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The Impact of Metaverse on Architectural Production: Opportunities and Challenges

Metaverse'ün Mimari Üretim Üzerindeki Etkileri: Fırsatlar ve Zorluklar

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ABSTRACT

Technological advancements are rapidly transforming our world and influencing architecture, which has evolved alongside human history. The relationship between humans and space is being redefined with the emergence of digital spaces and virtual environments. The new world order, based on internet interactions, has particularly positioned virtual spaces at the center of daily life, shifting spatial discussions towards the realm of digital interactions. Commitment to digital spaces has become more pronounced since the onset of the coronavirus pandemic. The Metaverse, a digitalization field connecting real and virtual worlds, is a contemporary phenomenon impacting architectural production. This study examines the effects of advancements in Metaverse technology on architecture and space production, aiming to raise awareness among researchers in this emerging field. Within the study, the role of architecture in the Metaverse is questioned, and the advantages and disadvantages of digitalization in space production are analyzed. The literature reviewed in the study was analyzed thematically, and the SWOT analysis technique was used to determine the strengths and weaknesses of digital production. The study provides crucial insights into the future of space production, offers information on how the Metaverse environment can be utilized in architectural design, and discusses the potential risks associated with its use.

Keywords: Metaverse, architectural design, digital design, virtual space, SWOT analysis.

ÖZ

Teknolojik ilerlemeler, dünyamızı hızla dönüştürmekte ve insanlık tarihi ile paralel olarak evrilen mimariyi etkilemektedir. Dijital mekanların ve sanal ortamların ortaya çıkışıyla insan ve mekân arasındaki ilişki yeniden tanımlanmaktadır. İnternet etkileşimlerine dayalı yeni dünya düzeni özellikle sanal mekânları günlük yaşamın merkezine taşıyarak mekân tartışmalarını sanal etkileşim alanlarına yönlendirmektedir. Dijital alanlara olan bağlılık koronavirüs salgınından bu yana kazandığı ivmeyle belirgin hale gelmektedir. Gerçek ve sanal dünyaları birbirine bağlayan bir dijitalleşme alanı olan Metaverse, mimari üretimi etkileyen güncel bir fenomendir. Bu çalışma, Metaverse teknolojisindeki ilerlemelerin mimarlık ve mekân üretimine olan etkilerini ele almakta ve bu yeni gelişen alanda araştırmacılara farkındalık yaratmayı amaçlamaktadır. Çalışmada, Metaverse içinde mimarlığın rolü sorgulanmakta ve dijitalleşmenin mekân üretimindeki avantajları ile dezavantajları incelenmektedir. Bu bağlamda, incelenen literatür tematik olarak analiz edilmiş ve dijital üretimin güçlü ve zayıf yönlerini belirlemek için SWOT Analiz tekniği kullanılmıştır. Çalışma, mekân üretiminin geleceği hakkında önemli ipuçları sunmakta, mimari tasarımda Metaverse ortamının nasıl kullanılabileceği ve kullanımıyla ilişkili potansiyel riskler hakkında bilgiler vermektedir.

Anahtar Kelimeler: Metaverse, mimari tasarım, dijital tasarım, sanal mekân, SWOT analizi.

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Introduction

While the idea that architecture is the creation of the environment, we live in is widely accepted, the relationship between architecture and space has been a subject of debate and conceptualization in various forms. The definition of space has transformed since it started to be based on the cognitive and perceptual qualities of the human user. At this point, space and humans are not considered separate independent elements; space is accepted to exist because of human interaction.

Today's discussions on space are not based on approaches that define boundaries and physical existence as emptiness, or on human-space interactions, but rather on concepts such as digital space, virtual space, and beyond space.

Virtual spaces have become increasingly central to daily life, to the extent that social-space relationships have acquired a new dimension in which there is no physical contact, and social encounters do not occur (Robins, 2021). Spatial displacement directly affects the production of architecture.

Lin (2022) refers to the platform that people see as a tool for transitioning to the digital age in the future as the "Metaverse." This platform is a collection of virtual environments worldwide where individuals' new forms of communication can occur on global computer networks (Schumacher, 2022). Therefore, the Metaverse is represented as the forthcoming evolution of the internet in virtual environment. It functions as a communal space where users can engage with both virtual objects and other individuals within a three-dimensional framework. In this virtual setting, individuals utilize virtual reality and avatar technologies to interact with each other, effectively inhabiting this digital world.

Metaverse integrates a universal single internet infrastructure with an integrated 3D virtual and physical world network, providing users with cyber-virtual experiences within the real world (Rawat & El Alami, 2023). The term "Metaverse" comes from the combination of the words "meta" and "universe". The concept of the Metaverse refers to a virtual, transcendent universe. According to Dionisio et al. (2013), what distinguishes this universe from metaphysical or other spiritual universes is that it is created by computers and technology.

The Metaverse can be defined as a multi-universe ecosystem where virtual and real worlds are integrated, and experienced through equipment such as computers, mobile applications, smart televisions, and specialized devices like glasses and headphones. This allows the ecosystem to become a digital reality that goes beyond the experiences of real life in virtual worlds, allowing users to experience alternative lifestyles through virtual spaces and share these experiences in real life.

In Schumacher's study (2022), he raises a question, "Who is designing and who should design the Metaverse?" highlighting the importance of architecture's role and fundamental competencies in Metaverse design. According to Schumacher, aesthetics makes a significant contribution to social functionality and are indispensable in directing communication between individuals. Therefore, like in traditional spaces, all environments that trigger senses and mediate social communication between individuals in digital spaces should be visualized by designers. Thus, designers' creations, from the urban to the building scale, interior design, landscape, furniture, fashion, and graphic design, will be digitized, and these digital productions will spread in the field of Metaverse design.

Metaverse is progressing towards creating a new and progressive digital universe and is expected to be one of the most significant technological developments in the coming years. This transforms the perception of Metaverse as a gaming platform and makes it an extension of the real world. Architectural space and digital/virtual space are two different concepts discussed by researchers, architects, and designers. In today's world, the relationship between architectural space and digital space has become complex and multifaceted.

Architectural space refers to the physical, material, and dimensional aspects of the built environment designed and constructed by humans, while digital space refers to the virtual, non-material, and temporal dimensions created with digital technologies. With the development of digital technologies, the boundaries of space have begun to expand beyond physical space into the realm of perception, changing how architects design, present, and produce spaces (Hou et al., 2024). Digital space can be manipulated and transformed in ways that are not possible in architectural space due to its lack of material qualities and sensory experiences, which are also what make architectural space strong. The mutual relationship between the two spaces is dynamic also complex because they can influence and transform each other in various ways. These developments also constitute the focal point of this research.

Recently, the increasing demand for the Metaverse has brought a surge in research focused on virtual spaces. These studies explore the technical infrastructure of the Metaverse, examining how the integration of technologies such as big data, artificial intelligence, and blockchain (Fu et al., 2023; Yang et al., 2022) can enhance the efficiency and effectiveness of these virtual worlds. Concurrently, research on avatar and human interactions (Davis et al., 2009; Zhang et al., 2020) investigates the potential for advanced collaboration and engagement within virtual environments (Pinkwart & Olivier, 2009; Weiss & Schiele, 2013) , providing significant insights into user behaviors and their outcomes. Particularly, studies focusing on the protection of digital identities in virtual environments (Spiegel, 2018; Wang et al., 2023) highlight the escalating privacy and security breaches within the Metaverse and discuss the associated risks and potential solutions for this new universe. Despite the current focus on technical and security aspects in Metaverse research, studies on architectural design and user experience (Ding et al., 2022; Moneta, 2020; Shakeri & Ornek, 2023) underscore the need for further investigation in these areas. Discussions on the potential impacts of the Metaverse on individuals, when linked with ongoing discourses in the literature, should expand to delineate clear research paths and questions, thereby opening up broader fields of inquiry.

The main problem under investigation is the relationship of architecture, architects, and digital space production in the creation of virtual worlds that appeal to users' cognitive perceptions, in tandem with the advancements in emerging technologies. It is imperative to explore the contribution of architects in designing and producing virtual spaces within the Metaverse environment. This, in turn, will significantly influence how users perceive virtual spaces. This research aims to develop a proactive approach towards this new production process. this paper draws theoretical implications concerning how the production of digital spaces, along with the interaction between users and space, will impact the architectural design and digital production process within the realm of human experience. In conclusion, the relationship between the concept of Metaverse and architecture, as well as digital space production, is addressed, considering the strengths and weaknesses, opportunities, and risks of this novel production form.

Background

Metaverse as a Digitalization Area

The Internet is a tool that facilitates access to information, communication, commerce, and entertainment on a global scale. In the period known as Internet 1.0, which lasted from the mid-1990s to the early 2000s, the Internet only had basic functions such as accessing information and sending emails, and websites were static, containing only text and images. Internet 2.0, which

is the current internet, allows users to actively produce content in the online environment, making it a more interactive period. With the proliferation of the internet and the popularity of mobile devices, the internet has become accessible from anywhere. Additionally, there have been significant developments in different areas such as search engines, social media, e-commerce, and cloud technology. This has contributed to the emergence of the digital age and has changed the role of the internet in our lives. In this new era, known as Internet 3.0, which is associated with the Metaverse virtual platform, technical developments will continue to increase rapidly and play a greater role in human life.

The concept of the Metaverse was first introduced in Neal Stephenson's (2016) science fiction novel "Snow Crash" to describe a fictional world that is separated from the real universe and exists as a virtual reality environment that can be accessed by people's avatars from various locations within a computer-generated world, allowing them to interact with each other through goggles and headphones in 1992. The first actual usage of the term was in a limited area with the "CitySpace" platform between 1993 and 1996. Later, different Metaverse environments emerged with the popularity of online games such as Active World: 1995 and Traveler: 1996. The concept was further popularized with the development of the "Second Life" virtual world by Linden Lab in 2003, which allowed users to create and customize their avatars and interact with others in a shared virtual space. With the widespread use of smartphones, virtual and augmented reality applications like Minecraft: 2011 and Pokemon Go: 2016 were introduced to users as game-based experiences.

The most significant work that discusses the Metaverse as a virtual world in the context we are discussing today is Ernest Cline's 2011 science fiction novel "Ready Player One," in which the OASIS is portrayed (Celine, 2018). The story takes place in a dystopian: 2045 where people spend most of their time in a virtual reality world from the moment they wake up. The real world has become poorer, gloomier, and more unjust, prompting people to increasingly participate in the OASIS world for work, education, and entertainment. The OASIS is a simulated world where gender, religion, language, race, gender inequality, and economic differences no longer matter, and people can assume different personalities through their avatars. The development of goggles and headphones that enhance the Metaverse experience and the continuous technological innovations in gloves and clothing that create augmented reality are integral parts of users' experiences in the OASIS.

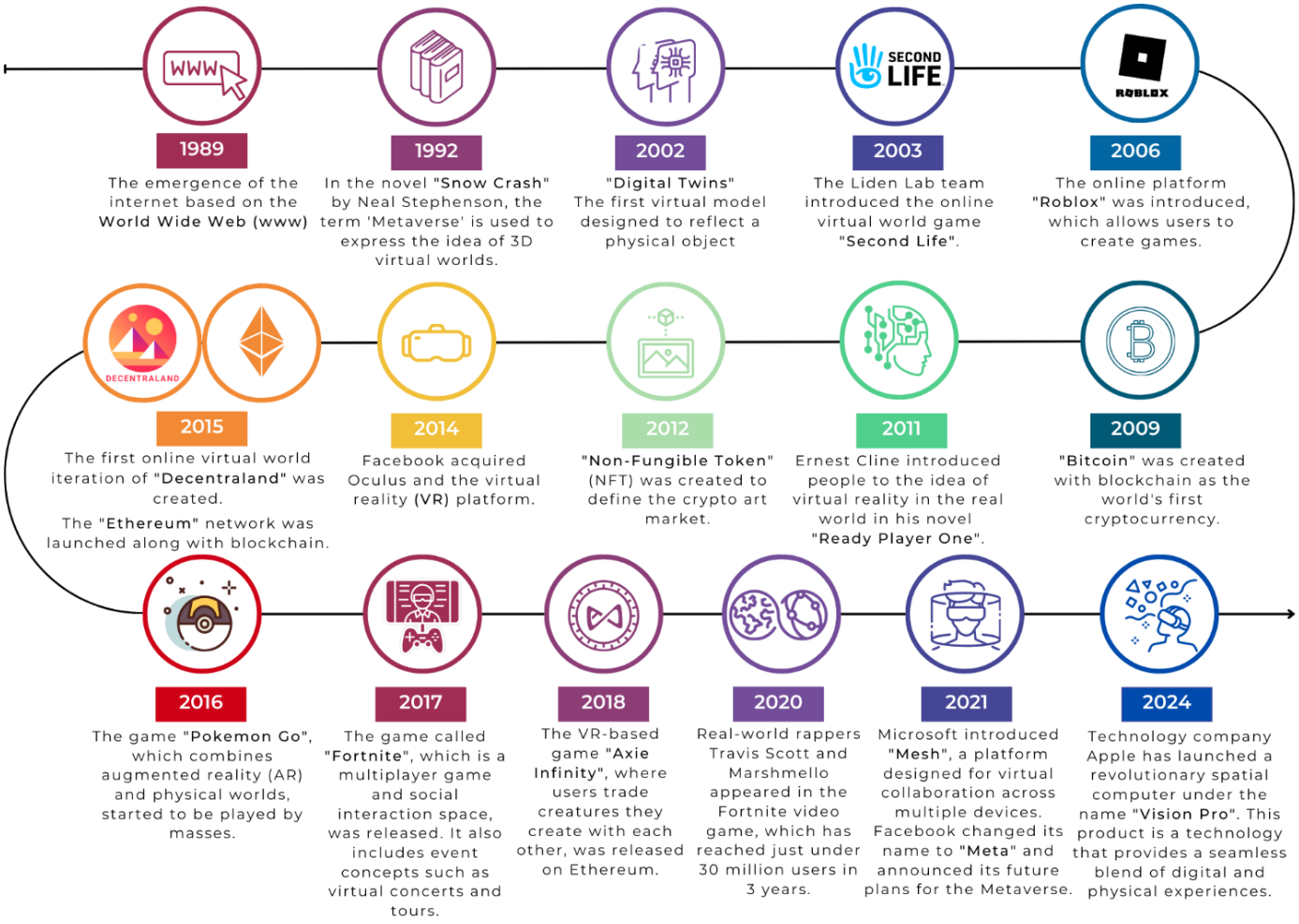

Figure 1. Timeline of Metaverse Development to Present (Produced by the authors)

Changes in work culture, the rise of e-commerce, and transformations in the way businesses operate (Sun, 2021) have shown that other types of economic and cultural interaction networks are possible. The covid-19 pandemic has forced people to adapt quickly to work, learn, meet, and participate in sociocultural events in virtual environments, resulting in radical changes in people's daily lifestyles. The effective use of intermediary communication platforms has led to a significant portion of individual and societal interactions being experienced in digital environments (Karadağ, 2022). This pandemic has led to a restriction in people's physical activities while increasing the demand for behavioral interactions in the virtual world. Online progress of daily activities such as work, education, meetings, and shopping has become people's new preferences, leading to an increased interest in the concept of the metaverse (Kexin et al., 2020). In recent years, large technology companies such as Facebook, Microsoft, and ByteDance have increasingly started researching the metaverse field. The year 2021 is also considered the year of the metaverse explosion (Fu et al., 2023).

Metaverse continues to evolve to include a wide range of virtual and augmented reality experiences, including video games, social media platforms, and virtual reality environments. For example, in 2024, Apple company released the mixed reality glasses, Vision Pro, which they introduced in 2023. On the other hand, the development of blockchain technology has enabled the creation of decentralized virtual worlds where users can own virtual assets using cryptocurrency and engage in mutual trade. Following these triggering developments in the development process, the metaverse is now referred to as a shared virtual space (Moneta, 2020) that is considered the foundation for the next version of the internet, incorporating all virtual worlds. It serves as a crossroads/intersection point in the digital space, allowing people from all over the world to connect without geographical barriers. It enables collaboration and creativity in a broader area using technologies that simulate real-life experiences and make virtual experiences more realistic. The Metaverse continues to evolve and progress with ongoing developments and technological innovations shaping its evolution (Figure 1).

Exploring the Potential of Metaverse as a Digital Space

When looking at the usage areas of the Metaverse, initially, the gaming, fashion, and film industries have adapted to it (Sun, 2021). Today, the use of the Metaverse, which is frequently used for gaming, commerce, marketing, and education purposes, has started to be discussed in various industries such as tourism, health, military, real estate, etc., as it has been included in the national policy of South Korea (Özenir, 2022). Although the perception of the Metaverse points to a platform based on the gaming industry, it is currently progressing towards becoming a new market for luxury brands. Large-volume trading brands such as Hyundai, BMW, Gucci, McDonald's (Özenir, 2022) and Balenciaga are making a transition from the real economy to the digital economy (Sun, 2021). Thus, new consumption spaces are also coming to the agenda.

The constantly changing and evolving nature of technology makes it important to focus on the mutual relationship between physical and digital spaces, rather than discussions that emphasize differences between them. Architectural and digital spaces are interrelated and dependent on each other's development. Currently, the influence of digital space shapes the perception, use, and experience of physical environments for individuals. Technologies such as sensors, smart systems, screens, 3D printing, holograms, and others have the power to transform the functionality and aesthetics of architectural space. This allows users to interact with physical space interactively, have immersive experiences, and develop new forms of participation.

The relationship between architectural and digital spaces continues to evolve, bringing new opportunities and challenges to the field of architecture. With the recent development of the metaverse universe, digital twins: virtual copies of physical entities or systems (Lee et al., 2021); digital heritage: the preservation and dissemination of cultural heritage in digital form (Rahaman & Tan, 2011); digital resources: all information sources, such as open-source software, music, videos, images, text, datasets, and other digital materials that are accessible and usable online (Teli et al., 2015); digital citizenship: individuals' participation or commitment to digital platforms and/or communities (Pangrazio & Sefton-Green, 2021); digital ethics: ethical issues or dilemmas arising from the use or misuse of digital technologies (Mace et al., 2020); and digital architecture: the creation of new forms or expressions of architecture in digital form (Schumacher, 2022) are emerging as new trends, opening up a renewed discussion on the roles and responsibilities of architects.

Metaverse is a developing technological field that offers innovative trends to its users through virtual environments, digital objects, and sensory interactions. It is changing people's lives, entertainment, work, and educational environments. Users can find unique interactions and opportunities to express themselves, socialize, experience, have fun, and learn. According to Dionisio et al. (2013), these virtual worlds are part of virtual reality applications. They refer to simulations of virtual objects or environments created through computer-mediated interactions with real users. At this point, the most fundamental difference between virtual reality and Metaverse is that virtual reality is performed in an environment that mimics the user's experience, while Metaverse has a permanent, original, and interactive infrastructure enriched with participation. Karadağ (2022) distinguishes between two different experiences: space (virtual reality), which is a place that an individual can participate in and observe alone, and an interactive, lively, and dynamic world (Metaverse) that includes social relationships and socialization experiences, emphasizing that the most critical point in designing the experience is the design of the experience.

Metaverse integrates physical and digital worlds in a strong interaction through various components. These components are technologies such as virtual reality (VR), augmented reality (AR), mixed/extended reality (MR/XR), the Internet of Things (IoT), and 3D data that we are accustomed to seeing in science fiction sources and will gradually become a part of our lives (Figure 2). Thanks to these technologies, the experience of the virtual space in Metaverse is realized in three dimensions. The user can perform the virtual world experience perceptually with full-body interaction and can experience virtual and real spaces together (Figure 3). This interaction enriches the potential of Metaverse.

One of the significant usage areas that emerged with these advancements is urbanism. Data-driven smart cities of the future have begun to be created. The creation of virtual cities is called the "digitalization of smart urbanism" (Figure 4). Seymen Aksu and Yalçıner Ercoşkun (2022) evaluate Metaverse technology as an opportunity in many areas, such as resource management, tourism, real estate, reducing and adapting to climate change,

and spatial formation for the smart cities of the future. In addition, these new digital spaces are not just imitations of the existing physical environment; they are also an extension that includes socio-cultural interactions, aesthetic searches, and interactive participation (Moneta, 2020). Designing this extension requires an in-depth analysis of the design steps because while form follows function in the modern age, in the digital age, the user will follow what they want (Ghisleni, 2022).

Figure 2. Entry to the Metaverse (Produced by the authors with AI)

Figure 3. Experience in Digital Space (Produced by the authors with AI)

Figure 4. A Digital City (Produced by the authors with AI)

The Production Process of Digital Spaces

The production of architecture started with the process of learning by doing, where experimentation precedes design, and it has been considered an art form for many years. As it encountered mechanical art over time, it brought about different challenges and placed mental production onto paper, as we know it today. With the advent of the digital age, architecture is preparing to move even further from physical production, engineering, and construction (Ghisleni, 2022). With the digitalization of the world, the sharp distinction between physical and mental has started to lose its clarity. As Schumacher (2022) expresses, environments that allow for specific social interactions are now designed both physically and mentally. These spaces are now being transferred to 3D virtual environments, which are systematic precursors that bridge architectural and interaction design. Concurrently, with the digitalization of the world, the sharp distinction between the physical and the mental has begun to lose its clarity.

Relationship began with the use of digital tools in architectural design processes. With the emergence of computer-aided design (CAD) in the 1960s, new forms and structures could be discovered, leading to the emergence of new concepts such as flexibility, adaptability, and achievability in architecture. With the development of digital technologies such as computer-aided manufacturing (CAM) and building information modeling (BIM), parametric modeling and productive design steps were developed, and projects were visualized and simulated in three dimensions from the design stage onwards. This facilitated both the design process and the efficient and functional outcome of the product. The digital revolution, along with all these tools, also facilitates communication between designers, users, and stakeholders.

Technological advancements in architecture have developed rapidly since the creation of the Sketchpad program in 1965. Today, computer-aided design techniques have become indispensable. Generative design, parametric design, and algorithmic design are all techniques that follow these developments. Instead of relying solely on experience and intuition, designers now direct the entire design process through abstract, systematic steps, selecting design parameters based on analytical justifications and making final decisions based on data obtained. Metaverse enables architects to design, test, and improve spaces developed or existing for architects, without the physical constraints and costs encountered in the real world, providing designers with greater creativity and flexibility. Metaverse also allows users to shape, enhance, and measure their digital space experiences. As a result, architects could improve functionality and user experience in design. Therefore, Metaverse is an important environment for the development of the built environment and architectural design due to its ability to provide a favorable environment for the use of computational design.

The current dimension of the mutual relationship between architectural space and digital space is formed by digital tools such as artificial intelligence (AI), machine learning (ML), big data, augmented reality (AR), virtual reality (VR), and Metaverse platforms. These technologies, which have been discussed in recent years, have enabled architects to create complex, dynamic, adaptable, and interactive spaces that surpass the limits of physical reality. Digital tools have also led to the concretization of fluidity, temporality, movement, and change in architecture, which has also changed the way people move and interact with their built environments.

The Metaverse is a permanent, continuous, and multi-user environment that combines physical reality with digital virtuality (Mystakidis, 2022) and is a cognitive transfer of physical knowledge, skills, and experiences (Güven & Güven, 2022). Virtual environments consist of technologies that activate multiple senses, such as digital objects, VR, and AR (Mystakidis,

2022). The transition from a series of independent virtual worlds to an integrated 3D virtual world network, which is expected to spread to all areas affecting everyday life soon, depends on progress in four areas: *realism, ubiquity, interoperability, and scalability* (Dionisio et al., 2013).

- Realism is the ability of an individual to feel immersed in a virtual environment with the help of all possible senses.
- Ubiquity is the ability to access the environment with all digital devices simultaneously.
- Interoperability is the ability of digital products used in creating or editing virtual environments to be interchangeable in certain applications. This ensures that users can move seamlessly between locations without interruption in their experiences.
- Scalability refers to the efficiency of the metaverse server system. Adequate power is expected to be provided to enable many users to benefit efficiently from the system.

In Metaverse design, many restrictive elements that we traditionally use as design parameters, such as geographical climate conditions, cultural values, history, current construction technologies, and costs, disappear. Therefore, Metaverse architecture transforms architecture into a free form. In traditional design production, these parameters are reference points that direct the design, while in Metaverse design, new reference points that are not yet clear are beginning to emerge, develop, and change. These new references, or lack thereof, may seem attractive at first glance as "limitless opportunities" that architects are not accustomed to. Especially since the limits of design, such as budget, material, and natural environment conditions, which constrain the design with ecological and economic sustainability concerns of the built environment, do not seem to be freeing design. However, it is also a fact that the production of virtual spaces that Metaverse designers will create new needs for time, financial, and energy resources. Moreover, architects producing on these platforms need to quickly adapt to technical equipment and technological software and must be proficient in them.

The aim is to produce any type of space, whether required in real life or not, for use in virtual environments and to develop solutions that benefit not only specific user profiles but also universally. Non-Fungible Tokens (NFTs) can be used to determine the value and artistic significance of unique designs created by architects. NFTs define the uniqueness, ownership, and value of a digital asset (Yılmaz, 2022) . Digital fabrication, artificial intelligence, virtual reality, and other technologies are used to express the design, production, and presentation of digitally produced objects. Therefore, the value of NFTs is understood as the validation of the "uniqueness" of digital production, which could include digital architecture (Kiong, 2022). Thus, architects can create unique buildings with NFTs and offer them for sale (Figure 5). This technology will cause a significant transformation in the way architectural design, production, and ownership are conducted.

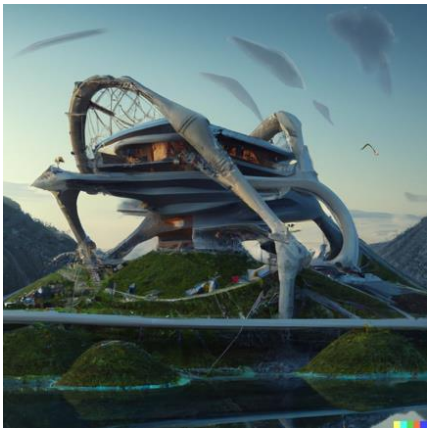

Figure 5. Example of NFT: A Digital Building (Produced by the authors with AI)

Digital production has made designs more testable and improvable by offering the possibility to design and produce much faster and more efficiently. Additionally, digital production enables the creation of spaces that are relatively difficult or impossible to produce physically. While digital production is used as a tool in designing the physical environment, it will become an aim in Metaverse design. For example, an NFT-backed digital home was sold for over half a million dollars, which is more than the cost of many physical homes (Sun, 2021). Moreover, the Danish architecture firm BIG allows offices and users to work on NFTs and other digital projects by designing a Metaverse platform called "ViceVerse" (Finney, 2022a) (Figure 6).

Figure 6. Example of NFT: A Digital Building (Scavnicky, 2022)

Another architecture firm that entered the Metaverse universe is Zaha Hadid Architects, whose "Liberland Metaverse" digital city can be accessed through a cloud-based platform called Mystaverse, allowing users to visit many buildings such as the municipal building, businesses, and exhibition center (Finney, 2022b). According to architect Schumacher (2022), who is part of the design team, parametric methods were used in the design of the digital city, and the absence of limits in any urban planning in the Metaverse universe plays an important role in the future development of parametric design and serves as a kind of catalyst (Figure 7).

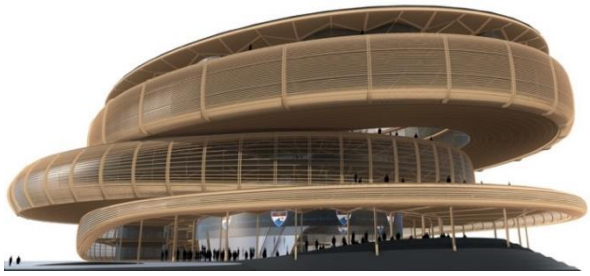

Figure 7. A Building in the Liberland (Shakeri, 2022)

In summary, in the Metaverse environment, individuals will be able to reshape all activities related to public spaces, such as socializing, through their mental activities. Architects will play a crucial role in this transformation by creating sensory responses to these new virtual environments. For example, they might design spaces that react to users' emotions or actions by changing colors, sounds, or even temperatures, enhancing the immersive experience. Another possibility is the creation of interactive surfaces that respond dynamically to touch or movement, simulating natural elements like water or foliage. The fact that various well-known companies are discussing their virtual spaces in addition to physical ones highlights the growing prevalence of the Metaverse concept. According to Turan and Kavut (2022), there is also potential for the physical presence of public spaces to be transformed into virtual spaces designed with surreal fiction.

Methods

This paper outlines a qualitative research process that begins with a thematic review, continues with SWOT and content analysis, and further details of the research method are elaborated in Figure 8. During the 2010s, technological advancements, particularly in VR, AR, and MR, intensified interest in Metaverse technology and initiated academic discussions. At the beginning of the 2020s, Facebook's rebranding to Meta in 2021 and its positioning of the Metaverse as the company's strategic focus for the future, interest in this topic further increased, sparking a new wave of academic research. For this reason, research focused on written sources from the years 2010 to 2024.

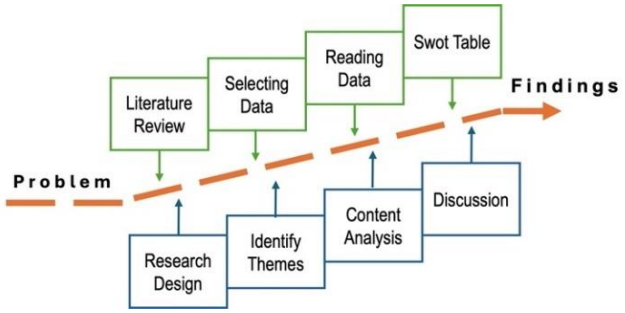

Figure 8. The Research Process

The scope of the study involved a literature review through descriptive content analysis of academic articles, books, internet materials, and news articles. We evaluated digital space, virtual space, and Metaverse studies from an architectural perspective in various disciplines. The Metaverse, a relatively new concept in literature, has limited sources available when researched in the context of architecture. Therefore, we continued the research using the thematic review technique.

Thematic literature review is a method used to collect, examine, and summarize literature related to a specific research topic or question (Cooper, 1998). This method helps researchers identify gaps in existing scientific literature, prioritize their research, and collect evidence they can use to answer research questions (Petticrew & Roberts, 2006). It also facilitates a better understanding of the topic and determines the data for the analysis (Fink, 2019), as well as identifying gaps that can contribute to existing knowledge in the research field.

Another technique we employ to establish a foundation for future research and enhance future-oriented awareness is SWOT analysis. This method assesses the current state of an organization, project, or topic and analyzes both internal and external environments during decision-making processes (Benzaghta et al., 2021; Leigh, 2010). We selected this analysis because it aligns with the proactive nature of our research and helps identify key changes. We anticipate that the results of the SWOT analysis, conducted based on findings from thematic scanning, will offer significant contributions that will be evident in our outcomes.

SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats. Analysis categorizes strengths and weaknesses as internal factors, while opportunities and threats are considered external factors (Benzaghta et al., 2021; Gürel, 2017). This technique helps to identify the strong and weak points of the topic discussed in scientific research, evaluate its opportunities and threats, and use this information in the strategic planning process while supporting the understanding of the structure of the discussed topic and the development of strategies suitable for this structure (Gürel, 2017). The most important feature of the technique compared to other analysis techniques is to assist in the development of these strengths and the evaluation of opportunities, enabling them to benefit from these opportunities based on the identification of strong and weak points. In addition, it adopts a proactive approach that helps to foresee threats and be prepared to cope with them.

Strengths are internal elements that facilitate an organization's goal achievement; weaknesses are internal elements that hinder organizational success. Opportunities are external elements that not only assist in reaching organizational goals but also represent chances to address gaps and initiate new activities. Threats are elements in the organization's external environment that pose or potentially pose barriers to achieving its goals (Benzaghta et al., 2021).

In the Metaverse environment, the strengths of digital space production are elements that enhance the success of design and designers, provide competitive advantages, or differentiate the industry. Weaknesses are elements that demonstrate poor performance, present deficiencies, or cause the industry to lag. Opportunities identified at this stage are elements from which the production sector in the Metaverse environment can benefit, such as trends, new markets, and other advantages. Threats include risks arising from competitors in the technology sector, changing market and usage conditions, demand, or other adverse factors.

Results

In the scope of the research, we conducted a thematic literature review on the themes of "metaverse" and "architectural design", "space design" and/or "space production", and "digital spaces" and/or "virtual spaces" in the databases. This search initially utilized Google Scholar, an open-source search engine,

and was subsequently continued via the Scopus database, which allows for comprehensive examination of scholarly works across various disciplines.

The written sources were reviewed without a predetermined categorization or framework, and each paper was subsequently categorized into "Strengths," "Weaknesses," "Opportunities," and "Threats" based on its primary focus (Table 1). The studies were categorized according to the dominant themes presented in the data and discussions. This categorization process was executed through a comprehensive examination of the studies' content, carefully considering the multifaceted nature of each paper. The purpose of this process is to precisely identify the core content of each paper while simultaneously preserving the overall coherence and integrity of the research.

Table 1. Findings of thematic review

Theme*	Author(s)	Publication Year	Source Type
Strengths	Taherysayah et al.	2024	Article
	Yang et al.	2022	Article
	Roy et al.	2020	Article
	Cai et al.	2022	Conference Proceeding
	He & Bai	2021	Article
	Sopher & Lescop	2023	Article
Weaknesses	Taherysayah et al.	2024	Article
	Far & Rad	2022	Article
	Díaz	2020	Article
	Smart et al.	2007	Report
	Turan & Kavut	2022	Article
	Onecha et al.	2023	Article
Opportunities	Hou et al.	2024	Article
	Ma et al.	2024	Conference Proceeding
	Alexenberg	2011	Book
	Far & Rad	2020	Article
	Polini & Corrado	2020	Article
	Duan et al.	2021	Conference Proceeding
	Huynh-The et al.	2023	Article
Threats	Abramov et al.	2024	Article
	Özenir	2022	Article
	Moneta	2020	Article
	Neustaedter & Fedorovskaya	2009	Conference Proceeding
	Spiegel	2018	Article

** The theme is determined for the strengths and weaknesses, opportunities, and threats of space production in Metaverse architecture.*

The findings of the study are as follows: Digital spaces are designed, produced, and experienced simultaneously by users in different locations only in virtual environments without any physical connection. The potential and limitations of this unfamiliar production process are expected. The production of digital space, which is discussed as a new field, has not been fully understood conceptually or in practical applications, and its scope has not been determined or implemented. Therefore, there are many gaps in the relevant literature and the field. The production of digital space, which intersects with the fundamental subject of architecture and the Metaverse world, should be discussed in a wide area. A SWOT analysis conducted on the production of digital space can reveal the basic guiding principles and provide a starting point for future research. This analysis technique will provide an evaluation of the strengths and weaknesses, opportunities, and threats related to the subject, thus providing an idea of the potential success or failure of the subject. Figure 9 shows the analysis findings of this study.

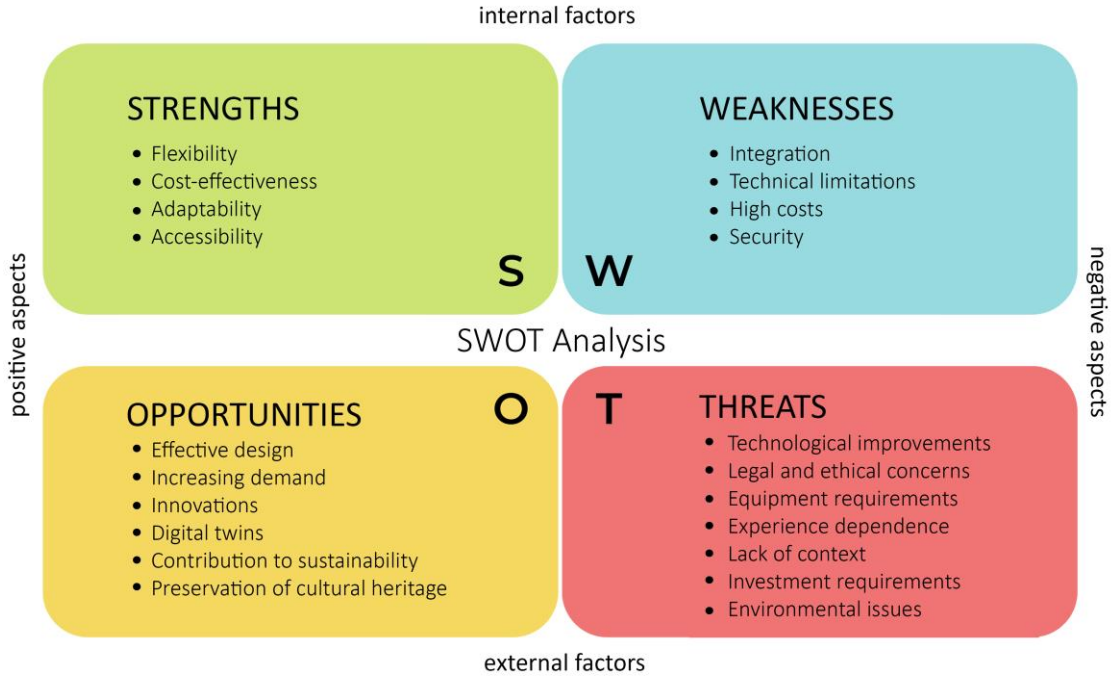

Figure 9. Findings of SWOT Analysis

Strengths of Digital Space Production in the Metaverse Environment

Flexibility: Digital space design provides more flexibility in design compared to physical space design because it is not limited by physical laws and can be easily modified. Functions that are difficult or impossible to achieve physically can be integrated into digital spaces, allowing for greater creativity in space design.

Cost-effectiveness: Digital spaces do not require physical structures or materials, making the design and production process cheaper. In addition, the labor required for digital production is much less than that required for physical production. Producing more space with fewer people makes costs much more affordable.

Adaptability: Digital spaces can be customized to meet the user's specific needs and requirements, and errors in design and/or production can be quickly identified and corrected. Changes in the process can be predicted and adapted before the life cycle of the space is complete. This makes digital spaces more personal and user-friendly.

Accessibility: The ability to access digital spaces from anywhere with internet connectivity makes them more accessible to a wider audience. Digital spaces eliminate physical limitations between people, facilitating communication and interaction worldwide.

Weaknesses of Digital Space Production in the Metaverse Environment

Integration: Despite the advances in virtual reality technology, digital spaces still lack the level of physical interaction that can be experienced in the real world. Metaverse technology is not yet fully developed or widespread, and one of the most important problems related to this is the acceptance and integration of Metaverse into society.

Technical limitations: The technology used to create and use digital spaces is limited by the computer hardware and software used. Due to the inadequacy of technical equipment, digital spaces do not provide sensory stimulation at the same level as physical spaces, resulting in a perceptually weak experience.

High costs: The hardware and software required for digital space design may be more expensive and complex than traditional design methods. The lower number of digital space designers compared to traditional designers also increases design costs.

Security vulnerabilities: The operation and reliability of digital spaces depend on a technology that can be subject to technical problems and failures. Protecting security and privacy in virtual environments can be challenging. The concept of cybersecurity continues to be important, as not all security-related problems have been solved despite technological advancements.

Opportunities of Digital Space Production in the Metaverse Environment

Effective Design: In digital space design, the production process can become faster and more efficient. Changes and predictions in the production and use of space can be seen and intervened in instantly. Due to the elimination of constraints that guide design (such as gravity, costs, material problems, etc.), more creative designs can be implemented.

Increasing Demand: There is an increasing demand for virtual spaces and designs with the growing popularity of virtual and augmented reality. This demand may increase investments in technology and competition. Digital spaces can promote the development of different sectors such as virtual tourism, virtual commerce, or virtual events.

Innovations: The digital space design field is constantly evolving and provides opportunities for creating new and innovative designs. Digital spaces can trigger development and quality experiences in education, health, or service sectors. Facilitating collaboration and communication among individuals, organizations, and communities can provide ease and speed for the development of innovations.

Digital Twins: This refers to the transfer of physical cities, buildings, and spaces to the metaverse environment. With digital twins, the life cycles of physical buildings can be more easily controlled. Thus, the efficiency of the design and development cycle will increase, and the shorter process, resulting in reduced resource use and costs.

Contribution to Sustainability: The widespread use of digital spaces in the metaverse environment can reduce the need for physical spaces, control building stocks, and reduce natural resource use for their production, contributing to sustainability.

Preservation of Cultural Heritage: The potential of digital twins in preserving tangible cultural assets is significant. It is difficult to preserve cultural heritage in the physical world, as heritage buildings are adversely affected by physical environmental conditions (such as disasters, climate change, wear, and tear, etc.). However, digital twins do not have such problems with wear and tear. Therefore, modeling cultural heritage buildings in the Metaverse is important for preserving cultures and passing them on to future generations for much longer periods.

Threats of Digital Space Production in the Metaverse Environment

Technological Improvements: Advancements in technology can lead to the rapid obsolescence of existing digital spaces, requiring constant updating and upgrading. This could lead to a decrease in demand for metaverse or digital spaces and a loss of interest in the field.

Legal and Ethical Concerns: Virtual spaces raise legal and ethical concerns such as privacy, intellectual property, and property rights. Exploitation or vulnerabilities in virtual environments can jeopardize people's safety and privacy.

Equipment Requirements: The experience of digital spaces is dependent on the hardware and software used to access them, which can be a barrier to widespread adoption. Technical infrastructure challenges in the design process that require internet power in the production of digital spaces can slow down and cause inefficiencies in the design process.

Experience Dependence: Experiences in digital spaces can negatively impact people's relationships and sensory connections to the real world. Metaverse could lead people to ignore real-world problems or losses. A designer who is accustomed to digital space design practice may experience integration problems when designing for physical spaces again.

Lack of context: Architects are trained to analyze and understand the location and surroundings of the space they design, both concrete and abstract elements. However, it may not be possible to refer to these elements for digital spaces. Designing without spatial, environmental, and technical boundaries can become tedious and complex. This also poses risks such as losing creativity and struggling with the design.

Investment Requirements: The production of digital spaces and digital twins requires resources such as labor, time, and money to be directed toward the process. Companies, public institutions, and politicians may be reluctant to spend resources on virtual worlds. Furthermore, an increase in production in this field can lead to a decrease in the number of workers in physical production processes. While workers in physical production processes may become unemployed, those working in digital design may experience an increased workload.

Environmental Issues: With an increasing population in the future, the amount of energy needed is already expected to increase, and energy will also be one of the most challenging issues for Metaverse. As the electricity consumed by hardware and software increases, the waste and non-recyclable materials from the increasing hardware will become a significant environmental problem. Additionally, the increasing design of digital elements and some of these having physical counterparts in the physical world may lead to an increase in resource usage and waste.

Conclusion and Recommendations

Innovations in communication and information technologies are driving unprecedented transformations in how people interact with spaces. Architecture, a significant component of human history and spatial production, is evolving in response to these changes. As the demand for digital environments increases and technology advances, the production of spaces is also becoming digitized. The emergence of digital and virtual environments has significantly impacted architectural production due to the direct relationship between user experiences and the design of these spaces. In the Metaverse, a new digital realm, designers must transcend viewing spaces merely as transit areas and instead consider them as immersive experiential zones that facilitate mental interaction with the environment. These experiences are shaped by factors such as design, lighting, sound, touch, and visual interactions. Therefore, with their ability to activate experiences that create perception-emotion relationships within physical environmental conditions, architects must play an active role in the production of digital spaces as well.

In the digital world, architects are as effective in directing the sensory factors that shape experiences as they are in the physical world. Additionally, architects' diverse cultural communication skills alter the context of the references they use when making aesthetic, functional, and technical decisions. Consequently, just as in physical design, architects can create perceptual triggers in virtual environments that enable people to establish a mutual relationship with the space. Thus, transitions to digital spaces can facilitate processes such as acceptance, belonging, and approval. At the same time, designers' experiential approaches to digital space production can be seen as a significant opportunity for the future of architecture.

The relationship between the Metaverse and architecture in digital space production is complex and multidimensional, presenting two intertwined areas that cannot be considered separately. The emergence of digital spaces and the Metaverse has significantly influenced architectural production and our perception of architectural spaces, a trend that will continue with evolving technologies. The Metaverse, with increasing interest in technologies like AR, VR, MR etc. has the potential to revolutionize architectural design and production. However, it also encompasses a complex interplay of forces, opportunities,

challenges, and threats, each contributing uniquely to the development of virtual architecture. This study has thoroughly examined the internal and external aspects arising from the interaction between the Metaverse and architecture. As evidenced by the thematic review, attributes such as unparalleled flexibility, cost-effectiveness, adaptability, and enhanced accessibility position the Metaverse as a formidable competitor to traditional space production in the future. These attributes facilitate new design paradigms that transcend traditional physical and economic limitations, enabling innovative interactions with space unbounded by material reality.

On the other hand, the inherent weaknesses of digital space production, such as challenges in user integration, technical limitations, high costs, and security vulnerabilities, highlight critical areas that require meticulous attention and improvement. These weaknesses represent technological and societal barriers that must be overcome to fully integrate and accept the Metaverse as a mainstream platform for architectural development.

Opportunities for digital space production in the Metaverse are substantial, supported by advancing technologies and increasing societal acceptance. The potential to develop immersive, responsive environments that appeal to a global audience offers unprecedented opportunities for architectural innovation. Moreover, the ability to simulate complex designs before physical implementation significantly enhances both the creative process and the operational feasibility of projects. However, these opportunities come with associated threats such as rapid technological obsolescence, ethical and legal concerns, and the substantial resources required for high-quality digital production. The pace of technological change demands continuous learning and adaptation, while also posing risks related to the sustainability and ethical implications of virtual spaces.

The widespread use of the Metaverse enhances the development of architectural design and promotes the advancement of non-physical design elements, while technological advancements and innovative design approaches in the field of architecture will also support the broader development, dissemination, and effective use of the Metaverse. It can be said that the relationship between these two fields will progress through mutual interaction. At this point, architects working with other designers such as game designers, content creators, and programmers will increase experimental and exploratory work in digital space production, helping to define criteria that will guide virtual designs and solve design problems.

The opportunities and potentials offered by digital space production, along with anticipated innovations, the increasing opportunities due to the proliferation of digital twins, contributions to sustainability, and the preservation of cultural heritage are foreseen. However, these expectations may face potential scenarios such as technological advancements, legal and ethical concerns, and a decreasing interest in the Metaverse. Experts discuss the negative impacts of future dependencies on hardware and experience, highlighting risks such as the lack of design criteria, contextual inadequacies, and investment needs that designers may encounter. Additionally, environmental issues arising from the growing technological infrastructure are also a concern.

The future shape of these potential opportunities and threats remains uncertain. To overcome these complexities, future studies should focus on developing robust frameworks that address both the potentials and pitfalls of digital space production in the Metaverse. Research should aim to create balanced approaches that leverage the strengths and opportunities of digital environments while mitigating the associated weaknesses and threats. Additionally, discovering economic models that make digital space design more affordable and sustainable, and expanding the scope of their application, should also be a key focus for future work. Research in this direction can enable Metaverse technologies to reach a broader audience, maximizing the societal benefits of technological innovations.

In conclusion, while the Metaverse offers a dynamic platform for redefining architectural applications, it requires a cautious yet proactive approach. By adopting a multidisciplinary perspective that includes technological, social, and ethical dimensions, architects and designers can fully harness the potential of digital spaces. This will not only enhance the human experience in virtual environments but also contribute to the sustainable evolution of architectural practices in the digital age. This research serves as a reference point for advancing the field and can lay the foundation for scientific studies by contributing to the development of the related literature. Furthermore, the opportunities and threats identified in the SWOT analysis can guide potential areas of inquiry and innovation for future investigations. This study provides a starting point for research focused on future Metaverse architecture, and the results obtained can play a significant role in the formulation of strategies and planning for future endeavors.

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