A study on the components of the Metaverse ecosystem

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메타버스 생태계 구성 요소에 관한 연구

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Abstract Despite the great interest in the metaverse from academia and industry, research so far has been focused on a specific area, and the background of the study is in the recognition that research is necessary from the perspective of the entire metaverse ecosystem. The purpose of this study was to derive the metaverse research framework and each component to study from the perspective of the metaverse ecosystem, and to study the development stage of the metaverse ecosystem. From an academic point of view, the ecosystem components were derived through the Metaverse IDC-Platform, a framework for applying Michael Porter's diamond model to the metaverse. From a practical point of view, the four components of the metaverse ecosystem interact with each other in terms of metaverse application and development. As the basis of this study, it can be used strategically because it is possible to identify areas for reinforcement in academia and industry and provide basic data for insight by closely examining the strengths and weaknesses of each component. The contribution of research is that it has created a foundation for research that has been limited to specific areas from an ecosystem perspective, unlike before.

Key Words : Metaverse Ecosystem, Metaverse Infra. Metaverse device, Metaverse content, platform

요 약 메타버스에 관련하여 학계, 산업계의 지대한 관심에도 불구하고 지금까지의 연구는 특정 영역에 편중되어 있어, 메타버스 생태계 관점에서 연구가 필요하다는 인식에서 출발하였다. 메타버스 생태계 관점에서 연구하기 위한 연구 프레임워크와 각각 구성요소의 도출과 메타버스 생태계의 발전 단계 조사 연구를 목적으로 하였다. 학문적 관점에서 마이클 포터의 다이아몬드 모델을 메타버스에 적용한 메타버스 프레임워크인 Metaverse IDC-Platform 통한 생태계 구성요소를 도출하였다. 실무적인 관점에서는 메타버스 생태계 4가지 구성요소는 메타버스 적용 및 발전에 상호 의존 적으로 작용한다는 것을 알 수 있었다. 본 연구의 토대로 메타버스 생태계 및 구성 요소를 기반으로 각각의 구성 요소의 강점과 약점을 면밀하게 조사하고 보강하기 위한 영역 파악에 대한 기초 자료 제공이 가능하기 때문에 학계와 산업계에서 메타버스 연구에 전략적으로 활용할 수 있을 것이다. 연구 기여도는 지금까지와 다르게 AR/VR 등 특정 영역에 한정되어 왔던 연구를 메타버스 생태계 및 생태계 구성요소 관점에서 연구할 수 있는 초석을 만들었다는데 있다.

주제어 : 메타버스 생태계, 메타버스 Infra, 메타버스 디바이스, 메타버스 콘텐츠, 플랫폼

1. Introduction

The background of the study is as follows. Interest in the metaverse is increasing day by day. On October 28, 2021, Facebook CEO Mark Zuckerberg announced that Facebook would change its name to Meta[12]. Roblox (USA), a metaverse platform where users can develop and register their own games and allow other users to enjoy games, is enjoying explosive popularity to the extent that 55% of youth under 16 are enrolled[3]. A US presidential candidate campaigned on the Metaverse platform, and the Metaverse platform is being used in various areas such as music concerts, entrance ceremonies, new employee training, and virtual real estate sales. Analysts said that eight of the world's top 10 companies by market capitalization (total market cap of about 9,800 trillion won, as of 2021) entered the metaverse market and started competing[14,15]. The metaverse is now a battlefield without borders. Tencent, a key Internet company in China, acquired a 40% stake in Epic Games in the United States in 2013[7]. As described above, it`s investigated that Tencent is continuously making large-scale investments in platform and content core companies, which are key areas for the future metaverse, such as games, social media, and content. The metaverse term was first used in Neil Stevenson's novel Snow Crash in 1992[15]. It is a compound word of meta meaning virtual and transcendental meaning and universe meaning world and universe[21]. It is being defined as a world where virtual and reality constantly interact and co-evolve and create new values through social, economic, and cultural activities in it [15,23]. As such, the convergence of virtual and reality is gradually becoming a reality with the help of a strong technology of 3rd, and 4th industrial revolutions. While the 1st and 2nd industrial revolutions achieved innovation in the real world, the 3rd and 4th industrial revolutions are expanding the scope of innovation through convergence with the virtual world[14]. By examining the preceding studies by 2021, a total of 191 publications on the Metaverse have been published in the SCOPUS database[22]. It was found that the research was expanding from the metaverse conceptual approach to the ecosystem approach.

The research necessity of this study is as follows. Despite the market's interest and importance, the reality is that it is difficult to find studies related to the study of the composition of the metaverse ecosystem. Metaverse is still a concept that is constantly evolving, and different participants are enriching its meaning in their own ways[22]. So most of the previous studies have many definitions of the concept of metaverse, and there are still no agreed standards. Some researchers defined it as a virtual world[19], while others defined it from the perspective of convergence of virtual and reality [20]. Also, it seems that there are not many papers that have gone one step further and have studied the ecosystem of the metaverse accurately. Although J. Y. Kim(2021) conducted research on the metaverse ecosystem[17], but it was limited to the content ecosystem. J. S Moon et al.(2020) conducted research limited to VR research[18]. As such, research is limited to a specific area of the metaverse. The reality is that the absence of an agreed standard for the metaverse's ecosystem composition may cause confusion in understanding and practical application of the metaverse. In some studies, the metaverse was approached and studied from the device side[18]. Another studies had been conducted from the perspective of games[20] or contents[17], but it is difficult to find a study that investigated the metaverse ecosystem as a whole. W. H. Seok(2021) mentioned the need for an approach from the perspective of the metaverse ecosystem[23]. So, I would like to study the ecosystem composition and maturity of the

metaverse. At the present time, these studies appear to be timely.

The purpose of this study is as follows. Academically, it is to lay the groundwork for clarifying future research areas by clarifying the overall metaverse ecosystem structure, rather than staying in specific areas such as metaverse display or metaverse device research such as VR, AR, and metaverse content ecosystem. By applying Michael Porter's diamond model, best known as an industrial competitiveness model, to the metaverse, the metaverse IDS-Platform framework was created to make a metaverse ecosystem diagram. Metaverse Device, Metaverse Contents, Metaverse Platform, Metaverse Infra, etc. will be the basis for detailed research. In addition, the study of the entire metaverse ecosystem is important from an academic point of view to further understand the metaverse itself. In practical terms, practitioners can give guidelines on which parts of the metaverse ecosystem need to be introduced. In addition, it can serve as a guide for introduction by identifying which parts of the ecosystem constituting the metaverse have limitations in application and which parts are suitable for application. From this point of view, the purpose of this study was to improve the understanding of the ecosystem composition of the metaverse.

The research distinction of this study is as follows. First, the Metaverse IDS-Platform framework, which is the overall structure of the metaverse ecosystem, is provided based on Michael Porter's Diamond Model beyond the study of specific areas of the metaverse. Second, it provided insight into the interaction and maturity of the ecosystem components constituting the metaverse. Finally, step-by-step advice is provided for those in charge of constructing the metaverse.

2. Theoretical background

2.1 Concept and development of metaverse

Metaverse is a concept and term that first appeared in Neal Stephenson's novel Snow Crash in 1992[13]. This metaverse or extended virtual world is a compound word of "Meta" meaning virtual and transcendental, and "Universe" meaning world and universe[13]. Also, in Snow Crash, the term "Avatar", which is indispensable in the metaverse, was used for the first time[5].

Table 1. Metaverse concept and flow of research

Period	Research topic	Main Features	Researcher
1990s	Metaverse Concepts (1992)	Snow Crash (1992), introduced the concept of metaverse, an internet-based 3D virtual reality world in which various activities in real life are performed as avatars.	Neal Stephenson
2000s	Metaverse Definition (2006)	A virtual world where people engage in social, economic, and cultural activities using avatars.	K.M. Son et al.(2006)
	CPS Study (2006)	Cyber-Physical Systems (CPS) is a new paradigm that seeks to converge the physical and cyber worlds. National Science Foundation (NSF) designates cyber-physical systems as a core research area	The US National Science Foundation
	Metaverse Definition (2007)	A virtual reality space where social and economic opportunities are given like living virtual worlds or real life	C.G. Ryu & J.K. Ahn (2007)
	Metaverse Roadmap (2007)	Metaverse Roadmap Announced the path to the 3D Web. Defined as a phenomenon of intersection/combination/convergence and convergence between the real world and the virtual world.	ASF (Acceleration Studies Foundation)
	Metaverse Definition (2008)	A space, method, and itself in which virtual space and reality actively interact	S. E. Suh(2008)
2010s	Metaverse Definition (2013)	A virtual space environment containing objects, residents, and relationships that exist in a virtually defined time.	IEEE (American Society of Electrical and Electronics Engineers)
	4th Industrial Revolution (2016)	Defining the concept as a technological revolution that converges as the boundaries of the existing digital, physical, and biological domains disappear	Klaus Schwab
2020s	Metaverse ecosystem	Mentioning the necessity of metaverse ecosystem research and defining metaverse as multi-technology convergence	W. H. Seok. (2021), H, S. Ning et al. (2021).

(source : S. H. Jung. (2021). How to prepare for Metaverse. Seoul : BOOKK Publishing. Some readjustments)

Fifteen years later, in 2007, the Acceleration

Studies Foundation (ASF) defined metaverse as "a world in which virtual and real constantly interact and co-evolve, in which society and economy arise and cultural activities create value"[13]. In 2003, Lind Lab in the United States implemented the Second Life metaverse service, but it failed despite much interest. And in 2006, Roblox started the metaverse service in the United States, and 55% of teenagers under the age of 16 in the United States signed up, and the average daily number of users reached 40 million(2021)[3]. That's more than three times more than YouTube, Instagram, Facebook, and TikTok. It turns out to be a lot of time consuming[16]. In terms of the economy system of metaverse, the participant compensation system was weak in the past. It had a simple profit structure such as games and social media advertisements. It simply focused on moving the real world into a virtual world. On the other hand, current and future metaverses are paying and rewarding using their own currency (Roblox 'Robux', Portlight 'V-bucks', ZEPETO 'Coin' and 'ZEM', Decentraland 'MANA')[8]. It is an environment in which the revenue generated within the platform can be utilized in the real economy (subscription model, content/item sales, revenue generation through advertisements and in-app payment system). It is also generating B2B revenue through collaboration with Gucci and Nike when developing content[15]. The American Accelerated Research Foundation (ASF) classified the metaverse into four categories in 2006 as follows. Augment Reality (e.g. Pokemon Go), Mirror World (e.g. Google Maps, Digital Twin), LifeLogging (e.g. Apple Watch), and Virtual World (e.g. VR Games)[13]. In actual application, it is common to create a new business model as the four world views are properly combined and fused/composited to accelerate the interaction. For example, With the new Ghost Pacer, unveiled on Kickstarter, users can wears AR glasses that create a running avatar, and the virtual avatar

runner runs in front of the user at a preset speed or at a speed suitable for his/her past running[2]. It runs and acts as a visual pacemaker. This is an example of convergence of augmented reality(AR) and life logging. Pokemon GO, jointly developed with Nintendo by Niantic, an in-house venture of Google in 2016, researched and developed augmented reality (AR) and virtual reality (VR) related technologies. This has laid the foundation for maximizing immersion through qualitative improvement in culture and technology.

2.2 Metaverse ecosystem and Key components

Up to 2021, a total of 191 publications on the Metaverse have been published in the SCOPUS database[22]. Total number of publications in web of science and SCOUPUS up to 2021 is below table 2.

Table 2. The number of publication of Metaverse

Period	Stage	Description	Numbers of Publication
1992-2007	Embryonic stage	Mainly based on literature and art	29 (11,18)[1]
2008-2013	Primary stage	Mainly based on video game	196 (91,105)[1]
2014-2019	Ebb stage	Restricted by many open issues	83 (40, 43)[1]
2020-2021	Development stage	Consolidate multiple technologies to achieve multi-field applications.	94 (69, 25)[1]

1) Total (the number of web of science, the number of SCOPUS)
(Source : Partially reconstructed classification of 191 publications related to metaverse by H, S. Ning et al. (2021))

H, S. Ning et al. (2021) shows that 96 studies of the development stage (2020-2021) were made in the metaverse from the perspective of multi-technology [22] or ecosystem[23]. The latest research trend seems to have begun to study the metaverse in terms of the ecosystem. The factors mentioned in many studies related to the metaverse are like the table 3 below.

First, looking at the metaverse infrastructure, in the past, 2G, 3G, and 4G-centered network infrastructure was provided, to the extent that 2D

images could be provided through mobile phones and mouse/keyboard. On the other hand, the current and future metaverse provides a communication network environment over 5G[16, 22] and an NFT that can protect the ownership of digital assets, and supports parallel processing through GPU[15]. Intra is expected to develop to the extent that it can easily provide 2D as well as 3D content.

Table 3. Key components of Metaverse

Key components		Major players	Researcher
Metaverse Infra	5G/6G, NFT[1)], D.N.A[2)], IoT, etc.	NVIDIA, Microsoft, Amazon, Google, Samsung etc.	H, S. Ning et al. (2021).
Metaverse Device	XR (VR/AR/MR), Smart ring, VR gloves, VR glass, Wristband, Haptic suit, etc.	Apple (VR Gloves), MS (HoloLens), Google(Glass), Meta (Oculus), etc.	H, S. Ning et al. (2021). W. H. Seok. (2021)
Metaverse Content	Game, digital fashion, exchange, avatar ,clothing, SNS, advertisement , performance, public service, education, etc	Individual: Produce and sell various contents (ex, games) Business: seminars, performances, meeting, etc.	W. H. Seok. (2021). S. H. Jung (2021)
Metaverse Platform	Metaverse Service Platform, Production/ implementation platform, Mobile AR development platform, Metaverse Implementation Platform	Service platformer: Roblox, Fortnite, Horizon, etc. Development platformer: Unity, Unreal, NVIDIA. Mobile AR development: Google ARCore, Apple ARKit	J. E. JEON. (2021), J. Y. Kim (2021), S. H. Jung (2021), J. M. Han. et al. (2021)

1) NFT : non-fungible token, 2) D.N.A : Data, Network, AI
(Source: Rearranged based on prior research of S.H.Jung(2021),etc.)

Second, in particular, device development such as VR (virtual reality) / AR (augmented reality) / MR (mixed reality) is in full swing. In order to generalize in terms of resolution, weight, and price, Apple (VR Gloves), Microsoft (HoloLens), Facebook (Oculus), and Google (Glass) are investing heavily in technology development[15].

Second, In terms of content, the metaverse of the past provided only the content made by the provider to the participants, and the immersion was not relatively high due to the game-oriented approach without setting goals[15]. On the other hand, the current and future metaverse provides an environment where users can directly create

and consume content. Immersion is increasing with visual special effects technology using computer graphics, and realistic content that guarantees real-time interactive activities between users is provided[15].

Lastly, in the metaverse platform area, there are metaverse service providers such as Roblox, Zepeto, Minecraft, Sandbox, Fortnite, and Decentraland that provide services[13]. There are metaverse implementation platform providers such as Unity, Unreal, Google ARCore, Apple ARKit, and Nvidia Omniverse that support the creation and implementation of metaverse.

3. Research Methodology

3.1 Metaverse Ecosystem Research Overview

For metaverse research, the composition of the metaverse ecosystem is important. Metaverse does not work with only devices such as VR, AR, and MR. The technology of the metaverse, it's not just VR[1]. What is important is whether Metaverse is competitive with other technologies that can increase the value of utilization to users[15]. In Michael Porter's theory of The Competitive Advantage of Nations (1990), extensive research was conducted in 10 major countries for 4 years to identify the sources of national prosperity and global competitiveness of enterprises. As a result, he created a diamond model [8]. When this model is applied to Metaverse, the Metaverse IDC(Infra, Device, Contents) platform framework, which is a metaverse competitiveness model, is as shown in Table 2.

First, the production condition (fact condition) is a product/service provided to consumers that corresponds to a competitive production condition[9], which corresponds to the content area of the metaverse. Metaverse creates and provides various contents to consumers. In the past, only companies produced and provided

content. The difference from the past is that participants can create their own and provide it to other participants.

Second, the demand condition is a factor that can satisfy the endless experience of demanding users [8]. In the metaverse, it corresponds to the device area such as VR, AR, MR, and XR. The device is a very important part of providing the end experience to the customer.

Third, strategy/structure/competition is a strategy, structure, or competitor that can provide competitive advantage[9]. In the metaverse, it corresponds to the metaverse platform area. The metaverse platform is a strong strategy and structure that the metaverse can mature[15]. It is a strong area where one can gain a competitive advantage by using the two-sided economy and network effect.

Fourth, the Related and Supporting Industry is the development and cluster of related industries[9]. It corresponds to the infrastructure area of the metaverse[15]. In particular, the network speed is a very sensitive area to the development of the metaverse. In addition, NFT, which supports secure transaction of metaverse contents, is also an important technology.

3.2 Metaverse IDC-Platform ecosystem

1The metaverse consists of a combination of four ecosystems: infra, device, content and platform. I would like to call this the metaverse IDC-Platform framework by prefixing the four components as shown in Table 4. It cannot be said that the metaverse is composed just because only one of the four elements is prepared. Metaverse The era of metaverse can be said to have begun only when all four elements of the metaverse IDC-Platform framework are considered to be competitive from the user's point of view. Each of the four ecosystem components of the metaverse IDC-Platform framework are interdependent[15]. For example, if you want to service 3D content, the minimum

communication infrastructure must be 5G or higher, and the device must be capable of VR and AR.

Table 4. Metaverse IDC-Platform Model

Component of Michael Porter`s Diamond Model and Definition and mapping			Metaverse ecosystem
R&S	Related & Supporting Industry	Development and cluster of related industries related to metaverse growth	Metaverse Infra
DC	Demand Condition	Factors that can satisfy users who are demanding in terms of users with a seamless metaverse experience	Metaverse Device
FC	Factor Condition	Product and service provision area that meets the content production conditions to provide a differentiated experience to consumers	Metaverse Content
SSR	Strategy, Structure, Rivalry	Areas of strategy, structure and competitor aspects that can give the metaverse a competitive advantage	Metaverse Platform

(Source : Based on the Diamond Model of Michael Porter`s "The Competitive Advantage of Nations", reorganized into a Metaverse ecosystem)

First, In the metaverse infrastructure area, a lot of progress is being made in terms of connectivity, convenience, safety, and automation in the infrastructure area. In terms of connectivity, it has evolved from 2G, 3G, and 4G to 5G, which has improved the transmission speed of metaverse content. In particular, 5G service is 20 times faster than 4G, 10 times faster response, and 10 times more people and devices can be connected[6].

Korea has a plan to commercialize 6G in 2028, and 6G has a data transmission speed 50 times faster than 5G and 1,000 times faster than 4G. This is expected to open the era of rapid communication development and full-fledged metaverse[16]. It is almost similar to the point of view of Facebook founder Zuckerberg that "the metaverse will be difficult in 2020, but the metaverse era will be possible in 2030". Wireless network performance is very important for metaverse commercialization. No matter how good 3D content is made, it is useless if the data transfer speed does not support it. It's like

building an innovative electric car, but unable to function properly at the level of the road a wagon passes by. In terms of convenience, it is evolving from carrying to wearing, from touch to motion and gaze, from 2D to 3D, and from CPU (direct heat processing, processing one by one) to GPU (parallel processing, simultaneous processing). In terms of safety, digital assets in the past could not be properly recognized as assets because they could be copied without restrictions due to their online nature. Therefore, the production, sale and exchange of digital contents was not active. All related information, such as NFT-based ownership and sales history, is stored in the block chain, making it possible to confirm the first issuer and impossible to forge[4]. NFT is being used as a means to digitally tokenize existing digital assets with clear asset ownership.

Second, the device area has an important influence on the UI/UX User Interface/User eXperience of metaverse users. It is a touchpoint designed for users to interact with the metaverse service, and it occupies an important area for the overall satisfaction of users. It is evolving from the past cell phones, 2D, mouse/keyboard to convenience (wearing), interactivity (movement, gaze), and spatial expandability (more than 3D).

Whether these will replace smartphones is an area of high interest. Although a new experience called VR (Virtual Reality) was provided to consumers, dizziness occurred due to the discomfort of wearing the VR device and cognitive dissonance of various senses such as vision[15]. In addition, the market was not activated due to the absence of content that satisfies the needs of consumers. Nevertheless, smartphone-based VR has disappeared, but high-performance VR based on Windows PCs and consoles has survived.

Third, the content area is one of the most important factors for the success of the metaverse business. Continuous and safe provision of valuable content to users is a key factor in metaverse growth. One of the biggest changes is that in the past metaverse, only content provided by providers was consumed. However, now, individual users can create and sell various contents such as digital fashion and games, and exchange them with the currency provided by the metaverse platform operator. And the created digital content can be clearly owned with NFT (Non-Fungible Token). In addition, users from companies, schools, hospitals, government, etc. will also create and provide content related to games, performances, seminars, civil complaints, and meetings. Virtually everything in the real world can be created, registered, and managed as content in the metaverse if there are no technical restrictions. In the past, it was pointed out that digital content lacks a lot of realism, but now it is possible to use a tool that can create special effects (VFX, CG, etc.) and virtual humans (Meta Human) using computer graphics. It has become so sophisticated that it is indistinguishable from. One of the biggest characteristics of metaverse content is that it uses NFT technology and digital currency to strengthen economic activities within the metaverse. In the past, it was impossible to distribute currency such as acorns with its ability to support economic activity, but it is providing currency that can be circulated, such as cryptocurrency and NFT. In particular, NFT makes asset ownership clear because all relevant information such as ownership and sales history is stored in the block chain, making it impossible to verify and forge the first issuer. In addition, NFT is being used as a means to digitally tokenize existing digital assets such as games/arts/real estate[15].

Last, metaverse service providers are expanding to social, economic, and cultural fields from the initial game or SNS-oriented focus[15]. Through the metaverse, users go beyond solving the missions of existing games,

users create virtual assets with their own ideas, generate profits, and interact with other users in various social, economic and cultural aspects. Looking at the metaverse implementation platform providers, it can be seen that Unity, which downloads more than 5 billion games per month, occupies 50% of smartphone mobile games and more than 40% of the PC game market[14]. In addition, Unity accounts for more than 70% of Nintendo Switch games and 3−40% of Xbox and PlayStation games[14]. Unreal, provided by Epic Games, is mainly used for blockbuster games because it can implement high−quality graphics. Unreal is famous for NCsoft Lineage 2M, Nexon V4, Kart Rider Drift, Star Wars Mandilorian, Game of Thrones, Haeundae, etc. CG, visual effects, Pyeongchang Olympics augmented reality effect, etc.[10]. The most important thing is to decide whether to become a metaverse platformer and get on the platform. To become a metaverse platformer, you need to prepare more than just a simple metaverse participant.

3.3 Metaverse Development Direction

As W. H. Seok(2021) mentions the need for an approach from the perspective of the metaverse ecosystem [23], many researchers are conducting metaverse ecosystem and ecosystem composition research with questions as shown in Table 5. H, S. Ning et al. (2021) defines essential communication technologies for metaverse as 5G and 6G[22]. 5G can provide basic functions of metaverse because of its fast communication speed, low delay, ubiquitous network, low power consumption and interconnection of all things. 6G is expected to remove the limitations of time and virtual reality and truly usher in the metaverse era[22]. XR(AR/VR/MR) technology is one of the technical pillars of building the metaverse[22].

Table 5. Metaverse ecosystem maturity questions

Stage	Major questions and assessment factors		Researcher
Infra maturity	Is it the level of providing 3D−based high−quality content seamlessly in real−time?	통신기술 : 1G(1964), 2G(2000, 3G(2006), 4G(2011), 5G(2020, 6G(2028) or more IoT, AI, etc.	H, S. Ning et al. (2021). W. H. Seok. (2021)
Device maturity	Is it at a level that provides users with accessibility, weight/resolution, reasonable price, and sense of presence?	PC, Smart Phone, XR[1] (VR, AR, MR) Smart ring, VR gloves, VR glass, Wristband, Haptic suit	H, S. Ning et al. (2021). W. H. Seok. (2021)
Content maturity	Is it at the level that protects digital assets from forgery and provides high−quality content based on 3D?	2D, 3D, 3D(+Currency[2]) 3D(+Currency+NFT)	W. H. Seok. (2021)
platform maturity	Is it possible to create network value through two−sided market management and manage the platform ecosystem in a virtuous cycle?	Single−siided market, Two−sided market, Two−sided market(+ Network externality[3]), Two−sided market (+Network externality+ D.N.A[4])	J. Y. Kim(2021), S. H. Jung (2021),

1) XR : Extended reality, Technology that includes all technologies such as VR, AR, MR, etc.
2) Currency that can be exchanged with real money, ex digital currency, cryptocurrency, etc.
3) The effect that a user group on one side obtains is directly affected by the number or consumption of user groups on the other side.
4) D.N.A : Data, Network, AI

H, S. Ning et al. (2021) was studied limitedly until 2021[22]. Therefore, in this study, as shown in Table 6, it was extended to the past, present, and future based on previous studies.

Table 6. Metaverse ecosystem maturity stage

Stage	Key features	Researcher
The first stage (2000s)	The metaverse trial period, PC, 2G environment, low realism of 3D content, low immersion	W. H. Seok. (2021)
The second stage (2010−2021)	The metaverse transition period, high expectations, but difficult to generalize, Introduction of smartphones, 4−5G based, NFT, etc.	J. Y. Kim. (2021)
The third stage (2021−2030)	The metaverse maturity period, Metaverse commercialization, VR/AR/MR popularization, 6G, etc.	W. H. Seok. (2021)
The fourth stage (2030s)	The metaverse expansion period, Exponential growth and expansion into the entire industry.	H, S. Ning et al. (2021).

(source : S. H. Jung. (2021). How to prepare for Metaverse. Seoul : BOOKK Publishing. Some readjustments)

The first stage is the metaverse trial period (2000s)[15]. Like Metaverse Second Life, it was an

attempt to put the real world on the virtual world with a big picture of the convergence of virtual and reality[27]. Although it was evaluated as a failure due to the lack of realism and immersion in the PC environment, 2G environment, and 3D content, it is meaningful that it left many lessons for future preparations.

The second stage is the metaverse transition period (2010-2020)[15]. During the transition period, interest in the metaverse is rapidly increasing. However, there are no businesses that are making huge profits and it is limited to the game platform[28]. There are evaluations that metaverse devices such as VR, AR, and MR will also replace smartphones, but no one can deny that smartphones are still the mainstream. It seems that it is still far from generating revenue from the platform side.

However, due to the Covid-19 pandemic, the aspiration for the fusion of the real world and the virtual world is higher than ever. This is the time when global big tech companies such as Apple, Facebook, and Microsoft are paying a lot of attention and investment, so it is expected to bear good results soon. Roblox, the representative company of Metaverse, was founded in 2004 by David Baszucki and Erik Cassel. Roblox is an online game metaverse platform company where users can program games and enjoy games created by other users. Roblox launched an online game platform in 2006, but it did not receive much attention. In March 2021, Roblox went public (IPO) and is now receiving a lot of attention.

The third is the metaverse maturity period (2021-2030)[15]. J. Y. Kim (2021) saw the 2021s as a full-fledged growth period for Metaverse at the Science and Technology Policy Research Institute [17], and Facebook CEO also saw the 2030 as a full-fledged growth period. Both academia and industry view the same period of 2021-2030. From the perspective of ecosystem maturity, the 2030s seem to be a period of full-fledged growth.

This is the time when the metaverse technology development bears fruit thanks to the investment so far. This is also the time Facebook CEO mentioned.

Most importantly, it is a time when 6G is commercialized in terms of infrastructure, and remarkable developments in resolution, weight, price and performance of VR, AR, and MR are expected in terms of devices. Facebook CEO Zuckerberg also predicted that the metaverse era would begin in earnest in 2030.

The fourth is the metaverse expansion (after the 2030s)[15]. This is the time when metaverse has expanded to all industries[22,26] and almost all work is done with metaverse. There will come a point where all organizations, including businesses, schools, hospitals, and governments, will not be able to live without the metaverse. It is a time when the boundary between virtual and reality is breaking down and work productivity is increasing several times compared to now. In addition, the gap between the rich and the poor is expected to widen even more than now.

4. Results of the study

Unlike research so far, research that has been limited to a specific area should be expanded from the point of view of multi-technoloy, ecosystem, and socio-cultural factors[27].

For this, extended research based on research framework that has already been verified in other industries is needed for metaverse research, which is being studied from various angles. An expanded metaverse IDC-Platform model based on the diamond model, which is Michael Porter's competitive model of The Competitive Advantage of Nations (1990), was created and applied to the metaverse ecosystem based on previous research.

The research result is to derive the metaverse

ecosystem components of Infra, Device, Content, and Platform. In particular, we found that the provision of a device that can realistically provide 3D content and that the metaverse can be applied to 5G and 6G or higher in the infrastructure area are also very important pillars. The four elements of the metaverse are developing in a close relationship with each other. In addition, based on the metaverse IDC-Platform, the metaverse evolution stage was extended and applied to the future only until 2021.

As a result, the metaverse ecosystem began to mature in the 2021-30, and it was possible to predict the era in which the metaverse would become common in the entire industry in the 2030s.

5. Conclusions and limitations of the study

A summary of the study results is as follows. The metaverse is an evolving concept and must be approached from an ecosystem perspective. Four major ecosystem components play an important role in metaverse evolution.

The academic implications are as follows. We derived metaverse IDC-Platform, a metaverse integration framework that can study metaverse research, which has been limited to specific areas, from an ecosystem perspective. Although each component evolves independently of each other, it has been identified that they are interdependent for the application of the metaverse.

it provided insight into the interaction and maturity of the ecosystem components constituting the metaverse. step-by-step advice is provided for those in charge of constructing the metaverse.

It will be an important cornerstone for future metaverse ecosystem research.

The practical implications are as follows. Metaverse is expected to evolve into an experiential metaverse service to an industry-specific metaverse service to an intelligent metaverse service, rather than being used immediately in all areas of the industry. In order to apply it to all industries, it is necessary to think Big, Start Small, and Learn Fast in consideration of the metaverse's technological maturity, ease of application, and social and ethical aspects[15].

Second, you need to think about which device and content to apply. In particular, in terms of devices, evaluation factors such as price, weight, and resolution are not mature, so there is not a wide range to choose from so far[15].

2D such as smartphones and PCs are common, but prices, weight, resolution, etc. such as VR/AR/MR and haptic suits are not yet common.

In most overseas countries, including Singapore and New Zealand, 2D forms such as online quizzes and bingo games for event participants are basically borrowed to provide basic gamification content. 3D content is partially applied. Metaverse operators should also consider inducing voluntary participation by providing tools and workshops for participants to create their own content, like YouTube.

Third, it is necessary to consider whether to create a metaverse platform that provides services on its own (whether to become a metaverse platformer), or whether to utilize existing platforms such as ZEPETO and Roblox[15]. In the case of self-produced metaverse platform, it is necessary to configure, manage, and supervise the platform ecosystem such as two-sided economy, network effect, and asymmetric price structure.

Fourth, it is necessary to consider what kind of infrastructure to apply and utilize to support the metaverse[15]. Recently, cases of protecting digital intellectual assets and facilitating transactions through non-fungible tokens (NFT)

are increasing. In addition, use cases of advanced technologies such as D.N.A (Data, Network, AI) and 5G are increasing. In addition, providing a sense of reality is important to increase immersion, and for that, high graphic performance is required. In the case of celebrities and exhibition halls, the degree of feeling of reality differs in how much it can be expressed in the same way as reality. As seen above, the metaverse needs to build a comprehensive ecosystem in the fields of device, content, platform service provider, developer and infrastructure, and it is necessary to prepare for the metaverse era by closely researching areas where companies can participate. Since metaverse can only succeed when a comprehensive ecosystem is well established, policy support must be provided at the same time for global competitive advantage.

The limitations of the study are as follows. First, there were many limitations to the study because there were not many successful cases or experts on the metaverse yet. Second, in order to increase the value in qualitative research, it is reasonable to conduct an expert Delphi interview, but it did not overcome the limitation that it was based on the main research of experts.

Future research directions are as follows. First, although the concept of the metaverse ecosystem and maturity is provided, additional research is needed to measure and generalize it by industry. Second, beyond qualitative research so far, quantitative research related to metaverse should be conducted.

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