

Navigating the Digital Frontier: A Comprehensive Analysis of Metaverse in ASEAN through Data Analytics

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Abstract

This research investigated the evolution and current state of the Metaverse through a comprehensive bibliometric analysis of literature from 2019 to early 2026. The research analyzed scholarly articles, conference papers, and books to identify key trends, influential contributors, and seminal publications that have shaped the Metaverse discourse. Initially rooted in science fiction, the Metaverse has evolved into a dynamic digital ecosystem with global relevance. In the ASEAN context, the Metaverse holds particular significance, as it presents unique opportunities and challenges for regional economic, social, and technological development. The findings highlight the evolution of the Metaverse, key emerging trends, and the current state of research in virtual reality (VR) and augmented reality (AR) technologies, with a focus on how these developments are impacting ASEAN nations. Furthermore, the research examined critical challenges, ethical considerations, and the implications of the Metaverse for privacy, security, user experience, and societal issues within ASEAN countries. The originality and value lie in its extensive bibliometric analysis, offering a fresh and detailed perspective on the academic landscape surrounding the Metaverse. By identifying influential research and key themes, this research contributes to a deeper understanding of the Metaverse's role and impact, particularly in the ASEAN region. The insights gained are invaluable for researchers, policymakers, and industry stakeholders in ASEAN, enabling informed decision-making in a rapidly evolving digital environment. This research provides a comprehensive foundation for future research and development within the region, addressing the growing importance of the Metaverse at the ASEAN level.

Keywords: metaverse, ethical considerations, virtual collaboration, ASEAN

Introduction

The technological revolution over the last decade has exposed humans to vast amounts of information and eased various tasks (Bahrin et al., 2016; Silbergliitt et al., 2006; Zambon et al., 2019). In addition to technology, human resources are essential to maximizing the benefits

of Industrial Revolution 4.0. The United Nations (UN) has developed 17 Sustainable Development Goals (SDGs), each describing interconnected global problem areas (Hunt, 2015). These goals provide a necessary framework for each UN member state to address pressing issues.

Notably, the implementation of SDGs in regions such as ASEAN has become increasingly significant, as the region confronts challenges related to rapid urbanization, environmental sustainability, and economic disparities. In ASEAN, countries have made considerable progress in addressing the SDGs through technological advancements, particularly in education, infrastructure, and health. However, data collection and management across member states remain inconsistent, highlighting the need for a unified approach to leverage technology for effective SDG implementation. This research explores the intersection of big data, AI, and the SDGs in the ASEAN context, examining the technological potential to address regional challenges and align with the broader UN SDG framework.

Data is no longer a scarce resource in the current technological era (Dantas et al., 2021). The volume of data in the world is increasing exponentially, with 64.2 zettabytes generated in 2020, a 314 percent increase over 2015. This data explosion presents both opportunities and challenges for governments, industries, and research institutions, especially in the ASEAN region. Governments and organizations in ASEAN are increasingly utilizing data to support SDG initiatives, from optimizing traffic management systems to enhancing educational infrastructure (Al-Emran et al., 2020; McRae et al., 2018).

Recent research has focused on applying big data and AI for smart cities. For instance, sophisticated traffic management platforms that leverage AI algorithms, big data, and image processing are being used to improve traffic flow and prevent accidents (Islam et al., 2021; Caraka, 2026). These technologies hold particular promise for ASEAN cities, where rapid urbanization often leads to infrastructure challenges. The use of AI for disaster detection, health monitoring, and industrial asset management is also growing, with significant applications in the ASEAN region (Abinaya et al., 2017; Shaik et al., 2018; Zantalis et al., 2019). To better understand the evolving role of data in achieving the SDGs, this research conducts a bibliometric analysis of articles published in the Scopus repository. This analysis focuses on the most recent research related to big data, AI, and the metaverse, with an emphasis on their relevance to ASEAN countries. The findings of this analysis provide valuable insights into the direction of future research, policy-making, and institutional strategies for leveraging data in pursuit of the SDGs.

Research Method

The literature study phase is crucial for gathering references that support the research. Primary sources include scientific journals, books, and articles. These references specifically focus on feature extraction methods for determining the quality of an author's self-citation. The underlying problems and proposed solutions form the foundation of this research (Khan et al., 2020; Schneider et al., 2017). The research focuses on three types of bibliometric

indicators. First is Quantity Indicators, which measure a researcher's productivity by quantifying output. Second is Quality Indicators, which assess research performance or impact based on outcomes such as citations. Third is Structural Indicators, which analyze relationships among publications, authors, and research areas. These indicators are crucial for researchers and organizations, as they play a significant role in decisions about research funding, promotions, and the overall evaluation of scientific contributions. As scientific discoveries increase, bibliometric indicators become more significant, enhancing the visibility and credibility of a researcher's work.

The vector space model represents a text, document, or query as a vector in a concept space. This space has as many dimensions as the number of concepts. In other words, for a text document with N words, N dimensions are needed. Each vector is plotted according to the weight of the current term (Çoğaltay & Karadağ, 2015; Ihsan et al., 2022). The terms present become coordinate axes in the number of terms, while the vector is a point whose position is based on the value of those axes. A two-dimensional matrix creates the vector space with columns as terms and rows as text documents. The content of the matrix is the term weight value of each word against each text document.

One of the vector space models in word embeddings is Word2Vec. Word2Vec provides an efficient implementation of continuous bag-of-words. The process of finding the value for each vector is obtained by comparing a word against all words using Equation 1.

$$P(w_o | w_l) = \frac{\exp(v'_{w_o} \top v_{w_l})}{\sum_{w=1}^{|V|} \exp(v'_w \top v_{w_l})} \quad (1)$$

Equation 1 calculates the conditional probability $P(w_o | w_l)$ of observing a target word w_o given an input word w_l . It measures semantic similarity via the dot product of their vector representations, normalized across the entire vocabulary $|V|$ using the Softmax function. This is followed by the value of the loss function in Equation 2.

$$E = -\log P(w_o | w_l) = -v'_{w_o} \top v_{w_l} + \log \sum_{w=1}^{|V|} \exp(v'_w \top v_{w_l}) \quad (2)$$

Equation 2 defines the cross-entropy loss function E (negative log-likelihood) used during model training. Minimizing this loss function maximizes the likelihood of correctly predicting co-occurring target and context words within the corpus. The value of $P(w | c)$ is defined by Equation 3:

$$P(w | c) = \frac{\exp(v_w \top v_c)}{\sum_{w' \in V} \exp(v_{w'} \top v_c)} \quad (3)$$

Here, $P(o|c)$ represents the probability of observing a particular word o given its context c . The numerator $\exp u_o^T V^c$ computes the exponentiated dot product between the vector representation u_o of the observed word o and the context vector representation V_c . This measures the affinity of the observed word with the context. The denominator $\sum_{w=1}^v \exp(u_w^T v_c)$ calculates the sum of exponentiated dot products between the vector representations u_w of all words in the vocabulary v and the context vector v_c . This normalization term ensures that the probabilities sum up to 1 over all possible words in the

vocabulary, providing a proper probability distribution. Overall, this equation represents the softmax function applied to the dot product of word vectors, producing probabilities that reflect the likelihood of observing a particular word given its context in Word2Vec models (Caraka et al., 2023; Justicia De La Torre et al., 2018).

The vector space model serves as a fundamental framework for representing text, documents, or queries as vectors within a concept space. This concept space encompasses as many dimensions as there are unique concepts present in the text, with each dimension corresponding to a specific term. In essence, the vector space model transforms textual data into numerical vectors, where each term's weight determines its position within the vector space. Through this representation, textual information can be analyzed and compared efficiently (Chatterjee et al., 2021; Petropoulos & Siakoulis, 2021).

One notable instantiation of the vector space model is Word2Vec, a powerful tool for word embeddings. Word2Vec employs algorithms such as continuous bag-of-words to capture semantic relationships between words within a corpus efficiently. By comparing a target word against its surrounding context, Word2Vec calculates the probability of observing a particular context given the target word. This process enables the generation of high-dimensional vector representations for words, supporting tasks such as natural language processing and machine learning.

TextRank, a method for word or phrase extraction, draws inspiration from the PageRank algorithm and operates on input modeled as a graph. This input can originate from single or multiple documents within a corpus. The graph consists of nodes representing words and edges representing relations between words. In this research, the edges of the input graph represent word co-occurrence, and the graph is modeled as an undirected type. The TextRank algorithm assesses the importance of a node by leveraging global information about the graph structure through iterative processes. Node weights are continually updated in each iteration until convergence is achieved. If denoted as $G = (V, E, W)$. Where V represents the set of vertices or nodes, E denotes the set of edges, and W signifies the set of weights, the TextRank formula is as in Equation 4 (Pathak & Barooah, 2013).

$$WS(V_i) = (1 - d) + d * \sum_{v_j \in \ln(V_i)} \frac{w_{ji}}{\sum_{v_j \in \ln(V_i)} w_{jk}} WS(V_j) \quad (4)$$

$WS(V_i)$ represents the importance score of node V_i , d is a damping factor, v_j iterates over the neighbors of node V_i in the graph, w_{ji} denotes the weight of the edge between nodes V_i and V_j , and w_{jk} is the sum of the weights of all edges incident to node V_i and V_j . Equation 4 captures the iterative process of updating node weights based on the contributions from neighboring nodes, with the damping factor controlling the balance between global and local information. The novelty of the TextRank approach lies in its use of graph-based algorithms, particularly inspired by the PageRank algorithm, for word or phrase extraction from textual data. Unlike traditional methods that rely solely on frequency-based metrics or linguistic rules, TextRank leverages the inherent structure and relationships within the text to identify key words or phrases.

One key aspect of TextRank's novelty is its ability to handle input text from multiple documents within a corpus, effectively capturing the broader context and semantic connections across documents. By representing text as a graph with nodes (words) and edges (co-occurrence relations), TextRank can identify important words or phrases based on their centrality within the graph structure. This approach enables extraction of meaningful information from large volumes of text, even without explicit linguistic annotations. Furthermore, TextRank's iterative node weighting approach incorporates global information from the graph structure, leading to robust and contextually relevant results. The algorithm continually updates the importance scores of nodes based on relationships with other nodes in the graph, ensuring that the extracted words or phrases reflect the overall semantic significance within the text (Khan et al., 2020; Nailah & Rusydiana, 2020; Schneider et al., 2017). Overall, the novelty of the TextRank approach lies in its effective integration of graph-based algorithms with natural language processing techniques, offering a powerful and flexible method for word or phrase extraction that can capture the inherent structure and semantics of textual data across diverse contexts. This research draws data exclusively from Scopus, a comprehensive academic database that provides extensive bibliometric information. Scopus offers valuable data on publication counts, citation impact, h-index values, and author affiliations. This platform is instrumental in analyzing the productivity, quality, and structural relationships of researchers' works. Scopus is regularly updated to include the latest scholarly publications, ensuring that the dataset reflects current academic trends and accurately represents researchers' academic performance.

The methodology used in this research includes a comprehensive review of recent literature, focusing on key research topics related to SDGs, big data, and AI in ASEAN. The research considers a range of data sources, including academic publications, government reports, and industry analyses. The research period spans from 2019 to early 2026, ensuring the inclusion of the latest developments in technology and policy. The data collection process also integrates co-word analysis to identify key themes and trends within the literature, allowing for a deeper understanding of the relationships between research topics. This research highlights the critical role of data and technology in advancing SDGs, particularly within the context of ASEAN. By examining the intersection of big data, AI, and SDGs, the research aims to provide a roadmap for future research and practical solutions for the region.

Table 1 presents the number of publications from 2019 to early 2026, providing a comprehensive overview of the evolving scholarly discourse on the metaverse. The Scopus database, renowned for its extensive coverage of peer-reviewed literature, is used to conduct this analysis. Subsequently, Table 1 outlines our data collection process, detailing the formats and quantity of documents retrieved through a keyword search for 'metaverse' in the 'Title-Abs-Key' field. Spanning from 2019 to early 2026, the 7,244 documents includes articles, books, book chapters, conference papers, and other pertinent contributions. Meticulous data extraction from Scopus resulted in the compilation of a BibTeX file, facilitating further analysis of the retrieved documents.

Table 1. Description of Main Information of Publication Metaverse from 2019 to Early 2026

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2019-2026
Sources (Journals, Books, etc)	2,732
Documents	7,244
Annual Growth Rate (%)	13.36
Document Average Age	1.03
Average citations per doc	8.71
References	0
DOCUMENT CONTENTS	
Keywords Plus (ID)	19,238
Author's Keywords (DE)	13,673
AUTHORS	
Authors	14,702
Authors of single-authored docs	1,002
AUTHORS COLLABORATION	
Single-authored docs	1,411
Co-Authors per Doc	3.63
International co-authorships (%)	28.15
DOCUMENT TYPES	
article	3,138
article article	18
article book chapter	3
article conference paper	6
article conference review	1
article editorial	1
article letter	1
article note	1
article review	3
book	106
book article	1
book chapter	798
book chapter article	4
book chapter book chapter	2
book chapter editorial	1
conference paper	2,258
conference paper article	6
conference paper book chapter	2
conference paper conference paper	11
conference paper conference review	1
conference paper editorial	2
conference paper review	1
conference review	231
conference review article	1
conference review conference paper	1
data paper	2
editorial	124
editorial article	1
editorial conference paper	1
erratum	17
letter	45

The dataset analysis reveals a rich landscape of Metaverse research from 2019 to early 2026, reflecting the evolution of scholarly inquiry over nearly three decades. The dataset comprises 7,244 documents from 2,732 different publications, including journals, books, and other sources. These documents have been integral in exploring diverse aspects of the

Metaverse phenomenon. Notably, the average age of these documents is approximately 1.03 years, indicating a dynamic and rapidly growing body of work. Moreover, the robust citation metrics demonstrate the impact and relevance of this research, with each document averaging 8.71 citations, underscoring the enduring interest in this rapidly evolving field. The analysis also offers insights into the diversity of document types and contents within the dataset. Document types range from traditional articles and books to conference papers, reviews, editorials, and more. Keywords play a crucial role in clarifying the thematic breadth of Metaverse research, with 19,238 Keywords Plus (ID) and 13,673 Author's Keywords (DE) identified. This comprehensive keyword analysis provides a nuanced understanding of the multidimensional facets explored within the Metaverse literature. Furthermore, the examination of authorship patterns reveals a dynamic landscape of collaboration and individual contributions. A total of 14,702 authors have contributed to the dataset, with 1,411 single-authored documents recorded. Notably, collaboration is prevalent, with 1,002 authors contributing to multi-authored works. The collaboration index of 3.63 reflects the cooperative nature of research in the Metaverse domain, highlighting the collective effort driving advances in this field.

Analysis

The development of the metaverse in ASEAN presents great opportunities for various sectors. Countries such as Indonesia, Vietnam, Thailand, Singapore, and the Philippines have begun exploring the potential of metaverse to support the digital economy, education, and entertainment, as shown in Table 2. For instance, Vietnam developed Non-Fungible Token (NFT)-based projects such as Axie Infinity, showing that blockchain innovation has strong potential to support activities in the virtual world. In Indonesia, the government encourages digital inclusion through data protection regulations and public and private sector collaboration, providing a basis for developing a safe and inclusive metaverse.

However, the development of metaverse in ASEAN also faces significant challenges. One of them is digital infrastructure inequality among member countries (Sakti et al., 2024), which can limit public access to advanced technologies such as AR and VR. In addition, regulations that are not yet fully clear or standardized for blockchain technology, NFTs, and virtual world transactions are a major obstacle to efficient industry operations.

Metaverse opportunities in this region also include increased regional cooperation to overcome these challenges. ASEAN can create a more integrated metaverse ecosystem by building joint regulations that support user security and technological innovation. Policies such as research grants in Thailand and strengthening data protection in Singapore show how countries in the region can use the metaverse to boost regional competitiveness (Knox, 2022). In the future, the key to successful of metaverse development in ASEAN will be balancing innovation and regulation. Cross-cutting collaboration, investment in digital infrastructure, and public education on new technologies will be important factors in ensuring that the metaverse is not only an entertainment tool, but also a tool for inclusive social and economic transformation.

Table 2. Comparison of Metaverse Focus in ASEAN

Country	Metaverse Policy or Regulation	Focus	Metaverse Related Laws or Policy
Indonesia(Julian et al., 2023; Sukardi et al., 2024; Sunindyo et al., 2024)	Promote metaverse utilization regulations through public and private sector collaboration for an inclusive digital ecosystem.	Digital inclusion, data protection, and development of metaverse technology.	There is no specific law on metaverse, but it is related to the Indonesia's Electronic Information and Transactions Law (Informasi dan Transaksi Elektronik - ITE) and the Personal Data Protection Law (PDP Law No. 5). 27/2022).
Vietnam(Julian et al., 2023)	It focuses on developing NFT-based metaverse projects such as Axie Infinity, with support for blockchain and AI.	Development of blockchain, NFT, and metaverse technology applications.	Refers to blockchain regulation and digital technology in the context of metaverse, although specific regulations have not yet been implemented.
Thailand(Gerdsri et al., 2024; Waidyaratne et al., 2024)	Provide research grants for the development of digital identity and NFT in metaverse environments.	Use of NFT for event access, identity verification, and other innovative applications	Supports research and development of metaverse technology through government grant policies but lacks specific legislation.
Singapore (Das & Kwek, 2024)	Partnering with technology companies to create a metaverse ecosystem that supports AR and VR.	Innovations in AR or VR, game development, and user-generated content.	The Data Privacy Act is used to regulate user protection in metaverse, plus support for technological innovation from IMDA.
Philippines(Blancaflor et al., 2024; Ulla et al., 2024)	Supports the use of metaverse for the democratization of AI technology, blockchain, and game development. Develop smart city initiatives to integrate digital environments including metaverse for city planning.	An affordable technology ecosystem, focused on game development and blockchain.	It uses blockchain regulation and digital technology development to support metaverse applications.
Malaysia(Julian et al., 2023)		Smart cities, urban planning, digital services.	Focus on digital economy and industry 4.0 regulations, but there is no specific law for metaverse.
Brunei Darrussalam (Ismail et al., 2024; Rohmad et al., 2024; Varkkey & Lupascu, 2024)	Encourage digital innovation with a focus on AI and blockchain in technology-based industries. There is no specific metaverse policy yet, although digital transformation initiatives are underway.	AI, blockchain , and digital infrastructure.	There is no specific regulation for metaverse but general digital technology regulations apply.
Myanmar(Machmud et al., 2021; Thida & Thazin, 2023)	Support the development of blockchain and AI technologies.	Digital transformation and technological innovation.	Digital technology and blockchain regulations can be applied but there is no specific law regarding metaverse.
Laos(Mutiarin et al., 2024)	Promote Information and Communications Technology (ICT) and digital transformation with a focus on technology startups.	Blockchain, AI , and digital innovation.	Digital technology regulations including blockchain but there is no specific law regarding metaverse.
Cambodia(Ong et al., 2023)		Tech startups and digital economy.	There is no specific law regarding metaverse, but ICT and digital economy regulations support technological development.

Primary Information of Metaverse Research

Research on the metaverse, as documented in Scopus, traces back to 2019. This marks the inception of scholarly exploration of this transformative concept. Within this body of research, several contemporary issues have emerged as focal points, including augmented reality, Second Life, virtual reality, information systems, artificial intelligence, and immersive technologies. These themes reflect the multifaceted nature of the metaverse and the diverse array of disciplines it intersects with. Notably, advancements in neural network and computer vision methodologies have played a pivotal role, driving rapid progress in data science and laying the groundwork for innovative research trajectories.

Figures 1 and 2 show the prevalent keywords employed by authors in publications related to the metaverse within the scope of this study. These visual clarify the thematic landscape of metaverse research, highlighting recurring concepts and areas of interest. These figures show that certain keywords hold significant prominence, serving as pillars around which scholarly discourse revolves. This analysis highlights the breadth of topics encompassed within metaverse research and underscores the interconnectedness of domains such as technology, artificial intelligence, and immersive experiences. Overall, these findings shed light on the evolving narrative surrounding the metaverse and the dynamic dialogue shaping its conceptualization and exploration within academic circles.

In the last few decades, NFT and Asset Management Protocol (AMP) publications have emerged (Guidi, 2020). The word 'sandbox' refers to two points. First, it is a subsidiary of the Hong Kong-based blockchain game and NFT unicorn, Animoca. The platform is built on the Ethereum blockchain, allowing users to interact in a virtual world using NFTs (Florea & Taralunga, 2020; Kearney & Perez-Delgado, 2021). The second is the 'sandbox' of regulators. For instance, the sandbox formed by Bank Indonesia is an effort to support financial technology innovation in the fintech payment system business (Yuspin et al., 2020). The space provided by Bank Indonesia aims to ensure that the products, services, technology, or business models of financial technology providers meet the criteria and are not disrupted by market conditions (Kathiravelu et al., 2022). Bank Indonesia released the Regulatory Sandbox in 2017 to support the technology-based financial industry and maintain financial technology innovation in the payment system business (Anggoro et al., 2022; Caraka, Kurniawan, et al., 2021; Garcia et al., 2014).

Furthermore, NFT, a digital asset that uses blockchain (digital ledger) technology that supports Ethereum, Bitcoin, and other crypto assets to record transactions, is the most discussed topic in the metaverse publications. NFT represents unique assets with irreversible exchange rates and have grown in the financial industry, marking a critical innovation in this digital economy era. Table 3 summarizes the publications with the highest number of citations in the field of metaverse. The table includes important information such as publication title, author name, year of publication, and number of citations. The publications listed typically address key concepts, applications, or challenges in metaverse development and implementation. The data in Table 3 gives an overview of the most influential research,

reflecting the extent to which these works contribute to understanding and innovation in this area.

Table 3. Most Global Citation regarding Metaverse

Paper	Journal	Total Citations (TC)	TC per Year	Normalized TC	Highlight
(Dwivedi et al., 2022)	INT J INF MANAGE	1,193	397.67	55.08	>The metaverse has the potential to extend the physical world using extended, augmented, and virtual reality technologies; >Interactive virtual environments and immersive games are considered as antecedents of the metaverse; >The transformative impact of the metaverse as well as societal effects relating to social interaction factors from widespread adoption; >Sectors potentially impacted by the metaverse include marketing, education, tourism, and healthcare. >The current Metaverse blends social activities with advanced technologies like deep learning and neural networks, reshaping the virtual experience.
(Park & Kim, 2022)	IEEE ACCESS	932	310.67	43.03	>The research presents a new Metaverse framework, analyzing it through hardware, software, and content, while focusing on user interaction, implementation, and application. >Success relies on immersive realism, accessibility, interoperability, and scalability.
(Dionisio et al., 2013)	ACM COMPUT SURV	640	53.33	11.92	>Institutional support and hardware improvements help, but computational limits and collaboration gaps remain challenges. >The paper highlights metaverse applications aimed at societal benefits, emphasizing the potential for creating a society with reduced racial, gender, and disability-related barriers
(Duan et al., 2021)	MM - PROC ACM INT CONF MULTIMED	578	144.50	9.68	> A proposed metaverse architecture with three components – infrastructure, interaction, and ecosystem – is discussed, along with a timeline and a blockchain-driven university campus prototype for practical insight >The metaverse's educational potential includes immersive learning through augmented reality, but challenges like privacy concerns and social disconnection need addressing.
(Kye et al., 2021)	J EDU EVAL HEALTH PROF	549	137.25	9.20	> Future metaverse tasks for education involve secure platforms, project-based learning, and fostering cooperative problem-solving among students.

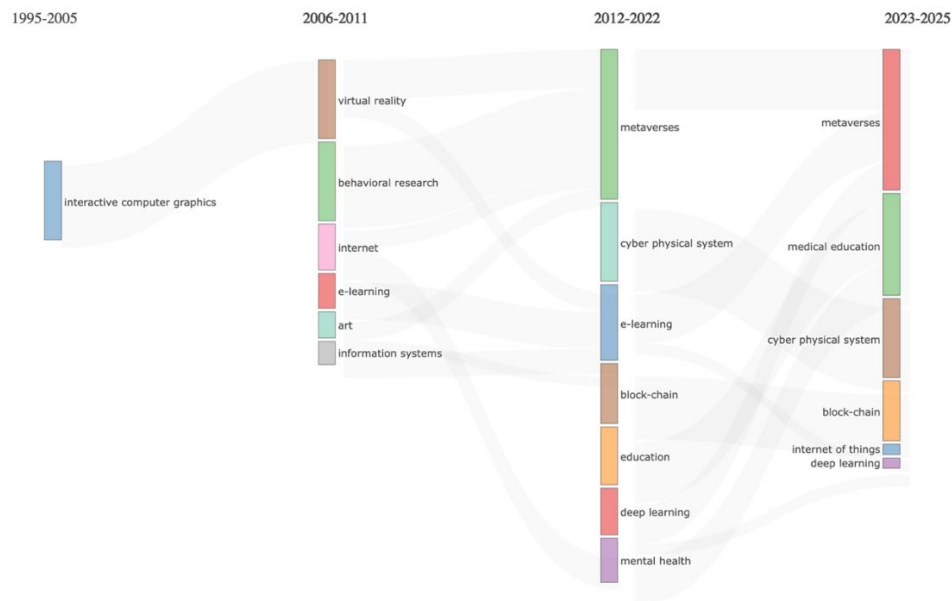


Figure 1. Research Period of Metaverse

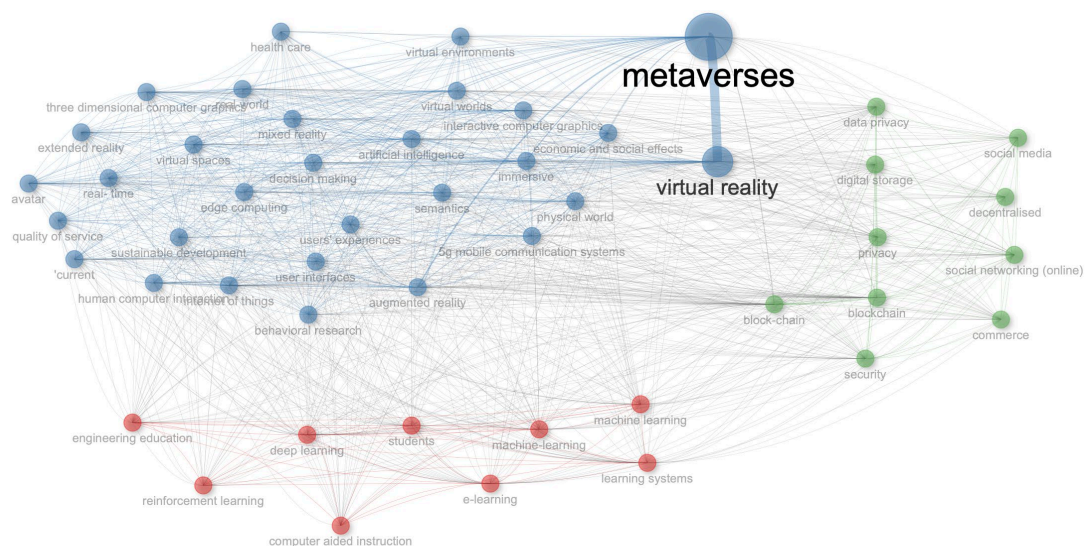


Figure 2. Most common word frequency

Table 4 shows the contributions of the major countries in the Metaverse research, highlighting the number of published articles, their frequency, and their contributions in the form of Single Article Contributions (SCPs), Shared Article Contributions (MCPs), and MCP Ratios. China is ranked first with a total of 10,936 article citations and an average of 8.90 article citations. Korea ranks second with 6,953 citations and an average of 13.00 citations, indicating strong research quality. Another high-contributing country is the UK, with 5,844 citations (average 24.70 citations per article), indicating that research from the country is highly valued in the Metaverse context.

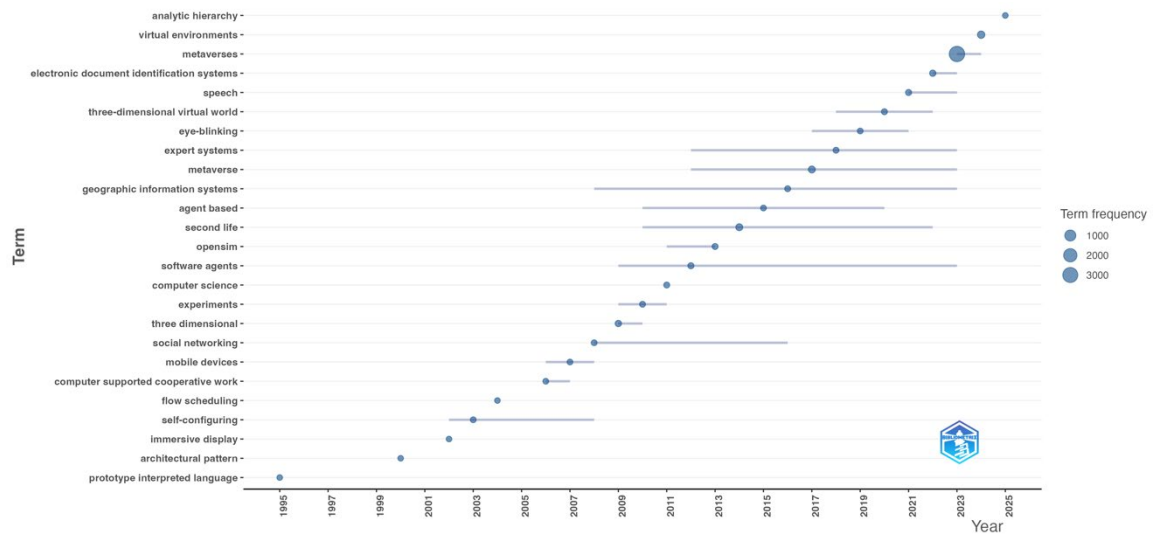
Although the United States recorded more articles (5,665 citations), the UK had a higher average citation rate. This suggests that although the U.S. has a larger volume of research, the UK had greater impact in Metaverse-related publications. In addition, Germany (15.70 citations/article) and Singapore (19.60 citations/article) also recorded significant contributions to the Metaverse research. One interesting insight is the high citations per article from countries such as Norway (39.90 citations/article) and Georgia (74.20 citations/article). This indicates that although these countries have fewer articles, each of their publications has tremendous impact and makes significant contributions to the study of the Metaverse. Although major countries such as China, Korea, and the United States dominated in the number of articles, countries such as Britain, Norway, and Georgia showed greater impact per article. This highlights the importance of quality of research, not just its quantity, in shaping Metaverse research progress.

Table 4. Description Most Contributive Countries

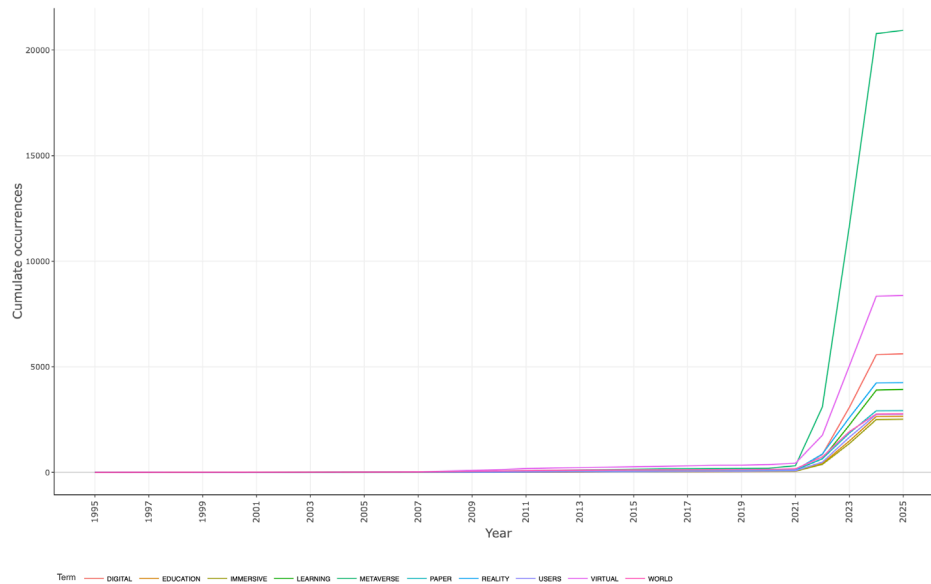
Total Citations (TC)	Country	Average Article Citations	Status
1,076	Singapore	19.60	Data Available
912	Malaysia	12.20	Data Available
503	Indonesia	5.50	Data Available
Data Not Available	Vietnam	Data Not Available	Not Found / Not Available
Data Not Available	Thailand	Data Not Available	Not Found / Not Available
Data Not Available	Philippines	Data Not Available	Not Found / Not Available
Data Not Available	Brunei Darussalam	Data Not Available	Not Found / Not Available
Data Not Available	Cambodia	Data Not Available	Not Found / Not Available
Data Not Available	Laos	Data Not Available	Not Found / Not Available
Data Not Available	Myanmar	Data Not Available	Not Found / Not Available

Exploring Avatar Dynamics, Computer Vision, and Virtual Reality

The publications of metaverse in the Scopus have been recorded since 2019. The critical topic associated with metaverse is the Virtual Reality Modeling Language (VRML). Technological developments are increasing very quickly, one of them is 3D technology, which brings a new color to computer visualization. Various IT products such as games. animation films and simulations from 2D to 3D are growing faster and faster. The application of the 3D concept began to connect with other technologies in the computing field. one of which is web technology. The web has become the leading information medium in this modern era. many functions have been developed, and one of them is supported by virtual reality representation. Virtual reality is a technology that allows users to interact with an environment that is simulated by a computer-simulated environment.



(A)



(B)

Figure 3. Trending Topics (A), and Word Growth (B)

Figures 3A and 3B show trending topics related to metaverse publications tracked in the Scopus database from 2019 to early 2026. Research on avatars in computer vision is one of the main topics of discussion. Avatars, or characters, are fundamental to video games, e-store sales, storytelling, and technical cinematography. Attractive avatars for animation are included in the film, video, and photography sub-sectors that have huge potential to absorb the labor force and boost a country's economy. It can also trigger the growth in other industries, such as video games, comics, and more. In addition, animation has a social and cultural impact and plays an essential role in promoting tourism.

Designing a good avatar is more than just drawing characters. As Jones (2005) notes, feelings matter more than a person's physical appearance and voice. The surface includes behavior shaped by their personality, thoughts, background, and experiences. These things

make a character unique. Three aspects of nature, namely soul, qualities, and expression, form the basis for character formation and development.

Soul, the basic foundation of a living character, is the part of a character that has a personality. However, they often have many characteristics with no clear origin or destination. In *Exploring Character Design* by Kevin Hedgpeth and Stephen Missal (as cited in Sidiyawati et al., 2020), a character is a collection of various traits and physical characteristics. It would not be easy to understand and develop characters without a basis and plot. Exploring a character's mind can help us understand the factors behind their behavior and actions and predict their responses in certain situations, as if the characters are telling themselves. A life story can shape the character's view of the world, which affects their desires and hopes for the world. When those desires and hopes clash with the wishes of others or nature, conflicts can arise that become the heart of the story. Finding similarities between characters and their readers in biographies can be an emotional connection. However, differences in characters' biographies can spark many stories. Personality structure is discussed further under character description point in the personality section. Characteristics and the inner diversity of characters must be balanced a variety of appropriate visual appearances. Various character traits help differentiate characters, not just clothing, hair, and faces. Details such as muscles, nose, mouth, size, and posture can help enrich the character.

No character design appears in a vacuum. When designing a character's appearance, a designer can use many existing real-world references, past creatures, and thematic sources, or draw on common physical stereotypes. Several thematic groups, such as the four seasons, seven sins, twelve zodiacs, or planets, can be used as character traits. After that, the designer can create a character blueprint, from full-body views to close-ups of the face from different angles, notes on the physique, costume details, and the character's preferred clothing style. This can be further seen in the point of describing the physical part of the character.

Expressive attitudes include gestures, body language, facial expressions, a character's emotional range, or a unique key pose. Maintaining consistency across all aspects of a character can increase the reader's persuasion toward the character throughout the storyline. In this modern era, virtual reality facilities can be embedded on the web. This has a positive impact on the development of the benefits of the web as a container of information that can be accessed easily worldwide. A-Frame is a framework for building a web-based virtual reality supported by WebVR. WebVR is an experimental JavaScript API that allows virtual reality devices such as the Oculus Rift, Google Cardboard, and other VR headsets to access virtual reality content through a browser. WebVR is still being developed by Firefox, Chrome, Opera, and Microsoft Edge.

Then there is the term of 'three dimensions (3D)'. Specifically, 3D models and 3D animation are mainly used on desktop devices because they have higher hardware specifications than mobile devices. 3D modeling on the desktop uses the high poly modeling method. However, high poly modeling on mobile devices risks the system not functioning properly.

Mobile devices have low hardware configurations and are classified as Low-Cost Access Devices (LCADs), so they require 3D modeling with the standard poly method. This is because there is no graphic accelerator on LCADs. 3D modeling with a low poly method can reduce file size, mesh density, and loading time for 3D objects on mobile devices. In a 3D model, when an edge connects three or more points known as vertices, they form a polygon. The more polygons in a model, the smoother the 3D model will be.

The model is designed using Blender version 2.76b. From the beginning, the model is designed by collecting information on an object to be made. Information can be collected by directly observing an object or by looking at pictures, then designing and modeling it in Blender. After the model is finished, it is given a texture to be processed in Unity.

In addition, object models can be designed by redesigning existing 3D models. The designed model is rechecked to optimize the number of polygons (mesh). The trick is to remove the non-mainstream part of the object. Then the removed portion is replaced with a different texture. After rechecking, the model is redesigned from scratch by the author. This redesign creates a low poly model. The design of the common poly model still maintains a resemblance to the original. The purpose of this common poly model is to reduce the workload of mobile processors.

Examining the Intersection of Economy and Cryptocurrency in the Metaverse

First introduced by Nakamoto, Bitcoin was the first cryptocurrency to use blockchain (Nakamoto, 2008). In contrast to existing currencies centrally controlled by regulators, cryptocurrency aims to enable transactions based on a distributed database in the form of peer-to-peer (P2P). Bitcoin transaction details are recorded and published in blocks like a chain. To solve the double-spending problem, a transaction (or transactions) is confirmed through a hash value-based Proof of Work (PoW) method and recorded in a block.

The previous block's hash value, nonce, transaction history, timestamp, and more, are noted in the building blocks. This block is verified by the PoW method, and a Bitcoin incentive is given to the subject who successfully proves and mines the block. On average, one block is generated every 10 minutes.

Transactions are transactions between the addresses of the transaction subjects, and many-to-many transactions are possible beyond one-to-one transactions. In this case, the address is generated from the wallet's public key that belongs to the transaction subject or the owner, and can be understood as a kind of 'account number' used for the transaction. A transaction consists of this send/receive address and amount, and values such as timestamps and fees are recorded together. To reduce storage size, it is stored in the Merkle tree structure. Moreover, research to analyze the characteristics continues.

Also, Ron and Shamir (2013) perform a statistical analysis of Bitcoin transactions, leading to a data-driven understanding of Bitcoin transactions for the first time. In addition, it is revealed that abnormal transaction behavior is discovered by representing transactions

as a graph, suggesting an attempt to hide the relationship between transactions. Thus, Table 5 shows the current research on bitcoin and cryptocurrency.

Table 5. Research about Bitcoin and Cryptocurrency

Purposes	Methods	Dataset	Main Results	Sources
Sentiment	supervised machine learning	Twitter (Bitcoin)	The supervised machine learning discovers a total score of 53,077 sentiments from the sampled 15,000 tweets. This score is from the artificial intelligence evaluation of eight emotions, such as anger (2%), anticipation (18%), disgust (1%), fear (3%), joy (15%), sadness (3%), surprise (7%), trust (15%) and the two sentiments, such as negative (4%) and positive (33%). The result indicates that the sample primarily contains positive sentiment	(Hassan et al., 2021)
Sentiment	psycholinguistic lexicon-based and VAR	news articles	the Bitcoin price to satisfy semi-strong form of market efficiency hypothesis, which is an indication of a mature market	(Karalevicius, 2018)
Bitcoin's price determinants	econometric modeling	Harrison Kinsley and the website Sentdex.com.	The explanatory power of sentiment significantly increases during the period of excessive volatility	(Bukovina & Martiček, 2016)
Sentiment	VADER-based Sentiment Analysis	Collect data for three main reasons manually during COVID-19 period	If the number of COVID-19 cases rises in specific regions and the tweets change, the proposed preprocessed strategies can work efficiently to provide well-fit representative data as long as we have the actual BTC price to compare with	(Pano & Kashef, 2020)
Bitcoin volatility	GARCH (1,1) and E-GARCH (1,1) models.	S&P500 Index, VIX Index, Bitcoin prices, and the sentiment about S&P500.	Bitcoin could act as a safe haven and that Bitcoin investors could consider sentiment about the stock market from social networks rather than market volatility when designing their investment strategies.	(López-Cabarcos et al., 2021)
Bitcoin Return	Newspaper and Internet	The predictive impact of EPU and EURQ of the US on Bitcoin returns.	The intensity of individual searches on the internet for words aiming to measure uncertainty, would allow investors to design better hedging strategies associated with Bitcoin in their portfolios.	(Bouri & Gupta, 2021)

Harnessing the Potential: Implementing the Metaverse in Islamic Finance

Indonesia is a Muslim-majority country, with Muslims making up 87.2% of the total population. In terms of development, the Islamic economy in Indonesia remains far behind

the conventional economy. However, Muslims desire to develop the Islamic economy, especially in Indonesia. This situation creates opportunities for business and economic targets in Indonesia (Abidin, 2022; Asroni, 2022; Hasan, 2022; Islam et al., 2022; Porter, 2004). Although there is no evidence from the above bibliometric analysis in Islamic finance, the metaverse is a topical issue that the banking industry has been eyeing to extend its business practices. Therefore, basic research on Islamic finance and the metaverse can be conducted. This can investigate industrial stakeholders' perspectives of the Islamic finance industry towards the metaverse. Challenges, human resources in the Islamic finance industry, and the related risks the industry will face are crucial for scholarly research. The basis of *Maqasid al-Shariah* (objectives of Islamic law) lies in the foundation of the business practices of Islamic finance industries (Al Anshory et al., 2020; Asutay, 2008; Caraka, Hudaefi et al., 2021; Hudaefi, Junari, et al., 2020; Hudaefi, Saoqi, et al., 2020; Hudaefi & Noordin, 2019). Thus, further exploration of shariah-compliance issues is an essential topic in Islamic finance and the metaverse.

In addition to commercial finance, Islamic social finance institutions, such as zakat institutions, have also been trying to adapt to the metaverse. For instance, Indonesia's national zakat board (Badan Amil Zakat Nasional Republik Indonesia-BAZNAS RI) launched zakat metaverse in 2022, aimed at zakat education and a zakat counter for zakat payments. This move provides research spaces in the Islamic social finance on the fundamental issues of religious practice in the metaverse. In addition, the digital divide is also critical for discussions of Islamic finance and metaverse. Future research needs to address the digital divide issues in emerging markets and how it can be a significant barrier in the metaverse practices of Islamic finance institutions. This digital poverty also relates to zakat institutions, which need further exploration of *muzakki* (zakat payers) and *mustahik* (zakat recipients) demographic issues. These topics are essential for future research on Islamic finance and the Metaverse.

In addition, blockchain technology is essential to metaverse. The potential of blockchain for Islamic finance practices has emerged in debates among academia and industry professionals. This creates significant room for scholarly work from industry perspectives, particularly in halal (permitted by Islamic law) industries. The halal value chain for meat products has been questioned, and breaches of halal have been significant in the industry. Blockchain technology, essential to metaverse, has been argued to be potentially industrialized for the halal food supply chain. Future work may focus on this particular topic to understand how such a halal supply chain, from the regulation, raw materials, food producers, food cargo and distributors, market players (be it wholesaler or retailer), and the consumers, can be tracked by blockchain technology for accurate, trusted, and fast recognition of the halal food supply chain.

Metaverse Ventures Revolutionizing Tourism

Consumers increasingly opt for metaverse hospitality and tourism knowledge, outcomes, and benefits (Gursoy et al., 2022). The metaverse in tourism integrates physical reality with augmented reality and virtual reality to connect needs and stakeholders in a shared space. However, 3D virtual space expands physical spaces into mixed-reality spaces, transforming the internet into a parallel virtual universe (Buhalis & Karatay, 2022).

In the digital era, metaverse tourism is a lucrative opportunity for Penta-helix contributors. The Indonesian Ministry of Tourism and Creative Economy introduces metaverse tourism titled 'WonderVerse Indonesia.' This metaverse tour offers the experience of exploring the beauty of Indonesian tourism with metaverse technology. In addition to promoting Indonesian tourism at the national and international levels, WonderVerse Indonesia was also created to encourage the creative economy industry, especially tourism and creative economy players, to promote their products digitally. Virtual tourism also offers a different sensation from traditional tourism and has no limitations in space and time. Users can visit destinations without being constrained by COVID-19 restrictions.

When a country enforces a lockdown to prevent the spread of COVID-19, this policy forces people to spend more time at home doing various activities. Lockdown also negatively affect people's psychological condition. Listening to music can reduce COVID-19-related stress as effectively as exercise and sleep (Cabedo-Mas et al., 2021; Vandenberg et al., 2021).

YouTube has been the most widely used social media platform since the pandemic, with a significant increase in users during the Covid-19 pandemic. Before pandemic, music concerts were among the most popular forms of entertainment. A music concert is a form of mass communication that conveys messages and emotions from one party to the community through music or songs. COVID-19 forced many concert organizers and musicians to adapt by holding concerts virtually or online through social media and YouTube to keep the public entertained. In general, online concerts use digital media to provide audiences' needs with access to the content that has been presented. Online shows are usually performed via live streaming, which can be accessed anywhere if one is connected to the internet. This new method of experiencing music has a different psychological impact than live music (Vandenberg et al., 2021). This phenomenon offers strong opportunity to expand the metaverse's potential for entertainment and to organize online music concerts or theatre, even though virtual singing cannot replace the experience of singing together at an offline concert (Botstein, 2019; Kantorová et al., 2021).

The opportunity to socialize with other singers is supposed to improve people's mental health and relieve feelings of loneliness. In addition, virtual concerts can increase closeness between the performing artist and the audience (Kusuma, 2020). Audiences can leave messages directly to the artist via the comments section available during the virtual concert. Audiences can also share their reflections and feelings with fellow viewers who are isolated due to the pandemic. This kind of connection has a good impact on people's psychological well-being.

Metaverse: Shaping Pedagogies, Learning, and Education

Education in the metaverse is more interactive for students. It can draw students into learning by immersing them in a visual world and students can interact directly using tools such as glasses and gloves that let them touch anything in the visual world. Education in this metaverse world must organize infrastructure, teaching materials, and a proper curriculum. The Covid-19 pandemic has nourished an overview of the continuity of the world of education

in the future with the help of technology. Nevertheless, technology still cannot replace the role of teachers, lecturers, and students-teachers interactions because education is not only about gaining knowledge but also about values, collaboration, and competence. This pandemic situation challenges each individual's creativity in using technology to develop education.

Online learning also has its benefits and drawbacks. Online learning is more comfortable and functional. Functional in terms of assigning assignments and reporting tasks at all times. However, online learning can be carried out anytime and anywhere. In terms of acquisition, knowledge and related material are delivered more rapid and straightforward for students to access.

Furthermore, the students' parents can instantly scrutinize or assist their children during their studies. Most importantly, teachers and students get a new understanding of online learning. Although online learning has benefits, it may also have drawbacks. The drawbacks of online learning include students being less engaged and having fewer opportunities for activity and participation. Then, this become challenging for some teachers to monitor and watch students directly during the exam.

Elevating Esports with the Metaverse

There are many advantages of esports. However, esports offers the experience of having a group team from different countries and locations. However, this effect does not change the view that esports is a community sport, like a traditional sport. The Industrial Revolution 4.0 is a massive leap in the industrial sector. Information and communication technology is fully utilized to achieve the highest efficiency in producing new digital-based business models. In Indonesia, esports is very popular among the millennial generation, and many content creators on YouTube produce online video games. The metaverse opportunity in this field is a different business model from traditional sports that have existed in the last decade. This is also influenced by the increasing use of smartphone and the development of internet access in Indonesia, which have further encouraged public interest in mobile games.

The latest research reveals that experience in esports, among other things, starts with the game launch. The user or game player is initially greeted with warm welcome sentences. At the beginning of the game, the user is greeted with pleasant words like 'Welcome to the game...' and 'Congratulations for accomplishing the mission.' At the same time, online games create emotional attachment and a sense of achievement after completing the game. Psychologically, players feel welcome and feel remarkably appreciated. However, in the real world, some users do not get that experience (Chiang et al., 2011; Coulson et al., 2012; Martey et al., 2014).

Exploring ASEAN Potentials in the Metaverse

Indonesia continues to advance the SDGs in many ways, playing a vital role in improving health and the global economy. Indonesia is the only ASEAN country that is a member of the G20, ranked 10th on the purchasing power parity list among G20 members, and

is undergoing a massive digital transformation. With the development of Industry 4.0, Society 5.0, and the metaverse, there are numerous issues that need to be discussed, particularly in Information and Communications Technology (ICT). For example, Indonesia is a maritime country with the most islands in the world. Nearly 75% of its total area is marine, covering 5.8 million square kilometers, making Indonesia the country with the largest sea area in the world. Thus, equitable access to ICT is necessary. Figure 4 shows the Submarine Cable Map in Indonesia. There are 49 cable maps connecting western, central, and eastern Indonesia.

Access to ICT is the lifeblood of a country's economic progress and help address challenges in achieving the SDGs targets. The government plays a central role in planning national-level SDGs policies. In this context, facilities are needed to establish research institutions led by citizen science and build data infrastructure to support development activities in the digital era. In addition, it is necessary to improve the quality of education and competence from the community side, especially among researchers and academics. Citizen science not only represents the government but can also contribute to big companies and collaborate with the government. It increases recognition and helps communities and organizations raise awareness of the value of the 2030 Agenda for sustainable development.

Indonesia has a demographic bonus, abundant internet and high social media users. By January 2020, mobile phone users in Indonesia amounted to around 338 million, exceeding Indonesia's total population of around 272 million. Around 160 million Indonesians actively use the internet, even some of them are of productive age and have used various modern digital tools. These statistics provide a clear picture of how big the digital opportunity is in Indonesia and reflect the relative weight index in Figure 5.

The current era of big data benefits for stakeholders in policymaking. The availability of large quantities of fast, diverse data encourages analysts to run calculations from aspects, generating various alternative policy proposals. For this reason, the penta-helix collaboration will accelerate Indonesia's development and be more prepared for the second-life metaverse.

Most SDG achievers in Indonesia still face major challenges, and progress has stagnated, specifically in SDG 11 (Sustainable Cities & Communities), the most dilemmatic SDG goal. The government can liberalize specific investment regulations for technologies that support data science. This concept can attract the interest of technology-owning companies to open businesses in Indonesia, and it could be even better if they could also produce in Indonesia. This could be done by collaborating with existing technology companies. The scheme can use a triple helix scheme (involving the government, businesses, and research institutions in Indonesia), use cities in Indonesia as use cases, and is expected to create a spillover effect through knowledge transfer from technology owners to Indonesia.

Furthermore, the government needs a grand design to use scientific data at the central level to guide city or district governments. These guidelines can determine which platforms each city uses to manage data. This concept is to reduce the potential for future interoperability issues. Another critical point is that the government needs to strengthen its data security infrastructure by using multiple layers of the Open Systems Interconnection (OSI) model. Suppose the government has implemented data security only at the

infrastructure and network levels. In that case, the government also needs to strengthen its data security at a higher level, such as at the application level. The government also needs to strictly prevent the storage of private data of Indonesian citizen abroad. If only data related to financial transactions cannot go abroad, the personal data of the Indonesian citizen should likewise be hosted domestically. Thus, Indonesian citizens' data security and privacy can be more protected.



Figure 4. ASEAN Submarine Cable Map (TeleGeography, n.d.)

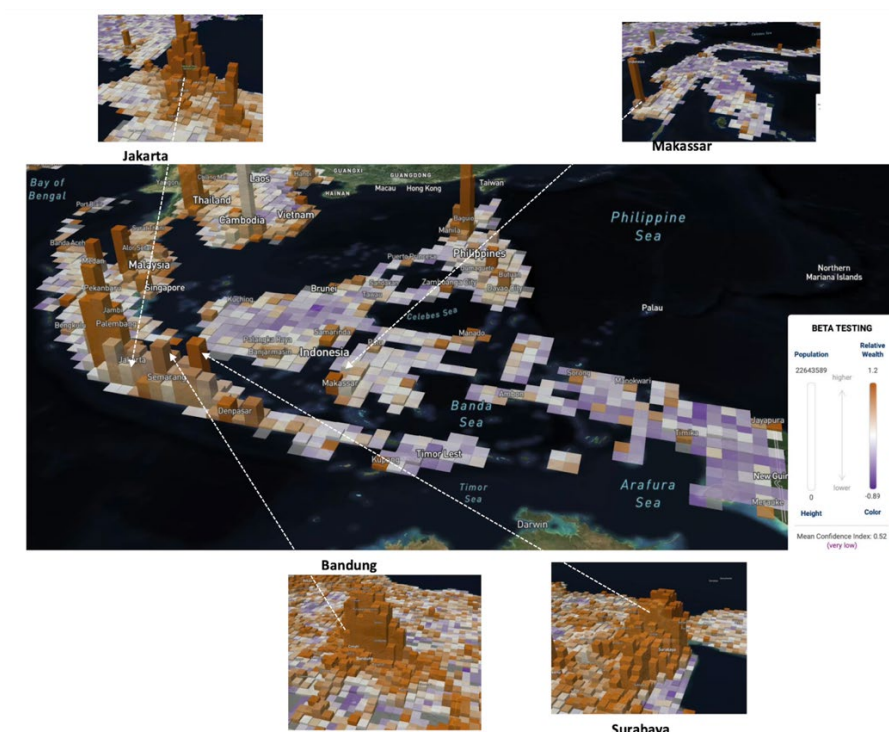


Figure 5. Relative Wealth Index (The Humanitarian Data Exchange, 2021)

The Metaverse in Organizations: Bright Side and Dark Side

The integration of the metaverse in organizations creates exciting opportunities for innovation and experimentation. Virtual environments offer a blank canvas for creativity, allowing businesses to explore new ideas, concepts, and designs in a risk-free space. From virtual product prototypes to immersive marketing campaigns, the metaverse gives organizations a platform to push the boundaries of traditional approaches and pioneer new strategies for success. This fosters a culture of innovation within organizations, encouraging employees to think outside the box and embrace unconventional solutions to complex challenges. By harnessing the power of the metaverse, organizations can differentiate themselves in the market, drive growth, and stay ahead of the curve in an ever-evolving business landscape.

The metaverse has the potential to democratize access to information and resources, leveling the playing field for businesses of all sizes. Virtual collaboration tools and platforms enable small and medium-sized enterprises (SMEs) to compete globally without the need for costly infrastructure or physical presence in multiple locations. This levels the playing field, allowing organizations to access talent, markets, and opportunities worldwide, regardless of location or financial resources. Additionally, the metaverse provides a platform for knowledge sharing and collaboration, enabling organizations to tap into a vast network of experts, mentors, and peers to exchange ideas, best practices, and insights. This democratization of information empowers organizations to innovate, grow, and thrive in an increasingly interconnected and competitive business environment.

The immersive nature of the metaverse may exacerbate existing mental health issues, as users may become increasingly reliant on virtual interactions at the expense of real-world relationships and experiences. This could lead to disconnection from reality and social isolation, with individuals spending excessive time in virtual environments to the detriment of their well-being. Additionally, privacy and security concerns loom large as organizations gather and store vast quantities of personal data within the metaverse. The risk of data breaches and unauthorized access raises significant ethical and legal questions about protecting individuals' privacy rights and responsibly handling sensitive information. Organizations must implement robust security measures and adhere to stringent data protection regulations to mitigate these risks and safeguard user privacy.

Moreover, ethical dilemmas abound in the metaverse, with complex issues surrounding digital ownership, virtual property rights, and the ethical implications of virtual interactions. As individuals increasingly invest time, resources, and emotional energy in virtual experiences, questions arise about who owns and controls virtual assets and creations. Furthermore, the blurring of lines between the virtual and physical worlds raises profound philosophical and ethical questions about reality, identity, and human existence. Organizations must grapple with these ethical considerations and strive to uphold principles of fairness, transparency, and respect for individual autonomy in their use of metaverse technologies. By proactively addressing these challenges, organizations can foster a more ethical and sustainable approach to the integration of the metaverse into their operations,

ensuring that the benefits of this transformative technology are realized while minimizing potential harms to individuals and society.

The Potential and Prospects of Metaverse in Improving Healthcare in Indonesia: A Case Study on Radiotherapy

The development of Indonesia's health sector through metaverse technology has great potential, but it also faces several challenges that need to be addressed for further growth. One of the main challenges is a lack of understanding among patients and medical personnel about the applications and benefits of metaverse technology in healthcare. In Indonesia, many patients do not fully understand how the metaverse can be used to improve access to health services, such as virtual consulting or telemedicine.

For medical personnel in Indonesia, knowledge and skills regarding the use of metaverse-related technologies remain limited. Although some hospitals and clinics in major cities have begun adopting aspects of digital technology, the use of the metaverse in everyday medical practice remains rare. In this context, more structured education and training on this technology are needed so medical personnel can make the most of it, especially in remote medicine or virtual-based medical training.

In the context of radiotherapy, metaverse can improve some important aspects of the treatment process. For example, doctors can use a virtual platform to simulate radiation treatments and create 3D models of patient anatomy. This allows for more accurate treatment planning and more personalized treatment adjustments, which are critical in managing complex cancer cases. However, Indonesia faces major challenges in terms of knowledge and skills related to the use of metaverse technology in radiotherapy.

In metaverse-based education and training, as in the health sector in general, the main challenge in radiotherapy is the limited understanding of metaverse applications. Hospitals or oncology centers in Indonesia may lack the infrastructure or trained medical personnel to implement virtual-based training simulations for radiotherapy procedures. Metaverse-based education can provide an immersive and interactive training environment, allowing medical personnel in remote areas to learn and practice complex medical procedures without attending specialized training centers. One major obstacle to the adoption of metaverse technology in healthcare, including radiotherapy, is regulatory uncertainty, particularly around patient data privacy. The use of the metaverse in healthcare will involve highly sensitive patient data, such as medical history, medical plans, and medical images. Indonesia's recently implemented Personal Data Protection Law (Undang-Undang Pelindungan Data Pribadi-UU PDP) emphasizes the importance of patient data protection.

Conclusions

This research delved into the current landscape of research surrounding the metaverse and explored its potential implications. Undoubtedly, the metaverse promises to usher in a

new dimension of human experience. However, it is imperative to address security concerns proactively. While this digital evolution offers myriad opportunities, its uninformed or mismanaged utilization may lead to adverse outcomes. Of particular concern is the potential erosion of privacy, with implications for data security and the exposure of personal information. Moreover, as the complexities of the metaverse continue to evolve, it is crucial to consider its impact on psychological well-being. There is a pressing need for further research to assess the psychological effects, including addiction and depression, stemming from immersive experiences within the metaverse.

From a regional perspective, the emergence of the metaverse carries profound implications for the ASEAN region. As ASEAN accelerates its digital integration through initiatives such as the ASEAN Digital Masterplan and the Digital Economy Framework Agreement (DEFA), the metaverse presents both strategic economic opportunities and regulatory challenges. Economically, immersive technologies offer immense potential to elevate ASEAN's key sectors, including cross-border e-commerce, digital tourism, remote education, and smart manufacturing. However, these opportunities are counterbalanced by the existing digital divide among member states, disparities in digital infrastructure readiness, and fragmented regulatory environments across the region. To harness the benefits of the metaverse effectively, ASEAN must prioritize regional policy harmonization, particularly concerning cross-border data governance, digital asset standards, and joint cybersecurity frameworks. Furthermore, collective regional efforts are needed to safeguard digital consumers while ensuring equitable access to immersive technologies across developing ASEAN economies.

Given its potential to significantly alter personal lives, the ramifications of metaverse engagement warrant scrutiny. As the metaverse emerges as a forefront technology, it necessitates a corresponding evolution in legal frameworks and governance. Governments, particularly within ASEAN, must anticipate and address potential cybercrime threats, regulatory gaps, and mental health challenges arising from metaverse interactions. Indeed, the metaverse has the capacity to exacerbate existing mental health issues, leading to feelings of disconnection and alienation from reality. In conclusion, the metaverse represents a groundbreaking frontier in information technology. However, its transformative potential must be tempered with responsible usage, robust regional policy coordination, and comprehensive safeguards. By addressing security, privacy, psychological well-being, and regional regulatory alignment, stakeholders can navigate the metaverse's emergence while mitigating potential risks and maximizing its benefits for society.

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