and in which the individual cost of the solution or service is less important while the value-added is much higher. For example, in the medical field a training application for surgeons includes CGI (computer generated image) with haptic input so the surgeon can train in VR but on a real (not virtual) dummy mannequin. A professional solution can also be a high specs 360°-camera, or an external device rented to a VR production company which then uses it for its business.

For professional use distribution channels and business models we distinguish 3 main categories: **professional solutions** (end-to-end solutions), **professional content or software**, and **VR experience**.

Often products and technical solutions are not even developed with a direct revenue model in mind, but rather to "**grow and get bought**", aiming to be purchased by larger companies once the technical solution proves to be feasible.

The list below gives a brief introduction to some of the most important mechanisms:

Table 10| Corporate or Professional VR Business Models, by category

Professional solutions	Sell of IP/ rights	Sale of whole solut ion with rights to it	Industry, training, content
	Single sale	One or multiple solutions are sold, seller owns IP	HW, customised solution
	Rental models	Solution rented for a fee on a long or short-term basis	HW
	Royalties model	Resellers monetise and pay back royalties	Industry, HW
Professional content or software	Direct/licence sale	A single license or rights are sold, free or paid updates	Professional SW
	Subscription	Access to content or SW with updates for a periodic fee	Professional SW
	Freemium/demo	Basic version free, advanced for a fee	Medical, SW engine
VR experience	Pay for time	Pay for time spent enjoying experience	Cinema, arcades, VR café
	Rental	Rent VR gear with content for a period of time	VR rental
	"Free"	Promotion purposes, at fairs and public spaces	Advertising

a. Professional Solutions

Within the professional solutions, the vast majority of which involve intellectual property (IP), there are two common IP strategies: **selling and licensing**. An entity who sells/assigns all of the rights to IP will generally be treated as having "sold their interest in the IP asset in exchange to a payment or income". In contrast, when IP is "licensed", it consists of an agreement between an IP rights owner ("licensor") and someone who is authorised to use the rights ("licensee") in exchange for monetary value in the form of a fee or royalties. Thus, based on that distinction we generally identify the following professional VR business models:

◆ Sale of the IP

One of the most common business models within the professional VR arena is the **sale of the IP**. This refers to the **transfer of ownership of the IP rights** by assigning or transferring the IP to a third-party. When selling the IP, all the rights initially possessed by the IP creator are transferred, which results in having no further responsibility of that IP nor the benefit of the commercial success of the product or service concerned.

Such strategy is common among defined or bounded technologies or services. In other words, an IP asset that serves a well-defined purpose or caters a specific audience. It is for example common within industrial applications and VR technologies, in training or for content purposes.

◆ Single Sale

A small variation of the previous model is the **single sales strategy**. In this case, there is a unique transaction of an IP or solution to a third-party, but the seller keeps the IP rights. This is the case of customised solutions in which the owner of the technology develops and optimizes the asset to the requirements of the buying entity, which can only use the technology for specific and exclusive purposes. This is a common business model within the software, hardware, and content verticals of the VR market.

Licensing Model

In this model, an inventor or licensor, who could be an individual or a company, develops a unique innovation and then protects the innovation by filing a patent, copyright, or trademark. In instances such as a formula or a software solution, no protection is necessary simply because the innovation is considered a trade secret.

In the licensing model, an inventor develops an innovation and then protects that innovation (through a patent, copyright, trademark, or trade secret), and thus creates intellectual property. The inventor-owner of the intellectual property then licenses the innovation or technology to a second party who takes responsibility for commercializing the innovation. In this context, the inventor will receive compensation in three separate, yet interlinked ways:

- ✓ **Down payment (upfront):** it consists of an upfront payment the operating entity makes to purchase a certain technology or IP.
- ✓ **Milestones:** a milestone payment is a certain percentage of the fee of a project the operating entity pays over the course of a project or transfer of IP. It is often linked to the successful development of certain technologies, meeting regulations or when concentrating a certain commercial burden (market share, number of sales, etc.).
- ✓ **Royalties:** refer to the agreed payment as a percentage of gross or net revenues derived from the use of an asset or IP or a fixed price per unit sold of an item or a service.

The vehicle through which the use of the IP is transferred from the inventor to the user/licensee is called a licensing agreement and it is the basis for the licensing business model. The four most important terms of every licensing agreement are always the same. They are:

- **Exclusivity**: Licensing agreements will describe whether the agreement provides for the exclusive or non-exclusive use of the IP.
- **Purpose**: the agreement will determine how the IP may be used. For example, it is possible that the inventor will license the innovation to one licensee for consumer purposes and to another licensee for commercial purposes.
- **Geography**: licensing agreements will detail where the licensee may market and sell the product derived from the IP. The licensing agreement may provide for worldwide authority or perhaps just authority to market and sell it in one specific country or region.
- **Term**: all licensing agreements have a term. That is, all agreements have a start date and an end date. At the conclusion of the agreement, the agreement may be extended, or the licensor may enter into an entirely new agreement with a new licensee.

Within the VR context, such model is more common between IP assets that can be horizontally used. For instance, any kind of VR software, hardware or infrastructure that could be used for several purposes or end-uses.

Rental Model

Like that of the consumer segment, with the proliferation of VR into so many aspects of the daily economy and functioning of companies, the demand for VR equipment is bound to rise. Given the often-expensive acquisition, maintenance and operative costs of VR hardware it is common to externalise those costs with a third-party who rents all the necessary equipment and has the expertise to operate and maintain them.

5.4. Analysing Potential Strategy and Competitiveness Landscape

5.4.1. Competitive Advantage: SWOT Analysis

Table 10 | VRTogether SWOT Analysis

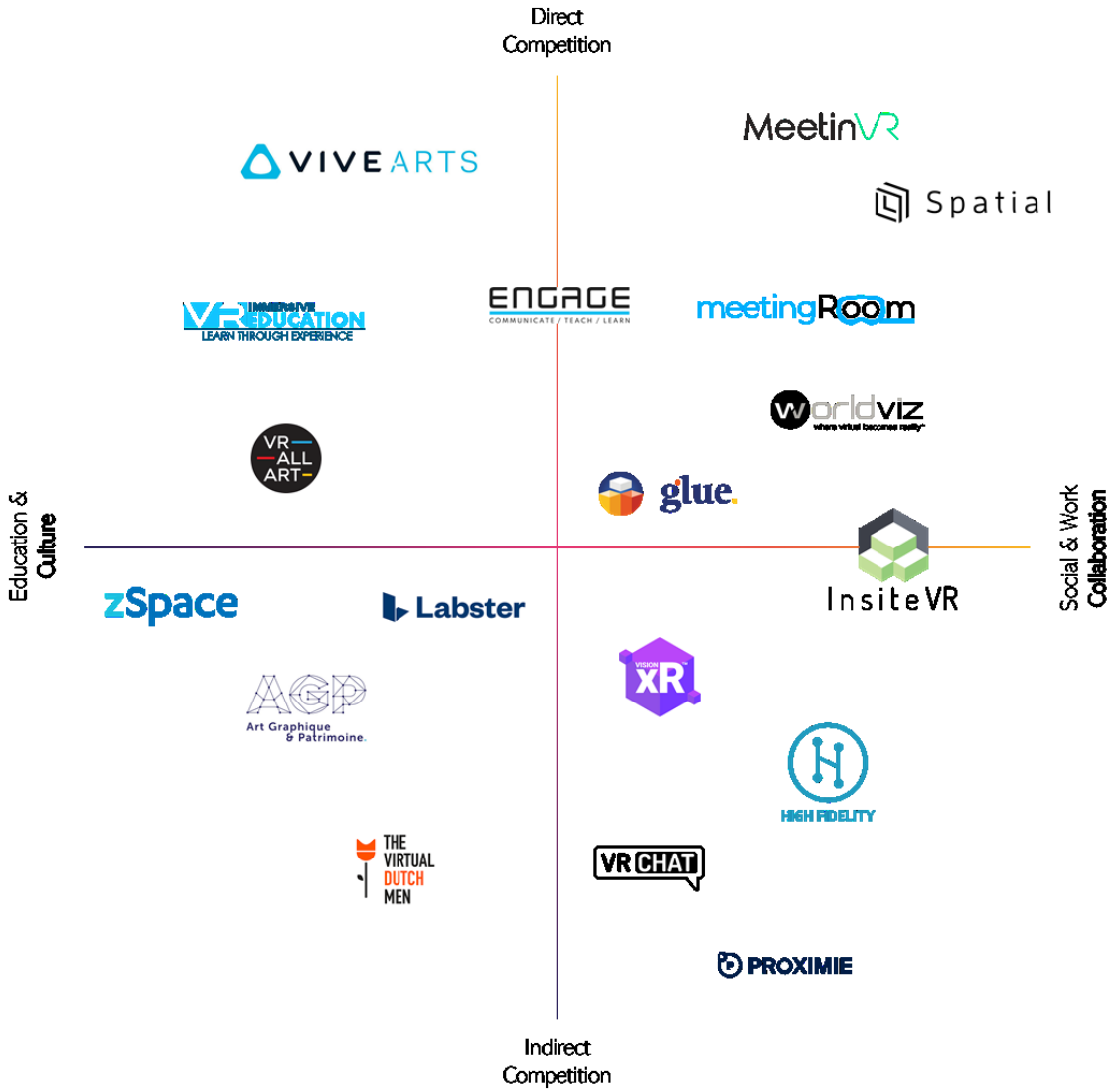
Opportunities	Threats
› **COVID-19 Effect**: upsurge of AR/VR demands as a result of increased online content consumption, social media, e-Work and e-Health platforms › **Consumers Perception Change**: VR is no longer regarded as an immature technology by consumers, it is starting to permeate new markets and uses. › **Adoption of 5G**: ultrafast and reliable connections will enable social VR to reach a wider audience while sustaining real-time, stable and high-quality conferencing and social applications. › **Edge Computing**: computation and data storage closer to the location where is needed, improves responses times and bandwidth in VR. Reduced need of powerful CPU and GPUs.	› Established HW or Tch Giants may work on their own VRT-like solution. › **COVID-19 economic impact** (economic contraction, productions shortages, supply chains disruptions, etc.). › **Risk of low or delayed adoption** of VR which will make the market and investments to stall. › Risks of psychological deviations and sickness due to VR.
Strengths	**Weaknesses**
› **Differentiation and USPs:** Photorealistic holographic technology provided by VRT is innovative and positions the project at the forefront of the market. › **Efficiency of VR for Education and Training has been proven.** › Helps people with disabilities & older people to develop their social interactions › **Enables cost savings for Companies** (fewer travels & logistics, less storage, time saving...). › **Adaptable and Modular** (can be moulded to specific customer requirements and market trends; platform-independent). › **Enables advanced personalised product/services offer.** › **Reduction of travel, carbon footprint, safety risks, etc. (remote collaboration)**	› **Lack of standalone HMDs and mobile VR** solutions, which translates to delayed adoption. › **Low adoption rates of the technology and installed base**. › Lack of risk funding/investments › Insufficient quality VR content. › Poor photorealistic self-representation (vs other emerging industrial competitors; see table 9). › Lack of interoperability in the ecosystem. › Not ready to go-to-market, further developments to be conducted, pilots to run.

5.4.2. Perceptual Mapping

Perceptual mapping is a visual representation of where a brand, product, or service stands among competitors. It is also known as positional mapping. This type of **competitive analysis framework** generally consists of two key attributes as a basis. In the case of VRTogether Perceptual Mapping, we have chosen to proceed from a bottom-down approach, in which we first depict which are the direct and indirect competitors of those market segments more relevant to the project and the technology developed: Education & Culture and Social & Work Collaboration.

Important to note that, the term direct competition is understood as those companies that are active on the same market segment and whose audience is similar as the one targeted by VRTogether. By contrast, indirect competitors are those that are also active within the same market segment but target a different audience. However, these are considered competitors given the fact that small technological developments or strategic shifts could mean those companies target the same audience. Below, it is presented the high-level perceptual mapping of VRTogether (please note technological differences have not been considered given these have extensively been reviewed throughout the document and in other deliverables).

Figure 84| VRTogether's Perceptual Mapping, by market segment and type of competition.



6. SHAPING VRTOGETHER'S FUTURE STRATEGY

6.1. VRTOGETHER'S SPECIFIC CHALLENGES TO FACILITATE GROWTH

Although a Minimum Viable Product has been defined (for mor information see Deliverable D5.6 section 1.12.2), **further developments** are needed to transform the current prototype into an innovative, marketable and sustainable product. Early adopters willing to collaborate with one or several VRTogether partners will be required to test further improvements that must be pursuit to meet user expectations and enhance the immersive experience. Such further developments shall for instance aim to

- Enhance the maturity of the real-time volumetric video capture technology
- Simplify the setting of the capture system
- Increase the quality of the photorealistic rendering of users with improved sensors and capture algorithms allowing higher resolution and more accurate volume definitions,
- Optimise the bandwidth for the transmission of the volumetric media formats by adding a 5G extension to the MVP which is expected to significantly support the widespread adoption of the VR technologies as it will reduce latency and provide more stable and secured connectivity.
- Upscale the number of users presents in the immersive experience
- Secure the transmission of streams.

As described in D5.3 (section 5.1), investments in 5G and high-speed networks will support real-time rendering of VR content streamed from cloud computing services. This will not only result in better experiences but also enable multiuser real-time VR experiences, such as Social VR or Work collaboration applications.

Furthermore, depending on the specific customers and use case scenarios targeted, **additional features** should be developed to commercialise a product that really serves as pain reliever and gain creators for those targeted customers and users, such reaching a true product-market fit. Such additional features which were discussed at different occasions (Joint Business Clinics, demos, webinar, VRDays, bilateral discussions with potential prospects or partners), could include for instance:

- An easy-to-use API
- Simplified hardware requirements (e.g. goggles required, capture system too complex)
- Flexible set-ups (the current set up/installation of the VRT solution have been assessed by JBC participants as too complicated).

Strong partnerships with large industrial leaders are were recommended, especially when discussing the development of additional functionalities and features. Keeping the focus on VRT's own strength and identify an ecosystem of strong partners leaders in the development of specific features would be key.

6.2. WAY FORWARD: RECOMMENDATIONS FOR A FUTURE EXPLOITATION STRATEGY

6.2.1. What are the top applications in the VR/AR industry?

The concept of a top or killer application that covers the whole of the VR/AR industry does not make sense given the wide range of applications across different industries. The future of VR/AR is being driven not by a single killer application for the whole market, but rather by "horizontal uses" of the technology.

Extending this exercise, those uses and applications with the most potential to generate a positive impact in relation to VRTogether's project are **(1) Training, (2) Telepresence, (3) Smart Information and (4) Entertainment.**

Given it horizontal nature, **training** mainly refers to that of employees in virtual environments, including both, hand-on and soft skills training and encompassing a wide range of vertical industries and end-use, most of them related to B2B segments. On the other hand, entertainment refers to those VR experiences consumed during a user's leisure time. These may include anything related from games, video, broadcasting, VR arcades and cultural activities. As opposed to training, this is consumer oriented.

However, those truly powerful market applications of the VR/AR industry sit in the middle, conveying both **business and consumer-oriented application from a wide-range of market vertical**, **Telepresence and Smart Information**. **Telepresence** is defined as the access to environment that users would otherwise be unable to physically visit due to financial, time, health, and other constraints. This includes live events, on-site construction progress reviews and virtual meetings. In the case of Smart Information, it relates to a real-world scenario to achieve a user's objective. This includes visual search and data visualisation.

In both cases, these two horizontal segments are often interlinked generating further synergies. This is the case of education, social interaction, or work collaboration end-uses, in which a social environment is provided to then present data in smart innovative ways improving engagement, productivity, or even reducing costs and time spent when compared to more traditional approaches. In addition, despite the wide range of audiences who could benefit from such technologies, it would be fairly easy to pivot from one end-use to another given the fact that the technology required would remain the same and requiring content to be adapted in most cases.

Therefore, it is here concluded that VRTogether should focus its exploitation strategy on any of those aforementioned horizontal applications in any given form or application.

6.2.2. Crossovers between market sectors can drive future innovation

VR/AR technology is already showing value in the enterprise space by creating more efficient or effective ways of training staff, designing physical products, and contextualising real world elements. As the technology develops, these applications will get stronger and it will become an integral operational tool for most businesses.

In this document, it has been extensively reviewed the potential applications of the technology for different market verticals. At this point, it is important to establish a well-defined use-case and audience of the technology.

VR/AR companies do not always clearly articulate the full suite of benefits involved with implementing a VR/AR solution and as a result are not selling the full value of their products. The benefit of implementing a VR/AR solution may be very clear to those in the industry but, given that a large portion of the population does not fully understand the technology, this needs to be explicitly outlined and ideally demonstrated first-hand.

In this context, VRTogether provides the most value to those applications, market segments, and by extension, end-users seeking to remotely collaborate, in real-time with a powerful virtual technology that allows for realistic representation of the participants providing a sense of connection and of being present.

In the light of such premise, those sectors have been identified as the most prominent in regard to VRtogether's value preposition and focus are Education & Training, Healthcare, Engineering & Manufacturing, Live Entertainment verticals, and Work Collaboration and Training horizontal segments.

First, building on the impact of the COVID-19 crisis on both the education and the cultural and creative sectors, strategic complementarities can be developed. Both sectors experienced accelerated digitalisation, which brings new opportunities for local and regional development but also risks of exacerbating inequalities without accompanying measures. Such accompanying measures include, for example, the development of methodologies and technological solutions for distance and distributed learning with digitally mediated access to cultural resources and experiences.

The lockdown and social distancing measures have also made evident the importance of arts and culture for people's mental well-being – and possibly, through the increasingly documented psychosomatic effects of cultural access, also health. This recognition provides a new opportunity to capitalise on the role of arts and culture in the prevention and treatment of illness across the lifespan, contributing to solutions for health and welfare systems, such as through reductions in hospitalisation or medication rates.

However, healthcare applications are challenging by nature to implement. These require extensive investigation on health benefits and risks as well as requiring thorough clinical analysis. Also, one of the biggest constraint for VRTogether to address the healthcare market would be the lack of experience from partners within the medical field. Also, healthcare VR solutions require long lead times and often involve long-term ROIs. Thus, despite being a good

market-fit in terms of market potential, we advise to not focus on health-related applications in the short-term.

Likewise, technical VR engineering & manufacturing applications stand far from the focus of the VRTogether value preposition. Such applications are often niche and require a level of expertise and technical knowledge within a specific field that would be not optimal in the case of VRTogether. However, like healthcare, those crossovers between engineering & manufacturing and work collaboration, holoconferencing or even social interaction could result in numerous synergies and should not be discarded, at least in the mid-term.

In regard to live entertainment and broadcasting, major hurdles need to be surpassed before representing a valid market segment. First and foremost, adoption of VR hardware among end-consumers is still lagging behind which hinders the development of live entertainment VR business models. Also, technical requirements such as super-fast bandwidth connections and powerful computing systems that can handle thousands or even millions of VR experiences simultaneously and in real-time it is still something of the future. However, despite it is here advise not to focus on such vertical it is definitely a market segment to monitor in the short-term, so when technology and consumers are ready rapidly capitalise the market.

Overall, the key takeaway is to establish crossovers between the different vertical markets embracing those applications related to not one but all industries, such as telepresence, work collaboration, training and social interaction. That is in fact in line with the previous recommendation, which is to focus on horizontal market segments, for which the technology is ready, and provide small technical and content updates to adapt the solution to any required or specific need of the client regardless of the market segment.

6.2.3. COVID-19 as an Accelerator of VR/AR

The COVID-19 crisis has affected societies and economies around the world and will permanently reshape the world as it continues to develop. While the consequences of the crisis amplify existing risks and create new ones, change on this scale also creates new opportunities to manage challenges.

One such opportunity has undoubtedly been that of digital adoption. The increased use of technology, for virtually everything and accelerated by the impact of the pandemic, has created new digital habits. Companies must adapt by implementing the changes and transforming themselves digitally to meet the new expectations that are emerging.

This Covid-19 crisis has made it clear that technology can be an important pillar for the survival of many companies, playing a great role to the extent that digitally transformed companies are those that have best survived this crisis, being able to continue their activity or mitigate the impact.

In just a few months the Covid-19 has accelerated the digital technologies that have been there for a long time, but which until now many companies did not even know existed. The virtual is replacing the physical everywhere: medical centres, hospitals, offices of large and small businesses, meeting places and entertainment, etc.

Many companies have seen with their own eyes how technology was the only way for their company to survive and stay afloat. Companies that before the pandemic refused to use this technology, with the Covid-19 have been forced to innovate and have been able to see that it works.

Furthermore, they have managed to understand that this digital transformation is going to be necessary to ensure that companies and countries remain competent in a post-Covid world, as it is increasingly impossible to return to the situation that existed before the pandemic.

The arrival of Covid-19 has accelerated many of the trends that were already in place before the pandemic, especially those related to remote work and collaboration, social interaction and entertainment

All in all, such digital, technological and even structural changes will prolong in the long term, and VR is anticipated to gain momentum from its rising application in a wide range of industries and end-uses. Despite the economic uncertainties, the favourable market and social environment justifies short-term investments and risks. It is therefore here recommended to build on this unique opportunity that COVID-19 is providing and take on the project of taking VRTogether to the next step, search for additional funding to finalise development and establish a robust go-to-market strategy.

6.2.4. Consider Revenue Funding – It is Challenging but will become easier over time.

As previously mentioned, the VRTogether solution still needs further development and, as a result, investment before reaching the mass-market. Before a company can assess an appropriate funding option, it needs to identify what stage its product is at. In increasing order of progression, these are:

- **Idea**: the product only exists in conceptual form and no technical development has taken place.
- **Minimum Viable Product (MVP):** this is the most basic form of a fully functional technical product.
- **Market ready product:** the product is feature complete and in a state that is customer-ready. No revenue is being generated yet.
- **Market ready revenue generating product:** the product has been fully released to the market and is generating consistent revenues.

The potential funding avenues required include:

- **Venture capital (VC):** companies that invest their clients' funds in relatively risky businesses with the expectation of high returns on the equity received in exchange.
- **Angel investors:** wealthy or high net worth individuals that invest their own money into a venture in exchange for equity.
- **Corporate venturing:** similar to VC company funding except the funds are being provided by a corporation.
- **Crowdfunding:** public call for funding where everyday individuals can pay in their own money with the expectation of kick-starting a company or bringing a particular product to market. In exchange, these individuals are either offered equity in the company, a reward for investing, or a mixture of both.
- **Crowdlending (peer-to-peer lending):** funding in the form of a loan from individuals through an online platform that usually results in lower interest rates for borrowers and higher returns for lenders than traditional lending schemes.
- **Revenue funding:** funding received directly through the successful sale of a company's products or services.
- **Government funding:** funding received from Government entities usually in the form of grants to achieve a specific purpose such as supporting the research and development costs of companies.

While most of these funding methods are technically available at all product stages, some are more suitable at different stages. See the table below for an indication of the earliest appropriate time for various funding avenues. As a general note, ease of access to finance increases with the maturity of the product.

Figure 85 | Funding option at different development stages

IDEA	MVP	MARKET READY	MARKET READY (revenue generating)
• Government funding • Crowdfunding • Crowdlending	• Venture capital companies • Angel investors	• Corporate venturing	• Revenue funding

In this context, VRTogether is standing at the MVP stage with a viable VR end-to-end solution for realistic and real-time holoconferencing purposes. At this stage **Venture Capital** is a popular and valid source of funding as well as angel investors. However, if seeking for large VC investment, recurring monthly revenue will be needed before investment, and as so, a simple pitch deck is not going to be convincing enough.

Access to VC money is competitive and VCs are in a position to be highly selective of which companies receive funding. Companies at a stage prior to the development of a minimum viable product may struggle to secure funding with VCs in the EU, some of which will even want to see a product generating recurring monthly revenue. Be that as it may, American VCs are much prone to risk investment and as so such option should also be considered at this point in development and time. Nonetheless, in both cases there is an important barrier to be surpassed, the generation of monthly recurrent revenue to secure big VCs investments to generate future growth.

Despite overseas funding is an attractive option, the VR market is rapidly evolving, in part accelerated by the COVID-19 effect on digitalisation and the consequent social and business behavioural change. As a result, it is here advised to consider **revenue funding** as a source of monetary resources, given that it represents one of the most stable funding options. In addition, funding through revenue generation allows to retain full ownership and control of the company and still retain option to pursue other forms of funding on more favourable terms five nth relatively high maturity of the business.

To do so, however, the consortium must first investigate how could revenue be generated, being the first step to **establish a Spin-off or independent Startup** (to which the IP would be transferred) to drive sales and generate revenue in the short-term. In fact, we consider this the most appropriate moment to establish such strategy, despite the many economic difficulties due to COVID-19, given the positive momentum of the VR market. We advocate, the upcoming months will represent an inflection point in terms of VR adoption, especially within enterprises and other professional users. Such opportunity may also represent a good time to generate revenues through early adopters of the technology which in turn may then attract big VCs to invest in the solution to refine the development of the technology.

However, the creation of a Spin-Off or independent startup entails numerous challenges, especially related to IP and revenue distribution among partners, which should be carefully studied and discussed between the consortium partners and all other interested parties. Regardless of the agreement, it is critical to identify and secure ownership of the IP rights in the technology before accessing any other venue of funding.

6.3. Final Recommendation - Unleashing VRTogether potential

Presence is a key ingredient for benefiting from a VR training session or immersive media on your own, but what really elevates virtual reality to the level of a "revolutionary communication tool" is **co-presence - the ability to share that virtual space with another or several live person(s) and to really feel connected and making distance irrelevant.** This is exactly what VRTogether is all about and represents the cornerstone and the most unique and differentiating quality of VRTogether among other solutions in the market.

VRTogether **value proposition** is to offer **photorealistic, real-time and remote immersive virtual reality content which can be co-experienced with colleagues or clients.**

VRTogether aims at being the **new reference** in terms of realistic VR conferencing software in domestic and business market by providing photorealistic and holistic rendering of end- users in 4D as well as realistic representation of environments. The first step is to develop and integrate cost-effective production and delivery techniques to provide photorealistic experiences.

Users expectations are high. It is impossible for now to virtually meet friends or colleagues with a real-time photorealistic representation of themselves and, by extension, impossible to perceive the emotions and body language of the person in front of them. Prior to VRTogether platform release, end-users seem to prefer typical video conferencing, since the existing immersive VR applications do not offer realistic content.

Thus, it is here recommended that, to fully exploit such value, VRTogether exploitation strategy focuses on those market segments and end-use in which **real-time, remote, co-presence that really feels like being together is most valued**: **1) Education & Culture (vertical market); 2) Communication, work collaboration and social VR, and 3) Training (Horizontal markets).**

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