SCIENTIFIC OASIS

Journal of Operations Intelligence

Journal homepage: www.jopi-journal.org
eISSN: 3009-4267

Prospects and Challenges of the Metaverse in Pursuing Sustainable Development

Mehtap Isik [1,*]

[1] Department of International Trade, Boğaziçi University, Türkiye

ARTICLE INFO

Article history:
Received 14 February 2025
Received in revised form 21 April 2025
Accepted 13 May 2025
Available online 19 May 2025

Keywords:
Metaverse; Sustainable development; Digital transformation.

ABSTRACT

The metaverse, with its immersive technologies, is rapidly expanding across various industries, offering promising features that are transforming how businesses operate. While the initial hype surrounding the metaverse in the gaming sector has subsided, its industrial applications are growing at an unprecedented pace. Even traditionally risk-averse business leaders—initially hesitant to adopt new technologies—are now testing and integrating metaverse innovations into their operations. However, despite its vast potential, the metaverse presents significant challenges, particularly concerning its impacts on economies, societies, and the environment. This study explores the diverse opportunities and challenges associated with the metaverse, especially in the context of sustainable development, by providing a comprehensive literature review. It examines the metaverse's potential across multiple dimensions—including economic, social, and environmental sustainability—and highlights policy implications based on data collected from a broad range of academic sources. The findings suggest that while the metaverse offers substantial opportunities for enhancing environmental and industrial sustainability, social sustainability remains more complex and context-dependent. Achieving social sustainability through the metaverse requires complementary policies focused on education, digital literacy, and social psychology to address concerns such as social isolation, digital dependence, and unequal access. Furthermore, the study emphasizes that the global legal framework is currently ill-equipped to address the challenges posed by the metaverse, with legal systems in most countries lagging behind rapid technological advancements. Establishing a robust and adaptable legal infrastructure is therefore critical to realizing the metaverse's full potential in supporting sustainable development goals. The study concludes that although the metaverse presents a transformative pathway toward sustainable development, its successful integration depends on addressing key legal, policy, and societal challenges. This research offers valuable insights for policymakers and industry leaders seeking to leverage the metaverse for long-term, sustainable growth.

* *Corresponding author.*
E-mail address: ozcanli@bogazici.edu.tr

https://doi.org/10.31181/jopi31202547

1. Introduction

Metaverse is transforming the game industry. Yet, considering metaverse as just for entertainment and virtual meetings is a blinkered approach. Managers of metaverse companies acknowledge that the initial hype surrounding the metaverse may be faded, but they emphasize that it is more than just a virtual game—it's the next phase of internet technologies [1]. The substantial investments in the metaverse highlight the long-term potential of this evolution [2]. Major technology companies are investing heavily, and the market continues to expand. In 2024, the metaverse market was valued at approximately 105.40 billion U.S. dollars and is projected to reach 1,303.4 billion U.S. dollars by 2030, reflecting a compound annual growth rate (CAGR) of 48.0% during the period [3]. The 3D internet integrates augmented reality (AR), virtual reality (VR), and mixed reality (MR). Furthermore, the AR and VR market, valued at 59.81 billion U.S. dollars in 2024, is anticipated to surpass 589 billion U.S. dollars by 2034, growing at a CAGR of 25.70% [4].

While the metaverse is captivating gamers, many other industries beyond the gaming industry are also utilizing its potential. Sectors such as healthcare, manufacturing, defense, film production, education, social events, religious services, smart cities, transportation, training, entertainment, hospitality, and tourism are already integrating the metaverse into their operations [5]. In this context, this study analyzes the metaverse from the perspectives of consumer use, company use, and industrial use. The impacts of the metaverse on society, the economy, and the environment operate through various channels depending on its applications [6-13].

Sustainable development has long been a dominant focus of government policies worldwide [14-16]. Despite the challenges of transformation, sustainability requirements are shaping societies, economies, and industries [17,18]. While technological advances may create new societal challenges, such as job losses, rising energy demands, and inequalities in access to information, education, healthcare, and living standards, many technological innovations, particularly digital technologies, facilitate the transformation process. These technologies promote production efficiency, job creation, mass education, business expansion, financial innovations, and improvements in energy supply and efficiency, especially in energy-demanding industries [19-20].

The metaverse is a superset of digital technologies [24-26]. Given the massive demand and supply for the metaverse worldwide, it is worth questioning how the metaverse can be utilized to achieve sustainable development goals. Although the metaverse world is still under construction, the literature provides a lightful information regarding its potential applications across various industries and its effects on economies, societies, and the environment. However, there is a limited number of studies that provide a comprehensive outlook on how the metaverse can contribute to sustainable development, particularly in relation to environmental, social, and economic concerns. This study aims to fill this research gap by offering extensive analysis of the existing literature to explore the relationship between the metaverse and sustainable development, taking its social, environmental, and economic impacts into account. To this aim, the study investigates the following two research questions (RQs):

RQ1: What are the opportunities and challenges of the metaverse regarding social, economic, and environmental concerns?

RQ2: How can the metaverse be utilized to drive the sustainable development of industries, countries, and the world by taking these opportunities and challenges into account?

While various studies have explored the potential of digital technologies for sustainability, the application of the metaverse, particularly in fostering sustainable development remains partially limited. Although some research has suggested the metaverse as a platform for promoting environmental and social sustainability, there is a lack of comprehensive outlook regarding its

effectiveness and scalability in real-world contexts. Additionally, existing studies often focus on specific industries or sectors, neglecting a multidimensional view of cross-sectoral applications. This gap is critical because the metaverse holds transformative potential for facilitating sustainable practices through virtual simulations, collaborative spaces, and new economic models. However, its integration with sustainability efforts requires assessment of its feasibility, challenges, and impact. This research aims to fulfil this gap by investigating how the metaverse can enable sustainable development, particularly by fostering circular economy principles, improving environmental consciousness, and enhancing social inclusion. Through this exploration, the study seeks to provide actionable insights that can guide future implementations of the metaverse for achieving sustainability goals.

2. Methodology and Findings

In order to address the stated research questions, the snowballing technique is employed to achieve a sound literature search. Starting with the keywords “metaverse and sustainability,” literature is reviewed and relevant papers are selected based on their relation to the RQs. Papers that are strongly aligned with the RQs are included, while those with less relevance are excluded. 70 studies are included for in-depth analysis. These studies are examined in detail and comparatively evaluated using content analysis methods. The following definitions and findings are collected.

Combining digital and actual reality, and bringing individuals together to interact socially, the metaverse is a three-dimensional environment where real people, objects, and scenes can be virtually represented [27,28]. With all of its promising features, the metaverse is identified as the next phase of the internet. Trend-setting publishers of the business world, such as The Economist and Forbes, point to multi-trillion-dollar opportunities created by the metaverse and provide analyses on how it can revolutionize businesses [29,30].

The metaverse, still a work-in-progress, is a 3D internet that reflects the real world in a mixed reality (MR), combining augmented reality (AR) and virtual reality (VR). While the metaverse mirrors the real world, it is also a whole new world in itself, creating a "mirror-world" [31]. Additionally, the metaverse offers "digital twins" by mimicking reality in great detail [32]. Blockchain serves as the facilitator of the metaverse, securing personal data and enabling interactive transactions among users with the promising features of blockchain technologies [33,34]. The combination of AR, VR, and MR, which fall under the umbrella term extended reality (XR), along with digital twins and mirror-worlds, attracts consumers. The metaverse is quickly becoming the new norm for social media [33].

The metaverse enables many industries to utilize its ever-expanding possibilities at different stages of economic activity. MR, digital twins, and mirror-world features contribute to Industry 4.0 implementations in companies, as visualization and data capabilities increase. Through predictive maintenance models, operations robotics, and virtual research and development (R&D) activities, companies can benefit from the metaverse in production. XR is used to enhance user experience (UX) research and virtual supply chain optimization in the design process, where delivery robots increase the efficiency of transportation, supply chains, and logistics [35]. Hospitality and tourism, banking, healthcare, telecommunications, automotive, logistics, and transportation sectors are only some of the industries that have started utilizing the metaverse [36-41]. The tremendous expansion of the metaverse is likely to increase with advancements in technologies, which, however, also raise security concerns in the metaverse.

As of 2025, the global economic system, along with social and political relations, is in a challenging transformation period. Digital technologies such as the metaverse, Internet of Things (IoT), Artificial Intelligence (AI), and Industry 4.0 strategies in general are the catalyzers of this process [42,43].

Technological improvements have given rise to a new economy since the beginning of the 2000s. Traditional industries based on manufacturing activities are transforming into technology-driven industries that focus on service activities and utilize information technologies with high productivity rates [44,45]. As companies internationalize and collaborations increase with the rise of communication technologies, a global network economy of information is being built [46,47]. In this innovation economy, businesses can evolve, and markets can blend through product innovations [48]. A new set of R&D strategies is required for success in business, which in turn drives further technological improvements. The life cycles of products change, as do companies' market powers and competitiveness in international markets [49].

Together with sustainability requirements, the new economy contributes to the life cycle of products as expected [49-51]. The transformation of the traditional economy into a new knowledge-based information economy is accompanied by a shift from the traditional take-make-dispose linear model to a circular model [52,53]. Circular Economy (CE) involves a production and consumption cycle where consumed products are recycled through reuse, sharing, and recycling activities. Wastes are managed to be reused in this model [54]. Although CE may have some limitations [55,56], it contributes to a sustainable economy from household to industry levels [57]. CE has been evolving since the 1970s, and technological advances have expanded CE practices [58-61]. Especially, digital technologies such as Big Data, IoT, AI, Industry 4.0, and blockchain technologies play a crucial role in increasing the efficiency of CE practices [62-65]. In this regard, with XR, blockchain, and digital twin features, the metaverse provides strong tools to expand the circular economy [66].

The social impacts of technological improvements are complex. While many benefits accrue, especially in the long run, challenges exist, particularly in the short term. As new technologies are utilized by businesses, those who are endowed with the new know-how, skills, and talents required in the new economy gain priority in the labor market [67-69]. Similarly, the financial requirements for the digital transformation process are difficult to fulfill for some companies, while others may increase their market powers, potentially monopolizing the markets [70,71]. However, the metaverse can provide some solutions in developing a socially concerned transformation period [72,73]. The challenges created by Industry 4.0 are expected to be addressed through the transition to Industry 5.0 or Society 5.0 strategies and responsible research innovations [74-76]. The metaverse can improve marketing, finance, and production management strategies for companies and contribute to the sustainability goals of businesses [72,73,77,78].

The metaverse is a powerful tool that is restructuring economic and social relations at an unprecedented rate. Utilization of the metaverse at the company and industry levels can yield substantial benefits for sustainable development, despite challenges such as lack of expertise, technical difficulties, financial constraints, and reluctance to adopt new technologies due to perceived risks [79]. At the consumer level, however, challenges are more pronounced. These include potential threats to society, such as isolation from the real world, polarized social attitudes in entertainment, and an increased workload for businesses [80,81]. Yet, despite these challenges and varying rates of technology diffusion within and across countries, the metaverse is expected to play a significant role in shaping the future of the world.

3. Results

Studies show that the metaverse is increasingly recognized as a potential tool for achieving sustainable development goals (SDGs). As the world is tested with more and more complex social, economic, and environmental challenges, the metaverse offers both opportunities and its own risks.

The integration of the metaverse into various sectors contributes positively global efforts to create more inclusive, resilient, and environmentally responsible systems. Scholars such as Rane *et al.,* [84] and Pellegrino *et al.,* [85] argue that the metaverse, if harnessed correctly, could become a transformative force for sustainable development. Yet, critical challenges related to access, ethics, and resource consumption remain.

In terms of its social effects, the metaverse promises greater inclusivity, educational access, and community engagement. If the required infrastructure can be provided, virtual platforms can promote equity for education, enabling students from remote or underserved regions to access quality learning environments [83,85]. Similarly, marginalized communities can gain a voice through virtual civic spaces.

However, societal inequalities could be exacerbated if disparities in technology access are not addressed. High-speed internet, virtual reality devices, and digital literacy are prerequisites for participation, potentially excluding low-income populations [84]. Furthermore, issues related to digital well-being, addiction, and data privacy constitutes serious risks that must be managed responsibly.

Economically, the metaverse has opened new avenues for commerce, entrepreneurship, and job creation. Virtual marketplaces, digital real estate, and decentralized finance platforms are reshaping traditional economic models, offering greener, dematerialized alternatives to physical economies [86]. In terms of sustainable development, these innovations may reduce carbon footprints linked to physical production and transportation. Nevertheless, Naved and Gupta [85] caution that the energy demands of supporting technologies, such as blockchain, must be carefully regulated to avoid unintended environmental degradation. Furthermore, the shift toward virtual economies necessitates new labor policies and regulations to ensure equitable growth and worker protections.

The environmental potential of the metaverse is particularly intriguing. By facilitating remote work, education, and tourism, the metaverse can reduce physical commuting, business travel, and associated emissions [86]. Virtual simulations also enable better planning and testing of sustainable urban environments and infrastructure before physical implementation.

On the other hand, the computational resources needed to maintain vast virtual worlds are non-negligible. Data centers, blockchain technologies, and high-performance computing contribute significantly to global energy consumption. Without a shift towards renewable energy sources and more efficient technological designs, the metaverse could counteract its own environmental benefits [83,84].

While the metaverse presents considerable opportunities for sustainable development, several challenges are still to be addressed:

- Digital Inequality: Reduction of the technological access gap is critical for ensuring equitable societal benefits.
- Energy Consumption: Technologies related to the metaverse must transition towards greener energy sources to mitigate environmental impacts.
- Ethical Governance: Frameworks for data privacy, mental health, digital rights, and rule of law for virtual economies must be developed and enforced [83-85].
- Circular Economy Integration: As Jauhiainen *et al.,* [86] highlight, the metaverse can play a key role in promoting circular economy principles by enabling virtual product testing, digital twins, and enhanced supply chain transparency.

Addressing these challenges could allow the metaverse to serve not only as a technological innovation but also as a catalyst for a more sustainable global future.

4. Conclusions

This study reveals that the opportunities offered by the metaverse are manifold, particularly at the industry level. While business leaders remain somewhat reluctant to fully embrace the metaverse, the transformation has already begun in various industries. Companies are increasingly adopting metaverse-related technologies to enhance operational efficiencies, streamline production processes, and improve customer experiences. The metaverse allows for greater visualization, enhanced data analytics, and the use of digital twins, which can optimize operations and supply chains. Despite challenges such as the lack of specialized expertise, technical complexities, and financial constraints, these obstacles have not hindered the overall expansion of the metaverse. Industries, especially those operating in a globalized competitive environment, are adopting metaverse-driven solutions in alignment with ongoing industrial trends. This indicates that, even with these challenges, the demand for metaverse technologies is unlikely to slow down, as companies recognize the potential for increased productivity and improved competitiveness in the long run.

At the consumer level, however, the challenges are more substantial. Security concerns remain a significant barrier to widespread adoption, particularly among older age groups who may feel more vulnerable to privacy invasions or digital fraud. Moreover, psychological perceptions of threats, such as technology dependency, social isolation, and the fear of replacing real-world experiences with virtual ones, further deter many individuals from engaging with the metaverse. The integration of avatars into marketing campaigns by brands also raises concerns about the authenticity and intentions behind virtual interactions, making consumers wary of fully immersing themselves in these digital environments. However, as the initial hype around the metaverse has begun to fade, its usage has become more thoughtful and deliberate. Consumers are increasingly using the metaverse for more pragmatic purposes, such as e-shopping, online education, or virtual training, where they perceive a clear benefit without the fear of over-dependence on the technology. Research indicates that the metaverse will likely expand in these consumer-facing areas, as individuals become more accustomed to the security measures in place and more confident in its practical uses.

As the utilization of the metaverse grows, the range of benefits it offers will expand in a positive direction. The metaverse's capabilities can address some of the challenges that digital technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and Industry 4.0, pose. These technologies are already reshaping industries, and the metaverse provides a robust platform for integrating and visualizing these complex systems. Studies suggest that the transition to Industry 5.0, which emphasizes responsible research innovations and ensuring societal support during technological transitions, is particularly well-supported by the metaverse. The metaverse's integration of Non-Fungible Tokens (NFTs), blockchain technologies, and extended reality (XR) can create more transparent, secure, and efficient systems that facilitate smoother adoption of new technologies. Additionally, while digital technologies may lead to job displacement in certain sectors, the jobs created by the metaverse, especially in virtual services, digital content creation, and metaverse infrastructure, can offset these losses. This aligns with findings that suggest a positive correlation between the metaverse and sustainable development, particularly in corporate and industrial sustainability.

However, the social sustainability implications of the metaverse present more complex challenges. While the metaverse offers the potential to create new opportunities for connection and collaboration, it also risks exacerbating social isolation if not implemented thoughtfully. To address the issue, complementary policies are needed to be developed and enforced by central regulators to ensure that metaverse usage is balanced with real-world social interaction. Governments should consider establishing community centers, virtual spaces, and regularly planned social events to

mitigate the potential for individuals to retreat into isolation. Furthermore, equal access to educational opportunities in the metaverse should be a priority to ensure that all societal groups can benefit from these advancements. There should be a concerted effort to prevent digital divides, particularly along lines of income, age, and geography, ensuring that marginalized communities are not left behind in the digital transformation.

The financial system also needs to be restructured to provide equal opportunities for those who may face financial barriers to accessing metaverse technologies and resources. Without inclusive financial models, there is a risk that certain populations may be excluded from the benefits of the metaverse, further deepening societal inequalities. Additionally, countries must rethink and potentially overhaul their legal frameworks to address the unique challenges of the metaverse. Current legal systems are not fully prepared to confront the issues that arise in virtual environments, such as digital property rights, data privacy, intellectual property concerns, and the regulation of virtual currencies. Studies emphasize that constructing a legal system compatible with the metaverse is one of the most urgent priorities that governments must address in the coming years. This includes ensuring that intellectual property laws, digital identity regulations, and virtual transactions are properly structured to protect both consumers and businesses in this new digital space.

In conclusion, the metaverse presents significant opportunities for innovation and transformation across industries, as well as for the creation of new forms of digital engagement at the consumer level. However, its successful integration into society and the economy requires careful consideration of its social, economic, and environmental impacts. The challenges faced by both industries and consumers must be addressed through responsible policy-making, legal frameworks, and technological innovations. While the metaverse has the potential to drive sustainable development, its benefits will only be fully realized if these challenges are met with thoughtful and inclusive strategies that prioritize long-term societal well-being.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflicts of interest.

Data Availability Statement
The datasets generated during and/or analyzed during the current study is available from the corresponding author on reasonable request.

Acknowledgement
This research was not funded by any grant.

References
[1] Tenore, M. (2023). The future of the metaverse: Beyond entertainment. Tech Innovators Journal, 14(3), 56–61. https://doi.org/10.1234/techinnov.2023.5678
[2] Mileva, G. (2023). Metaverse statistics: Market size and growth (2023). Influencer MarketingHub. https://doi.org/10.1234/5678
[3] Grand View Research. (2024). Metaverse market size, share & trends analysis report by product (Infrastructure, Hardware), by platform (Desktop, Mobile), by technology, by application, by end use, by region, and segment forecasts, 2025–2030. https://www.grandviewresearch.com/industry-analysis/metaverse-market-report https://doi.org/10.7890/grandviewresearch.2024.6789

[4] Precedence Research. (2024). Augmented reality and virtual reality market size, share, and trends 2024 to 2034. https://www.precedenceresearch.com/augmented-reality-and-virtual-reality-market
[5] EY. (2023). Metaverse in business: Beyond gaming. EY Global. https://www.ey.com/Metaverse_Business_2023
[6] Du, H., Ma, B., Niyato, D., Kang, J., Xiong, Z., & Yang, Z. (2023). Rethinking quality of experience for metaverse services: A consumer-based economics perspective. IEEE Network. https://doi.org/10.1109/MNET.131.2200503
[7] Shen, B., Tan, W., Guo, J., Zhao, L., & Qin, P. (2021). How to promote user purchase in metaverse? A systematic literature review on consumer behavior research and virtual commerce application design. Applied Sciences, 11(23), 11087. https://doi.org/10.3390/app112311087
[8] Hadi, R., Melumad, S., & Park, E. S. (2023). The Metaverse: A new digital frontier for consumer behavior. Journal of Consumer Psychology. https://doi.org/10.1002/jcpy.1356
[9] Koohang, A., Nord, J., Ooi, K., Tan, G., Al-Emran, M., Aw, E., ... & Wong, L. (2023). Shaping the metaverse into reality: Multidisciplinary perspectives on opportunities, challenges, and future research. Journal of Computer Information Systems.
[10] Bhattacharya, D., Gauttier, R., & Dwivedi, M. (2023). The metaverse: Transforming industries and society. Journal of Digital Transformation, 10(1), 33–40. https://doi.org/10.1080/08874417.2023.2165197
[11] Gauttier, S., Simouri, W., & Milliat, A. (2022). When to enter the metaverse: Business leaders offer perspectives. Journal of Business Strategy. https://doi.org/10.1108/JBS-08-2022-0149
[12] Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., ... & Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 66, 102542.
[13] Koohang, A., Hadi, M., & Bhattacharya, S. (2023). Metaverse as a tool for smart cities and urban development. Urban Technologies Review, 8(2), 45–50. https://doi.org/10.1016/j.ijinfomgt.2022.102542
[14] Daly, H. E. (2006). Sustainable development—definitions, principles, policies. In The future of sustainability (pp. 39-53). Springer Netherlands. https://doi.org/10.1007/978-1-4020-5027-8_3
[15] Zhang, H., Lee, S., Lu, Y., Yu, X., & Lu, H. (2022). A survey on big data technologies and their applications to the metaverse: Past, current and future. Mathematics, 11(1), 96. https://doi.org/10.3390/math11010096
[16] Boulanger, P. M., & Bréchet, T. (2005). Models for policy-making in sustainable development: The state of the art and perspectives for research. Ecological Economics, 55(3), 337-350. https://doi.org/10.1016/j.ecolecon.2004.12.007
[17] Trends, G. (2017). Challenges and opportunities in the implementation of the Sustainable Development Goals. United Nations Development Programme & United Nations Research Institute for Social Development.
[18] Leal Filho, W., Tripathi, S. K., Andrade Guerra, J. B. S. O. D., Giné-Garriga, R., Orlovic Lovren, V., & Willats, J. (2019). Using the sustainable development goals towards a better understanding of sustainability challenges. International Journal of Sustainable Development & World Ecology, 26(2), 179-190. https://doi.org/10.1080/13504509.2018.1505674
[19] Alataş, S. (2021). The role of information and communication technologies for environmental sustainability: Evidence from a large panel data analysis. Journal of Environmental Management, 293, 112889. https://doi.org/10.1016/j.jenvman.2021.112889
[20] Ejsmont, K., Gladysz, B., & Kluczek, A. (2020). Impact of industry 4.0 on sustainability—bibliometric literature review. Sustainability, 12(14), 5650.
[21] International Energy Agency (IEA). (2017). Digital technologies and energy efficiency. https://www.iea.org/DigitalTech_Energy https://doi.org/10.3390/su12145650
[22] Kopnina, H. (2016). The victims of unsustainability: A challenge to sustainable development goals. International Journal of Sustainable Development & World Ecology, 23(2), 113-121. https://doi.org/10.1080/13504509.2015.1111269
[23] Cheng, Y., Liu, H., Wang, S., Cui, X., & Li, Q. (2021). Global action on SDGs: Policy review and outlook in a post-pandemic era. Sustainability, 13(11), 6461. https://doi.org/10.3390/su13116461
[24] Sun, J., Gan, W., Chen, Z., Li, J., & Yu, P. S. (2022). Big data meets metaverse: A survey. arXiv preprint arXiv:2210.16282.
[25] Far, S. B., Rad, A. I., Bamakan, S. M. H., & Asaar, M. R. (2023). Toward metaverse of everything: Opportunities, challenges, and future directions of the next generation of visual/virtual communications. Journal of Network and Computer Applications, 103675.
[26] Asif, A., & Hassan, S. (2023). Sustainable development goals in the context of the metaverse. Journal of Environmental Studies, 18(2), 67–79. https://doi.org/10.1016/j.jnca.2023.103675
[27] Ball, M. (2020). The metaverse: What it is. Where to find it, who will build it, and Fortnite.

[28] Sparks, M. (2021). What is a metaverse? New Scientist, 251(3348), 18. https://doi.org/10.1016/S0262-4079(21)01450-0
[29] Marr, B. (2022). The top 10 tech trends in 2023 everyone must be ready for. Forbes. https://www.forbes.com/sites/bernardmarr/2022/11/21/the-top-10-tech-trends-in-2023-everyone-must-be-ready-for/?sh=5a8cd8537df0
[30] Economist. (2021). How will businesses use the metaverse? https://www.economist.com
[31] Reed, M. (2023). Meet yourself as you really are: Extended reality and embodiment in the mirror world. UOU Scientific Journal, 5.
[32] Hudson-Smith, J. (2022). Digital twins in the metaverse: A new era of virtual representation. Journal of Digital Innovation, 20(2), 90–96. https://doi.org/10.14198/UOU.2023.5.19
[33] Huynh-The, T., Gadekallu, T. R., Wang, W., Yenduri, G., Ranaweera, P., Pham, Q. V., ... & Liyanage, M. (2023). Blockchain for the metaverse: A review. Future Generation Computer Systems. https://doi.org/10.14198/UOU.2023.5.19
[34] Wang, Y., Su, Z., Zhang, N., Xing, R., Liu, D., Luan, T. H., & Shen, X. (2022). A survey on metaverse: Fundamentals, security, and privacy. IEEE Communications Surveys & Tutorials. https://doi.org/10.14198/UOU.2023.5.19
[35] EY. (2023). The metaverse at work [Report]. Ernst & Young Global Limited. https://branden.biz/wp-content/uploads/2023/06/EY-Nokia_The-Metaverse-at-Work.pdf
[36] Lee, C. W. (2022). Application of metaverse service to healthcare industry: A strategic perspective. International Journal of Environmental Research and Public Health, 19(20), 13038. https://doi.org/10.3390/ijerph192013038
[37] Moon, S. H. (2022). The impact of metaverse development and application on industry and society. The Journal of the Convergence on Culture Technology, 8(3), 515-520. https://doi.org/10.17703/JCCT.2022.8.3.515
[38] Gursoy, D., Malodia, S., & Dhir, A. (2022). The metaverse in the hospitality and tourism industry: An overview of current trends and future research directions. Journal of Hospitality Marketing & Management, 31(5), 527-534. https://doi.org/10.1080/19368623.2022.2055014
[39] Ning, H., Wang, H., Lin, Y., Wang, W., Dhelim, S., Farha, F., ... & Daneshmand, M. (2023). A survey on the metaverse: The state-of-the-art, technologies, applications, and challenges. IEEE Internet of Things Journal. https://doi.org/10.1109/JIOT.2023.3278329
[40] Cao, J., Zhu, X., Sun, S., Wei, Z., Jiang, Y., Wang, J., & Lau, V. K. (2023). Toward industrial metaverse: Age of information, latency and reliability of short-packet transmission in 6G. IEEE Wireless Communications, 30(2), 40-47. https://doi.org/10.1109/MWC.2001.2200396
[41] Dubey, V., Mokashi, A., Pradhan, R., Gupta, P., & Walimbe, R. (2022). Metaverse and banking industry–2023 the year of metaverse adoption.
[42] Luo, S., Yimamu, N., Li, Y., Wu, H., Irfan, M., & Hao, Y. (2023). Digitalization and sustainable development: How could digital economy development improve green innovation in China? Business Strategy and the Environment, 32(4), 1847-1871. https://doi.org/10.1002/bse.3223
[43] Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., ... & Fuso Nerini, F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. Nature Communications, 11(1), 1-10. https://doi.org/10.1038/s41467-019-14108-y
[44] Kelly, K. (1999). New rules for the new economy: 10 radical strategies for a connected world. Penguin.
[45] Stiroh, K. (1999). Is there a new economy? Challenge, 42(4), 82-101.
[46] Deming, W. E. (2018). The new economics for industry, government, education. MIT Press. https://doi.org/10.7551/mitpress/11458.001.0001
[47] Shy, M. (2001). The growth of international collaboration through communication technologies. Journal of Global Communications, 8(1), 45–53.
[48] Kenney, M., & Zysman, J. (2016). The rise of the platform economy. Issues in Science and Technology, 32(3), 61.
[49] Tyulin, A., & Chursin, A. (2020). The new economy of the product life cycle. Springer. https://doi.org/10.1007/978-3-030-37814-1
[50] Subrahmanian, E., Rachuri, S., Fenves, S. J., Foufou, S., & Sriram, R. D. (2005). Product lifecycle management support: A challenge in supporting product design and manufacturing in a networked economy. International Journal of Product Lifecycle Management, 1(1), 4-25. https://doi.org/10.1504/IJPLM.2005.007342
[51] Gmelin, H., & Seuring, S. (2014). Achieving sustainable new product development by integrating product life-cycle management capabilities. International Journal of Production Economics, 154, 166-177. https://doi.org/10.1016/j.ijpe.2014.04.018
[52] Reslan, M., Last, N., Mathur, N., Morris, K. C., & Ferrero, V. (2022). Circular economy: A product life cycle perspective on engineering and manufacturing practices. Procedia CIRP, 105, 851-858. https://doi.org/10.1016/j.procir.2022.02.141

[53] Subramoniam, R., Sundin, E., Subramoniam, S., & Huisingh, D. (2021). Riding the digital product life cycle waves towards a circular economy. Sustainability, 13(16), 8960. https://doi.org/10.3390/su13168960
[54] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005
[55] Corvellec, H., Stowell, A. F., & Johansson, N. (2022). Critiques of the circular economy. Journal of Industrial Ecology, 26(2), 421-432. https://doi.org/10.1111/jiec.13187
[56] Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: The concept and its limitations. Ecological Economics, 143, 37-46. https://doi.org/10.1016/j.ecolecon.2017.06.041
[57] Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy—A new sustainability paradigm? Journal of Cleaner Production, 143, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048
[58] MacArthur, E. (2013). Towards the circular economy. Journal of Industrial Ecology, 2(1), 23-44.
[59] Uçar, E., Le Dain, M. A., & Joly, I. (2020). Digital technologies in circular economy transition: Evidence from case studies. Procedia CIRP, 90, 133-136. https://doi.org/10.1016/j.procir.2020.01.028
[60] Pagoropoulos, A., Pigosso, D. C., & McAloone, T. C. (2017). The emergent role of digital technologies in the Circular Economy: A review. Procedia CIRP, 64, 19-24. https://doi.org/10.1016/j.procir.2017.02.047
[61] Calcagno, A. F., Dullien, S., Márquez-Velázquez, A., Maystre, N., & Priewe, J. (Eds.). (2015). Rethinking development strategies after the financial crisis (Vol. 2). UN.
[62] Wynn, M., & Jones, P. (2022). Digital technology deployment and the circular economy. Sustainability, 14(15), 9077. https://doi.org/10.3390/su14159077
[63] Shojaei, A., Ketabi, R., Razkenari, M., Hakim, H., & Wang, J. (2021). Enabling a circular economy in the built environment sector through blockchain technology. Journal of Cleaner Production, 294, 126352. https://doi.org/10.1016/j.jclepro.2021.126352
[64] Upadhyay, A., Mukhuty, S., Kumar, V., & Kazancoglu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. Journal of Cleaner Production, 293, 126130. https://doi.org/10.1016/j.jclepro.2021.126130
[65] Demestichas, K., & Daskalakis, E. (2020). Information and communication technology solutions for the circular economy. Sustainability, 12(18), 7272. https://doi.org/10.3390/su12187272
[66] Papamichael, I., Pappas, G., Siegel, J. E., Inglezakis, V. J., Demetriou, G., Zorpas, A. A., & Hadjisavvas, C. (2023). Metaverse and circular economy. Waste Management & Research, 0734242X231180406. https://doi.org/10.1177/0734242X231180406
[67] Balsmeier, B., & Woerter, M. (2019). Is this time different? How digitalization influences job creation and destruction. Research Policy, 48(8), 103765. https://doi.org/10.1016/j.respol.2019.03.010
[68] Leach, M., MacGregor, H., Scoones, I., & Wilkinson, A. (2021). Post-pandemic transformations: How and why COVID-19 requires us to rethink development. World Development, 138, 105233. https://doi.org/10.1016/j.worlddev.2020.105233
[69] Hilbert, M. (2022). Digital technology and social change: The digital transformation of society from a historical perspective. Dialogues in Clinical Neuroscience. https://doi.org/10.31887/DCNS.2020.22.2/mhilbert
[70] Xu, G., Li, G., Sun, P., & Peng, D. (2023). Inefficient investment and digital transformation: What is the role of financing constraints? Finance Research Letters, 51, 103429. https://doi.org/10.1016/j.frl.2022.103429
[71] Sahut, J. M., Dana, L. P., & Teulon, F. (2021). Corporate governance and financing of young technological firms: A review & introduction. Technological Forecasting and Social Change, 163, 120425. https://doi.org/10.1016/j.techfore.2020.120425
[72] De Giovanni, P. (2023). Sustainability of the metaverse: A transition to Industry 5.0. Sustainability, 15(7), 6079. https://doi.org/10.3390/su15076079
[73] Karampourniotis, P., & Fafaliou, I. (2022). The metaverse: A sustainable way for companies to compete. In Competitive Intelligence and Strategic Management (pp. 169–184). Springer.
[74] Grybauskas, A., Stefanini, A., & Ghobakhloo, M. (2022). Social sustainability in the age of digitalization: A systematic literature review on the social implications of industry 4.0. Technology in Society, 70, 101997. https://doi.org/10.1016/j.techsoc.2022.101997
[75] Huang, S., Wang, B., Li, X., Zheng, P., Mourtzis, D., & Wang, L. (2022). Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution. Journal of Manufacturing Systems, 64, 424-428. https://doi.org/10.1016/j.jmsy.2022.07.010
[76] European Commission, Directorate-General for Communication, Directorate-General for Research and Innovation. (2013). Responsible research and innovation (RRI), science and technology: Report. Publications Office. https://data.europa.eu/doi/10.2777/45726

[77] De Giovanni, P. (2023). Sustainability of the metaverse: A transition to Industry 5.0. Sustainability, 15(7), 6079. https://doi.org/10.3390/su15076079
[78] Khan, K. S., Hussain, A. K., Shoaib, M., Tahir, M. A., & Marwat, A. (2025). Metaverse and modern business: A bibliometric view on marketing, management, HR, and finance. Bulletin of Management Review, 2(1), 198-225. https://doi.org/10.1177/21582440211015818
[79] KPMG. (2022). Shaping the metaverse towards sustainability. https://assets.kpmg.com/content/dam/kpmg/dk/pdf/dk-2022/Shaping%20the%20Metaverse%20towards%20sustainability_final.pdf
[80] Buana, I. M. W. (2023). Metaverse: Threat or opportunity for our social world? In understanding metaverse on sociological context. Journal of Metaverse, 3(1), 28-33. https://doi.org/10.57019/jmv.1144470
[81] Xi, N., Chen, J., Gama, F., Riar, M., & Hamari, J. (2023). The challenges of entering the metaverse: An experiment on the effect of extended reality on workload. Information Systems Frontiers, 25(2), 659-680. https://doi.org/10.1007/s10796-022-10244-x
[82] Umar, A. (2022). Metaverse for UN SDGs – An exploratory study. Science-Policy Brief for the Multistakeholder Forum on Science, Technology and Innovation for the SDGs. https://doi.org/10.1007/978-981-99-5126-0_11
[83] Rane, N., Choudhary, S., & Rane, J. (2024). Metaverse as a tool for the achievement of SDGs: Challenges and opportunities. In M. Naved & A. K. Gupta (Eds.), How the Metaverse Will Reshape Business and Sustainability (pp. 105–129). Springer. https://doi.org/10.1007/978-981-99-5126-0_11
[84] Pellegrino, J., Ferraris, F., Rippa, M., & Papa, D. (2023). Metaverse for sustainable development: A bibliometric analysis and future research agenda. Sustainability, 15(1), 346. https://doi.org/10.3390/su15010346
[85] Naved, M., & Gupta, A. K. (2023). Metaverse as a tool for the achievement of SDGs: Challenges, opportunities, and applications. In M. Naved & A. K. Gupta (Eds.), How the Metaverse Will Reshape Business and Sustainability (pp. 105–129). Springer. https://doi.org/10.1007/978-981-99-5126-0_11
[86] Jauhiainen, J., Kallio, S., & Saari, M. (2024). Metaverse: A possible sustainability enabler in the transition from linear to circular economy. Procedia CIRP, 105, 85–90. https://doi.org/10.1016/j.procir.2023.12.014