

Sustainable Engineering Paradigm Shift in Digital Architecture, Engineering and Construction Ecology within Metaverse

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Abstracts—In the post COVID 19 pandemic, the demand for virtual world and digital economy accelerated and became more popular and the term Metaverse is now a hot topic in different sectors in the community and society. Digital technology development in augmented reality (AR), virtual reality (VR), and networks has become more mature in recent years, the racing of the application of Metaverse in different aspects is more vigorous. Metaverse in digital architectural, engineering and construction being one of the major players in future should not be overlooked. More understanding of Metaverse which includes the Architecture, Engineering and Construction (AEC) industry is crucial and this is important for stakeholders in the AEC industry to start early development to match with the quick development, expansion and global trend of Metaverse.

Keywords—Metaverse, internet of things, smart city, NFTs, digital economy, blockchain.

I. INTRODUCTION

THE term “Metaverse” was coined by science fiction writer Neal Stephenson in his 1992 novel “Snow Crash.” In the novel, it describes the Metaverse as a massively popular virtual world experienced in the first person by users equipped with AR technology. Basically, metaverse refers to video conferencing, gaming, email, VR, AR, social media, and live streaming while the metaverse system considers user-centric elements including Avatar, Content Creation, Virtual Economy, Social Acceptance and, Security and Privacy. In this paper, the background and latest development of Metaverse and digital economy is reviewed and the paradigm of Metaverse in future digital AEC ecology is discussed for further research. Case study of world first Metaverse city projects in Seoul, Korea are presented and the lesson learnt from the project is expected to provide insight for other researchers to carry out further study.

II. PRINCIPLE OF METAVERSE?

In Neal Stephenson's science fiction novel “Snow Crash” in 1992, humans are described as avatars who interact with each other and software agents in a 3D virtual space that uses the metaphor of the real world. [5] Stephenson used the term to describe a VR-based successor to the internet, it constitutes Stephenson’s vision of how a digital world might evolve in the near future [6].

Users can access to metaverse through their personal terminals from a first person perspective while the project with

high quality of VR is displayed onto goggles or from grainy black and white public terminals in booths [13].

Trend of Development of Metaverse in Digital Economy

In metaverse, all activities can be taken place in a shared 3D virtual world by using augmented and VR equipment. The platform has gained popularity in recent years as people have shifted their activities online during COVID-19 pandemic.

The Metaverse is the hot top of shifting the real economy to digital economy around the world during pandemic in recent years. The traditional lifestyle, business model and work culture in different industries and communities changed which also acted as a catalyst to accelerate the deployment and development of the digital economy. Apart from the early practitioners in Metaverse like gaming, cryptocurrency, we see the trend of Metaverse will change the business model in other aspects. In this paper, we will focus on the impact and potential development of Metaverse in the AEC industry.

Essential Technologies for Metaverse Development

Metaverse development relied on the advancement of technology development like extended reality, 5G, artificial intelligence, blockchain, computer vision, IoT and robotics, edge and cloud computing and future mobile networks [16], [15]. The Metaverse comprises interdisciplinary aspects and it can be broadly named as technologies and ecosystems. The Avatar denotes the digital representation of users in virtual spaces and their physical embodied agents and the technology plays an important role to support the Metaverse and its ecosystem development.

According [11], the matrix of key elements of technologies for development and supporting the development of Metaverse is discussed.

Metaversal Economy - Virtual Property

In Metaverse, everything including knowledge, art piece or even a virtual building has its virtual value and it can be exchanged by the wide explosion of interest in NFTs (Non-fungible tokens) and cryptocurrency - Blockchain technology. Avatars in Metaverse can own their non-duplicated digital commodities, digital goods, digital assets, etc. and trade them in the digital economy.

The NFTs technology is a trust technology in the real and virtual world. It allows users in the Metaverse to own their

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unique and bespoke items and cryptocurrencies, provide a clear roadmap for development and shape Metaversal economy. The first digital NFTs virtual house “Mars House” designed by digital artist Krista Kim was sold for US\$514,557.79 and the owner got the 3D files and uploaded them to his Metaverse for future trading [10].

TABLE I
MATRIX OF KEY ELEMENTS OF TECHNOLOGIES FOR DEVELOPMENT AND SUPPORTING THE DEVELOPMENT OF METAVERSE

Extended Reality (VR, AR)	Full Integration of Virtual-Real Environmental Super-Realism Multi-Cyberspace User Collaborations
User Interactivity (Mobile Input Technology, New Human Visions through Mobile Handsets, User Feedback)	Fine and Accurate Registration Invisible Interfaces Ubiquitous User Interaction Alternative Feedback and User Cues Telepresence
Internet of Things (IoT) and Robotics (VR/AR/MR Driven Human IoT Interaction, Connected Vehicles, Robots with Virtual Environment) Artificial Intelligence	XR-IoT Interaction Avatar-robot Interaction Immersive Connected Vehicles Novel Social Robots AI-drive User Experience Lightweight AI Models Automatic and Constant Conversation for digital Twins
Blockchain	Real-time or Swift Proof-of-work Data Transparency against Data Privacy Interoperability
Computer Vision	All Round Scene Understanding Human-avatar Micro-gesture/ Expressions
Edge and Cloud	Interconnected Real-virtual Ontology Last Mile Latency Lightweight Service Platform Edge and Cloud Orchestration Decentralization Security Protocols
Network - high speed network with low latency	Sub-ms Latency Network capacity Exposure Network Slicing Application Driven Protocol

The Change of Business Model and AEC Vision in Metaverse

In the traditional architecture and building industry, clients will look for creative architects, engineers and contractors to participate in their project to complete a project with lowest price and shortest construction time. Meanwhile, other ideas created by other AEC competitors will not be used if they fail to get the project contract [2], [3].

Metaverse provides a virtual city full of all possibilities and without any constraints like the physical world. ACE has the great opportunities to create their own and unique digital design for any people who desire for the AEC design art piece like architecture design, structural engineering product, etc. around the world. In the physical world, a building project takes at least 5 to 7 years from design stage to final delivery of the project. During the whole process, it involves different ideas, experience and technology input from AEC. The AEC also works collaboratively to resolve over thousands of constraints in design, structure, MEP, budget and construction management. Metaverse provides a platform where AEC can participate and work together to bring all knowledge from different disciplines together and stimulate the project virtually

which speeds up the overall coordination process in the digital world [8], [9], [12], [17]. The stimulated project can stimulate different scenarios to test and verify different real-life parameters in Metaverse and the data collected which help to improve the creativity, buildability and sustainability of the project in the physical world. Unlike the traditional 3D model concept, NFT architecture is more than just an instrument for project presentation, it can be more specifically and precisely described as a form of art even before it is built. This allows AEC to develop concepts that take their profession to other levels and create the opportunities for AEC to create and sell their digital version of design in the digital economy.

With the advancement of AI development, it was about the next-generation virtual world using artificial intelligence in AEC industry, for example, users can use artificial intelligence to have their avatars learn professional skills and perform professional work in a virtual world and Metaverse. [7] In the real world, the problem of labor resources, time and cost is easily replaced and compromised by using artificial intelligence in Metaverse. In the real world, a complicated task will have to go through a lot of work and take time. However, in the virtual space and Metaverse with the utilization of artificial intelligence avatars, it is possible to develop the task quickly and continuously for a long time.

TABLE II
KEY ELEMENTS IN A VIRTUAL PROJECT TEAM IN VIRTUAL WORLD AND METAVERSE [1]

Key Element	Role
Metaverse	A 3D virtual world formed a platform for people to interact with each other as avatars and using the metaphor of the real world without its physical limitations
Virtual World Project	It describes a virtual project conducted partially or wholly in a metaverse through collaboration of team of people/avatars The term Avatars represented the user-created digital representations of people created by users and they are unique character that symbolize a user's presence in a virtual world.
People/ Avatars	The aviators has the ability to interpret verbal and nonverbal cues from the representation of other avatars and can react with appropriate responses
Metaverse Technology Capabilities	People/avatars have the capabilities for communication, rendering, interaction, and team process that allow participants to act and interact in the project inside the metaverse.
Behaviors	People outside the metaverse controlled the behavior and manifested inside the metaverse through the interaction and communication of avatars.
Outcomes	In the virtual world and real world, artifacts that represent the result of team activities.

“NFTism” Project by Zaha Hadid Architects (ZHA)

Zaha Hadid Architects (The Pfizer prize winner architect, Zaha Hadid) presented a virtual art gallery at Art Basel Miami to explore the interaction of architecture and social interaction in metaverse. The event was to introduce how the metaverse supports new forms of creative cultural production like digital art and virtual art museums. It also served to demonstrate how cyberspaces enable human to human communication through computer networks, coupling the spatial and interaction experience of cyberspaces with social, community which forming and economic infrastructure [4]

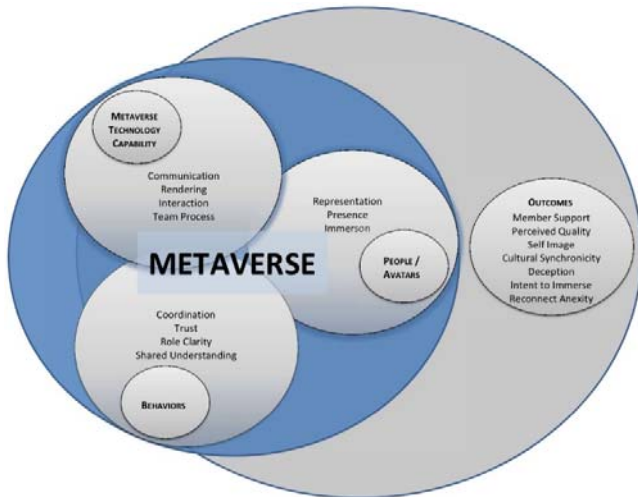


Fig. 1 An illustration showing the relation of key element in a virtual project team in virtual world and metaverse [1]

III. CASE STUDY OF SEOUL'S METAVERSE

Korea being one of the major economy and technology hubs in the world has announced in December 2021 that it will be the first major city to enter the metaverse. The project provisionally called 'Metaverse Seoul' intends to create a virtual communication ecosystem for all areas of its municipal administration and it aims to include economic, cultural, tourism, educational and civic service in the coming year.

The South Korean capital has invested about €2.8 billion into the project, as part of the city's mayor Oh Se-hoon's Seoul Vision 2030 plan. It aims to make Seoul "a city of coexistence, a global leader, a safe city, and a future emotional city," the mayor said. This nationwide plan is also targeted to hold digital [14] and AI tools to improve the economy in different sectors like healthcare and infrastructure and assist the recovery of economy in post COVID 19.

The Korean Government expected that if this project becomes a reality, Seoul citizens will be able to put on their VR headsets to meet city officials for virtual consultations and able to attend mass events such as the Seoul Lantern Festival.

The Seoul's Metropolitan Government (SMG) works collaboratively with different stakeholders including the Virtual Mayor's Office, Seoul FinTech Lab, Invest Seoul and Seoul Campus Town, on its metaverse platform and provide various business support facilities and services to develop the plan.

Application of Metaverse under "Metaverse Seoul" Project

The SMG will open the "Metaverse 120 Centre" (tentatively named), a virtual public service center in 2030 and the avatar represented as a public official in the metaverse will provide consultations and necessary civil service. The plan will also expand Seoul's major tourist attractions including Gwanghwamun Plaza, Deoksugung Palace and Namdaemun Market, which will be introduced through the "Virtual Tourist Zone". The SMG will also develop services for the socially vulnerable including safety and convenience content for people with disabilities using extended reality (XR). [14]

Seoul Metaverse Alliance

The Korean key industry players have already formed an alliance and their target are to invigorate the development of metaverse technology and critical aspect in the technology, media and telecoms industries and taking the next steps toward the evolution of the internet. The Korean technology alliance composed of 17 Korean market leading companies and the aims of this alliance are all set to work together to undertake a joint development of metaverse projects and share the results of metaverse trends and technology development. They will define a national metaverse platform with 5G technology and open to all participating and providing virtual services. [14]

IV. ANOTHER SMART CITY IN ASIA PACIFIC

Other than Singapore, Korean governments are using digital technology and real-time data to optimize city operations as part of the "smart cities" movement. The South Korean city is planning to use artificial intelligence (AI) in the following aspects in coming years for transformation to a smart city:

- 1) use AI to monitor its sewers and water waste centers.
- 2) use AI chatbot as a public concierge, fielding public questions and complaints related to everything from parking violations to COVID-19 protocols.
- 3) establish the plans for a public internet of things network with an installation of sensors and base stations within the city to collect data like traffic, public safety, and environmental metrics and transfer them into a central operations platform managed by government.

XI. CONCLUSION

Research on metaverse in the AEC industry is still at an early stage and most metaverse research is now being conducted at the conceptual level. From the AEC industrial point of view, this research can shed new insights to metaverse service entrepreneurs about future directions for the industry. To further extend the transformation of the traditional AEC industry in the virtual world, the aspects discussed in this paper can be considered by future researchers.

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