

XR EXPRESS TW
ENGAGE · ELEVATE · EXPLORE

2017-2018
WHITE PAPER XR
of Taiwan Industry



| From the Minister of National Development Council (NDC) |



Dr. Chen Mei-ling
Minister of National Development
Council (NDC)

陳美伶

With the arrival of the digital economy era, Artificial Intelligence (AI), Internet of Things (IoT) and Big Data are growing rapidly, which not only changed the industrial ecology but also becomes the juncture of Taiwan's industrial transformation.

Rated by World Economic Forum (WEF) as one of the world's four super innovators in the latest Global Competitiveness Report, Taiwan has proved to possess a solid industrial foundation, talents and energy for innovations.

To capture the crucial moment, the government has actively executed several action plans for optimizing the investment environment for new ventures since 2018. Through 40 measures focusing on capital, talents, regulations and market, these plans are bound to create a favorable ecosystem for startups to flourish.

As many startups put efforts on virtual reality (VR) and augmented reality (AR) applications in recent years, their great potential for international growth has received high attention from large multinational corporations and venture capitalists; and extended reality (XR) further integrates AR/VR applications to present users with fully immersive sensory experiences, which is regarded as the next business battlefield for the industry.

The publication of "2017-2018 White Paper of Taiwan XR Industry" in both Chinese and English will provide a comprehensive understanding to the innovation energy of Taiwan's XR-related industries, and serves as a roadmap for the government to lay out future strategies for future developments.

Facing the upcoming 5G era, many countries are eager to compete for great business opportunities, in which XR is expected to grow quickly thanks to the completion of 5G infrastructure. The National Development Council will play the role integrating and bridging resources as well as coordinating government ministries to drive the XR industry forward. Furthermore, we are willing to collaborate with the industry and utilize the existing advantages to accelerate integration of software and hardware applications.

We will strive to grasp business opportunities of the 5G digital economy and lay a solid ground for XR industrial developments. Let's work together for a prosper and promising future.

| From the Principal Investigator |

Since AR/VR technologies emerged to become the focal point of international markets in 2016, corporates and entrepreneurs alike are optimistic about the business potential of such developments and therefore committed substantial investments on the subject. Today, development of AR/VR hardware, contents, commercial applications and online/offline channels are being completed as the essential elements of interconnected cross-industry, cross-country ecosystems.

Two years ago, VR arcades bloomed in Chinese and US markets and had attracted immersive technology companies from Taiwan, Korea and Japan to invest in arcade operations and content development, which contributed to the founding of many innovative startups and enterprises such as The Void (US), HTC Viveland and VAR LIVE (Taiwan), VR Zone (Japan) and SKonec (South Korea).

In 2018, Taiwan's Industrial Development Bureau, Ministry of Economic Affairs and Kaohsiung City Government jointly elevated their support to this emerging industry. Through the "Somatosensory technology base-Somatosensory district project" under the government's Forward-looking Plan infrastructure, AR/VR and somatosensory technologies are given more chances to conduct experiments and ecosystem establishment in Kaohsiung. The project was one of the most aggressive plans supported by Asian country governments.

In response to the booming international AR/VR business demands, Taiwan's National Development Council (NDC) proposed the "Asia Silicon Valley Development Plan – Promote Augmented and Virtual Reality Industry to Expand Global Business" project. For execution with the "XR EXPRESS TW" brand since 2018. The project leads Taiwan's AR/VR enterprises to explore international markets and promote Taiwan's AR/VR industry as a whole; and over 100 startups, NT\$130 million of overseas business opportunities and 7 potential unicorn companies were successfully developed in just one year.



Principal Investigator
The XR EXPRESS TW project
Cori Shieh

謝京蓓

In addition, "XR EXPRESS TW" further assembled industrial and academic experts to compile and publish "2017-2018 White Paper of Taiwan XR Industry" in hope to draw more government agency and private sector attention to AR/VR startups through comprehensive market analyses and policy recommendations. The white paper also describes the roadmap for AR/VR technologies in the next three to five years as well as how 5G networks would benefit Taiwan's competitive advantage in cross-industry, cross-market and cross-technology niche business developments.

The future is now, and the future of the digital economy has already arrived. We are looking forward to seeing Taiwan's industries and enterprises to grow strong and soar high in it.

| From the Chief Editor |

Technologies have been transforming faster than ever today, and new innovations continue to iterate as well. However, one thing never changed: technological progress makes people's lives easier.

Immersive technologies are rapidly drawing public attention while multinational hardware companies such as HTC, Samsung, Facebook (Oculus) and Sony launched a variety of head-mounted VR (Virtual Reality) displays since 2016, and they gradually influence and benefit people's lives in every aspect during the past three years.

Since 2017, VR and AR (Augmented Reality) are employed in diverse industrial aspects like movie and television entertainments, e-commerce, medical care or education to improve people's lifestyle and convenience consequently. Furthermore, these developments and related digital infrastructures are finally converged into the concept of XR (eXtended Reality).

Guided and profoundly supported by the National Development Council (NDC), the "2017-2018 White Paper of Taiwan XR Industry" consolidates information on international XR markets in the past two years and describes the current status of countries, mainly Taiwan, dedicated to XR developments. We believe that this research is definitely the best starters' guide to the evolution of XR industry.

Moreover, this white paper also offers advices that are expected to enhance the growth and competitiveness of XR industry in conjunction with assistance from government agencies. XR is not an independent technology but a combination of integrated knowledge from various fields, and the advantages of XR technology will in turn guide many industries to overcome difficulties and create a broader vision.



Chief Editor,
Richman Hsiao

蕭富仁

During the compilation of the white paper, our research team collaborated with Taiwan Institute of Economic Research to gather industry information with tremendous efforts and thankfully received guidance from many industry leaders. As the chief editor, I'd like to sincerely express my gratitude to all the companies and entrepreneurs participated in the survey and interviews on behalf of the editorial team.

Meanwhile, we are also indebted for policy-related advices from industrial experts and entrepreneurs from the Taiwan Association for Virtual and Augmented Reality (TAVAR). As we strived to represent the XR industry in this white paper as complete as possible, corrections or suggestions are of course appreciated since they'll make the next edition even better.

We sincerely hope this white paper could give better ideas on the potential of XR and its business opportunities to the academia, government agencies and the industry; and we're also looking forward to more resources and investments from the government to support Taiwan's XR companies to enter the international stardom for more achievements for us to be proud of.

Recommendations

As the XR industry is expected to reach a total value of US\$80 billion by 2025, it is one of the most productive digital economy applications to come. More than 70% of the components and core technologies of the relevant hardware are dominated by Taiwanese companies, which makes XR an vital opportunity for Taiwan's hardware and software industries to move toward the future digital society. With more support to XR startups and attention to the industry trend, we are looking forward to more investment on research and development that empowers the players to aggressively explore the global markets.

Chairman of Taiwan Association for Virtual and
Augmented Reality (TAVAR)

Cori Shieh

Smart mobile devices will play an important interface role in technology applications in the future 5G era, and the development of XR industry is also tightly interconnected with the progress of such devices.

Today we can see XR applications are employed in digital contents, medical rehabilitation, industrial applications, education and tourism fields, which all call for the help from the government's industrial policies; and we are counting on more innovative XR applications, a strengthened XR industry and more domestic XR companies to seize the opportunities of future developments.

Deputy Secretary General of
Taipei Computer Association

Project Principal Investigator of
Digital Content Industry Development Plan
organized by the Industrial Development Bureau,
Ministry of Economic Affairs

Charles Y. P. Huang

In the era of the digital economy, the development of AR/VR/MR brings neoteric forms of human-machine interaction and also challenges the imagination of all professions and trades to launch a revolution of innovative applications. With abundant XR software and hardware capabilities and high-quality digital content development talents, we hope that the domestic culture and technology industries can work together as a team and win a place for Taiwan in the international XR arena.

CEO of Culture Tech Alliance, Taiwan

Wan-Hua, Huang

The research, development and presentation of innovative XR applications require cross-discipline efforts from hardware, software and content industries; therefore more supports and investments from government officials and research institutes are indispensable for building a more complete and mutually beneficial ecosystem. It is hoped that these inputs could drive the overall development of Taiwan's industry and academia forward for a more promising future.

Professor of National Taiwan University,
Chairman of TAIPEI ACM SIGGRAPH,
Chairman of Taiwan Association of
Computer-Human Interaction

Bing-Yu, Chen



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Chapter 1

The Infinite Future: Development Trends of Global XR Industry



I. A Brief History of XR Industry

Goldman Sachs, a highly recognized multinational financial institution, is optimistic about the market value of XR industry, which is estimated to reach as high as 80 billion US dollars in 2025 and will attract investment on XR industry from many global industry leaders.

The term "XR" (Extended Reality) is a collective term covering AR, VR and MR. VR (Virtual Reality) presents virtual 3D spaces for the user's body and senses to immerse in a virtual world, while AR (Augmented Reality) embedded VR objects in real scenes. Finally, MR (Mixed Reality) technologies apply VR and AR on one device and switch between them freely.

Since MR covers AR and VR, most research reports merge its market value in AR applications.

VR (Virtual Reality) has been existing for more than half a century. In 1957, Morton Heliing invented Sensorama, a large simulator that projected 3D images; however, its prohibitive production cost and bulky size limited its applications to only high-value fields such military, technology, science and medical researches.

Thirty years later, Japanese video game makers SEGA and Nintendo collaborated to release SEGA VR-1 and Virtual Boy game consoles in 1995. However as these were desktop models and lacked game contents, the sales never took off.

The Scope of AR/VR/MR Definitions



Virtual Reality (VR)



Augmented Reality (AR)



Mixed Reality (MR)



Real Environment



Source: XR EXPRESS TW, 2018

In 2012, Oculus revealed its head-mounted display, a technologically advanced VR headset, on Kickstarter for crowd funding. With US\$2.6 million raised in the initial period, the market gave high expectation to its future. In anticipation to the social media revolution that VR technology would foment, Facebook, the social media magnate, acquired Oculus for US\$2 billion and released its own VR products in 2016. This ignited the VR zeal that had disappeared for 20 years.

The concept of AR was proposed very early as well. In 1966, Ivan Sutherland and his team researched and developed "The Sword of Damocles" system and built a prototype of this early AR system in 1968 successfully.

Later in the 1990s, the "Virtual Fixtures" virtual assistance system developed by Boeing and the U.S. Air Force engineers and "KARMA" maintenance assistance system developed by Columbia University brought AR technology into practical applications. However, just as the results of earlier developments, the huge overall size and extremely high cost confined them in only aerospace and defense applications.

In 2012, Google announced that its Project Glass project will produce an AR glasses called "Google Glass" and launched it in 2014. Unfortunately, its advanced, compact design was too small to contain enough battery power for consumer needs – it was terminated as a result.





Even though the glasses-like AR hardware devices seemed to have failed, some platform operators found great business opportunities in AR. In 2015, Nintendo and Niantic joined forces to release "Pokémon GO", a wildly-popular game for players all over the world to breed AR pets and compete with others. The game hit the US\$500 million mark in just 2 months and became the fastest profit generator of the year.

In the same year, Microsoft unveiled its next-generation headset: HoloLens. HoloLens features both VR and AR functions so that Microsoft called it an "MR headset". Currently HoloLens is already used in military and aerospace fields and is expected to gradually expand from professional B2B markets to consumer markets.

In 2016, Magic Leap raised a considerable amount of financing for its Digital Lightfield technology. With a different display mechanism from Google Glass, it can combine AR images and real environments seamlessly and has an estimated market value of US\$4.5 billion. In 2017, Apple released ARKit toolkit that helps developers to produce AR applications quickly. In the same year, Google also presented ARCore and released a full version in 2018. The release of these two toolkits means the two biggest mobile platforms are optimistic to AR applications and think highly of the market development as well.

In conclusion, merging virtual scenes and the real world is a technology trend that promotes long-term development of the XR industry. Better yet, the advance of recent semiconductor technology will bring XR industry from niche markets to mass markets to become prevalent in our daily life.

The XR industry can be divided into two major segments: AR and VR. MR is categorized into AR in this report since it's a concoction of AR and VR. In 2018, VR and AR had different growth paths - VR drew a lot of attention from the market during 2016-2017 but slowed down ever since, and AR is expected to catch more eyeballs for the XR industry again in 2019.

II. Overview of Global XR Industry Developments

As AR integrates virtual objects with actual scenes and VR lets users enjoy an alternative reality, XR integrates the two for more business opportunities. As a combination of AR and VR, XR will eventually merge the two technologies in MR devices (MR is categorized into AR in this report). In general, XR applications could change people's lifestyle in many ways and therefore generate enormous potential value.

According to Digi-Capital research institute, the XR industry will enjoy high growth rates between 2018 and 2022, and the estimated market value of XR industry in 2022 will reach US\$105 billion; in which US\$90 billion will come

from 3.5 billion AR devices and US\$15 billion from 60 million VR devices.

As the AR/VR industries went through the hustle and bustle in 2016 and entered stagnation in 2018, the public became familiar with AR/VR and surpassed one-time AR/VR experiences to observe more prudently on how AR/VR fit into daily purposes. As a result, the VR market will focus more on consumer applications and matured AR hardware in 2018 while developers explore more possibilities.

In fact, the market trend was not far from the prediction made by Digi-Capital: the overall market value of the AR is greater than that of VR. According to Digi-Capital, AR will take up 80% of the entire XR (include AR, VR and MR) market value in 2020 and proceed to 85% in 2022, while VR takes up 20% in 2020. However, as VR growth becomes slower than AR, its proportion in the entire XR will decline to 14%.

Since AR can merge virtual images and real environments, it fits more application scenarios than VR. For example, with its wider applications in ecommerce and advertising fields, AR will have a better chance to attract more investments from platform and network operators.



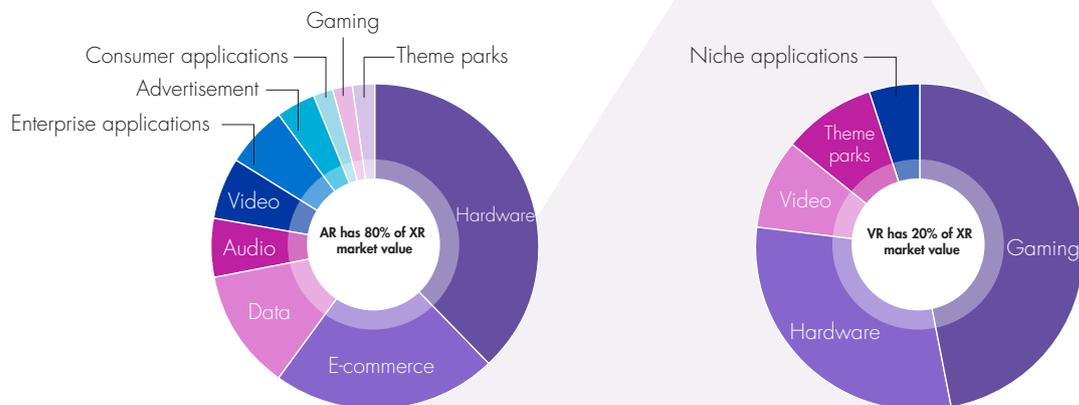
On the VR side, since VR headsets require a lower technology level than AR headsets, they become market pioneers to have consumer products released. Although hardware products were offered in a wide price range, but the software ecosystem failed to keep up. Consequently, the consumer craze for AR devices declined gradually in 2018.

According to the data surveyed by IDC, an international research institute, the global market share of VR headsets in the first half of 2018 has decreased for more than 20% mostly due to cancellation of several "Mobile VR-smartphone" bundles. In the second half of 2018, there will be more affordable VR headsets on the market to stimulate the overall sales volume. IDC estimated that the sales volume of AR/VR headsets in 2018 could reach 8.9 million units (YoY+6%), in which VR units occupies more than 90% of the market.

In terms of AR, Apple CEO Tim Cook unveiled the slogan in 2017: "AR is going to change everything." In Apple's idea, AR technology shares the same development phases with multi-touch: most people didn't realize that multi-touch would be important until it becomes the de facto human interface for almost all mobile devices. Apple, as the leader in consumer electronics, predicted that AR will be everywhere into people's daily life in the future.

In 2018, AR applications were mostly designed for businesses since AR headsets are too costly to consumer markets. IDC data shows that in 2018 AR headsets occupied 8.2% of the overall AR/VR products with annual shipment of 750,000 units. As Apple joined the AR competition, many research institutes started to consider Mobile AR as a viable competitor that could become the leading force of future AR markets.

Forecasted 2020 AR/VR Market Value Percentages of Applications



Source: Digi-Capital, 2016

IDC forecasted that in 2022 AR/VR headset shipments will reach 65.9 million units and AR will take up about 40%, or 26 million units. Since AR applications can connect virtual scenes and the reality to provide more immersive virtual world experience than VR, it's believed to have more market potential. Digi-Capital forecasted that in 2022 AR market value might reach US\$90 billion, which is higher than the US\$15 billion from VR.

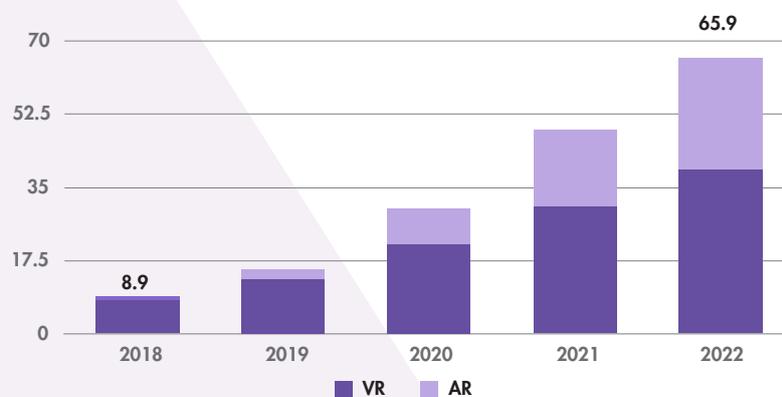
In the period between 2019 and 2022, 5G communications will be deployed and operated in many countries and its high-speed is expected to benefit the market penetration of AR/VR headsets.

The contents for AR/VR headsets require considerably wider bandwidth and lower latency. For example, the data amount for a VR headset to display a 360-degree panorama instead of

individual pictures is four times higher; AR applications also require high-bandwidth data transmission and computing power to identify characters and types of actual images in order to blend virtual objects into the scenes perfectly.

The proposed 5G infrastructure will be a boost for presenting AR/VR scenes, and the huge market potential of AR/VR will also encourage many countries to accelerate 5G deployments.

Forecasted Worldwide Market Share of AR/VR Headsets (million units)



Source: IDC, 2018

III. Development of Global VR Industries

VR technology successfully drew public attention in 2016. As growth of the smart phone market declines, many research institutes predicted that annual growth rates of the smart phone market will shrink to below 5% during 2017-2022, while VR HMD (Head-Mounted Display) headsets from Sony, HTC and Oculus (acquired by Facebook) are highly expected and may become the next hardware platform with desirable growth potential.

In 2017, the market embraced a favorable vision toward VR. The data from Tracxn indicated that the number of VR projects seeking financial investments stayed high at around 130, while the invested fund also grew from US\$630 million in 2016 to US\$1.1 billion in 2017. At the same time, Gartner, an international research institute, in its 2017 Hype Cycle forecast also pointed out that VR was entering the "Slope of Enlightenment" stage with stable growth and will mature in 2 to 5 years.

In 2017, VR headsets began to expand from powerful, deeply immersive tethered VR for desktop computers or game consoles to Mobile VR for short teaching sessions, demonstrations and hands-on video clips.

Capable of providing affordable consumer experiences, Mobile VR products such as

Samsung's Gear VR are bundled with high-end smart phones to increase penetration rate, while Google Cardboard takes a step further by offering an exceptionally low US\$30 price tag. However, the Google Cardboard-type of Mobile VR headsets are not comfortable to wear due to poor lens focusing and low image refresh rates that could cause dizziness.

The low satisfaction level and lacking software applications led to a low shipment volume of affordable Mobile VR products in 2017 (less than 5% of the 1.5 billion smart phones units shipped). However, the affordable Mobile VR products did accomplish the objective to educate consumers and allowed them to become more familiar with VR experiences. According to Neilson, a market research institute, the percentage of consumer recognition to VR grew from 36% in 2016 to 63% in 2017.

In general, the VR industry market in 2017 headed for two very different hardware platform strategies: one goes for tethered VR products at over US\$700 for games and business applications, while another set the price of affordable Mobile VR units to under US\$100 for video clips or experience applications.

The sales from the first strategy was limited by the high price, while the second hindered by

the less-than-satisfactory experience due to the overly simple design. As a remedy, VR device manufacturers released more Standalone HMD with better prices and experiences than Mobile VR to stimulate the overall VR market in 2018. The change paid off: the growth of hardware shipments became stable in the second half of the year.

IDC forecasted that standalone HMD shipments will keep growing during the 2018-2022 period and become the mainstream VR hardware. The institute also forecasted that even though the 2018 mainstream market called for tethered VR headsets that offer better experiences, manufacturers still unveiled more Standalone VR units with better value for the price. The trend is expected to push the market share of Standalone

VR in all VR hardware shipments to grow from 16.1% to 55.8% in 2022.

The annual growth of VR headset shipments slowed down in 2018, and IDC forecasted that AR/VR headset shipments in 2018 to reach 8.1 million units despite that annual shipment growth rate declined from double digits of the previous year to single.

The main reasons of the slowdown could be attributed to prohibitively high prices and lacking killer applications; and data from IDC also indicated that the worldwide VR headset shipments in the first half of the year declined more than 20% since the bundle prices of Mobile VR units and mobile phones are no longer offered.

Growth Trend of VR Hardware Categories



Gear VR

Mobile VR



Oculus Go

Standalone VR



Oculus Rift

Tethered VR

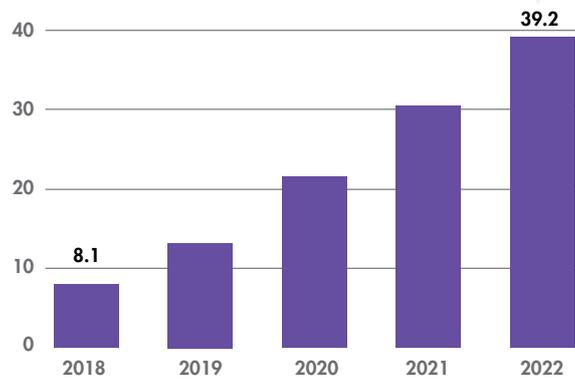
Categories used in the report	Categories defined by IDC	2018	2022
Mobile VR	Screenless Viewer	37.6%	7.8%
Standalone VR	Standalone HMD	16.1%	55.8%
Tethered VR	Tethered HMD	46.3%	36.4%
	Total	100%	100%

Source: IDC, 2018

However, more VR headsets with affordable prices were expected to appear on the market in the second half of 2018 to stimulate the overall sales volume. IDC also forecasted that with more Standalone VR units and applications being released, shipments of related products should reach 39.2 million units in 2022.

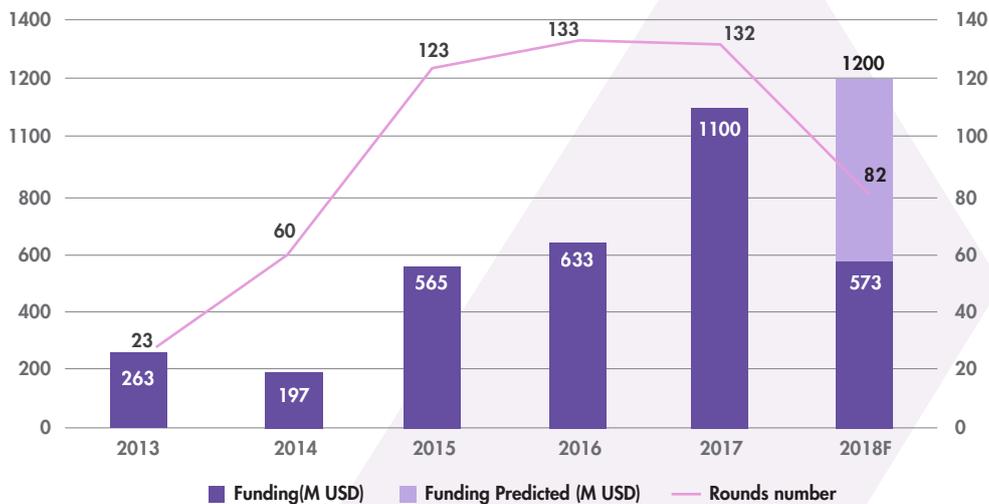
According to Tracxn, the number of innovative VR companies succeeded in attracting investments reached the peak during the 2015-2017 period; in 2018, investments on the XR industry shifted from VR to AR and led to a reduced number of financed projects.

VR Headset Shipment Units (million units)



Source: IDC, 2018

Statistics of Worldwide Investments on VR Startups



Source: Tracxn, 2018

To the overall VR industry, the high peak of investment stayed at 2017. In that year, many VR headsets were launched, and the market had great expectation to all kinds of VR applications and hardware; the trend also pushed up the market cap of VR companies. Even though VR companies received over US\$1.1 billion of investment in 2017, the VR headset heat waned in the first half of 2018 and caused investors to inspect VR projects more prudently and conservatively.

By the third quarter of 2018, the total investment received by VR companies had reached US\$573 million. Tracxn also forecasted that the amount received by the entire industry in the end of 2018 could reach US\$1.2 billion.

According to Tracxn, the VR industry had received a total of US\$3.07 billion from 2013 to 2018, in which the highest three categories were content authoring toolkits, applications, and

human interface tools. Content authoring toolkits include 360-degree panorama filming tools, game engines and cross-platform support tools.

Among the categories, VR content authoring toolkits was the most attractive one which have an accumulated fund of US\$1.5 billion. For instance, Improbable, the company behind the Spatial OS distributed computing cloud platform service, received US\$502 million in 2017.

In the early stage of VR industry, every hardware manufacturer would build their own software platform and that caused inconsistency and low efficiency for integrations. Spatial OS offered a solution for developers to deal with the problem by allowing them to design their contents with a unified tool and convert to VR for multiple platforms to reduce the development cost.



As VR has a wide range of suitable applications, the application categories have the most companies, up to 772 companies; however, their successful rate of receiving investments was only 20% since a successful application business calls for more specific, high-potential models and products. For instance: Timefire, a social media application, and MindMaze, a neuroscience application, drew the most attention. The MindMaze solution provides remedies to help patients repair damaged neurons through interactions in the VR world.

Through advanced human interfaces, VR can extend interactions from only sights and sounds to touches, smells and even tastes to immerse users more deeply into the virtual world. Key players in this field include Eyefluence, an eye-tracking application, and Leap Motion, a hand gestures interaction tool. As these are not yet as precise as screen buttons for games and control operations, further technology breakthroughs are much anticipated for other applications to be realized.

Major Fund-raising Categories of VR Startups

Categories	Total	Had fund raised	Total fund raised	Major companies
Content production tools	304	120	15.00 Billion US dollars	Lytro 、Improbable
Applications	772	168	8.31 Billion US dollars	Timefire 、MindMaze
Human-machine interaction tools	203	69	3.07 Billion US dollars	Eyefluence 、Leap Motion
Studios	229	36	3.07 Billion US dollars	Recall Studios 、JauntVR
Display devices	195	26	2.24 Billion US dollars	Oculus VR 、Varjo Technologies

Categories	Total	Had fund raised	Total fund raised	Major companies
Live media streaming	22	4	1.99 Billion US dollars	Voke 、NextVR
Chips and sensors	5	5	1.67 Billion US dollars	Movidius 、Triad Semiconductor
Platforms	182	41	1.45 Billion US dollars	EVR Holdings 、Jaunt XR
Marketing / Advertisement	38	18	0.21 Billion US dollars	Immersv 、MediaSpike
Web browser VR	8	2	0.01 Billion US dollars	SuperXYZinc 、WebVR

Source: Tracxn, 2018

IV. Development of Global AR Industries

Although the sales volume of Google Glass, unveiled in 2013, did not successfully make a breakthrough, but it made the world to realize that AR applications could have a huge potential impact. In 2015, AR game "Pokémon GO" swept the world and created a US\$500 million revenue within only 2 months; and Apple claimed that AR would be a future trend. In 2016, AR topics became relatively silent while VR turned hot and kept on cultivating all kinds of possibilities on B2B market.

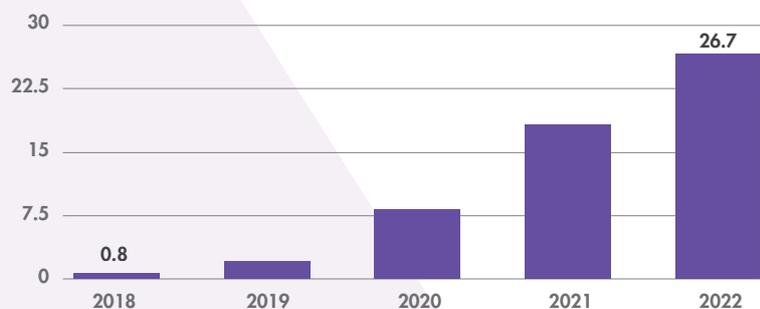
In the same year, Magic Leap acquired US\$2.3 billion of investment with its Digital Lightfield technology. This technology beams light into eyeballs for users to see the real world and lifelike virtual images smoothly fused together, which pushes AR to the MR level. In 2017, Apple and Google expressed their interest in AR and released ARKit and ARCore tools

respectively for AR development to pave the way for more AR applications in 2018 and 2019.

On hardware shipment, IDC forecasted that AR the estimated hardware shipment will grow from 0.8 million units in 2018 to 27 million units in 2022. There are two factors responsible for the momentum: 1. head-mounted AR devices in both niche markets and B2B business markets will increase, 2. increasing Mobile AR applications promoted by giant platform operators such as Google and Apple will help boosting the overall AR market penetration.

Research institute IDC forecasted that AR headsets with entry-level prices would have the most share of Mobile AR shipments at about 61% in 2018. Low-price Mobile AR products allow the market to have a taste and to understand more about AR applications; in the long run, however,

AR Headset Shipment Units (million units)



Source: IDC, 2018

they might be too simple to provide perfect experiences and could be completely replaced by Standalone AR and tethered AR.

In terms of Standalone AR headsets, the Microsoft HoloLens is the best example for today. Due to its relatively expensive price, it currently focuses only on B2B applications such as facilitating intuitive communications through AR on staff training and equipment maintenance to reduce costs for enterprises.

As a result, Standalone AR headsets like HoloLens is expected to become the next-generation of mainstream office computing platforms.

On the tethered AR side, in the beginning most PC manufacturers followed the Microsoft standard and released low-price, entry-level Mixed Reality helmets for enterprise AR applications. In the future, with the increasing enterprise domain AR application, they can push up the overall tethered AR headset shipment.

According to the Tracxn statistics, the number of AR companies receiving investments reached its peak during 2015-2016 declined thereafter.

Though the potential market size of AR applications is huge, it still needs a strong technological foundation to support the vision. After 2016, the market was more prudent toward

Growth Trend of AR Hardware Categories



Lenovo Mirage AR

Mobile AR



Microsoft HoloLens

Standalone AR



Microsoft Windows Mixed Reality

Tethered AR

Categories used in the report	Categories defined by IDC	2018	2022
Mobile AR	Screenless Viewer	61.0%	2.5%
Standalone AR	Standalone HMD	26.8%	52.1%
Tethered AR	Tethered HMD	12.2%	45.4%
	Total	100%	100%

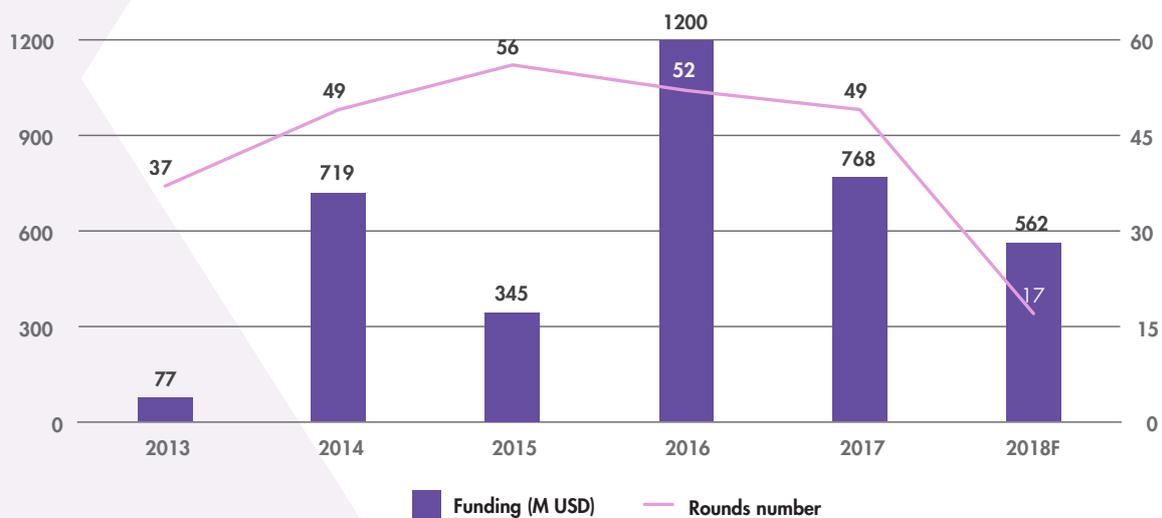
Source: IDC, 2018

AR investments and the first choice was the fundamental technologies that materialize AR application designs. The amount of investment received by AR companies reached US\$1.2 billion in 2016, in which AR headset business had US\$790 million – more than 50% of the entire AR investments. After the 2014 Google Glass market test, operators also realized that "display quality issue" was the key for AR applications to become a business success.

In AR investment categories, display devices were of the highest investment priority and received most funds. Different from key AR display technologies, VR focused on enhancing the quality of current mobile devices with higher resolutions and refresh rates.

AR is a totally different story. As most AR displays employ micro-projection technology to deliver sharp, high-lumen images into human eyes

Statistics of Worldwide Investments on AR Startups



Source: Tracxn, 2018

Major Fund-raising Categories of AR Startups

Categories	Total	Had fund raised	Total fund raised	Major companies
Display devices	109	48	30.00 Billion US dollars	Zebra Imaging · Magic Leap
Applications	493	106	4.72 Billion US dollars	Flyby Media · Augmedix
Content production tools	161	40	3.68 Billion US dollars	Layar · Blippar
Studios	11	7	0.69 Billion US dollars	Eyefluence · uSens

Source: Tracxn, 2018

without adverse effects, it takes a considerable amount of investment to satisfy such strict requirements.

In terms of AR or VR, most companies devoted themselves in production of applications. Since AR entered the market later than VR, it received less funding than VR as well. The makers of content authoring toolkits, also kicked off later like AR, were also less in number and therefore had less successful funding rounds than VR companies.



Chapter 2

High Growth and High Value: Major Countries of XR Development



I. Current AR/VR Developments in Major Countries

As the AR/VR industries see a promising long-run growth, the huge potential value draws investments from many countries. According to a Digi-Capital survey, investments on AR/VR industries from Asia will surpass which from Europe and North America. The investments from Asia landed on industries such as game platforms, OEM and components supply chains, while the European and North American companies invested mainly on platforms and content operators.

1. North America

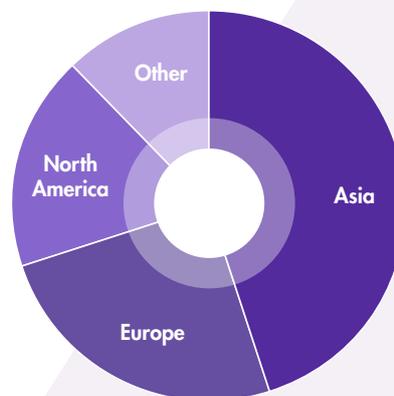
As the world leader of technology industries, the US/Canada area plays the locomotive role of AR/VR industries as well. The three largest operators in North America are system platform providers; they not only provide software

development engines, but also work with developers to expand the ecosystems toward their respective directions.

For instance, Facebook mainly employs social media along with hardware of different price ranges from various operators and countries to accelerate acceptance. Google, on the other hand, strengthens software and hardware integration ability through Google Pixel team, the recently joined hardware team, and all-aspect software developments.

As a brand-new but costly design focuses on enhancements of corporate productivity, Microsoft's HoloLens has been updated less frequently than the other two.

Forecasted Worldwide Investment Scale on AR/VR



Source: Digi-Capital, 2016

a. Facebook

Facebook is the first mainstream companies to promote consumer VR headsets. With a huge customer base of over 1.3 billion Messenger users, 2 billion Facebook users and 800 million Instagram users, Facebook considers that an AR/VR strategy can strengthen its customer base while expanding the social media coverage from text, audio and video to 360-degree panorama visions.

Facebook had not only developed their own hardware, but also aligned with strategy partners from different fields. On the hardware side, it unveiled Oculus Go, Oculus Quest and Oculus Rift with three different price ranges to cover most users.

Designed for games and video-intensive applications, Oculus Rift requires a PC, while Oculus Go are suitable for playing video clips and lightweight game applications. In 2018, Facebook promoted the Oculus Go standalone headset that has three degrees of freedom (DoF) to turn along with the user's head, while Oculus Quest, expected to join the series in 2019, can detect the environment and has 6 DoF for head movements.

On software applications, the Facebook VR Store already has more than 1,000 VR apps focused on social media, game and live streaming entertainments. In the future, Facebook will strengthen the live streaming features such as live VR sports events as well as cultural activities like VR streaming concerts. In addition, sound reception for live VR panoramas will be improved to enhance user experience.

Facebook's VR Developments

facebook

Hardware platform



Oculus Go \$199

Expected launch in April, 2019

Oculus Quest \$399



Oculus Rift \$599

Software applications



Social Applications



Gaming Applications



Live Streaming Applications

Data: XR EXPRESS TW, 2018

On the AR side, Facebook tried to replicate its VR strategy. The company's advantage on software and a huge customer base will fully utilize its investment on new hardware and further integration. Facebook is also developing its own AR glasses by acquiring Surreal Vision, an AR display technology company, and Pebbles, a hand gesture control technology company, in 2015 for the key technologies.

On software ecosystem, Facebook provides an AR Studio development engine for users to develop AR applications, and it unveiled camera effects that trace human face features to strengthen animation effects and AR digital image entertainment functions. The technology is also used on information identification, which helps users to choose the items they'd need.

b. Google

As the world's leading search engine and smart phone OS supplier, Google is also a major player in AR and VR investments. Optimistic on early AR developments, the company shipped

AR Google Glass. However, as most software-focused Google developers did not fully realize how hardware cost and performance issues would limit customer experience, Google Glass didn't become a hit on the market.

A few years later, Google started to lay their hands-on low-price VR hardware. With a price tag as low as US\$15, Google Cardboard swept the market in 2017 and reached 10 million units of shipment that successfully raised market recognition to VR with the low-price device. Google followed up with Daydream VR, which works in combo with a smart phone. Surfing on the good wave of standalone VR headsets, Google also cooperated with Lenovo to ship the US\$399 Mirage Solo headset.

Currently Google still focuses on consumer applications and expects to unveil highly integrated VR headsets (Tethered VR) suitable for future business applications. On the VR side, Google acquired Skillman & Hackett, a business application software company, and its product

AR/VR Companies Acquired by Facebook

Category	Year	Company	Type	Price
VR	2014	Oculus VR	Display devices	20 Billion US dollars
	2016	Two Big Ears	3D spatial audios	
AR	2015	Surreal Vision	Display technology	
	2015	Pebbles	Gesture control	6000 Million US dollars
	2016	FacioMetrics	Face recognition	
	2017	Fayteq	Computer vision	

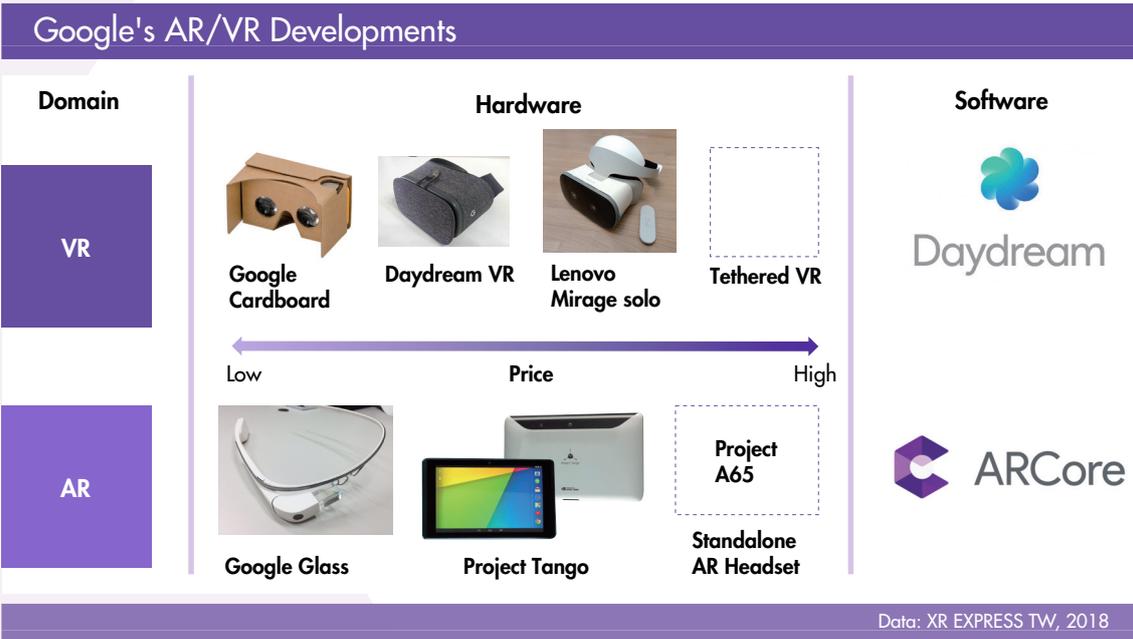
Source: XR EXPRESS TW, 2018

Tilt Brush. Tilt Brush allows users produce 3D artistic creation in VR space in a more intuitive way. In addition, Google also acquired Eyefluence, a company with eye-tracking technology that can be used to track user preference toward VR contents or other business researches.

Google's early AR development projects were mostly experimental, such as the commercialized Google Glass and Project Tango for indoor navigation. Unfortunately, the hardware performance at that time did not meet Google's

expectation for AR application as the enormous computing involved caused the visions to lag and significantly shortened the time of hardware operations.

Recently Google shifted to a "software first" strategy and unveiled the ARCore development engine to expand AR applications in the Android ecosystem. In particular, Google acquired Quest Visual's Word Lens that translates foreign text instantly for users to read in an AR view.



AR/VR Companies Acquired by Google

Category	Year	Company	Type	Price
VR	2015	Skillman&Hackett	Graphic software	
	2016	Eyefluence	Eye tracking	
	2017	Owlchemy Labs	Game engine	
AR	2015	Quest Visual	Translation technology	

Data: XR EXPRESS TW, 2018



In summary, Google's AR developments tend to become more business-oriented. In 2018, there were rumors that Google would follow Microsoft to build an AR helmet, code-named A65, for productivity applications. Since it requires deeply integrated software and hardware to present perfect AR applications, it's not surprising that Google acquired HTC's mobile phone team to build Google Pixel Series.

c. Microsoft

As a productivity software company, Microsoft AR/VR deployment is initially on business applications. As a result, its HoloLens MR headset is capable of both AR and VR in one headset.

On VR, Microsoft thinks that VR products must be opened to all kinds of devices and applications, so they do not ship VR helmets for closed game consoles such as Xbox to compete with PS VR. On ecosystem development, Microsoft opened some MR hardware designs for developers of VR helmets to work on Windows 10 with PC ODM makers. In addition, Microsoft acquired AltspaceVR, a VR social media company, to expand VR applications in social media.

For AR applications, HoloLens is mainly designed for manufacturing, engineering, medical and health as well as education purposes. Unveiled in 2018, Microsoft Remote Assist allows users to share graphics and virtually markup the graphics to help factories to solve first-line issues,

while Micro Layout enables developers and designers to setup virtual machines according to the on-site sceneries through integrating virtual and actual images to eliminate the needs to move and place actual heavy machineries.

The price for the first-generation HoloLens is at the whopping US\$3,000. In order to improve the penetration rate, Microsoft cooperated with Econocom from UK to rent HoloLens at 260 GBP per month for a lower threshold. Microsoft also said that they will release the next-generation HoloLens in 2019 that not only features a new HPU, but also uses AI computing to connect virtual images and the real world more seamlessly.

d. Magic Leap

Magic Leap is an innovation powerhouse that worth paying attention to. Its five financing rounds gathered US\$2.3 billion from top-tier investors such as Google, Alibaba, Qualcomm, A16Z and KPCB. According to Crunchbase statistics, the fund Magic Leap received as of 2018 exceeded 41% of the entire AR industry, far more than the 10% harnessed by Unity Technology at the second place.

Since hardware technology the key to AR glasses, it's not surprising that Unity, a company focuses on AR computing engine, raised less funding than Magic Leap, a hardware company.

It's interesting that Google, the developer of Google Glass device, also invested in Magic Leap. This could mean that Magic Leap has its own

unique hardware design as well. According to tear-downs revealed by the iFixit website, Magic Leap adopted LCoS optical projection engine similar to other AR glasses; but the difference is that it adopts a multi-layer waveguide transmission method to project images on different glass layers to produce several images with different focuses. This design may hopefully reduce the tiredness caused by conventional AR glasses that projecting images on a fixed focus.

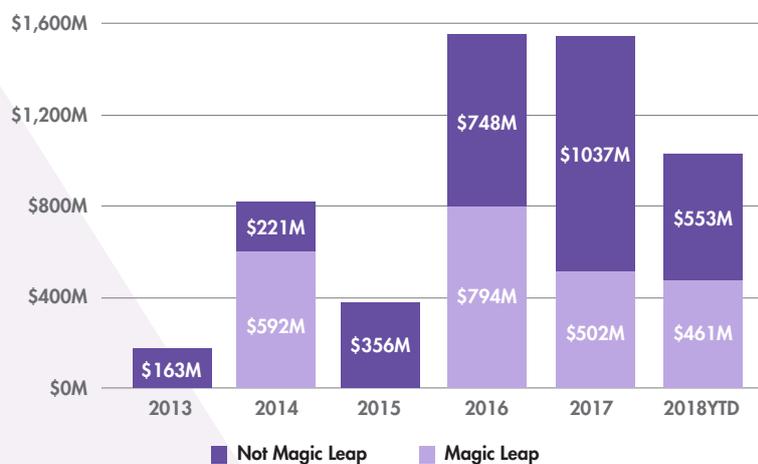
Magic Leap One was released in the US in August 2018 with a price tag of US\$2,295 each. Since it was released not long ago, the software ecosystem is yet to mature, and the key type of software development is still uncertain. However, in the near future the Magic Leap One applications will be still mostly for B2B markets.

e. Apple

As the smart phone industry becomes saturated, Apple has to exploit AR technology to extend its market advantage. With more than one billion iOS devices having AR applications installed today, the company released ARKit in 2017 and keeps updating it in 2018.

In terms of future hardware platform, we could conclude that Apple is highly possible to release its own AR helmet in the future as it acquired several AR software and hardware designs. One of the acquired companies include Akonia Holographics that owns more than 200 patents on holographic displays; it also boasts a display technology capable of "displaying vivid, full colors and wide images on lightweight, thin transparent smart glasses".

Magic Leap: an AR Innovation Powerhouse



Source: CrunchBase, 2018

Apple prioritizes software development over exclusive hardware in terms of its AR development strategy. On the software side, Apple takes advantage of the large number of iOS developers in the ecosystem to build more iOS-exclusive AR application based on its ARKit.

Since smart phones are not the best platform for AR applications, independent AR glasses are a more viable hardware solution; however, there are still many component issues to be resolved. For instance, many manufacturers will compete for the market of AR displays and such makers are expected to become key investment targets to Apple and other major enterprises.

Apple's AR Developments

AR

Tim Cook: "AR is the next Big Thing"

Hardware platform



PHONE



PAD

AR Headset ?

Software applications





Social



Advertisement



Gaming

Data: XR EXPRESS TW, 2018

AR/VR Companies Acquired by Apple

Categories	Year	Company	Type	Price
AR	2015	Metaio	AR engines	
	2015	Faceshift	Facial motion capture	
	2016	Flyby Media	Image recognition	
	2016	Emotient	Facial motion recognition	
	2017	Vrvana	Display devices	3000 Million US dollars
	2017	RealFace	Face recognition	200 Million US dollars
	2018	Akonia Holographics	AR display lenses	

Data: XR EXPRESS TW, 2018

2. England, France and Germany

Different from North America, Europe consists of many countries speaking different languages and Europeans look more for cultural contents and industrial efficiency. In general, England, France and Germany are more advanced in terms of technical capability than other European areas and have heavier AR/VR investments on more companies. The major technology companies are listed as follows:

a. ART (Advanced Real-time Tracking)

Established in 1999, ART is an important infrared positioning solution provider. Its products are widely used to automobile, aerospace and other industrial applications. ART provides diversified tracking input applications includes Flysticks and Fingertracking applicable to the human interface for AR/VR headsets.

In 2018, the company released Large Scale Motion Tracking technology that can be used on AR/VR helmets for precise positioning in vast exhibition and performance spaces.

b. Bosch

Bosch is a European manufacturer of automobile electronic with a long history. Its subsidiary, Bosch Sensortec, provides multi-axis motion sensors for AR/VR headsets, while Bosch itself invests mostly on Industry 4.0 efficiency enhancements.

In 2018, Bosch released an AR app for the automobile industry, which displays an

automobile's circuit diagram for technicians to improve working efficiency and to reduce the time for inspection and maintenance.

In addition, Bosch also released CAP (Common Augmented Reality Platform) to effectively reduce time and efforts for development of AR applications that improve industrial efficiency.

c. BAE Systems

BAE Systems is not only a UK manufacturer of military and aerospace equipment, but also the largest aircraft maker in Western Europe. The company employs XR technologies to improve productivity of workers through Microsoft HoloLens, which projects 3D images to the material and helps shorten the time of manufacturing by 40%.

BAE Systems also uses VR in personnel training to provide a safer working environment, while aircraft engineers visualize 3D parts to simulate and analyze how they can be assembled accurately and safely. Nevertheless, XR opens the door for BAE Systems to enter the next generation of manufacturing.

3. China

With continuous GDP growth in the past years, China has become the second powerful country after the US in many ways. China not only invests in emerging areas such as AR/VR sparing no efforts, but also provides incentives for private enterprises to innovate.

China's keeps on improving its own communication standards and strives to expand its influence on the next generation of international 5G standards. The 5G infrastructure empowers the high speed and high capacity needed by AR/VR application, vehicles networks and IoT. 5G and AR/VR applications complement each other as diversified AR/VR applications stimulate market need for the 5G infrastructure. As a result, China sees AR/VR as one of the key 5G-related development projects.

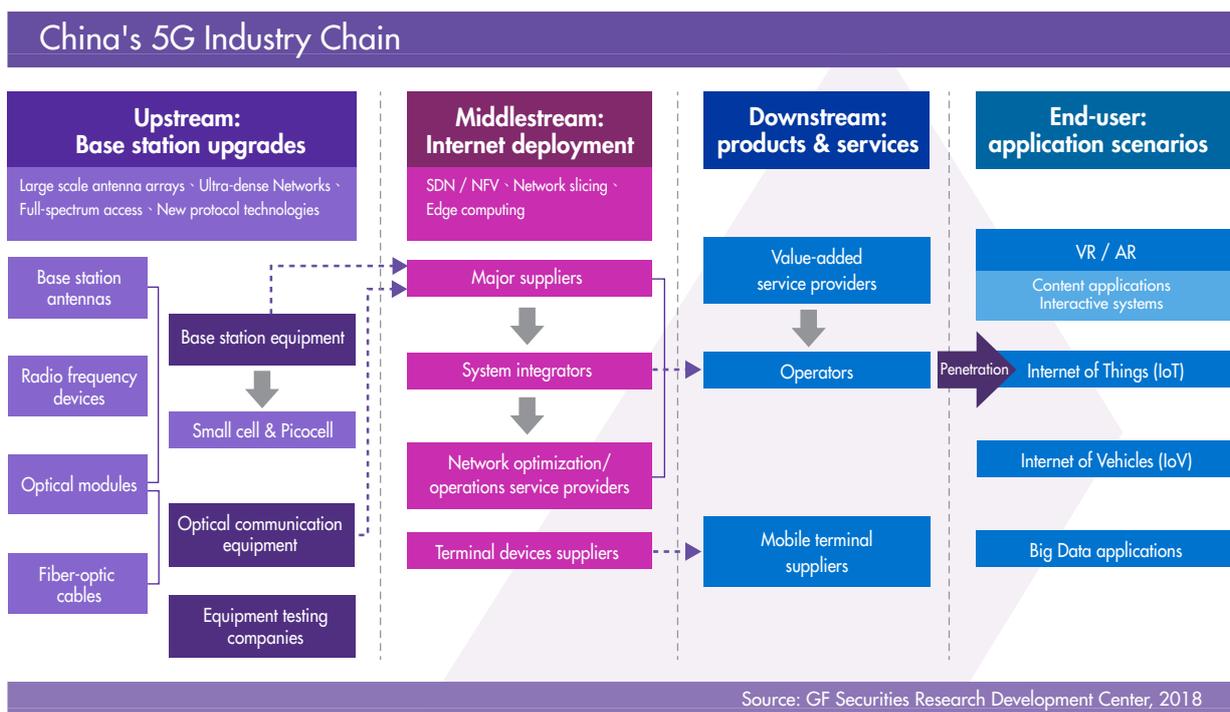
a. China Telecom

China Telecom is China's leading broadband service provider with more than 150 million customers. China Telecom thinks highly for the cloud VR developments and unveiled its "One cloud, Two networks" strategy framework for better VR experience.

In 2018, the three major telecommunication companies in China considered that the VR industry should go for cloud solutions and boost standalone VR market with lower latency, faster graphics and lower product price.

According to the third-party researches conducted in China, the forecasted standalone VR shipment will grow from 400,000 units in 2017 to 4.5 million units in 2022. In 2018, the market value of consumer VR contents was expected to reach to RMB 1.2 billion.

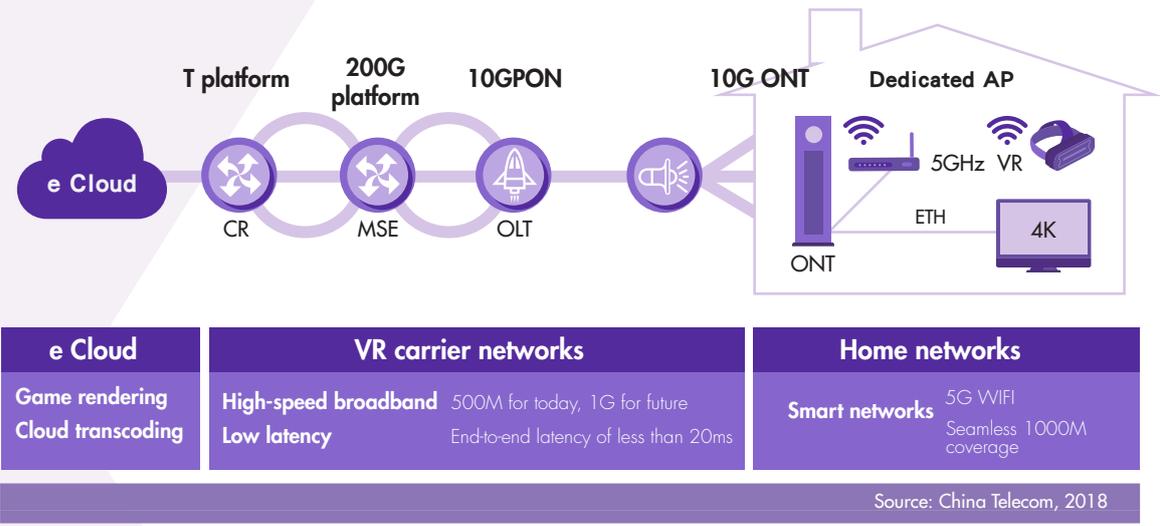
The "One cloud" does game graphics rendering and video transcoding, while "Two networks" include VR carrier networks and home networks. A VR carrier network provides high bandwidth (currently at 500M and will reach to 1G in the future) and low latency (with end-to-



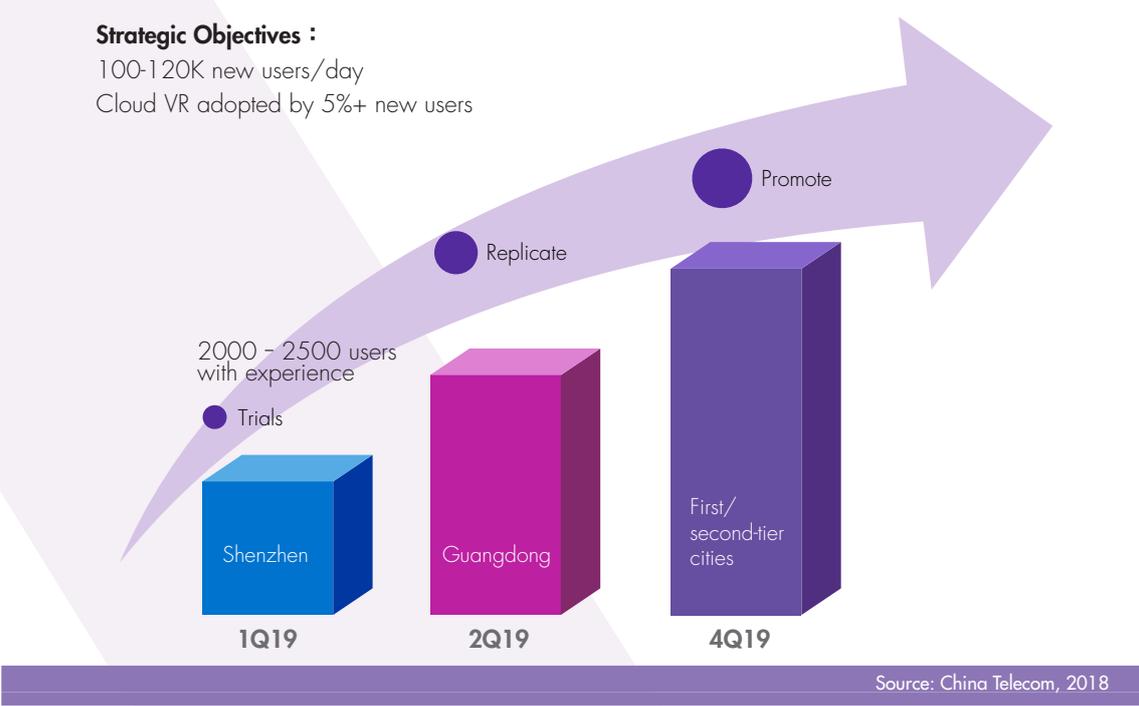
end latency below 20ms), while a home network provides low latency, high quality of service (QoS) wireless connectivity at no less than 300Mbps for "intelligent networking 2.0 services".

To provide smooth cloud VR experiences, China Telecom improves its services in three areas: 1. enhanced cloud rendering capability; 2. 8K or even 12K-resolution panorama VR; 3.

China Telecom's "One Cloud, Two Networks" Strategy



Objective of Cloud VR Growth



building immersive interfaces through curved-surface display technology for immersive, dizzy-free VR experience.

Aside from fostering new standards, China Telecom tried reducing product costs through order-made mass production to keep the price of standalone VR devices with interactive game capability under RMB 2,000.

China Telecom puts all video games and clips on the cloud and worked with BesTV to organize a VR video clip contest; it also co-hosts the VR Short Film Festival 2018 with Shanghai's Oriental Pearl Television Tower to promote VR films and the ecosystem. In addition, China Telecom also plans to upgrade their 100+ service points for customers to enjoy hands-on VR experiences.

China Telecom also planned to start trial cloud VR operations in Shenzhen as the city offers better Internet infrastructure and over 2,000-2,500 potential customers in the first quarter of 2019. In order to provide better experiences, China Telecom will optimize end-to-end fiber-optic network in Shenzhen.

Starting from the second quarter of 2019, the company will kick off a large-scale promotion to cover areas including the Pearl River Delta in Guangdong Province and will provide comprehensive VR services in the fourth quarter in other major cities, provincial capitals as well as level-1 and -2 cities of the country.

b. Tencent

Tencent provides communication services such as WeChat and QQ that covers 1 billion customers from 362 Chinese cities and cooperates with more than 20 million business partners. Since Tencent has already invested substantially in games and social networks, it would invest more on AR/VR as a result as it already invested on AltspaceVR, India's "Hike" VR social network, content company "Original Force" and ZANADU, a Chinese VR travel agent.

Tencent's main purpose of such investments is to understand VR applications. The company expects the upcoming 5G mobile network will change people's communication activities and VR is also a possibility. The company had planned to bring VR to WeChat in 2018.

On AR applications, Tencent developed an AR game, "Let's Hunt Monsters", with Chinese-style contents to resemble "Pokémon GO". As one of the three Chinese Internet giants, Tencent tried to enter the VR hardware market in 2015 and released the Android-based "Ministation" system; however, the hardware performance at that time hindered user experience and the company decided to cancel the following development and turned to software instead.

c. Huawei

Huawei has the largest market share of end-user products in China and it has plans on AR/VR as well. The company entered the VR field in 2015 and collaborated with Nvidia, Intel, iQIYI and

more than 50 operators to promote "VR OpenLab plan" for a better focus on cloud VR researches.

Huawei released a prototype of integrated end-to-end Cloud VR home gateway system that could significantly reduce 60% of the home deployment cost. The entire system includes a standalone VR and a set-top box that provides a smart 300M wireless network to centralize VR contents, rendering and unified management on the cloud server.

To Huawei, live Cloud VR streaming covering NBA games, Olympics, superstar concerts and news scenes is the most profitable application. Since cloud rendering lowers the requirement for performance on the end-user side, it lower the hurdles for VR cloud game to enter homes and to become the application that users are willing to pay for. In addition, Cloud VR theaters with huge screens and high-definition IPTV are also promising businesses.

Huawei developed an AR Engine in hope to have it pre-installed on mid- and high-end smart phones that are expected to ship over 50 million units a year. As the AR Engine supports both the Kirin processor and other mid-range chips developed by the company, Huawei is going for the "AR Engine + AR Core" strategy for AR applications to take advantage of both.

On end-user products, Huawei currently focuses on developing a phone-based AR platform and had recently conducted a research

project on AR glasses. In terms of the ecosystem, Huawei unveiled an AR/VR developer support plan dubbed "Shining Star" offering a RMB10 million fund to foster quality AR/VR applications and contents and the plan provides 1,000 devices for qualified small- or medium-size developers to produce AR/VR applications.

4. Japan

Japan has a well-developed industry with AR/VR applications mainly on gaming and recreation. The major Japanese players include Sony, Nintendo, Meleap and more.

a. Sony

Sony is a world-leading company in game consoles. In 2016, the company released the PS VR accessory that allows VR gaming to stimulate user excitement and to extend the lifecycle of PS4. From 2013 to 2018, PS4 sold well 5 years in a row and maintained the leading position in the game console market.

In 2018, Sony estimated that PS4 sales volume would decline comparing to the previous year and speculated that PS4 was entering the end of product phase; however, the sales of PS VR accessory also declined in the same period of last year. The accumulated sales volume of PS VR reached 3 million in 2018 in contrast to 85 million units of PS4. That is, the overall PS VR sales is less than 3.5% of PS4 and it shows that the gaming VR market is yet to mature.

To SCE (Sony Computer Entertainment), the strategy is to reduce hardware cost and

increase software service income. In terms of reducing hardware cost, recently Sony licensed China's Lenovo for PS VR hardware design for license fees to recover part of the original development cost, while the upgraded PS VR2 might push back to follow the launch of PS5.

The great potential of AR also interested Sony. Sony adopted the Google AR engine to develop the "Ghostbuster World" mobile game app in October 2018 and it is worth paying attention that how Sony would combine mobile cloud games and the existing console gaming ecosystem.



b. Nintendo

Reaching from TV console games to mobile games, Nintendo had made four games by 2018; among them "Pokémon GO" received the best popularity.

The Pokemon company is a subsidiary of Nintendo (which owns 32% of Pokemon stocks), and the profits from Pokémon GO is shared between Niantic and Pokemon. To enhance Pokémon GO's AR gaming experience, Niantic has proposed new AI-based multiplayer technology for lower latency.

On AI, Niantic finds that recent AR games are easily to have "AR image floating on reality world image" phenomena so as to let the users have the sense of unrealistic; therefore, using AI to identify the object's contour and depth in the reality image so as to fusion AR image and reality image seamlessly to increase the sense of reality.

With the current technology, cell phones connecting to each other through base stations require 100ms transmission time to refresh the status of nearby players. If the phones could communicate directly with each other, the transmission time could be reduced to less than 10ms to improve the sense of real-time online interactions.

c. Meleap

Meleap is a Japanese company that received JPY 720 million investment in 2018 with an accumulated fund of JPY 1.12 billion. The

company's AR game unit, HADO, is planning on organizing a professional gaming league and opening more stores worldwide for its live gameplay broadcasting business.

HADO adopts head-mounted displays and sensors worn on arms so players can compete with others using AR energy balls and shields. Two teams of 3 players each compete with others in rounds of 80 seconds. HADO held a world cup competition in 2018 with 7 teams from Japan, England, Korea, Singapore, Malaysia, Indonesia and Hong Kong.

Thanks to the well-received competition, HADO's overseas business occupies 60% of the total sales; and this encouraged the company to explore overseas opportunities with more stores

to welcome more participants and audience. In 2018, the company planned to open a total of 52 stores in 23 countries worldwide.

5. Korea

With Samsung's AMOLED panel and semiconductors, Korea has a solid foundation for AR/VR developments. During the initial stage of VR developments, Korea's advantage on key components attracted many opportunities of international cooperation, while domestic businesses such as Samsung, LG and SKonec also invested heavily on the AR/VR industry.

a. Samsung

As a major player in the VR industry, Samsung made substantial investments while its AMOLED is pursued by almost every VR

Meleap's HADO AR Games









Source: Meleap, 2018

helmet manufacturer as well. Due to the limited hardware performance at that time, high refresh rate AMOLED panels are crucial for resolving the uncomfortable sense caused by display latency.

Thanks to this advantage, Samsung obtained many cooperation opportunities, include Facebook that uses Gear VR for phone calls, and Samsung Odyssey that works in combination with Microsoft's Tethered VR headset using PC. Samsung also bundled Gear VR with new smart phones sold to expand the company's VR market share.

In addition, Samsung uses its image sensor semiconductor departments, Samsung CIS, and lens manufacturing facility to develop Samsung 360 Round cameras for professional users as well as consumer-level Gear 360 cameras for VR video recording.

Samsung slowed down the developments of end-user VR devices in 2018 and focused more on developing high-end VR headset panels. In the first half of 2018, the company canceled the bundling program of Gear VR and new flagship smartphones and did not follow competitors to release standalone headsets immediately.

In addition, Samsung did not release any updated new cameras that record 360-degree VR films in 2018; and due to the price and shipment issues, Samsung's AMOLED panels were not used extensively in standalone VR headsets. But the company still keeps on improving its AMOLED.

Currently Samsung provides panels for VR helmets mainly with specifications of 3.5 inch/615 ppi/90 Hz, but in SID 2018 the company unveiled a new AMOLED panel reaching 2.43 inch/1200 ppi/120 Hz. The new panel should make future VR helmets lighter and capable of displaying clearer images.

b. LG

In Korea, LG is the second largest OLED manufacturer, and it jumped on the VR bandwagon in 2016 to release a series of products. Taking advantage of the hot "Project Ara" modular phone concept at that time, the LG G5 phone could have various accessories attached to add functions. It had VR modules as well: the "LG 360 VR" and "LG 360 CAM".

After LG announced the G5 modular phone in early 2016, Google terminated the development of "Project Ara" in September and left the G5 Series unsuccessful.

The G5 Series failed to recover its development cost due to strategic shift and the continuing loss of LG's smart phone department, which decided to reduce loss partly by becoming conservative on VR and AR end-user products.

In 2018, LG did not release new end-user AR or VR products and shifted its VR development to components. For example, Google and LG collaborated to develop a high-definition VR panel of 4.3 inch/18 million pixels (4,800 x 3,840/1443 ppi).

c. SKonec

SKonec is a large VR game developer from Korea. As its own "Mortal Blitz" shooting game was developed with VR in mind, it's been ported to the Samsung Gear VR platform and then to Sony PS VR, HTC Vive, Facebook Oculus and other platforms to become the most active IP in VR shooting game category.

In order to increase VR game popularity, the company built "VR SQUARE", a massive VR gaming experience hall, in 2018 to introduce a range of third-party VR games and it features spaces exclusively for five game types: Walking Attraction, Battle Arena, Escape Room, VR Arcade and Party Room.

In Walking Attraction games, players can move around freely for shooting and RPG actions, while Battle Arena emphasizes on real-time interactions suitable for multiplayer fighting. Escape Room is for horror games while VR Arcade offers various kinds of simulations and a scale-up VR version of Beat Saber, a pop music console game that brings enhanced user interaction. Lastly, Party Room is the company's own IP game.

With games of different scopes and designs, SKonec hopes to boost popularity for VR entertainments. Since SKonec expects that business VR market would surpass the consumer market in the next five years, the company has already started to work on the new applications.

SKonec's VR Developments



Third Party IP



Own IP



SKonec five VR arcade platforms for the market



Source: SKonec, 2018

II. Southeast Asia: AR/VR Potentials, Opportunities

As one of Taiwan's important business partners, the rapidly growing Southeast Asian countries, mainly Thailand, Malaysia, Indonesia, are already demonstrating good potential on AR/VR developments.

1. Thailand

Thailand is currently focusing on the development of "Industry 4.0" to enhance the existing industries such as automobile, intelligent electronics, high-end agriculture, high-value tourism and food products and foster five future industries on the existing foundation: automatic machinery and industrial robots, fintech, biofuel and biochemistry, health care in addition to aviation and logistics. In which automatic machinery and industrial robot, fintech and health care are suitable for AR/VR applications.

With rich experience on manufacturing of high-end electronic products and a complete supply chain of machine tools, Taiwan has the advantage to introduce AR/VR headsets into industrial automation and robot applications to help enhancing efficiency and reducing costs for Thai factories. For fintech developments, Thailand and Taiwan both have complete network coverage, advanced social media and matured creative industry; the two countries can exchange experiences to forge a more globalized

AR/VR commercial and advertising strategy.

In terms of health care, Taiwan can take advantage of its abundant medical experience to facilitate personnel training through AR/VR tools such as headsets to improve the overall quality of medical service in both Taiwan and Thailand.

2. Malaysia

Malaysia is rich on natural resources. Its top-five industries are manufacturing (electronical/electronic and chemical products), agriculture (palm oil) and mining (petroleum, natural gas).

The annual growth rate of Malaysia's service industries reached 6.2% in 2017 and among them real estate, business services and logistics have higher annual growth comparing to which of 2016. In the real estate sector, AR/VR technology can offer virtual visit services to properties. Since Malaysia has 6,356 islands, moving among these islands can be extremely difficult; but it will be a relief to offer virtual property visits for clients to save time and efforts.

In logistics, AR headset can provide assisted navigation assurance on package size for correct quotation and enhanced processing speed. In the manufacturing industries, the growth rate of electronics products was above average to reach

8% in 2017. Taiwan can integrate AR/VR headsets with its manufacturing experience and introduce Industry 4.0 ideas for enhanced efficiency and lowered cost for staff training.

In terms of infrastructure engineering, Malaysia plans to invest RM 168 billion on mega infrastructure constructions, including the Kuala Lumpur-Singapore High-Speed Rail (with a value of RM 60 billion), the East Coast Rail Link (RM 55 billion), the third stage construction of Kuala Lumpur MRT system (RM 40 billion) and the Pan Borneo Highway in Sarawak State (RM 13 billion).

With AR/VR headsets, people can visualize how the finished constructions look like and combine the real and virtual images to minimize the error between the design and completed buildings for the best material efficiency.

3. Indonesia

Indonesia has 263 million people and is the world's fourth largest country in terms of population; however, due to the unevenly distributed habitation density, metropolitans occupy 45% of the population and the largest city, Jakarta, has more than 10 million. Indonesia has a huge population bonus and median of citizen age is under 30. Together, the productivity and the huge consumer base support the country's prosperous economic development.

In 2017, the economic growth of Indonesia was mainly from consumer products and services,

investment on fixed assets along with growth on exports. The country's agricultural lands took up 74.5% of the overall soil with palm oil production occupied the world's 50%. However, Indonesia's manufacturing industry was still in development and contributed only 21% of the GDP.

Taiwan's manufacturing experience in combination with Industry 4.0 and AR/VR headsets can help improving production efficiency for Indonesia.

It's worth paying attention that the Internet population is low in Indonesia, as such the initial entry point of AR/VR opportunities in Indonesia is mainly business applications. As the third largest motorcycle market only next to China and India, the sales volume in Indonesia was 5.886 million units (YoY-0.7%) in 2017, which means that the motorcycle market is approaching maturity and female motorcyclists is increasing. That is, promoting relevant services becomes a potential business opportunity since multimedia AR/VR headsets can present luxurious product images to promote motorcycle sales.

Taiwan is the most important source of Indonesia's plastic machinery with 40% market share. Since only a small percentage of Indonesia's machinery was locally made, its industry requires frequent maintenance services for the imported equipment. AR/VR headsets can improve remote maintenance quality and shorten the training period of local personnel to reduce maintenance costs.

Thanks to the growing economy, Indonesia's home appliance market keeps on growing, and AR/VR headsets can help people to experience and understand how these large appliances work in real life contexts to increase sales. Since the Internet population is low in Indonesia, PC consumers are mainly users of low- to medium-priced laptops and tablets. Consequently, the expected business opportunities for AR/VR headsets in Indonesia will be in low-price Mobile AR/VR applications.

Local operators can strategically promote AR/VR concept in the mass market, and then promote higher-end AR/VR headsets as the country's GDP grows.

4. Singapore

With the benefit of pivotal geographic location, Singapore has become Asia's hub of aviation. In the past 20 years, the value of Singapore's aerospace industry was growing 8.6% annually as the largest center of aircraft maintenance, repairing and overhauling with more than 10% of the world's aviation-related factories.

AR/VR headsets can improve maintenance efficiency for technicians, increase feasibility of remote maintenance and customer services while boosting productivity and reducing maintenance costs. The high-value aerospace industry can easily afford professional AR/VR headsets designed for high-level AR/VR applications.

Singapore encourages small and medium enterprises to develop "Industry Digital Plans" (IDPs) to strengthen investments on pioneering technologies such as Artificial Intelligence (AI), Data Analytics, Cybersecurity, Immersive Media and Internet of Things. Among them AR/VR is categorized as immersive media and is welcomed by the Singapore government.

At the same time, electronic commerce (EC) is also a key category actively fostered by the Singapore government. In 2016, the country's EC revenue exceeded US\$1 billion and the number would be as high as US\$5.4 billion by 2025, which takes up as much as 6.7% of the overall retail sales. The AR/VR headsets that provides virtual experience are expected to help consumers to enjoy better shopping experience and therefore increase EC transactions.

Chapter 3

Cultivation and Growth: Taiwan's XR Industry



I. Overview of Taiwan's XR Industry

As Taiwan has established a comprehensive IT industry supply chain in the PC era, local IT companies such as Nuvoton Tech, PixArt Imaging, AU Optronics, InnoLux and HiMax Technologies can serve as the foundation to Taiwan's XR industry development since they're holding the key components technologies like sensors, microprocessors and high-end display panels required by head-mounted displays. HTC - the VR hardware device pioneer, the world's leading VR industry player and a well-established brand - is the perfect candidate to lead and drive the growth of Taiwan's VR peripheral industries.



TAIWAN XR INDUSTRY LANDSCAPE-HARDWARE

360 Camera



VR Headset/Smart Glasses



PC



System Integration



Components



Peripherals



ODM / OEM



TAIWAN XR INDUSTRY LANDSCAPE-SOFTWARE

Games



Live Events



Consulting



Retail



Video Entertainment



Real Estate



Education



Marketing



Engineering



Medical



Tools



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As the industry is growing prosperously, the market calls for lower hardware prices to further facilitate XR popularity. Taiwanese hardware ODM/OEM makers such as Foxconn, Wistron, Pegatron, Compal, Quanta and InvenTech can consider entering the industry at this stage to further propel the development of XR industry.

Apart from hardware developments, software application is another sector that attracts many Taiwanese enterprises and startups. In areas such as gaming, video entertainment and live broadcasting, education, engineering and marketing are seeing rapid developments. Digital content providers that have devoted their efforts in creating contents for games and videos have

the upper hand in becoming the leader of this new industry. The players will strive for new opportunities to drive the software industry value and Taiwan's XR industry forward.

Based on the research results, the figure clearly presents Taiwan's XR industry in 2018, the current industry development, and its future opportunities.



II. Analysis of Taiwan's Current XR Industry

From September to December 2018, this survey sent questionnaires to 250 XR companies in Taiwan. Respondents of the 76 valid questionnaires collected are from 52 startups founded less than five years ago, as well as 24 companies and listed companies of more than five years.

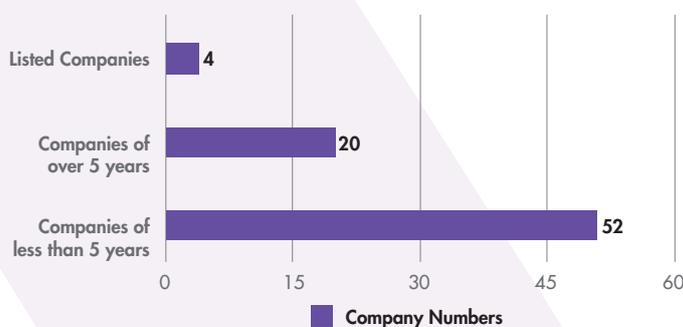
This survey analyzes distribution of Taiwan's XR companies and their revenues, profits, operating expenses, technology sources, sales channels and human resources in 2018, and also examines the prospect for Taiwan XR Industry in 2019.

1. Distribution of Taiwan's XR Companies and Sectors in 2018

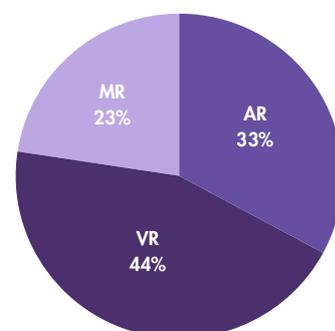
This survey focused on companies in Taiwan's XR sector in 2018, among which 68% are startups founded less than five years, and 32% are listed companies or companies founded more than five years. This shows that XR is a relatively young and blooming industry in Taiwan.

As VR receives more attention in recent years, the field received the most resource for XR companies in Taiwan (44%); meanwhile, many companies involved in AR for its growth potential in the future (33%). MR (Mixed Reality), which incorporates AR and VR applications, received 23% of the resource.

Age and Technological Categories of XR Companies



Technology Categories



Source: XR EXPRESS TW, 2018

Most XR companies choose to develop proprietary application technologies in the categories above. Most companies focused on XR content development due to its diversified prospects; the second-place category contained hardware manufacturers and platform service providers (5-10%); applications from product distribution, off-line experience, marketing and curating come in third (5%).

Fewer companies focus on hardware manufacturing because of the higher fund requirement and the technological entry barrier. For platform services, since XR is relatively new and there is yet a mainstream content platform that has an definite market advantage, many companies launched own-brand applications and platforms in hope to dominate the market as the industry incumbent.

It's believed that as the XR industry grows and matures, the leading content platforms

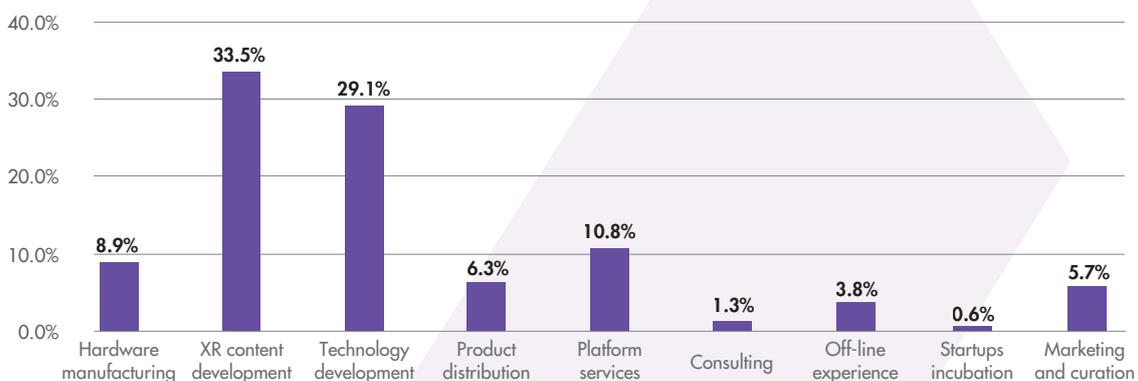
would continue to grow while driving smaller platform providers out of the market. As a result, the number of platform service providers would continue to drop.

2. Revenue Statistics of XR Companies in 2018

According to the survey, the production value of the XR sector in Taiwan totals NT\$3.93 billion in 2017 and NT\$4.66 billion in 2018 with a growth rate of 18.4%. The calculation of production value had ODM/OEM companies excluded.

The annual revenue of most companies (34.2%) in the XR industry ranged between NT\$10 to 100 million in 2018. 22.4% of the respondents generated their annual revenues between NT\$1 to 5 million, while 18.4% of the companies made a yearly revenue of NT\$5 to 10 million.

Core Business Distribution of XR Companies

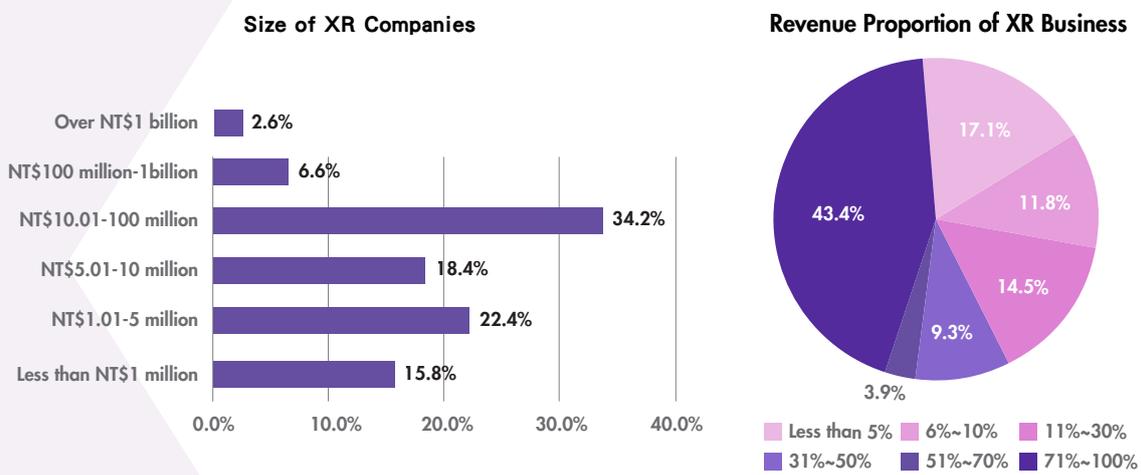


Source: XR EXPRESS TW, 2018

Regarding revenue contribution, XR is the core business for 43.4% of the respondents, accounting for 71% to 100% of the total revenue and followed by 17.1% of the companies that saw XR as an emerging opportunity for growth and were interested in exploring this field, which accounts for less than 5% of the total revenue.

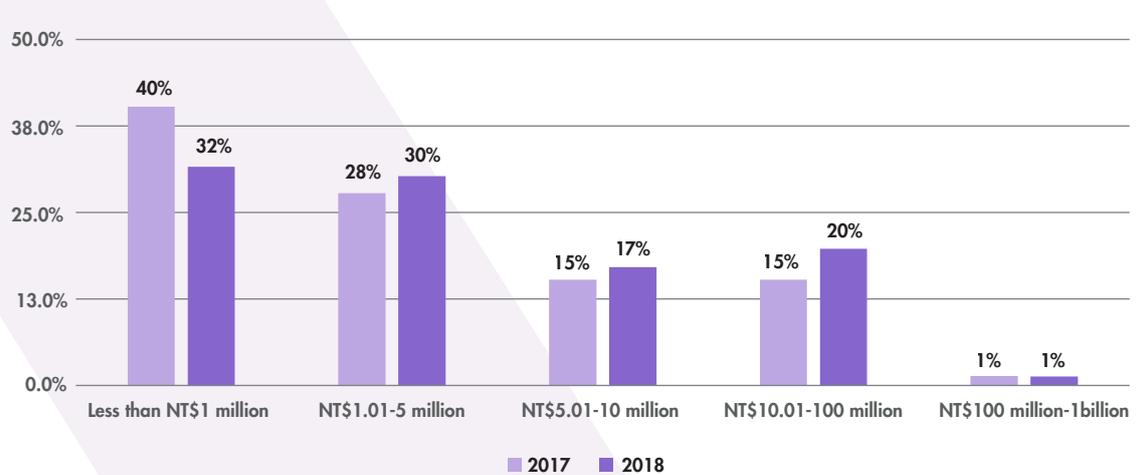
In terms of the revenue generated by the XR department in each company, the XR department of 60 to 65% of the companies generated less than NT\$500 million in 2018; that of 15 to 20% of the companies made NT\$5 to 10 million, and that of 20% of the companies generated more than NT\$10 million in revenue.

Revenue Scales of XR Companies and the Proportion of XR Business



Source: XR EXPRESS TW, 2018

Revenue from the XR Sector



Source: XR EXPRESS TW, 2018

Benefited from XR's secular growth, the survey shows that 8% of the XR companies have grown in scale as the revenue of these companies increased from less than NT\$1 million in 2017 to more than NT\$ 1 million in 2018.

According to the survey, in 2017 and 2018, most companies generated less than NT\$5 million in XR revenue, accounting for 60 to 70% of all XR companies for two consecutive years. This indicates that making more than NT\$5 million in revenue is a pivotal milestone for most XR companies.

The XR companies' momentum for revenue growth benefited from secular growth of the entire industry; in 2018, 68.1% of the XR companies in Taiwan enjoyed positive growth in revenue, 23.6% of the companies maintained

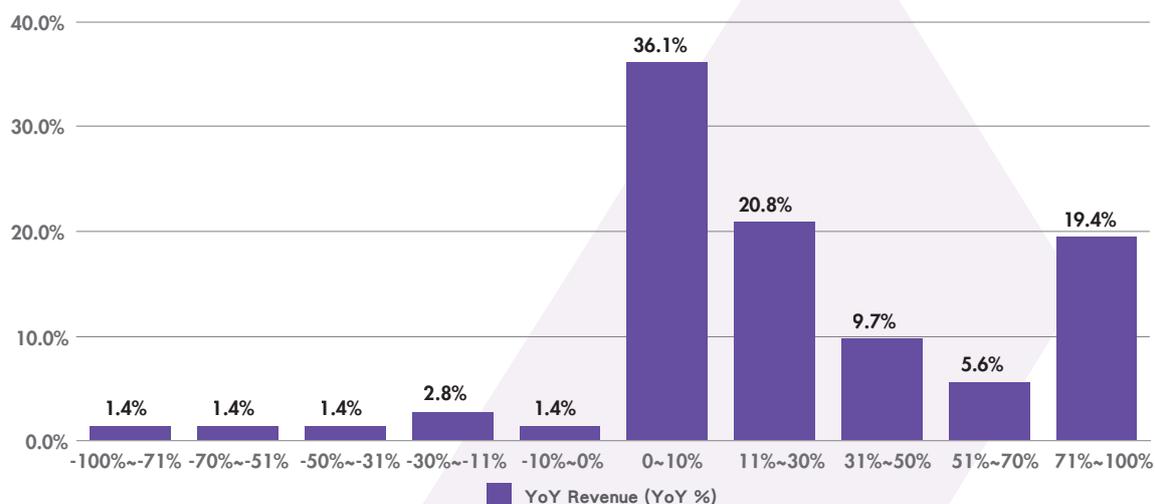
similar revenue levels and only 8.3% of the companies suffered from declined revenue.

In 2018, the average growth for XR companies in Taiwan reached 26.5%; 55.5% of the companies enjoyed double-digit growth, indicating that the XR industry is blooming.

Regarding XR applications in Taiwan, the four application categories of the highest revenues are gaming, marketing, video entertainment, and education, accounting for 23.0%, 15.1%, 14.5% and 11.8% of the total revenue respectively.

The four application categories enjoying the most rapid growth are medical, retail/e-commerce, video entertainment and Industry 4.0, which experienced double-digit average growth in terms of revenue contribution.

2018 Growth Rate of XR Revenues



Source: XR EXPRESS TW, 2018

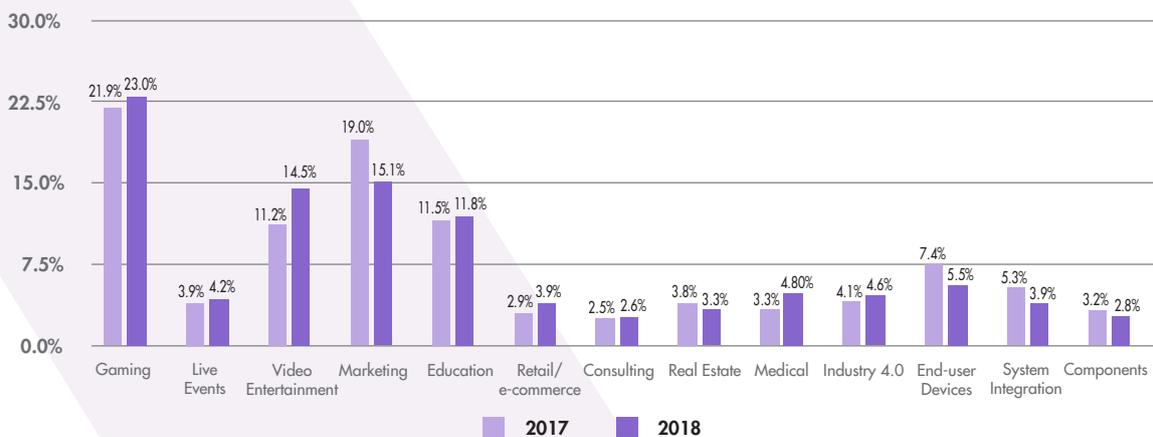
Gaming plays a central role among all application categories; whereas most applications focused on VR technologies in 2018. Because gaming was the focus in the earlier stage of VR developments, it accounts for 23% of all XR applications. However, the growth of revenue contribution of gaming has slowed down. Since XR technologies could be applied to a variety of fields, many companies started exploring XR applications in other categories, resulting the slowdown.

As online video platforms and social media sites such as YouTube and Facebook started supporting videos in various VR formats, the proportion of video entertainment among all XR applications have been on the rise, growing from 11.2% in 2017 to 14.5% in 2018, which is the highest growth among all categories.

Besides, affordable 360-degree VR cameras entering the market have lowered the barrier to VR content production. It is no longer reserved for professional photographers – anyone could become a VR content creator. Consequently, the amount and diversity of XR contents have increased, driving up the proportion of video entertainment in all XR applications.

Marketing is a crucial category for XR applications because AR applications could provide a new form of user experience that connects the virtual and the physical environment and increases the probability of successful sales. In the education area, due to the policies that encourage adaption of innovative technologies, educational institutes started to take advantage of XR interactions to enhance student engagement in classrooms.

2018 Distribution of Application Categories for XR Companies



Source: XR EXPRESS TW, 2018

The introduction of XR applications in the industries and medical take longer because of safety concerns for the human body as well as factory facilities. According to the survey outcome of 2018, the growth rates for XR applications in medical and Industry 4.0 have reached double-digits, indicating that the development of XR technologies has been consistent enough to be introduced into these application fields.

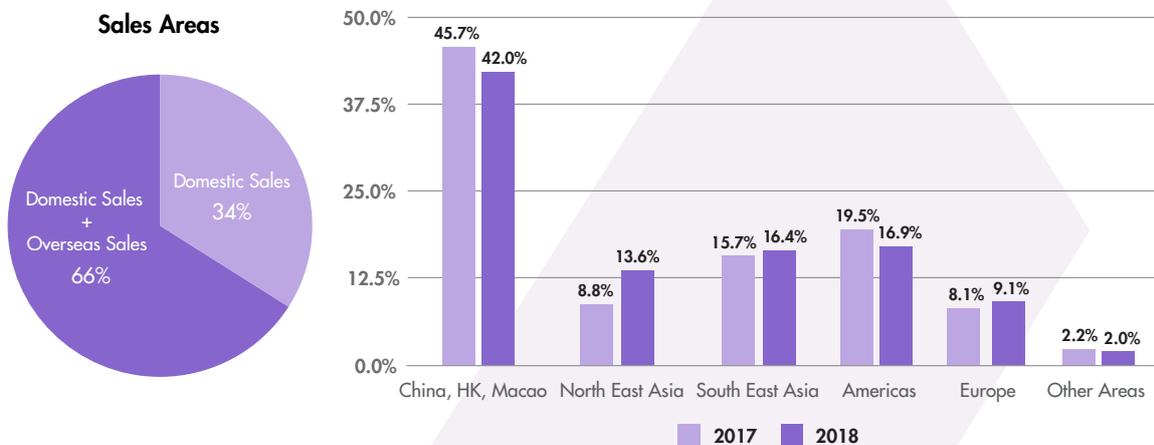
Furthermore, XR applications in retail/ e-commerce are on the rise as well, mainly due to the secular trend of converting brick-and-mortar stores into online distribution channels. The compound annual growth rate (CAGR) for e-commerce in Taiwan is 15 to 20%; hence, we can also expect to see double-digit growth in the revenue of retail and e-commerce companies that apply XR technologies.

Export-wise, 66% of Taiwan's XR companies generated revenue through exports. Since there are XR business opportunities worldwide, it's expected to see the 34% of the companies, whose entire income comes from the domestic market, exporting XR products to the global market.

In summary, exports from XR companies in Taiwan are growing. Among the companies branching into the global market, exports account for 45% of the total revenue in average. In 2018, the revenue of XR exports came from (from high to low): China/Hong Kong and Macao 42.0%, Americas 16.9%, Southeast Asia 16.4%, Northeast Asia 13.6%, Europe 9.1% and other regions 2.0%.

The Greater China regions (China, Hong Kong and Macao) tops the export due to its proximity and language; meanwhile, Americas have long been Taiwan's main export destination,

Export Ratio of XR Companies in 2018



Source: XR EXPRESS TW, 2018

and XR is no difference. Regarding other neighboring regions, exports to Southeast Asia and Northeast Asia are similar.

In 2018, the most significant momentum of export revenue growth came from China with growth of 42.3%; the opportunities for growth in regions such as Americas, Southeast Asia, and Northeast Asia are relatively similar.

Europe, on the other hand, has the weakest momentum as its niche XR application markets, diverse languages and longer distance from Taiwan are expected to cause slower growth.

3. Profitability of XR Companies in 2018

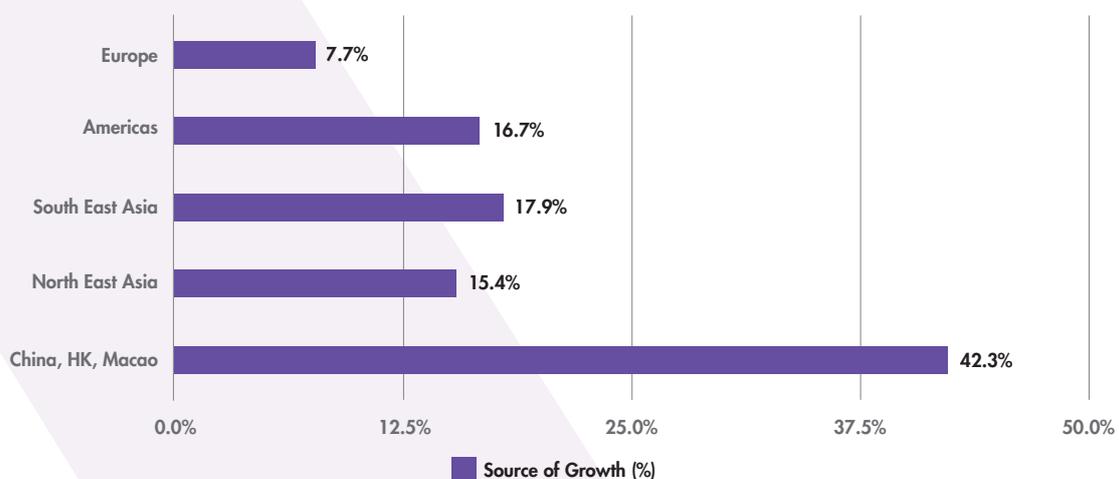
In 2018, more XR companies (about 44.7%) became profitable and more achieved break-even. 32.5% of the companies enjoyed profit growth in

2018 and 12.2% of the companies turned losses into profits. These show that the XR industry continues to grow, driving companies to break even and generate more profits.

In 2018, the average profit growth for XR companies in Taiwan was approximately 16% as most XR companies reached 11% to 30%. This shows that secular growth of the XR industry led more companies to break even and generate more profits. The growth prospects of XR remain strong and are heading into a booming cycle.

According to the results of the survey, the average profit growth for XR companies in Taiwan is approximately 16% in 2018, slightly lower than the average revenue growth (25.6%). There are two likely explanations: first, since XR technologies have yet to reach maturity, the companies were increasing R&D expenses to

Sources of XR Export Growth in 2018

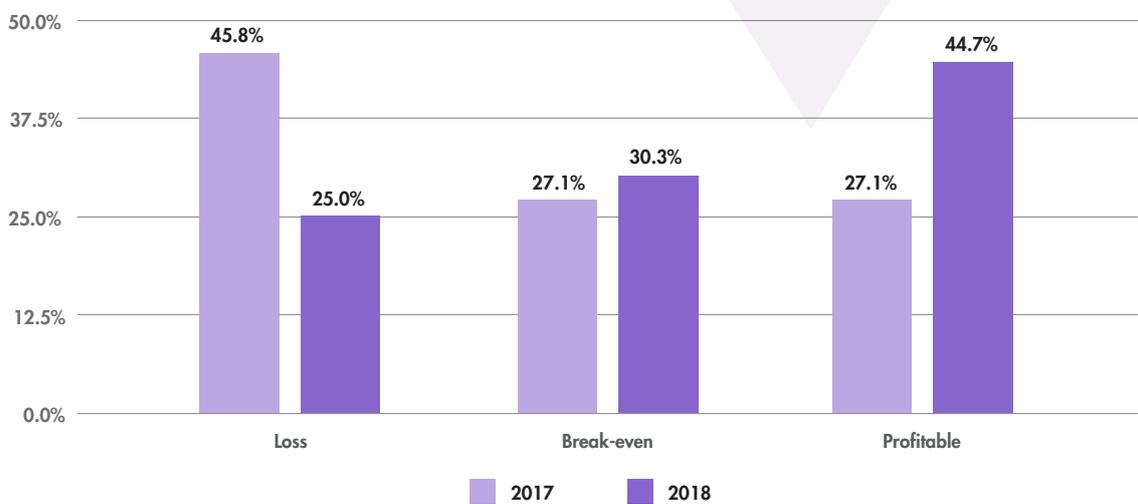


Source: XR EXPRESS TW, 2018

cultivate XR capabilities and thus decreased short-term profits; second, the diverse XR applications and products take time to achieve the economy of scale.

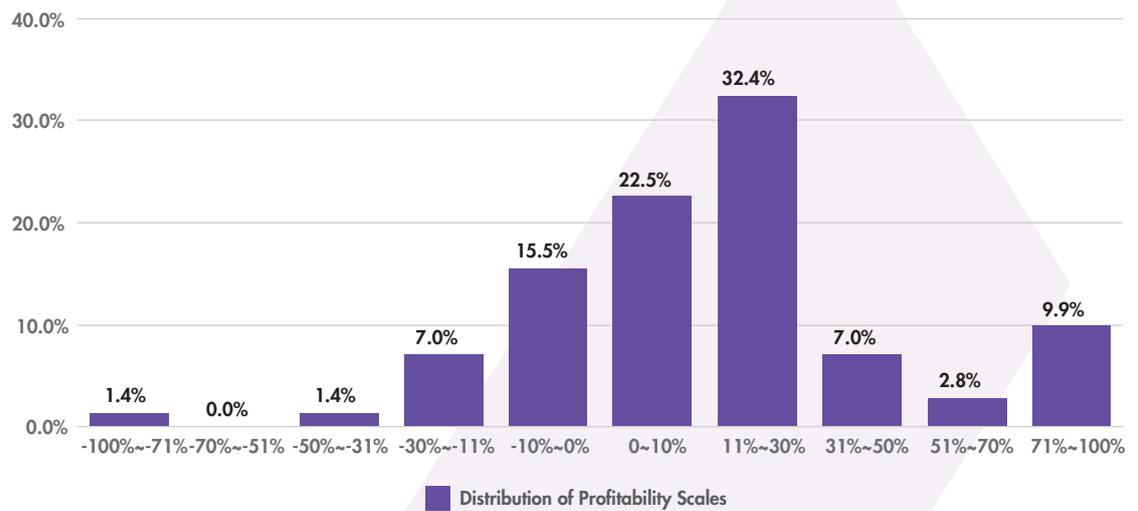
According to the results of the survey, 58% of the respondents have funding needs with a total of NT\$2.9 billion. 25% of the companies are seeking Seed round funding while 30% are in

Profitability Statistics of XR Companies



Source: XR EXPRESS TW, 2018

2018 Profitability of XR Companies



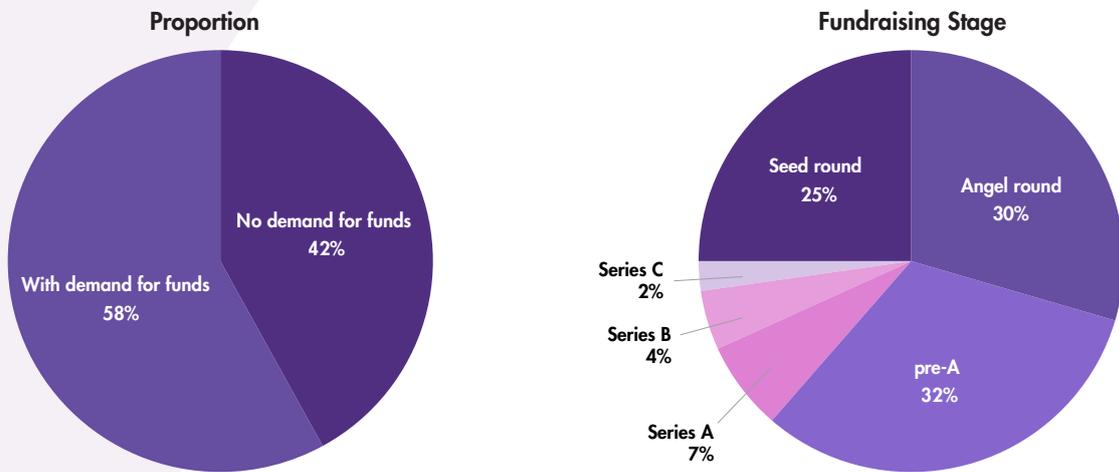
Source: XR EXPRESS TW, 2018

Angel round, and 32% of the companies are trying to secure Pre-A money. XR startups (founded in less than five years) accounts for 84% of the companies with funding needs with a total of NT\$2.6 billion.

4. Operating Expenses of XR Companies in 2018

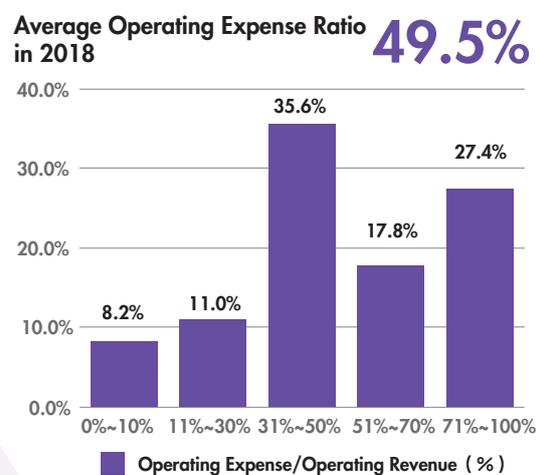
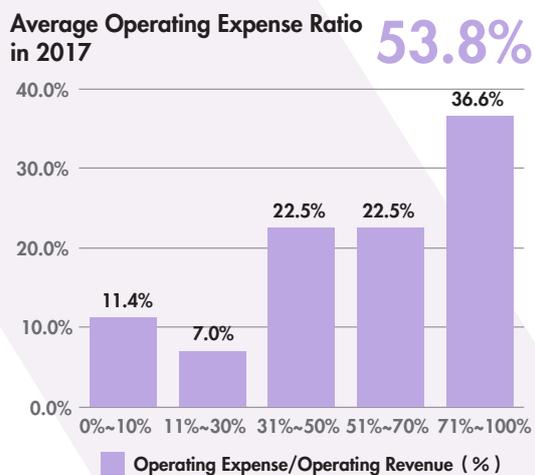
The Operating Expense Ratio (Operating Expenses divided by Operating Income, OER) of XR companies declines as the scale of revenue grows. The average OER dropped from 53.8%

Funding Needs of XR Companies in 2018



Source: XR EXPRESS TW, 2018

Operating Expense Ratio of XR Companies



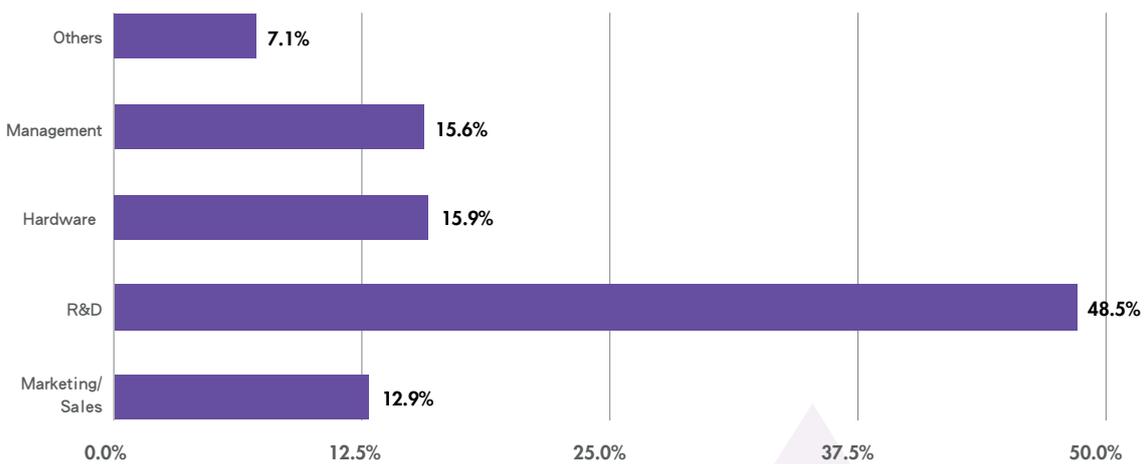
Source: XR EXPRESS TW, 2018

in 2017 to 49.5% in 2018. The decline in OER shows improvements on a company's overall profitability.

Among the Operating Expenses, the OE items of XR companies in 2018 include (from high to low): R&D 48.5%, hardware 15.9%, management 15.6%, marketing 12.9% and miscellaneous 7.1%.

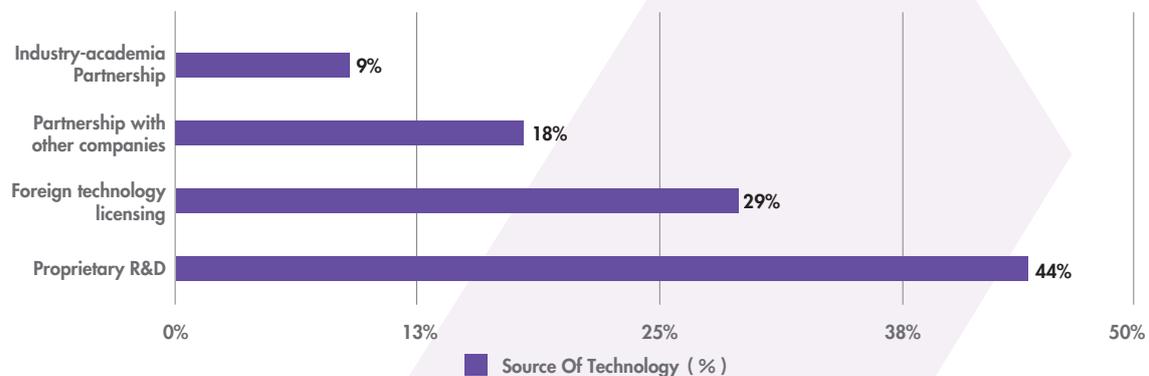
As revenue grows, the following items increased (from high to low): R&D, marketing, hardware and miscellaneous, while decline of the following items could improve profitability (from high to low): hardware, R&D, management and marketing.

Breakdown of XR Company Operating Expenses



Source: XR EXPRESS TW, 2018

Sources of XR Technologies



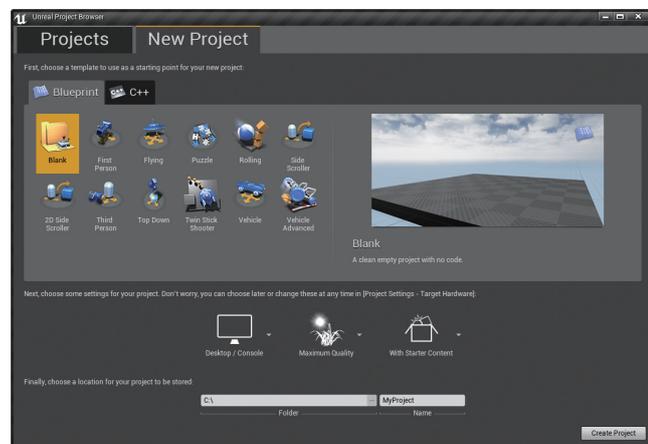
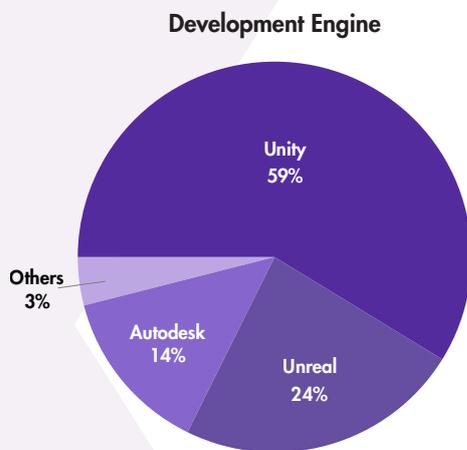
Source: XR EXPRESS TW, 2018

5. Technology Source Statistics of XR Companies in 2018

Technological Research and Development (R&D) is where XR companies spend their money, which account for 48.5% of their overall

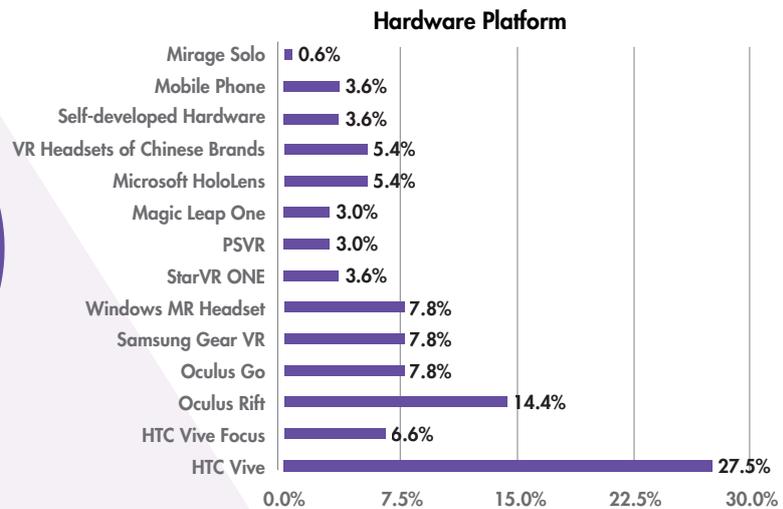
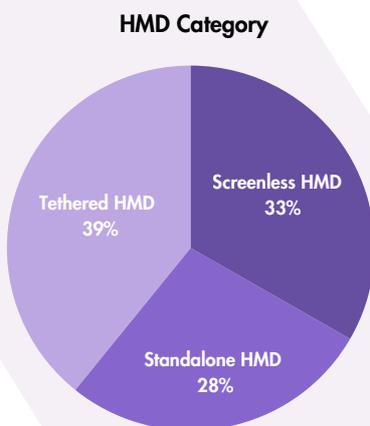
expenses. The sources of technologies include proprietary R&D (44%), foreign technology licensing (29%) and partnership with other companies (18%).

XR Software Platforms Employed



Source: XR EXPRESS TW, 2018

Statistics of XR Hardware Platforms



Source: XR EXPRESS TW, 2018

Since XR devices are often complicated in design and require integration of multiple technologies, most companies aim to develop proprietary expertise in a particular field while collaborating with other companies via licensing agreements to develop fully functional XR products.

Regarding software engines, the major software engine employed by XR companies are Unity, Unreal and Autodesk, while some companies use C language, OpenGL and OpenCV. Unity and Unreal are mainstream software engines popular among game developers: Unity is a popular game engine among mobile game developers in the past decade for its ease of use and rapid modeling, while Unreal has an even longer history in development of independent online games with sophisticated graphics.

Autodesk is a graphic engine for industrial modeling suitable for developing niche AR/VR applications. Autodesk acquired Bitsquid and launched the Stingray software engine to be more grounded in both industrial and game development fields.

Regarding hardware device categories, 39% of the XR companies use Tethered HMD (head-mounted display), followed by 33% of the companies that use Screenless HMD and 28% that use Standalone HMD.

Such distribution is coherent with the evolution of XR hardware devices as Tethered HMD launched first, and then Screenless HMD becomes more common after primary mobile platform providers such as Google, Apple, and Samsung entered the XR market. Recently customizable low-power, high-efficiency chips appeared on the market to drive the emergence and market share of high price-performance Standalone HMD.

On hardware platforms, XR companies in Taiwan prefer HTC and Oculus devices which accounted for 34.1% and 22.2% respectively. HTC and Oculus platforms have higher market share because of the first-mover advantage and branding success. Other platforms such as Windows MR, PSVR, Microsoft HoloLens and Chinese VR headsets entered the market at a later stage and have lower market shares of below 10% respectively.

6. Sales Channels of XR Companies in 2018

The XR industry leverages two marketing channels: online and offline. In Taiwan, most XR companies publish their apps to online app stores such as Mac/iOS App Store and Google Play. Video entertainment is delivered on social media such as YouTube and Facebook while PC applications are distributed on HTC Viveport, Steam, Oculus Store and more.

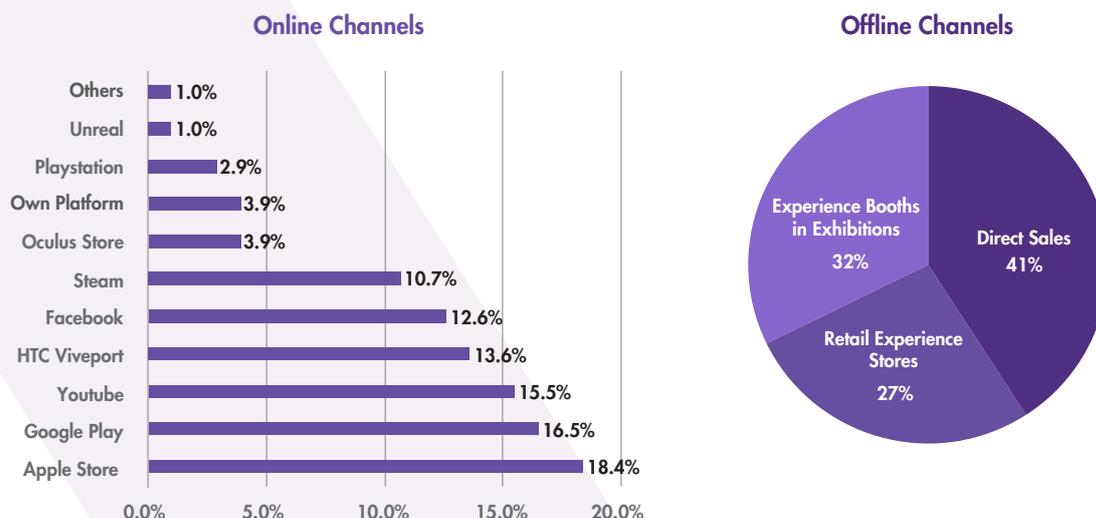
On the other hand, due to the high costs involved in developing an offline channel, most companies rely on direct distribution to save expense. This model represents the largest offline channel, accounting for 41%, compared with exhibition booths, the second largest, at 32%, and the costliest retail experience stores at 27%.

7. Human Resource Allocation of XR Companies in 2018

According to this survey, 89.5% of all XR teams consist of less than 20 members in 2018, whereas team sizes of 21-50 and 50-100 only take up 6.6% and 3.9% respectively. Judging from the overall headcount of a company and the size of an XR team, it can be inferred that a team of 6-20 is the most likely size of a sprinting XR startup. It is worth noting that teams having fewer than 5 members are common (27.6%). Teams of this size are often spin-offs or small startups at an early stage.

As for the total headcount of companies investing on XR, those having more than 100 employees occupy 7.9%. Generally speaking, these Taiwan companies are mainly "light asset" firms instead of core manufacturers. Therefore, companies at a size over 50 employees only account for 10.5%.

XR Sales Channels: Online & Offline



Source: XR EXPRESS TW, 2018

Based on the chart below, thanks to the growing revenue and profit generated by the XR industry, more than 52.6% of Taiwanese XR companies had an increasing demand for talents

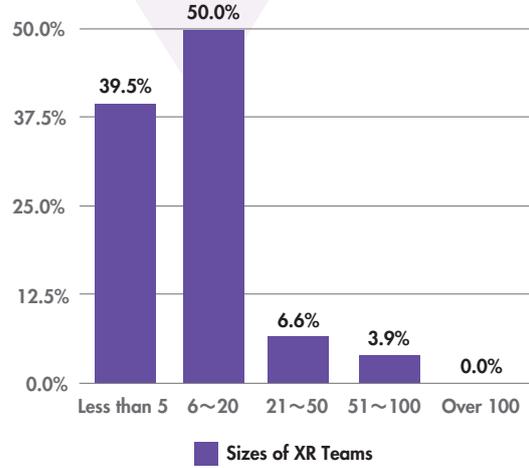
in 2018 and 35.5% at the same level. Looking forward to 2019, Taiwanese XR companies hold an even more positive outlook. As a result, talent demands rise to 73.7%, 21.1% higher than 2018.

Human Resource Allocation of XR Companies in 2018

Total Employees

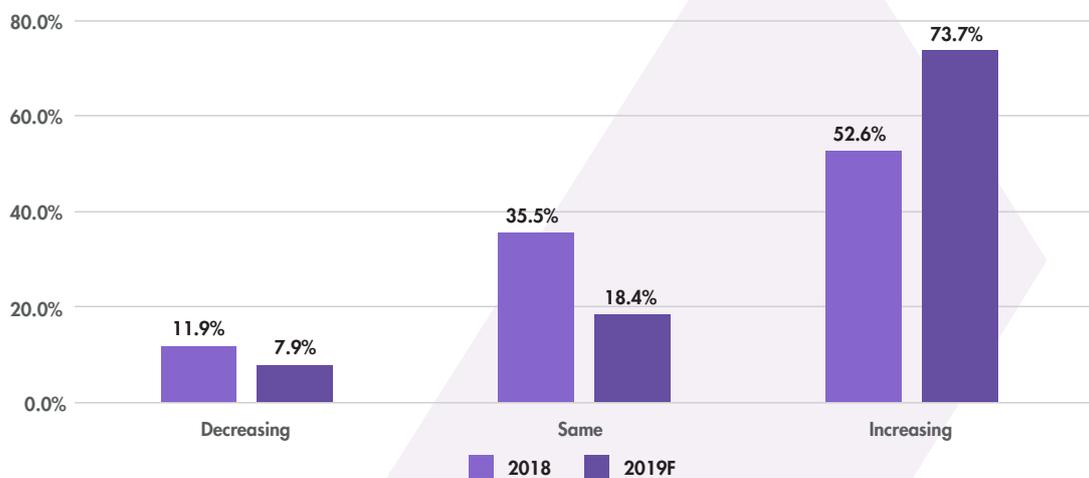


Sizes of XR Teams



Source: XR EXPRESS TW, 2018

XR Company Demands for Talents



Source: XR EXPRESS TW, 2018

III. Prospects for Taiwan's XR Industry

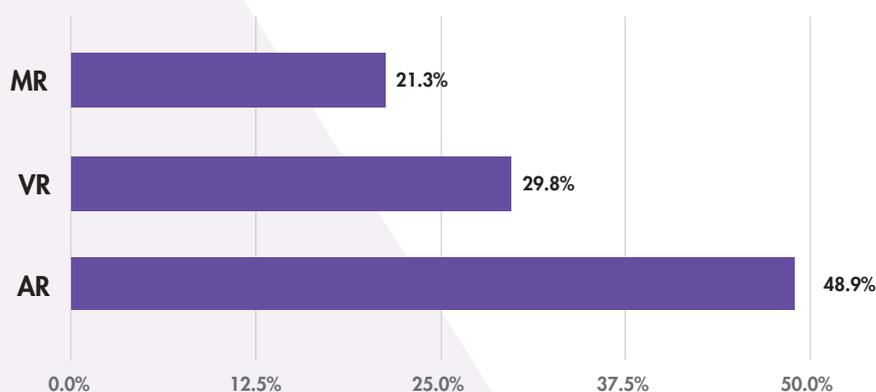
Most XR companies in Taiwan consider 2019 a promising year of growth, the highest one being AR at 48.9%, VR at 29.8% and lastly MR.

As a combination of real-world environments and computer-generated information, AR is still a new territory yet to be explored. Most companies believe that AR and VR industries are likely to take off in the next two years, where chances are higher for AR rather than VR.

Approximately 40.8% of the companies predicted that the AR industry will boom in the next 12 months whereas MR, a mixture of AR and VR technologies, is less likely so due to technical integration hurdles. Most XR companies suggest that it still takes another 2-3 years before the MR industry catches up.



Favored Technologies in 2019



Source: XR EXPRESS TW, 2018

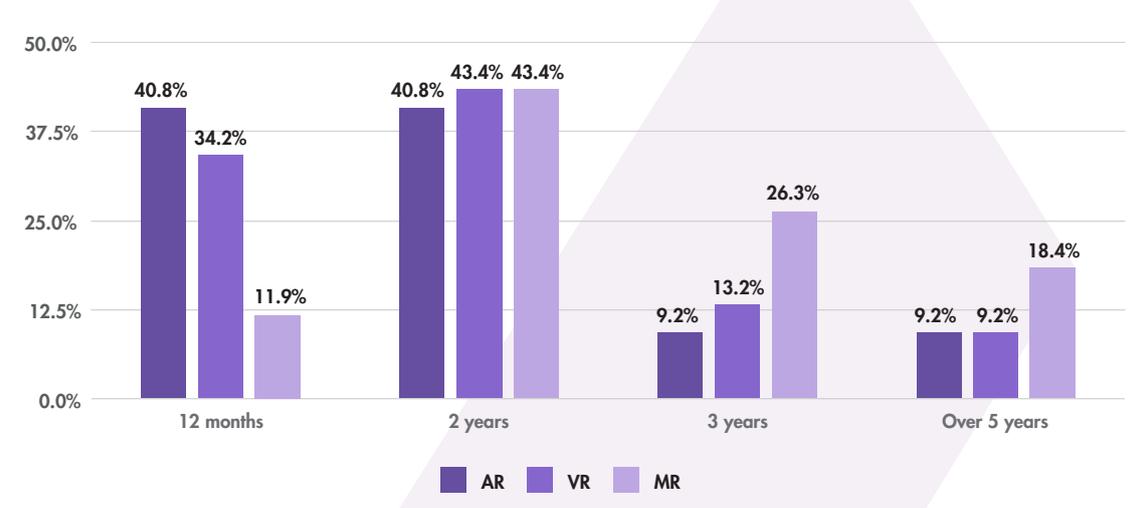
Taiwan XR companies argue both AR and VR industries are faced with the same bottleneck - lack of contents; however, this is a challenge as well as an opportunity. The industry is still too young to have abundant contents, but it also means fewer competitors in each application field. If an XR company dare to be the first to dive deep in a particular field, it might become the leader to take all the profit.

In terms of the AR industry, most companies in Taiwan reckon that lack of contents and low user awareness are the two major impediments to its success. The former accounts for around 30.6% while the latter 20.6%. For low user awareness, the majority of companies believe that AR will see a higher growth than VR, so media attention in the XR industry might shift from VR to AR to increase the latter's visibility and user awareness as well.

The VR industry, on the other hand, has higher user awareness as it rolled out a range of devices and received considerable media coverage in 2017. That said, the industry is experiencing setbacks such as affordability, lack of contents and poor user experience caused by dizziness, representing 26.4%, 22.5%, and 24.2% respectively in the survey.

In terms of price, hardware cost is bound to drop in the future and more standalone VR devices with better price-performance will be launched. Needless to say, contents will also be enriched following the industry's growth. As for popular video streaming applications, 360-degree videos used to be pricey in terms of production hardware and the main audience were professional photographers as a result. In the future, affordable models are expected to hit the market, allowing general consumers to record 360-degree videos and produce more contents.

Forecasted Take-off Time of XR Industry



Source: XR EXPRESS TW, 2018

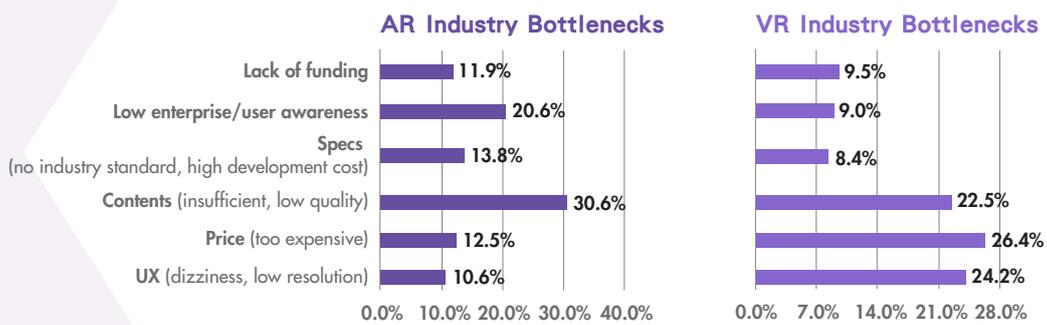
Lastly, dizziness felt during the VR experience is largely caused by long latency between hardware rendering and display. As computing power continues to break records, the uncomfortableness will eventually disappear.

XR software is also highly anticipated in 2019, especially in gaming and education fields, 20.8% and 18.4% respectively according to the

survey. Other potential fields include video entertainment, marketing, medical, Industry 4.0 and more, taking up 12.1%, 11.1%, 10.6% and 8.3% respectively.

Gaming was the most popular XR application category in 2018 at 23%, and new varieties of XR games are likely to further increase the volume and market value. In 2018, education applications

AR/VR Industry Bottlenecks



Source: XR EXPRESS TW, 2018

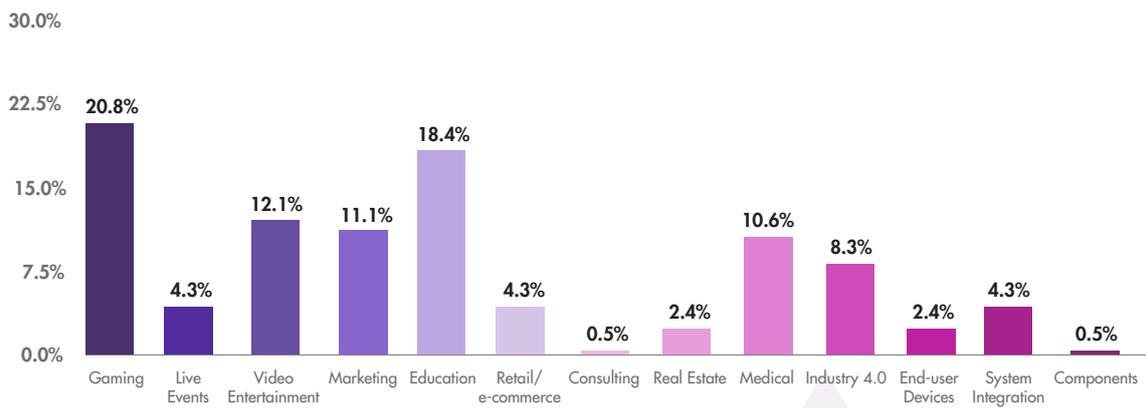


accounted for 11.8% of XR application category; this could be explained by a better learning experience in a highly interactive XR setting.

Students can learn from a first-person point of view with VR or access a virtual explanation of real-world learning materials in real-time with AR. Having such a great potential, education applications are thus considered the second fastest growing field by XR companies in 2019.

In terms of hardware, XR companies in Taiwan expect to see growth in Standalone HMD with high price/performance value in 2019. As for hardware platforms, HTC and Oculus will continue to enjoy first-mover advantages and account for 33.3% and 25.7% respectively in Taiwan's XR industry in 2019.

Growth Potential of XR Fields in 2019



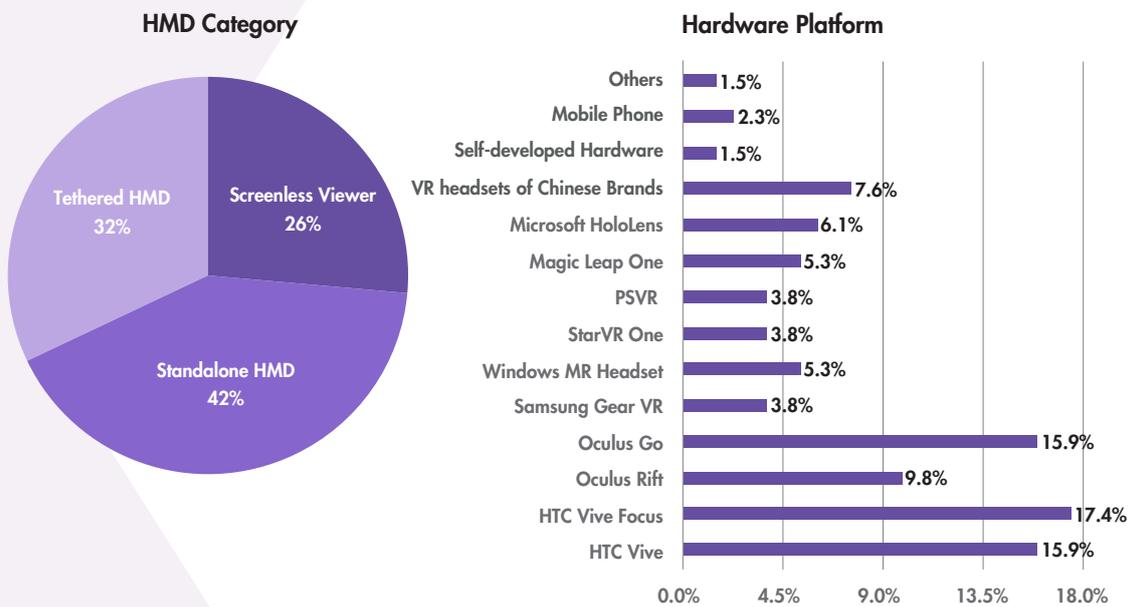
Source: XR EXPRESS TW, 2018



Data also shows that growth of standalone HMD is higher than that of Tethered HMD of the same brand; HTC hardware users choose HTC Vive Focus while more Oculus users tend to use Oculus Go rather than Oculus Rift.

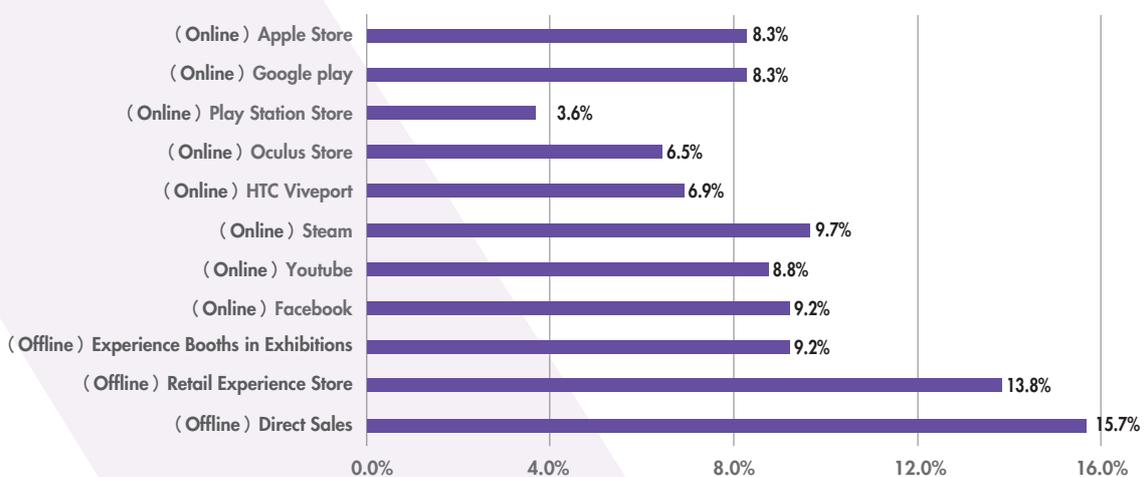
For sales channels, in order to increase user recognition to XR, the importance of better offline experiences echoes around Taiwan XR companies. Offline channels include companies' direct distribution, accounting for 15.7%, retail

Hardware R&D and Growth in 2019



Source: XR EXPRESS TW, 2018

XR Product Sales Channels in 2019



Source: XR EXPRESS TW, 2018

experience store, 13.8%, and exhibition stand, 9.2%. As there are already various online sales platforms, the XR industry has yet to mature; therefore there is not a leading platform featuring

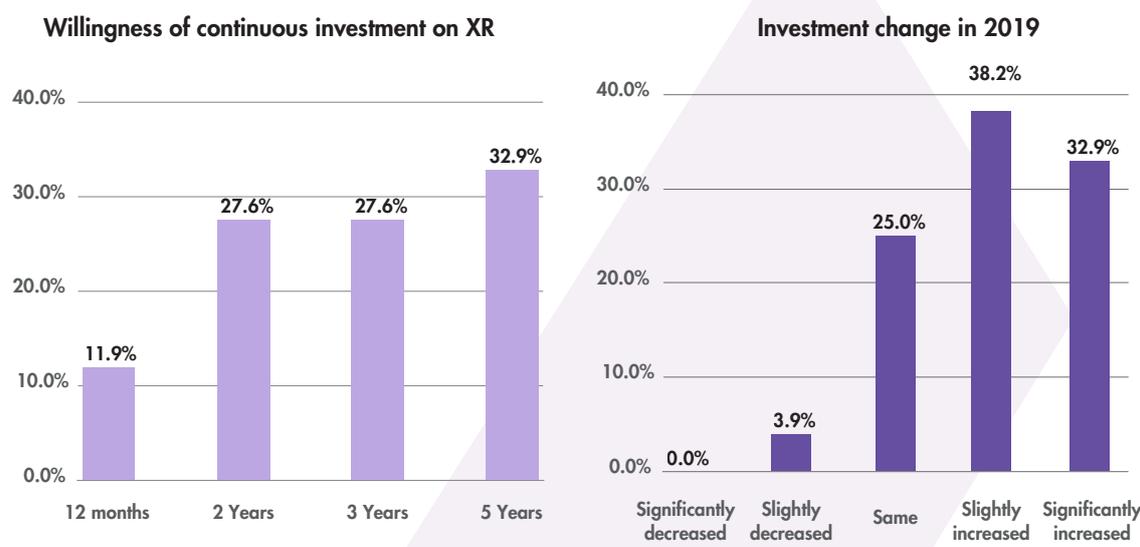
applications, and most XR companies strive to support as many platforms as possible to avoid missing any business opportunity.

Overseas Sales Opportunities of XR Products in 2019



Source: XR EXPRESS TW, 2018

Investment Timeline and Funding of XR Industry



Source: XR EXPRESS TW, 2018

In terms of overseas sales, XR companies in Taiwan believe that the neighboring Greater China Region (China, Hong Kong and Macao) has the highest growth potential due to the language similarities; sales growth in this region is expected to be 43.5%.

Other areas including Americas, Southeast Asia and Northeast Asia are expected to have sales growth of around 14%-18%, while the chance for Europe is lower due to its longer geographic distance from Taiwan.

In summary, the survey demonstrated optimism on the XR industry in the long term. 88.1% of the stakeholders will invest on XR for at least 2 years or more; 32.9% of them will significantly increase their investment in the industry, which would benefit the long-term development of the domestic XR industry.

Conclusion

According to the survey, the market value of the XR industry in Taiwan reached NT\$4.66 billion in 2018 with double-digit growth in both profits and revenues. The industry looks healthy overall. In 2018, XR companies that achieved profitability or break-even status hiked from 54.2% to 75.0% with 12.2% of them turned losses into profits.

XR companies are young in general, where 68% of them are start-up companies founded within 5 years and 79% of them have annual XR-related revenues of under NT\$10 million. These companies are expected to grow in size along with the industry as a whole.

The XR industry is an emerging industry, and there are still numerous application markets to be explored and developed. 71.1% of the XR companies are willing to increase their investment to step up the industry revenues and market share. The survey shows that there are a variety of key XR technologies that require more funds, and therefore 96.2% of the companies hope that the government can provide supports to the industry.

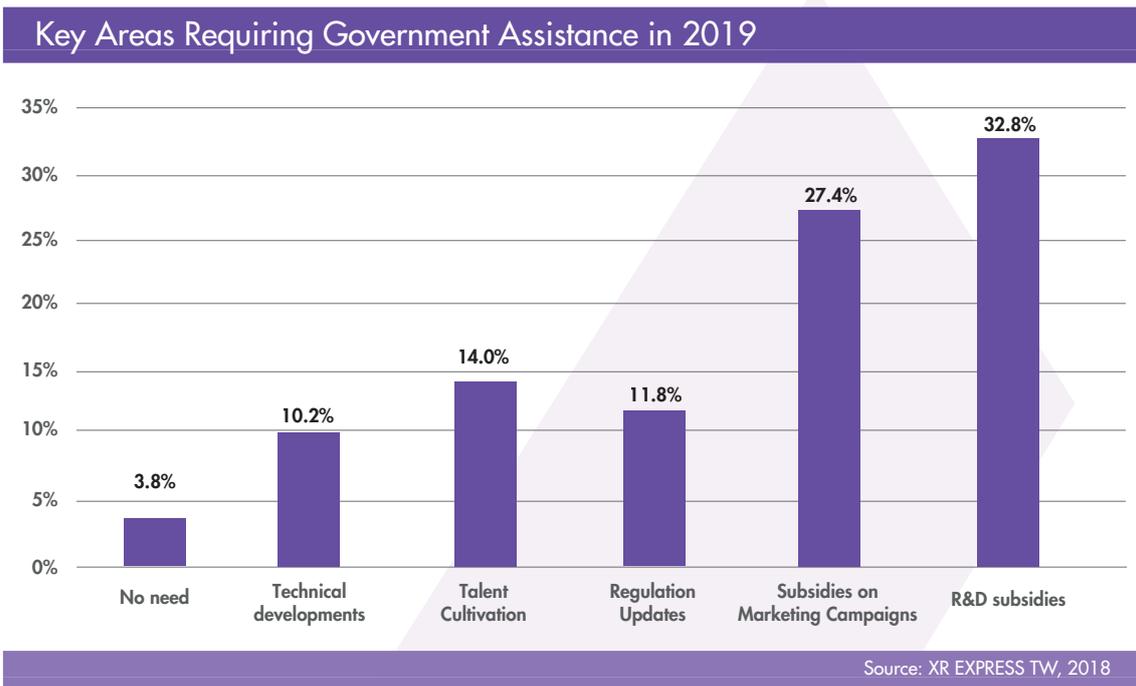
Furthermore, 32.8% of the companies hope that the government can fund research and development whereas 27.4% of the companies expect to receive subsidies for marketing campaigns.

The XR industry is also a promising source of international business opportunities. Since 66% of the companies in the survey have overseas sales revenue, the government may utilize resources available to help Taiwanese XR companies to attend more overseas exhibitions and forums in the future.

In the aspect of applications, AR is expected to replace VR to become the next popular application in the XR industry; 48.9% of Taiwanese XR companies believe that AR applications are going to become the momentum of the XR industry in 2019.

The XR industry covers a variety of applications include gaming, video live broadcasting, video entertainment, marketing, education, retail/e-commerce, real estate, Industry 4.0 and more. With enormous potential growth expected, XR applications will be the next-generation IT category to improve productivity and economic efficiency.

As 88.1% of Taiwanese XR companies have confidence in the industrial growth and will keep investing for at least two years or more, the XR industry still has ample room for growth and further investment.



Chapter 4

From Virtual to Reality: Advices for Taiwan's XR Industrial Policy



I. Learning from Other Countries

Since HTC, Oculus, Samsung and Sony released VR headsets in 2016, immersive technology has caught public attention within a relatively short period. International corporations such as Google, Microsoft and Facebook have also made an all-out effort in the XR industry, while startups focusing on AR/VR have multiplied in numbers and are finally attracting attention from governments.

This report collects the policies governments employed to support the XR industry and separates them into two categories: the first category, represented by the United States, encourages free market competitions. The US has a large domestic market and promotes free, effective competition in the marketplace. As a result, the governments seldom formulate subsidy policies for the XR industry; the second category involves special markets or cultures and therefore the governments offer special subsidies to promote the industry.

South Korea, for instance, mainly focuses on exports due to its relatively small domestic market, so the government formulates subsidy plans and provides funds to help propel its XR industry into the global market. On the other hand, China tends to establish its own market rules and technical standards to serve its huge domestic needs and industry development objectives.

Different government policies that support their respective XR industries and industrial developments are as follows:

1. UK

UK Research and Innovation (UKRI), the British Government's non-departmental public body for innovation and research, had announced its investment in immersive technology companies in April 2018. Its largest and most pronounced commitment to immersive technology has been £33 million (around US\$41.89 million) of funding made available for those companies throughout 2018 and 2019. It is hoped to fundamentally change products and services in the next 20 years as well as to find talents who can transform the industry.

Around £16 million has been used in the Audience of the Future Demonstrators program. A further £12 million has been pledged to fund research and development projects and £5 million has been provided for training and research programs to develop the creative talent pool.

Immersive tech companies also enjoy the tax incentives the government is offering. Tax incentives available to companies include:

- a. Companies that work on innovative technology projects can claim back as much as 33% of their R&D costs while larger companies can claim up

to 12%.

- b. Companies can enjoy tax breaks as low as 10% of profits earned from patented inventions.

2. France

La French Tech, launched by the French government in 2013, is a publicly funded initiative to promote French startups and industrial transformation. More than funding startups, La French Tech also supports entrepreneurs and organizations that contribute to startup ventures.

The three pillars of La French Tech are as follows:

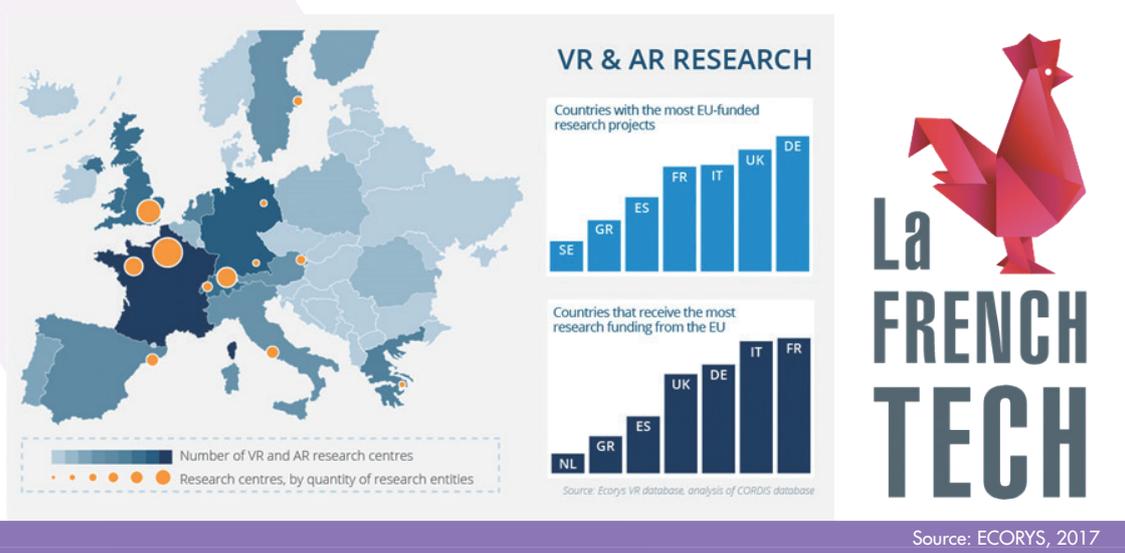
- a. Connection: gather related resources of startups by connecting influential cities.
- b. Acceleration: €200 million managed by the French Public Investment Bank helps startups to develop new business models.
- c. Promotion: a further €15 million has been

allocated to help French digital companies that has succeeded internationally.

The XR industry is one of the industries that La French Tech supports. France has the most European R&D centers focusing on immersive technology specializing in the manufacturing, engineering and film entertainment industries. In other words, it is well-positioned for the development of XR software applications and contents. The applications for end-users in the French market are diverse as many of the world's leading luxury brands were originated in France.

As the second largest European consumer market, France attracts 70 million consumers with high purchasing power. This is why 17 out of the global Top 200 companies are currently operating in France. With these advantages and government support, France is well-positioned

France attracts worldwide investments with the most XR R&D Centers



for attracting XR talents from around the world.

In terms of integrating resources, the French Government geared up to shape its international dimension through the French Tech Hub brand, which is aimed at providing an international online platform for entrepreneurs, investors and executive agencies to exchange ideas.

This platform, led by French entrepreneurs, has built a network helping startups create their international projects and has involved around 50 large French corporations and over 1,000 startups. Currently metropolises such as Tokyo, New York, San Francisco, London and Moscow have joined the French Tech Hub network, bringing the number of participating cities to 22. French Tech Taiwan was also established in 2016 and the number of French startups in Taiwan has reached 50 in 2018.

To accelerate innovation and startups, the French Government launched the French Tech Ticket in 2015. This program was designed for entrepreneurs from all over the world so that they can create startups in France. To encourage talented teams to start their businesses in France, the government provides a 130,000 square-meter space for incubators and offers startup founders a simplified fast-track procedure to obtain a residence permit in merely 3.5 days.

The French government also provides tax exemptions to startups through Jeune Entreprise Innovante (JEI) and Crédit Impôt Recherche (CIR). Following the JEI status, startups can enjoy a 100% exemption in corporate tax during the first year and a 50% exemption for their second year. The CIR offers tax breaks on R&D costs: 30% of R&D costs are exempt from taxes to encourage startups to cultivate their R&D competitiveness.

In June 2017, the French Tech Visa was implemented and allowed internationally to qualified talents, whether they were entrepreneurs, employees or investors, and their family members to apply. Applicants were requested to hand in startup projects that are not only innovative but also helpful to the development of French industries. With this visa, foreign workers with a master's or higher graduate degree can work in France without a work permit. As for investors, they have to invest at least €300,000 either directly or via a company in which they have at least 30% of the shares. The eligible applicants are entitled to a renewable four-year Passport Talent visa.

The French government also helps local companies to attend the Consumer Electronics Show (CES). In 2016, 130 new French technology companies went to Las Vegas for CES 2016; in 2017, 172 French companies attended the CES Shanghai in China. In 2018, the number of French startups accounted for 1/3 of the companies in Las Vegas CES Eureka Park as the reputation of French startups has been rising year after year.

3. China

China's 13th "Five-year Plan" includes the XR industry and deems its development a priority. In December 2018, the Ministry of Industry and Information Technology of the Chinese government issued the Guiding Opinions on Accelerating the Advancement of the Development of the Virtual Reality Industry, pointing out that virtual reality integrates technologies such as multimedia, sensors, new displays, the Internet, artificial intelligence and more as they will change product and service models, thus creating profound effects on the economy, technology, culture, military and people's life.

China's mid-term development goals for the VR industry are to construct a complete industry chain by 2020 that can be applied to important industries, establish industry technology innovation centers, research and develop core and critical technologies as well as to create exemplary applications and solutions that can be replicated and promoted. Long-term goals are for the VR industry to rank high in the world, possess core industry patents and standards, establish VR corporations that are competitive internationally as well as to propel development quality and related benefits.

Priority Development Tasks for China's VR Industry (I)

Core Technology Breakthroughs	Effective Supply of Products	Promote Priority Applications
<ul style="list-style-type: none"> • Near-eye Displays • Perceptual Interaction • Rendering • Content Creation 	<ul style="list-style-type: none"> • Whole-set Equipment • Perceptual Interaction • Content Acquisition Equipment • Software Tools for Developments • Industrial Solutions • Distribution Platforms 	<ul style="list-style-type: none"> • VR+Manufacturing • VR+Education • VR+Culture • VR+Healthcare • VR+Commerce



Source: Ministry of Industry and Information Technology, 2018

Priority Development Tasks for China's VR Industry (II)

Establish Public Service Platforms	Create a System of Standards	Strengthen Security Protection
<ul style="list-style-type: none"> • Innovative Common Technology Services • Incubation Services for Innovative Startups • Inter-industry Matching Services 	<ul style="list-style-type: none"> • Promote the System of Standards • Accelerate Establishment of Priority Standards • Certification of Standard Compliance 	<ul style="list-style-type: none"> • Strengthen VR Platform Security • Enhance Protection on Important VR Data and Personal Information

Source: Ministry of Industry and Information Technology, 2018



The VR industry creates new opportunities but also faces many challenges, such as an insufficient supply of core technologies and high-end products, lack of content and services and a limited support system. To accelerate developments, the Ministry of Industry and Information Technology states six priority tasks: 1. breakthrough in core technologies, 2. increase the effective supply of VR products, 3. promote the application of priority products, 4. establish public service platforms, 5. construct a standard specification system and 6. strengthen security capacities.

In pursuant to the six VR priority tasks instructed by the Ministry of Industry and Information Technology, 13 of China's provincial, city, and local governments have started planning industry strategies. For example, Beijing has issued Measures on Facilitating Innovative Development of Zhongguancun's Virtual Reality Industry, using Zhongguancun Science and Technology Park Shijingshan Park as a center to promote technological R&D, transformation of achievements, service platforms for industry promotion and other measures. Nanchang has also issued Policies on Accelerating Development of the VR/AR Industry (Amended), instructing that the Honggutan New Area VR Technology Park and the newly built AR Hardware Technology will be the primary exemplary zones to promote R&D, attract companies and talents, market promotions and other developments through incentives, subsidies, funds and other financial support. Fuzhou has also announced

its Ten Measures to Accelerate VR Industry Development to build the Changde Technology Park to promote growth from complementary measures, attracting corporations, innovative startups and other aspects.

4. Korea

South Korea has invested immense efforts in promoting AR/VR. Other than establishing special funds and subsidy measures, the South Korean government also provides an infrastructure and has already mapped out the next generation of developments for the content industry in the early phases to prepare themselves for new application models. The South Korean governments initiated a government AR/VR special fund, the first in the world, of around US\$35.8 million in a span of 7 years. The special fund leverages the government to promote the development of VR ecosystem, invest in AR/VR games, build theme parks and establish companies that integrate educational resources. Other than providing funds to develop the industry, the South Korean government is also focused on the next-generation content industries such as VR and gaming, movies, theme parks, pop music and more.

In October 2016, the Ministry of Science, ICT, and Future Planning of the South Korean government officially issued its Constructing an AR/VR Ecosystem national policy. The Ministry would partner up with the Ministry of Culture, Sports, and Tourism as well as Ministry of Trade, Industry, and Energy, other governmental

agencies and private corporations to invest 405 billion won (US\$390 million) in the next five years.

South Korea has competitive hardware and Internet industries but are lacking in platforms and content creation. As such, the MSIP industry promotion measures include:

- a. Strengthen horizontal connections: establish a fund by working across agencies and encourage innovation in VR devices and content creation;
- b. Expand vertical applications: help corporations explore application services or develop VR content through subsidy plans.

5. Singapore

Singapore's Ministry of Communication and Information issued the Infocomm Media 2025 Masterplan in hope to solve the challenges of the next ten years through industrial innovations. The masterplan lists out the nine major innovative technologies of the next decade: Big Data and Analytics, IoT, Cognitive Computing and Advanced Robotics, Future Communication and Collaboration Technologies, Cyber Security, Immersive Media, Mobility and Increased Connectivity, Media Content Breaks Free from Platforms and Infocomm Media Convergence.

In 2017, the Ministry announced their Infocomm Media Industry Transformation Map, and the three major strategies:

- a. Guide corporations and employees to adopt digital technology: develop industry digitalization plan targeting SMEs and assist

businesses adopt digital technology.

- b. Increase investments in frontier technologies for improved capacity: frontier technologies are defined as artificial intelligence and data analytics, cybersecurity, immersive media, IoT and other items of similar importance. The immersive media include virtual reality, augmented reality or other advanced display technologies, human-computer interaction and more to create diverse consumer experiences.
- c. Strengthen infocomm media corporations and professionals.

The goal of Singapore's policies is to grasp the opportunity of the digital economy and move towards an Intelligent Nation through assisting industries adopt emerging technologies, cultivating ICM talents and corporations as well as facilitating future digital transformations.

II. Advices on Taiwan's XR Industrial Policies

With the development of emerging technologies, XR hardware equipment, content services and application models have become matured. In the future, XR will integrate 5G technologies to foster a new generation of ergonomic wearable devices that manage daily information and provide personalized services for users. Since XR will change the way industries work as well, how we could build a XR ecosystem is a subject that deserves our attention and government involvement in the process.

To offer policy advices to the government, the research team selected six primary fields for XR applications including smart manufacturing, education, health care, business, entertainment and smart city, and then conducted one- to two-hour interviews leading businesses and professionals to collect policy advices on developing the XR industry.

This paper interviewed the following 17 leading large corporations and notable startups :

List of Interviewed Businesses

No.	Category	Company name
1	Smart Manufacturing	SYSTEX Corporation
2	Smart Manufacturing	WE JUMP AR CO., LTD.
3	Smart Manufacturing	National Taipei University of Technology
4	Smart Manufacturing /Medical	Jorjin Technologies Inc.
5	Education	Shadowworks Co., Ltd.
6	Education	Axis 3D Technology, Inc.
7	Medical	Augmented Intelligence, Inc.
8	Medical	DeepQ Technology Corp.
9	Medical	Taipei Medical University Hospital
10	Business (Retail)	iStaging Corp.
11	Business (Retail)	ARPlanet Digital Technology Co., Ltd.
12	Business (Retail)/ Smart Manufacturing/ Entertainment	StarVR Corporation
13	Entertainment	HTC VIVE VR Enterprise Solutions
14	Entertainment	HTC VIVE VR Content Center
15	Entertainment	Brogent Technologies Inc.
16	Smart City / Entertainment	Taiwan Mobile Co., Ltd.
17	Smart City	OSENSE Technology Co., Ltd.

To perfect the study, this paper also includes additional comments from TAVAR (Taiwan Association for Virtual and Augmented Reality) experts and startup pioneers.

As a result, a total of 20 policy advices on five primary aspects have been carefully compiled. The five aspects are the environment, regulations, capital, talents and the global market. We also urge the government to carefully formulate practical policies and devote substantial resources in a timely manner to nourish a better environment for the development of Taiwan's XR industry.

1. Policy Advices

a. The Environment

Advice 1. Promote the "Follow the Pack Leaders" strategy and facilitate cooperation between software and hardware manufactures to create a "X-Team" for the XR industry

- In 2003, Taiwan's two bicycle powerhouses, Giant and Merida united to collaborated with parts suppliers to form an "A-Team". The A-Team ensured that the roots of Taiwan's bicycle industry stayed at home and stopped the virulent price competition often found in conventional industries. According to the Taiwan Bicycle Association, Taiwan's bicycle export doubled up until the A-Team was disbanded and transformed into a society in 2016. During the A-Team years, over 20 members of the same industry competed but also cooperated with each other to help Taiwan's bicycling industry remain globally

competitive up to the date.

- On December 25, 2016, the National Development Council spearheaded the establishment of "IoT Alliance of Asian Silicon Valley" with Mr. Stan Shih serving as the honorary president. The Alliance has two goals: 1. creating an alliance of Taiwanese IoT companies to meet industry demands on R&D, field trials to international marketing, 2. accelerate industrial development by encouraging cooperation between startups and system integrators to incubate more innovations with new communication platforms. There are currently 370 members in the alliance and a total of 90 "Smart City" applications were granted with subsidiaries.
- Hardware manufacturers of Taiwan's XR industry has OEM/ODM capacities for international orders. Unfortunately, the gap between the scale and mindset of hardware and software manufacturers make it difficult for either side to initiate collaboration. We advise the government to learn from the Asian Silicon Valley model and facilitate collaborations among hardware and software manufacturers to establish a X-Team for XR industry developments.
- As Taiwan's XR industry is in its initial phase, involved companies should work as individual entities. The government should provide resources and encourage large corporations to play the leader role to help software manufacturers, mostly SMEs, commercialize their concepts for further development of the XR industry chain. For example, telecom

companies can act as market leaders during the advent of the 5G era and guide SMEs or startups to invest in exemplary XR applications. Investments from the private sector along with government resources are expected to stimulate growth in the 5G sector.

Advice 2. Convene strategy meetings for industry innovation, create action plans for XR Industry development and establish inter-department projects.

- In the 2nd Science and Technology Strategy Conference, the Korean government selected AR/VR as one of its nine priorities with goals to close the technology gap with the U.S. to 0.5 years by 2020. The Ministry of Science, ICT and Future Planning issued the national policy aiming at construction of an AR/VR

Ecosystem. For the policy, the Ministry of Science, ICT and Future Planning, Ministry of Culture, Sports and Tourism, South Korean Ministry of Trade, Industry and Energy, and private sectors planned to invest a total of 405 million won (US\$390 million) in the next five years and began collaboration with Facebook in April 2017 in an attempt to propel XR companies and startups in the global market.

- The Ministry of Industry and Information Technology (MIIT) and National Development and Reform Commission (NDRC) of China compiled "The Special Program for Innovative Developments in Smart Hardware Industry (2016-2018)" in pursuant to the three-year "Internet Plus Implementation Plan". The goal is for China-made smart hardware to reach 30% of the global market



share and for the scale of the industry to exceed RMB500 million. The plan includes AR/VR under the smart hardware framework and is connected to the thirteenth Five-year Plan. On December 25, 2018, the MIIT issued the "Guiding Opinions of the Ministry of Industry and Information Technology on Accelerating the Advancement of the Development of the VR Industry", which defined targets for the future: establishing an AR/VR industry chain by 2020 and becoming a global AR/VR powerhouse by 2025.

- As China and Korea both issued nationwide strategies for the XR industry in 2016, Taiwan continues to remain relatively silent without a strategic counterpart. However emerging industries rely on the well-orchestrated efforts from the industry, government and academia, so we'd recommend the government convene a meeting similar to the one convened by the Board of Science and Technology, Executive Yuan in 2018 for 5G SRB meeting. The meeting should invite experts to discuss a nationwide XR industry development policy and establish inter-department groups to establish yearly goals.

Advice 3. Establish or support XR research institutions to offer recommendations on long-term policy directions and intelligence.

- XR is poised to become an important trend for the next two decades. We advise the government to invest in an institution or provide financial support to an existing think tank that is capable of conducting

technological, cross-market and cross-industry researches on XR to provide long-term assistance and information to related institutions for the entire XR industry to become more competitive.

b. Regulations

Advice 1. Enact special laws that regulate somatosensory services to establish a comprehensive law-conforming environment.

With the rapid development of somatosensory technologies around the globe, XR applications has expanded from gaming to industries such as manufacturing, healthcare, film, commerce and more, which brings opportunities for changes and transformations. Yet the broad definition of XR technologies also creates confusion when the derived products and services are being categorized.

The Electronic Game Arcade Business Regulation Act defines VR devices as a type of electronic game machine and thus must abide by the same regulations. VR technology services, however, is drastically different from the electronic gaming industry at its core and in its future. To expand the diverse commercial uses of VR, the Ministry of Economic Affairs and the Department of Commerce convened a meeting on January 5, 2018, resolving that reality technology equipment meeting specific conditions shall not be regulated by the Electronic Game Arcade Business Regulation Act and are applicable for evaluations. The resolution began with a one-year trial starting on March 1, 2018.

By the end of 2018, 44 operators have signed and agreed to adjust their spaces according to regulations, design better operation flows and rate the games more rigorously.

- As the one-year trial period of the Reality Technology Service Self-Regulatory Rules ends on February 28, 2019, several central government agencies such as local governments, experts, scholars, related associations and the Taipei Computer Association held a meeting in mid-January in which competent authorities agreed to extend the period of this regulation, continue promoting a friendly environment for reality technology and encourage more commercial XR applications.
- XR technology continues to mature and the underlying market possesses a wealth of business opportunities. Large corporations such as Apple, Facebook, Google, Microsoft, Samsung, Sony and HTC have been paving their way into the XR industry, which is a milestone indicating that XR is a key to transform the digital economy. We therefore recommend the government to help the emerging industry develop by easing the Electronic Game Arcade Business Regulation Act or enacting new regulations for XR Services.

Advice 2. Lower related taxes to support development of somatosensory technologies.

- Commercial VR applications are currently more mature in the gaming industry but local

governments impose a 5-10% entertainment tax on such services. In August 2018, the Kaohsiung city government, to create a more comprehensive somatosensory technology industry chain, lowered the tax rate from 5% to 1%. The tax cut will decrease operating costs for manufacturers and attract more somatosensory companies to do business in Kaohsiung.

- Other local governments still maintain a 5%-10% tax rate which is not conducive to the development of the somatosensory industry. We therefore recommend central government agencies to continue the communication with local governments on providing tax cuts for XR applications in order to accelerate development.

Advice 3. Expand definition of VR films in the movie rating system and ease the regulation of film contents.

- XR has recently been employed to many films around the world and certain international film festivals already have a category for such films; for instance, the Cannes Film Festival first used VR technology to screen short films and TV series in 2017. In the same year, the Venice Film Festival also added a VR category. In 2018, the Taipei Film Festival, Kaohsiung Film Festival and the Taipei Golden Horse Film Festival included a newly-added VR category as well.
- VR films are still constrained by traditional movie regulations in Taiwan and have faced many obstacles when applying for movie rating. La Camera Inssabiata, a VR work created by Taiwanese new media artist Hsin-Chien

Huang and American avant-garde musician Laurie Anderson, won the Best VR Experience Award at the Venice Film Festival in 2017, but faced difficulties in rating. The film was sent to the Bureau of Audiovisual and Music Industry Development in pursuant to The Motion Picture Act but was not recognized as a VR film. The Ministry of Culture addressed the issue in a press release on October 9, 2018 in which the minister instructed the bureau to reevaluate its rating regulations and convene talks with the industry for professional opinions.

Advice 4. Ease the Government Procurement Act to relax purchase limitations for software and hardware by public schools.

- XR technology can break limitations in traditional learning environments. Since XR allows students to simulate different experiences and processes to make learning more effective, it's now increasingly accepted by more and more schools. Today, public elementary schools, middle schools and universities are restricted by the Government Procurement Act, which forces schools to call for an open tender when the software or hardware exceeds a certain price point or the planned budget from the previous year. If schools are unable to purchase the items not listed in the budget proposal in time, promotion and applications of XR technology for education will likely be seriously affected.
- We demand the government to ease software/hardware procurement regulations on public institutions for XR to enter schools or

public agencies. It's desirable to amend the Government Procurement Act or to add an additional executive order to the Government Procurement Act to ease the situation.

- We recommend the Ministry of Education to encourage public schools to take advantage of the Unified Supply Contracts for startups managed by the Small and Medium Enterprise Administration for future procurements of applicable technology products. With SMEA as the contacting agency for the supply contracts, schools across Taiwan can list required items (e.g. XR software/hardware equipment) as the annual procurement target with a certain percentage of XR products. With helps from the government fulfilling the academic demands, a single tender submission would serve multiple agencies to drastically lower the procurement and administrative costs.

Advice 5. Establish a hospital accreditation mechanism to encourage application of innovative technologies.

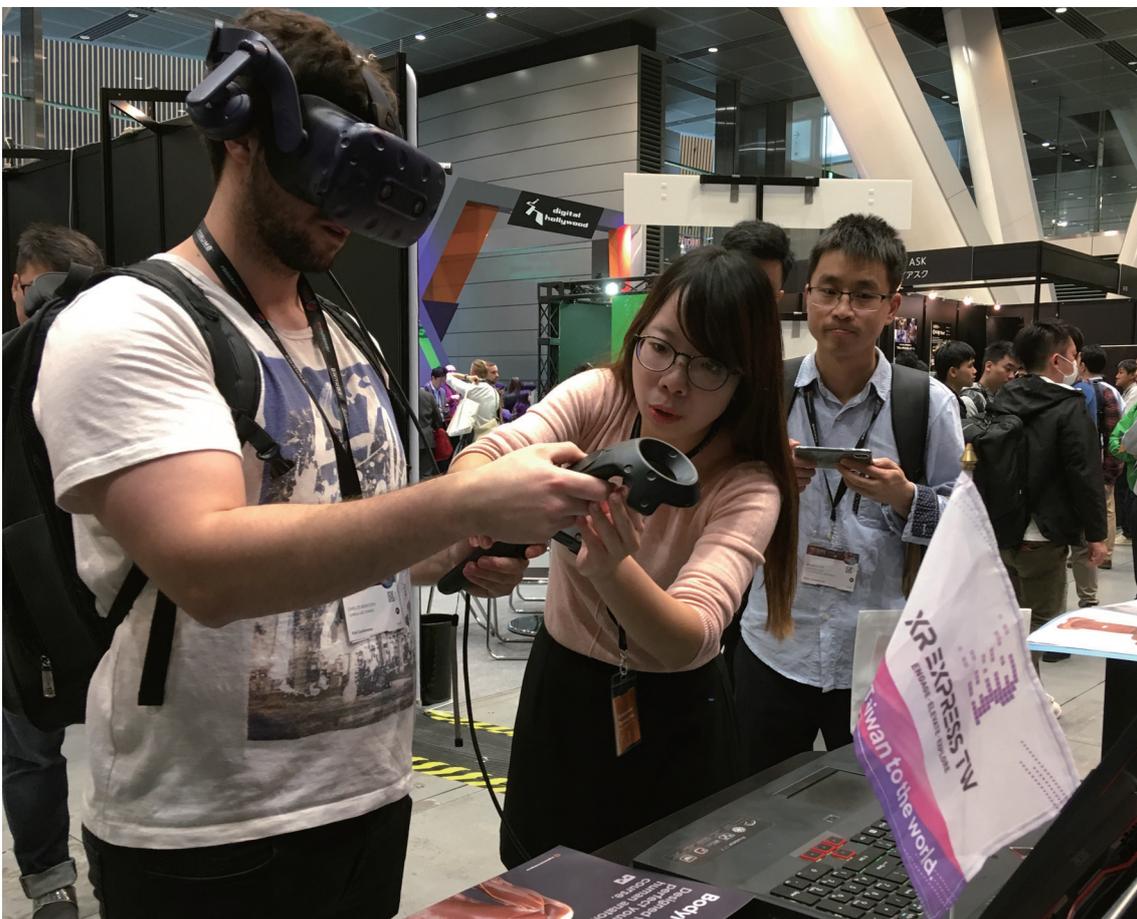
- VR technology can help surgeons to have a comprehensive grasp of the situation before surgeries, which increases success rates and lowers risk. The technology can also be used to facilitate communication. For instance, doctors can employ VR to explain the body part in question for better communication efficiency and patient satisfaction. Different applications include management of smoking addiction, sleep, stress, pain, senior dementia and other medical purposes.
- When procuring new equipment, hospitals

usually consider cost recovery and profitability over the added value, making it difficult for XR equipment manufacturers to promote new applications. We therefore recommend the Ministry of Health and Welfare to amend the Hospital Accreditation system to include a mechanism that encourages the use of new technology services in hospitals. The mechanism will hopefully guide hospitals to provide better healthcare services through the innovative medical applications.

c. Capital

Advice 1. Simplify government subsidy mechanisms and processes and give rewards to startup incubators.

- Even though relevant startup development policies and measures are in place, i.e. National Development Council's Asia Silicon Valley Development Plan and subsidy projects under the Ministry of Economic Affairs, the Ministry of Science and Technology, the Ministry of Education and the Ministry of Culture, the barrier is still high for XR startups and small companies due to the cumbersome application processes.



- We advise the related agencies to: 1. simplify the current application processes for subsidies. For instance, the Small and Medium Business Agency, Ministry of Economic Affairs' Small Business Innovation Research (SBIR) program designed for startups has simplified the application and incubation processes to 3 phases -soliciting ideas, election of the best projects and startup assistance- to lower the common risks of capital, technology or marketing failures. 2. reward businesses and incubators that help startups apply for government programs. Taiwan Innovation and Entrepreneurship Center, established by the Ministry of Science and Technology, has hosted selection events to encourage incubators in Taiwan to foster startups heading for the Silicon Valley. Rewards are given to incubators whose startup projects are chosen.

Advice 2. Form reward measures for traditional industries and SMEs that adopt XR to encourage investment in the XR industry and industrial upgrade.

- A survey on the current development of XR industry in Taiwan has shown that the following areas have the most growth potential in 2019: gaming, education, video entertainment, marketing, medical and Industry 4.0.
- We recommend the government to form reward measures for traditional industries and SMEs adopting XR and encourage businesses in the aforementioned industries to invest in and adopt XR technologies for industrial upgrades in hope to strengthen their

competitiveness in order to drive Taiwan's economy in the future.

- The SBIR and Conventional Industry Technology Development (CITD) program are designated to assist developments of innovation and industrial upgrades in traditional industries and SMEs. With the current innovation programs, we advise the government to include program collaborators in addition to colleges, universities and research institutes. The inclusion of XR technology startups as program collaborators will increase traditional industries and SMEs' interest in knowing more about the potential of XR.

Advice 3. Increase subsidies for academia-industry collaboration and R&D projects in XR to close the gap between XR industry and research capabilities.

- It is difficult for XR startups to acquire the capital they need for a multitude of reasons: investment strategies in the XR industry require long-term planning whereas short-term profits from software investments tend to be unlikely. In Taiwan, domestic capital is also limited due to the increasingly conservative venture capitals and the traditional industries are lacking a deep understanding of XR. Attracting capital from abroad is also an arduous effort because the stringent review and approval measures for offshore funds, established by the Investment Commission, Ministry of Economic Affairs, are in place.
- To drive its R&D capability on AI, Singapore has launched subsidy programs such as "AI

Research", "AI Grand Challenges" and "100 AI Experiments" under AI Singapore, coupling with financial support mechanism for collaborations among academic and industrial institutions. We advise the government to learn from Singapore's experience that increases financial support for XR-related collaboration projects, relieves capital burden for XR startups and provides more opportunities for monetization of R&D results in current program frameworks under the Ministry of Science and Technology's Applied Research Project Incubation Program, Industry-University Cooperative Research Project on Advanced Technologies (the Major League) and Industry-University Technology Alliance Cooperative Research Project (the Minor League).

d. Talents

Advice 1. Formulate policies for improving information education in academic institutions

- College graduates of multimedia, animation, game design and information-related departments have greater access to game design, gaming and other relevant industries as other professionals such as civil engineers, mechanical engineers, naval architects, chemical engineers and medical specialist do not receive adequate information education like the former group. The limited understanding of information technology prevents graduates from introducing XR applications into their respective professions.
- We advise the Ministry of Education to enforce

mandatory information education (e.g. to take certain credits of information-related courses) in educational institutions to enhance students' information literacy. Through such approach, there is a higher possibility for the manufacturing, healthcare and engineering sectors to adopt the latest technologies.

Advice 2. Establish regulations for temporal assignment of industry experts to the academia and research entities to cultivate talents in higher education

- The current education system has yet to put adequate emphasis on XR-related disciplines such as algorithms, computer vision and human-machine interaction; and since development of XR applications requires a higher level of professional knowledge and across-discipline integration while education institutions are unable to focus on talents with potential, a huge talent gap is foreseeable in the future development of XR-related industries.
- The existing policies and programs include the Executive Yuan's "Cultivation of Interdisciplinary Digital Talents" program under Digital Nation & Innovative Economic Development Program (DIGI+) and other programs proposed by the Ministry of Education and the Ministry of Science and Technology. Although policies and programs for cultivation of innovative technology talent are already in place, XR application research and development requires a higher level of cross-discipline professional knowledge and the current education system is not ready for

fostering such industry-savvy talents.

- We advise the government to promulgate rules on temporal assignments of industry experts to the academia and research institutions. With the mechanism established, businesses can provide industry experts and internship to train students and organize case study seminars for students to discover solutions on their own.

Advice 3. Promote XR apprentice programs to establish a desirable environment for talents to hone their skills

- XR development is an integral part of solutions that meet people's needs with innovation technologies. Other than constant innovation on software applications, strengthening students' interdisciplinary knowledge in liberal arts, management and technology is also crucial. Interdisciplinary talents in areas such as manufacturing, health care, education and business are also needed to advance XR applications. Unfortunately, such talents are still scarce in Taiwan, and that's why we need incubation programs to meet such demands.
- Singapore's AI Apprentice, launched in 2017, is a talent cultivation program under its national-level program AI.SG (AI Singapore). The program, where the government subsidizes participating businesses, adopts the industry-academia collaboration mechanism to foster AI talents and invites industry experts from the related fields to mentor apprentices. Moreover, the apprentices can access internal resource of the businesses partners and receive one-on-one tutoring. During their apprenticeship,

free AI technology courses by experts and a salary of NT\$44,000-78,000 are provided. This program aims to initiate discussions and exchanges between apprentices and experts, inspire apprentices to think further, broaden their knowledge and develop research mindset and skills. Possible career paths for these apprentices are AI engineers, AI developers, consultants, etc. when the apprenticeship is completed.

- We suggest the government to financially support ICT businesses to launch programs like Singapore's AI Apprentice program. Backed with the resources from XR-related businesses, expert mentoring and XR technology training courses, the programs provide comprehensive training to cultivate interdisciplinary talents with the ability to innovate.

Advice 4. Promulgate international professionals recruitment regulations to improve the quality of foreign manpower in Taiwan

- Fostering Interdisciplinary digital talents under DIGI+ aims to reinforce the connection between Taiwanese businesses and young foreign talents, and this goal is to be realized by the Ministry of Education's New Southbound Talent Development Program where digital capability cultivation as well as degree programs through academia-industry collaborations. As innovative XR talents can be from Asia or Western countries, we advise the government to expand the scope of international talent

employment for more top-notch XR experts to consider working in Taiwan.

- To recruit foreign white-collar talents, relevant government agencies should continue to properly deregulate laws and regulations. The Recruitment and Employment of Foreign Professionals Act, proposed by the National Development Council, has been effective as of February 8, 2018 under the Executive Yuan's order.

To complement the Act, the Ministry of Labor are issuing particular foreign professionals work permits with a maximum of 5 years, and the adult children of such professionals obtaining permanent residency are eligible to apply for work permits.

The Ministry has also amended the definition of "multinational corporation" to include businesses headquartered in Taiwan with



overseas offices. Starting from July 2, 2018, foreign white-collar employees in the aforementioned businesses can be seconded to Taiwan after their first year in the company.

In addition, since July 24, 2018, limitations on the amount of capital and revenue for businesses in "5+2 Innovation Industries" to recruit foreign professionals are lifted by the Ministry. Although several measures are carried out to give Taiwanese businesses more flexibility in recruiting foreign talents, the government needs to further make laws and regulations transparent, and such advantages public to business to maximize the intended effects.

Advice 5. Cultivate innovative technology and application professionals and experts through national-level XR research programs

Since 1997, the government has launched numerous national-level technology development programs in three categories: economics, biotech and people's daily lives. The technologies include telecom, internet, silicon chips, smart electronics, nano technologies, energy, agriculture/biotech, pharmaceutical, digital archives, digital learning and more. We advise the government to include XR development in the national programs and collaborate with international research institutes to cultivate future world-class professionals.

e. Global Market

Advice 1. Discover corporations with international potential and foster their global competitiveness with strengthened multilingual and marketing capability.

- We suggest the government discover excellent startups that have the potential to handle business expansion and develop new business models in international markets, or the ones have a strong desire to go global.
- Startups have to participate in international business events and competitions for more opportunities. As many Taiwanese startups still need to improve their verbal presentation and marketing skills, we suggest the government to organize classes or programs with speakers from around the world to provide training on marketing and product promotion for the startup entrepreneurs.
- To compete in the global market, startups have to improve themselves in fields such as market development, business negotiation and marketing. We suggest that the government to collaborate with the private sectors to assist startups to explore new markets.

Advice 2. Assist Taiwan's XR corporations to global markets and provide business matching opportunities

- When exploring business opportunities overseas, stay in line with the local market is the key to success for startups; so, the government should effectively utilize resources from Taiwanese business and official agencies abroad, so startups can stay in sync

with the market pulse, access local industrial organizations and build connections with less effort. In other words, the government can save time for startups entering new markets.

- We suggest the government to encourage established businesses to play the leader roles in supporting innovative startups and offering more opportunities, which would in turn help startups to better equip themselves for the global market.
- We also advise our government agencies abroad to organize investment fairs regularly as a bridge between startups and local investors or buyers. With the possible participation of local XR industry decision makers and distributors, startups can have more matching opportunities and publicity in a short period.

Advice 3. Provide substantial landing assistance and connect local resources in overseas markets.

- In order to help SMEs explore overseas markets, the Korea Trade-Investment Promotion Agency (KOTRA), a state-funded trade and investment promotion organization operated by the Government of South Korea, was established in 1962. Since then, KOTRA has facilitated and promoted South Korean corporations to enter the global market successfully. Currently there are more than 80 South Korean business centers and logistics centers in various countries.
- In 1958, the Japan External Trade Organization (JETRO) was established to facilitate economic development. To help Japanese

companies operate in developing countries, JETRO helped the countries by cultivating their industries, developing functional operating systems and offering training to their talents.

- "Localization" is the key to success when a company explores a new market, since more knowledge to the local market means more chance. We suggest our government to follow Japan and South Korea with a "one-stop service" system for startups planning to operate in a new country. Tasks such as finding office space, applying for startup visa as well as intellectual property, legal and accounting issues could be painstaking chores that require official assistance to save time and cost.

Advice 4. Make Taiwan's technology startups identifiable by unique brands

- In order to promote French startups and industrial transformation, the French government launched "La French Tech" project at the end of 2013. The three pillars of La French Tech are as follows:
 1. Connection: Gather related resources of startups by connecting influential cities.
 2. Acceleration: €200 million managed by the French Public Investment Bank (BPI) helps startups to develop new business models.
 3. Promotion: A further €15 million has been allocated to help French digital companies succeed internationally.
- In addition to improving the industry environment, the French government offered

an international online platform, the French Tech Hub, for entrepreneurs, investors and executive agencies to exchange ideas. La French Tech has become a unique brand in the world.

- We recommend Taiwan's government to learn from France and then establish our own world-class brand using the La French Tech model. In addition, the government should plan budgets to promote startups and therefore increase our own brand exposure. What's more, when government agencies are subsidizing Taiwanese exhibitions abroad, they should pool their resources into a singular Taiwan pavilion rather than scattering resources into separate booths.
- Last but not least, we encourage Taiwan technology startups join to attend technology startup exhibitions at home and abroad. In Taiwan, there are famous exhibitions such as Taipei Game Show, Smart City Summit & Expo, InnoVEX at COMPUTEX and Meet Taipei Startup Festival. Well-known exhibitions abroad include Slush in Finland, TechCrunch in the US, Rise in Hong Kong and Smart City Expo World Congress in Barcelona, Spain.

Chapter 5

Vision Unlimited: Future Trends of XR Industry



I. Forewords

As new smart phones started to support low-cost VR headsets, consumers are now aware of the new technology and industries such as education, commerce and health care are starting to reshape their business models. In addition, VR, AR and MR applications are also gaining grounds in smart factories following the Industry 4.0 trend.

Technologies are now being developed toward big data, high bandwidth and lag-free response, while end-user devices are becoming lighter, smaller, smarter and more affordable in the near future. XR is no exception as it also requires 5G bandwidth, high transmission speed and low latency to revolutionize itself to stay in the mainstream.

In convergence with technologies such as 5G, AI (Artificial Intelligence), Industry 4.0 and IoT (Internet of Things), XR has great opportunities in a variety of new applications for people to enjoy "Smart Spaces" with virtual experiences on life, work and other aspects. Smart Space is a concept of physical or digital environments that offer open, coordinated and intelligent interaction between human and technology to create immersive, interactive and automated experiences for people and industries.

In this chapter, the development and major applications of 5G as well as how it benefits XR

will be discussed; followed by the influence of Smart Spaces incorporating AI, Industry 4.0 and 5G communications. Lastly, how XR in Smart Space would facilitate new applications in manufacturing, education, health care, business, entertainment and smart cities will also be described.

II. 5G Communications

1. Development of 5G Technology

Since 2015, standard organizations around the world ignited discussions on new application scenarios of 5G, the next-generation specification of cellular communications. For instance, ITU (International Telecommunication Union) of the United Nations unveiled its draft plans and time tables on 5G in June 2015 to set industrial objectives and frameworks, and predicted that 5G commercial operations will start in 2020.

In September 2015, ITU released the Recommendation ITU-R M.2083, which defined 5G as IMT-2020 (International Mobile Telecommunication-2020), to set 5G objectives and frameworks after 2020 and specified three major scenarios as:

- Enhanced Mobile Broadband (eMBB)
- Ultra-reliable and Low Latency Communications (URLLC)

- Massive Machine Type Communications (mMTC)

In addition to discussions on key elements of 5G technologies and applications, the Recommendation also offered several parameters as indicators of related developments.

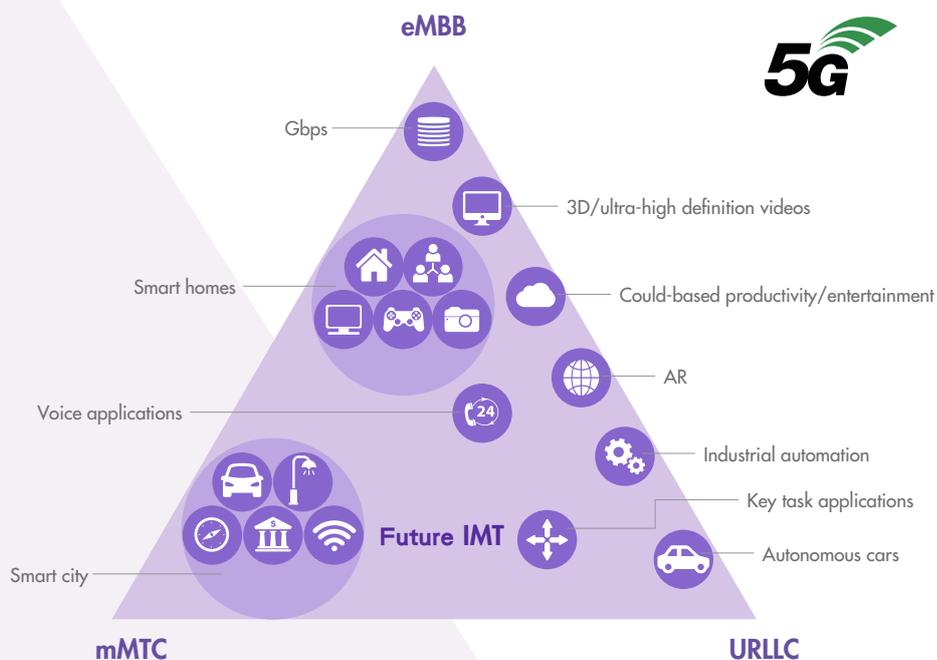
eMBB fulfills user demands on media contents, services and data communications through 3D, Ultra HD and AR/VR that require mobile broadband, while URLLC supports Internet of Vehicles, industrial automation, remote medical care and smart power grids that call for low latency and high availability.

Through the powerful 5G connectivity, mMTC benefits IoT infrastructures involving large-scale end user access to facilitate in-depth integration of smart cities, smart homes and environment monitoring.

2. XR Competitive Advantage Brought by 5G

Since most XR applications are based on high-quality images, the high bandwidth, high capacity, low latency and improvements on cloud infrastructures brought by 5G as well as new technologies, such as AI and IoT, enable XR users to experience, share and interact on a new level. The development also allows industries to freely employ XR in applications other than

Scenarios of 5G networks



Source: ITU, 2015

entertainment for more business opportunities and growth.

Introducing 5G technologies may solve the following difficulties XR applications may encounter:

a. Cloud computing for lower end-user device costs

Image quality and viewing angles are the major limitations to XR. To address the difficulty, high-definition 4K or 8K videos now available while expanded viewing angles make the experience more immersive and gives more depth. As high-quality 3D images in mobile environments require a considerable amount of data transmission, storage and computation,

cloud computing eases the tasks by moving data handling and processing to the cloud and having results sent back to end-user devices through 5G networks.

Aside from 5G broadband, the Mobile Edge Computing (MEC) supports also contributes to break the bottlenecks for XR. Based on 5G, MEC is a distributed computing technology that send data to edge nodes that are closest to the user for processing. This not only cuts the time for data travel, but also reduces network loading and cost to create high-performance, high-bandwidth and low-latency services for users to enjoy high-quality, immersive experiences.



High-performance, cloud-based XR reduces costs of end-user device to make them affordable and more popular in consumer markets. With prevalence of 5G and mobile cloud computing, XR devices don't need top-tier CPU or GPU to perform complex calculation as only low-cost components are needed for transmission and decoding.

b. Improved quality of XR experiences

One of the current bottlenecks of XR products is user dizziness after an extended period of use. According to VRDC (Virtual Reality Developers Conference), the "dizziness" is a major concern of consumers considering AR/VR devices; and it's the main reason VR devices couldn't compete with smart phones in terms of usage time.

The reasons caused the dizziness were low-quality graphics, sensory conflicts during the human-machine interaction as well as inconsistency of focus and depth between both eyes. To relieve the symptom, the screen latency must be under 20ms and refresh rate over 100Hz to exceed the perception limit.

However, such high-quality images can only be achieved by data rates far faster than the current 4G networks. We can only expect the future 5G standard to solve the dizziness problem with its enormous bandwidth for the market to embrace the new XR applications.

c. Wireless VR devices

Today, most VR headsets are connected to a backend computer with one or more cables for data transmission. The cables could be easily stretched to limit the movements as well as flexibility of applications. Some headsets offer optional wireless kits for short-distance data and power supply, but this is still not the real "wireless" solution that fulfills user and application needs.

To eliminate difficulties for wireless VR devices, the bandwidth and low-latency characteristics of 5G networks is a viable answer for the huge amount of data required by the ultra-high images that match real human vision.

With theoretical peak transmission speeds at 10-20 Gbps, the 5G capacity has already surpassed which high-resolution VR needs. On the other hand, as VR displays are close to the eyes comparing to normal monitors, its Motion-to-Photon Latency (MTP) must be under 20ms to prevent user dizziness.

However, no wireless technology currently available is capable of reducing MTP to less than 20ms; even faster WiFi protocols are still over 100ms – too slow for quality wireless VR. With 5G, MTP can become as little as 10ms to offer more enjoyable wireless VR services.

III. 5G and New Technology Applications

1. Artificial Intelligence

Artificial Intelligence (AI) is a category of software applications that performs human-like cognition, interaction, learning, analyzing and decision-making intelligence. Today, in addition to the enormous amount of data generated by applications, AI also poses high demands on the speeds of data transmission and processing.

To future development of AI, 5G will be a boost thanks to the faster response, richer contents, smarter applications and more intuitive user experience it's bound to offer. Conversely, AI also facilitates automation and advancement

of 5G since the huge data set produced by online devices is simply too much for human to comprehend.

That is, AI can help handling such information and even more complex application scenarios with construction of antenna arrays and millimeter wave communication technologies. However, such infrastructures would bring more planning, optimization and maintenance jobs to 5G networks in return – also too much for human technicians to consume.



With the assistance from AI, operators can accurately predict future demands on 5G network coverage and capacity to elevate working efficiency while reducing operating costs.

The collaboration of 5G and AI will also bring changes to XR applications. For instance, cloud in 5G speeds turns every XR device, such as a pair of smart glasses, into a computing powerhouse without the need for a computer or a phone; and the data delivered to the device will take advantage of AI to analyze and sieve for meaningful AR information.

2. Industry 4.0

The "Industry 4.0" concept introduces network, digital and intelligent elements into manufacturing with innovative Cyber Physical Systems, smart manufacturing, Digitalized Factories and IoT. In this infrastructure, suppliers, factories, assembly lines, machineries, products and end consumers are interconnected by a giant smart network.

This giant smart network converges physical networks, intelligent controllers, sensors, embedded end-user systems, cloud computing and big data technologies to improve efficiency and cost effectiveness, which in turn transforms conventional manufacturing into highly intelligent, customizable, versatile and service-oriented manufacturing to offer products that satisfy different customer needs.



In the factory, data acquired by a large number of sensors, robots and information systems is sent to an AI system for analysis and decisions returned via the high-capacity 5G wireless network. In the meantime, the wide-area 5G coverage of customers, products and suppliers also helps manufacturers to monitor the entire lifecycle of their products.

In summary, 5G networks will benefit Industry 4.0 in many ways:

- Large-scale Industrial Internet of Things (IIoT): improves efficiency of operations and preventive maintenance through a network of sensors, equipment and other assets, and handle the data from the network with the help from 5G technologies.
- Mobile robots: build smaller, cheaper and

more flexible robots that utilize the high speed and large bandwidth of 5G networks. 5G allows robots to become more agile and faster in decision making for more complex tasks, which in turn relieves worker burdens and improves manufacturing efficiency.

- XR technology: 5G enables workers to take advantage of XR applications such as training, machinery maintenance, data visualization and design anywhere in the factory. For instance, machinery maintenance guides with visualized data would help reducing human errors for better safety.
- AI and machine learning: smart factories in the future require high-quality data to work efficiently. IIoT assisted by high-speed 5G networks allows AI to learn from errors and make better decisions over time, or even predict supply chain problems for more productivity and security.

3. Smart Spaces

As one of Gartner's "Top 10 Strategic Tech Trends 2019", Smart Space is a physical or digital space that empowers people, objects, processes and services with open, connected, coordinated and smart elements. With additional assets such as communication networks, IoT, sensors, wearable devices, AI, big data, voice recognition and image recognition, more immersive, interactive and automated experiences can be created within.

For example, 5G enables at-home health care, remote diagnostics and round-the-clock biometric monitoring through wearable devices;

or it could team up with indoor positioning and navigation to assist consumers locating desired products while recording the buying preferences for future targeting efforts.

In essence, Smart Spaces is a fusion of IoT and AI, or AIoT (Artificial Intelligence plus Internet of Things), in spaces with XR wearable gears that visualize the interaction among people, objects and locations.

As a combination of IoT, AI and advanced computing, AIoT brings AI to every IoT node and enables them with the ability of self-learning, analysis, control and management to create new ways of interaction, new technologies and new frameworks. With AIoT applications and XR visualization devices in Smart Spaces, people will enjoy a new way to interact with the surrounding environment.

The advancement of modern smart end-user devices and mobile applications significantly increases the data flow between human and machine, and this calls for more high-performance, convenient and safe data communication methods that can only be satisfied by the 5G technologies.

IV. 5G Smart Space and XR Application Trends

1. Education Applications

VR brings more enjoyable and effective immersive learning environments to students, among many more benefits.

a. Relieving problems of conventional education

As some topics of the essential knowledge are difficult to convey and some could have been better explained by more attractive means, VR can be helpful to make these topics more

interesting. It will be easier for teachers of science or engineering subjects to visually demonstrate, for example, the inner works of machineries or animal anatomy.

b. Vocational training

It's traditionally difficult to provide certain types of vocational training, such as welding, spray coating, chemical engineering and disaster relief that are potentially dangerous; or aviation, astronomy nuclear engineering that could involve

Scenario of VR Live Streaming Education



Source: Shadoworks

considerable cost and high complexity. These can all be aided by VR to reproduce to shape, size, weight, feel, noise or even temperature in the lab.

c. Live VR broadcasting

Live VR broadcasting is a new way of communication that blends VR into live video broadcasting to embed virtual contents into 360-degree scenes for users to enjoy immersive experience via wearable gears. It can be used for educational purposes to deliver more contents to remote schools as well.

Thanks to the 5G support, VR is bound to bring more possibilities, enjoyable experiences and results to the education scenarios today and in the future.

2. Medical Applications

Experienced medical practitioners today are already taking advantage of three-dimensional images to assist judgment of conditions, and now XR can be employed as well to improve accuracy of clinic diagnostics and treatments. XR applications in the medical fields include:

a. Clinical diagnostics

XR can be used to recreate patient conditions in 3D for doctors to observe from different angles, which could improve accuracy of diagnostics. For example, "virtual endoscopes" that reconstructs 3D body interiors with CT, MRI and ultrasonic images now allow doctors to simulate conventional endoscope visions with XR.

b. Pre-surgery planning

With 3D visualization and XR technologies, doctors can become fully aware of the condition of tissues, blood vessels and nerves in high precision to make better judgments and plans on surgical operations. In addition, simulated operations can be repeatedly performed on the 3D model for higher chance of success.

c. Better communication with patients

XR allows patients to accurately, visually understand the situation of the affected region and possible treatments, which improves communication with practitioners and reduces the risks of misunderstanding.

d. Remote diagnostics

Thanks to the 5G networks, medical institutions can easily share CT, MRI and ultrasonic images with remote practitioners, perform interactive instructions and diagnostics, trainings or even remote participation of operations. To rural areas or even battlefields, this could become a true lifesaver.

3. Manufacturing Applications

Enterprises need to introduce several necessary technology elements before transforming to Industry 4.0. These elements include robots, cloud computing, Industrial IoT, XR, security and more. Among them XR plays a pivotal role on fulfilling new mission and production requirements with applications like:

a. Remote control

Perform remote interaction and intelligent control in harsh environments with industrial robots through XR. This guarantees not only safe production and minimum human error, but also maintains visible control over the entire process.

b. Employee training

Present training materials in VR format for easy understanding and better results. Trainees can also receive hands-on experiences through simulated VR operations.

c. Equipment maintenance

VR helps workers to perform preventive maintenance to save repair costs, improve data

acquisition accuracy and simplify operations. Technicians can inspect and maintain systems with smart AR/MR glasses while using verbal commands to complete the checklist for complex tasks.

d. Logistics management

AR/MR technologies can be employed in identifying, marking and sorting packages in warehouses or in transportation for effective management and delivery.

e. Workplace safety

The video relay, heat signature analysis, voice communication and remote marking functions of smart AR/MR glasses allows on-site workers to



be informed of the situations and dangers, which significantly reduces the risks of accidents. The communication functions also allow personnel to call for assistance when necessary.

4. Business Applications

Today, XR has already been used widely in real estates, home appliances, apparels and other retail businesses. In 2018, IKEA stores in Sweden introduced VR technology to allow customers to walk in virtual kitchens; meanwhile US cosmetics brand Sephora offered a product trial app for customers to try and find their favorite products from several virtual examples.

AR apps can also capture customers' body shapes and fit virtual clothes on the image, allow hotel guests to see the world in their rooms or enable car makers to offer virtual test drives.

Despite the great experiences brought by XR, there are still some difficulties to overcome. For instance, the devices such as headsets, smart phones or tablets are heavy, and high-quality products that can prevent user dizziness are still too expensive to become popular.

It's believed that such difficulties will gradually disappear as 5G becomes commonplace, since it allows fast, low-cost cloud computing to relieve the works from XR devices for better image quality and thus better experiences. That means XR business applications will benefit from 5G in the following ways:

a. Panoramic shopping streets

The combination of 5G and VR is suitable for creating holographic streets that welcome customers to immerse in shopping, strolling, sightseeing and even actually buying things.

b. More real-time interaction

As e-commerce operators are now selling products online, 5G can bring more realistic experiences or overseas shopping to customers and allow more shoppers and sellers to communicate directly.

c. AI virtual assistants

With support from 5G, XR can take advantage of AI to offer useful product information and reviews. A user can tell the AI assistant his or her own preference and let the assistant find the right products immediately while displaying prices, discounts and customer comments, then arrange door-to-door shipping if the user decides to buy.

d. New retail

The "New Retail" idea, brought forward by Jack Ma, is to amalgamate technologies such as big data and AI to optimize the production, distribution and sales process of products with integrated online services, offline experiences and modernized logistics. 5G networks will realize the speed and capacity of business information required to achieve more retail possibilities.

5. Entertainment Applications

Since AR/VR becomes popular in 2016, most related applications focused on gaming and entertainment purposes. According to VRDC researches conducted in 2018, as many as 78% AR/VR developers are considering or will consider exploring the two areas as well.

Mainstream VR platforms such as HTC Vive, Oculus Rift and PSVR are all in this category as most users purchase VR headsets mainly for gaming and entertainment activities such as VR social media, concerts, movies and live broadcasting of sports/e-sports competitions.

a. VR live broadcasting

As sport events are very popular among fans everywhere in the world, VR can be a viable solution for seating and geographical limitations. To the audiences, conventional live broadcasting

falls short on providing "being there" experiences while live VR broadcasting brings the stadium to every living room. Currently the NextVR platform in the US is the most successful broadcaster of live VR sport games and concerts.

In 2015, NBA announced the collaboration with NextVR to provide live VR broadcasting services. Aside from NBA, NextVR also works with large content channels such as MLB, FOX Sports and Live Nation. In February 2018, Korea's SK Telecom teamed up with Samsung and Intel to organize a range of large-scale 5G commercialization experiments in Pyeongchang Winter Olympic Games. The experiments include 3D images from athlete angles, real-time 360-degree tracking of specific athletes, audience-controllable timeline and interactive viewing angle/timeline slicing that give viewers more control over the events.

VR Social Media



Source: Rec Room

In concerts, the audience can virtually get even more closer to performers as VR turns every seat into a personal "rock zone". Samsung cooperated with Live Nation in 2017 to broadcast Coldplay's "A Head Full of Dreams Tour" taking place in the Soldier Field and allowed viewers to participate by wearing the company's Gear VR.

b. VR social media

Social media bring people together from offline to online and expand connections as technologies evolve. The next-generation VR social media can even gather people from different places all over the world and communicate face-to-face. There are currently ventures like Spaces

VR, AltspaceVR, VRChat, Rec Room and SteamVR; and they are bound to get a boost from the future 5G networks.

Comparing to conventional social media, the VR versions offer many advantages. Firstly, the highly immersive experience of interaction with headsets, which allows the user to interact with others to watch the same movie, enjoy painting or play games together – just like what people do in the real world.

Secondly, VR can be used to conduct non-verbal communications as conventional media are unable to convey non-verbal messages such



as face expressions, hand gestures and body languages that are totally possible in VR scenes.

The VR entertainments described above are already existed ones, but they're still hindered by lower 4G image quality and bulky, wired VR headsets. Some users who chose low-price glasses for live VR broadcast rather than expensive, high-quality headsets just to find the experience undesirable and then quit trying ever since.

All these challenges are expected to be solved by the high-bandwidth, high-speed and low-latency 5G standards. 5G is not only practical for delivering enough data and high-quality visual contents to multiple users, but also immersive, smooth viewing angle transition that solve dizziness problem in prolonged usage.

In addition, the high-speed 5G and cloud computing trends enable VR devices to get rid of the wires to become more portable and affordable. In the future, global-scale live broadcasting of events and concerts will be prevalent and VR-based e-sport games are absolutely feasible – thanks to the lightning-fast 5G infrastructure. Players will be able to ditch keyboards and mice to compete in VR while their fans immerse in the excitement through VR as well on the other side of earth.

6. Smart Cities

Smart cities take advantage of technology elements such as 5G, IoT, AI, cloud computing, big data and XR to offer new ways of interaction among governments, enterprises and people for intelligent, swift responses on economic, environment, public security and business issues. Among the technologies 5G plays a pivotal role for connecting everything else for better results.

a. Smart traffic management

Onboard AR systems can assist car drivers by projecting road information on the windshield, so drivers don't need to look down for the dashboard. With AR, information such as navigation, driving safety and local attractions are received and displayed via 5G networks. Cars can even "talk" to each other when moving in high speed with 5G.

b. Smart public safety management

With 5G networks, environment sensors can be used to perform meteorological observation and warning, suggest safe routes in natural disasters, simulate air currents and pollution conditions in extreme weathers for public safety. On construction sites, progresses can be simulated with VR to discover potential problems and protect workers from possible risks.

V. Conclusion

New XR applications are now infiltrating into different markets as the XR technology attracts more attention, and new demands emerge as well. Since the ever-growing XR experiences requires higher network bandwidth to realize, the high-speed, low-latency 5G standards have become the necessary foundation of XR developments.

To address the XR bottlenecks, 5G moves heavy-lifting computations to the cloud to lower the CPU and GPU specifications, and therefore costs. For end-user XR devices only need to perform transmission and decoding tasks. The simplified architecture also eliminates the

need for cables connected to the headset. The new lightweight, wireless devices will be more affordable than ever, and the combination with AI and Industry 4.0 is bound to derive more innovative, productive applications.

As described, XR has very promising future in the following six areas:

1. Education: expanding depth and richness of classroom materials with VR and 5G for better flexibility and results.
2. Medical: 5G-enabled remote inspection, diagnostics, treatments and even operations as well as online training purposes.
3. Manufacturing: smart AR/MR glasses can



facilitate data transmission, posture detection, voice communication, thermal image analysis and remote marking functions for effective equipment status diagnostics and maintenance.

4. Business: ubiquitous 5G connections provide consumers with "being there" strolling, shopping and traveling experiences, while sellers can show worldwide customers their products in live VR broadcasts as a new way of marketing.
5. Entertainment: 5G enables rich, real-time VR social media as well as concerts, movies, sports events and e-sport competitions.
6. Smart cities: 5G empowers wider coverage, faster speed and more reliability for wireless sensors that bring city services together to offer citizens with better transportation, security and other public affair solutions.

All the applications listed above can be

seen as a part of the Smart Space scenarios that, in collaboration with 5G, visualize interactions among people, objects and locations to create immersive, interactive and automated environments for new service possibilities.

In the future, the in-depth integration of 5G and XR will release more potential power and create enormous business opportunities; and XR may replace today's smart phones as the next-generation mobile computing platform that changes both our lives and industries. As the 5G standards are being established, XR companies must work in parallel on technologies, contents and platforms for swift but stable future developments.





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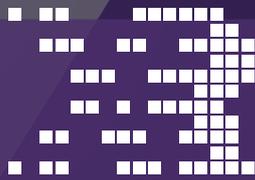
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