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Sustainability Management in the Metaverse

A Multiple Case Study of Finnish Metaverse Developers

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ABSTRACT:
Kestävyyden integroimista metaversumin kehittämiseen pidetään edelleen vähän tutkittuna aiheena. Vaikka metaversumi nähdään yhä useammin merkittävänä digitaalisena kehitysympäristönä, sen yhteyttä kestävään kehitykseen – erityisesti ympäristön, yhteiskunnan ja hallinnon (ESG) näkökulmista – tarkastellaan tutkimuskirjallisuudessa edelleen rajallisesti. Useimmat aiemmat tutkimukset keskittyvät teknologisiin ulottuvuuksiin, jolloin jää epäselväksi, miten kestävyys ymmärretään ja toteutetaan käytännössä, erityisesti siirryttäessä teollisuuden neljännestä vallankumouksesta (Industry 4.0) viidenteen (Industry 5.0). Tässä tutkimuksessa pyritään paikkaamaan tätä aukkoa selvittämällä, miten kestävyyttä johdetaan suomalaisessa metaversumiekosysteemissä. Tutkimus tarjoaa uusia näkökulmia kestävyyden mahdollisuuksiin ja haasteisiin. Tutkimus toteutetaan laadullisena monitapaustutkimuksena, jossa tarkastellaan neljää suomalaista organisaatiota teollisuuden, pelialan ja julkisen sektorin piiristä. Aineisto kerättiin kuudella puolistrukturoidulla haastattelulla ja täydennettiin toissijaisilla lähteillä, kuten yritysraporteilla. Analyysissa on hyödynnetty Gioia-metodologiaa, jonka avulla suoritettu systemaattinen koodaus ja siitä rakennettu empiiriseen aineistoon pohjautuva malli kuvaa kestävyyteen liittyvien strategioiden, käytäntöjen ja mittareiden keskinäisiä suhteita. Liitettäessä empiiriset havainnot Industry 4.0– ja Industry 5.0 -viitekehyksiin, hahmottuu metaversumi kehittyvänä ekosysteeminä sen sijaan, että sitä tarkasteltaisiin vain teknologisena alustana. Tuloksista ilmenee, että kestävyys asetetaan strategisella tasolla tärkeäksi tavoitteeksi – painopisteinä ovat muun muassa resilienssi, eettinen suunnittelu ja hiilidioksidipäästöjen vähentäminen. Käytännön tasolla kestävyys kuitenkin näyttäytyy hajanaisena. Ympäristönäkökulmia tuetaan esimerkiksi digitaalisten mallien hyödyntämisellä materiaalinkulutuksen vähentämiseksi sekä etäyhteyksien avulla saavutettavilla päästövähennyksillä. Sosiaaliset ja eettiset ulottuvuudet, kuten saavutettavuus ja osallisuus, tunnistetaan kyllä, mutta ne jäävät usein tavoitteiksi ilman konkreettista toimeenpanoa. Tutkimuksessa havaitaan myös useita kehityshaasteita: korkeat kustannukset, nopea teknologinen vanheneminen, hajautunut yhteistyö sekä riskit, jotka liittyvät digitaaliseen eriarvoistumiseen ja markkinoiden keskittymiseen. Vaikka kestävyys sisällytetään organisaatioiden visioihin, se huomioidaan käytännössä usein vasta teknologisten tavoitteiden saavuttamisen jälkeen. Tämä osoittaa selkeän kuilun strategisten tavoitteiden ja operatiivisten käytäntöjen välillä. Tämä tutkimus edistää akateemista keskustelua kestävyyden ja Industry 5.0:n yhdistämisestä immersiivisiin digitaalisiin ympäristöihin. Tulokset korostavat tarvetta monitieteiselle lähestymistavalle, jossa teknologia, liiketoiminta ja kestävän kehityksen tavoitteet yhdistyvät. Käytännön tasolla tutkimus tuo esiin, että kestävyyden tulisi ohjata metaversumin kehitystä jo sen alkuvaiheista alkaen. Lisäksi suositellaan eri sektoreiden välisen yhteistyön vahvistamista sekä kestävyyden sisällyttämistä rahoitus- ja sääntelykehyksiin. Tutkielma päätetään suosituksiin, joissa kehotetaan kehittämään yhtenäisiä kestävyyden mittareita ja eettisiä periaatteita, joiden avulla voidaan tukea kestävämmän ja osallistavamman metaversumiekosysteemin rakentamista.

KEYWORDS: Metaverse, Sustainability, Industry 5.0, Industry 4.0, Human-centricity, Finland

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ABSTRACT:
The integration of sustainability into the development of the Metaverse remains an underexplored area of research. While the Metaverse has gained attention as a transformative digital environment, its intersection with sustainability, particularly across environmental, social, and governance (ESG) dimensions, has received limited academic focus. Much of the existing literature emphasises technological aspects, leaving gaps in understanding how sustainability is conceptualised and operationalised, especially during the transition from Industry 4.0 to Industry 5.0. This thesis addresses these gaps by exploring how sustainability is managed within the Finnish Metaverse sector, offering insights into both opportunities and challenges. This qualitative multiple case study focuses on four Finnish organisations across industrial, gaming, and public sectors. Data were collected through six semi-structured interviews and complemented by secondary sources such as company reports. The analysis followed the Gioia methodology, enabling systematic coding and the development of a grounded model illustrating the relationship between sustainability strategies, practices, and metrics. By integrating empirical findings with Industry 4.0 and Industry 5.0 frameworks, the study provides a novel conceptualisation of the Metaverse as an evolving ecosystem rather than a fixed technological platform. The findings reveal that sustainability is prioritised at the strategic level through goals related to resilience, ethical design, and carbon reduction. However, its operational integration remains fragmented. Organisations primarily focus on environmental sustainability, for example by using digital models to reduce material consumption and enabling remote operations to lower emissions. Social and ethical dimensions were less systematically addressed, with inclusivity and accessibility remaining largely aspirational. Key challenges include high development costs, rapid technological obsolescence, fragmented industry collaboration, and risks of monopolisation and digital exclusion. Although sustainability is embedded in organisational visions, it is often addressed only after technological milestones are achieved, highlighting a gap between strategic aspirations and operational practices. This study contributes to academic discourse by extending sustainability and Industry 5.0 debates into immersive digital environments. It underscores the need for interdisciplinary approaches bridging technology, business, and sustainability studies. Managerially, the research highlights the importance of embedding sustainability early in Metaverse development, strengthening cross-sector collaboration, and integrating sustainability criteria into funding and policy frameworks. The thesis concludes with recommendations for developing standardised sustainability metrics and ethical guidelines to support a more sustainable and inclusive Metaverse ecosystem.

KEYWORDS: Metaverse, Sustainability, Industry 5.0, Industry 4.0, Human-centricity, Finland

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1 Introduction

1.1 Background for the study

In 2021, the European Commission emphasised that the features of Industry 5.0—human-centricity, sustainability, and resilience—are essential for European industries to remain competitive, future-ready, and adaptable to geopolitical, economic, and technological disruptions. Within this evolving landscape, the Metaverse has emerged as a transformative digital ecosystem, raising questions about its sustainability, governance, and societal impact. Finland has explicitly positioned itself as an aspiring leader in Metaverse development within Europe, supported by public initiatives such as Business Finland's national Metaverse strategy. However, while technological development has advanced rapidly, sustainability considerations remain underexplored in both academic research and practice. This study seeks to address this gap by investigating how sustainability is conceptualised and managed within Finland's Metaverse initiatives. This research also reflects my academic interest in sustainability management and digital innovation, aligning with my background in examining the intersection of emerging technologies and responsible business practices.

1.2 Research gap

The integration of sustainability within the Metaverse presents a complex and underexplored area due to its emerging nature. While the Metaverse itself has gained attention in academic and industry discussions, the intersection of sustainability and the Metaverse remains largely unexplored. The term "Metaverse" is still in development, and its broad, evolving nature creates significant challenges in defining and integrating sustainability principles effectively. Current literature tends to focus primarily on technological aspects, leaving a gap in understanding how sustainability considerations such as environmental, social, and governance (ESG) are managed in this new digital space. The lack of comprehensive literature on this topic presents a critical gap, as there is still much, we do not know about how sustainability applies to the Metaverse. This research seeks to fill that gap by exploring sustainability challenges, such as energy consumption, equity in technology access, and responsible consumption, and their relationship with the development of the Metaverse.

The challenge of conceptualising sustainability in the Metaverse is compounded by its status as an emerging concept. As this virtual space is still in its infancy, its long-term development and the full integration of sustainability principles remain speculative. This situation is further complicated by the lack of clear regulations and established frameworks. Given that the Metaverse is a novel digital space, it is crucial to understand how it fits within the broader technological landscape, particularly in relation to Industry 4.0 and the ongoing shift to Industry 5.0. The transition from Industry 4.0 to Industry 5.0 represents a shift from automation and efficiency to human-centricity, resilience, and sustainability. However, this shift and its influence on the Metaverse's sustainability development are not well-documented, and the potential challenges and opportunities it presents have been largely overlooked. One of the key research questions this study will address is: How is sustainability conceptualised in the Metaverse, and how is it positioned within the frameworks of Industry 4.0 and 5.0?

While significant technological changes are underway, the future implications of these shifts on sustainability within the Metaverse remain uncertain. Existing literature primarily focuses on technological advancements but fails to adequately address how the transition to Industry 5.0 will affect the sustainability goals of Metaverse development. This gap underscores the need for further research to examine the evolving role of sustainability as it intersects with these broader industrial shifts. The evolving nature of these frameworks necessitates research to better conceptualise how sustainability will be integrated into the Metaverse as part of Industry 5.0. Research Objective 1 (RO1) specifically aims to explore these conceptual challenges by examining how sustainability is positioned within these two industrial paradigms.

Another significant gap in the literature is the limited understanding of the opportunities and challenges involved in managing sustainability within the Metaverse. As the Metaverse is still an emerging space, the opportunities it presents, such as new digital markets, operational efficiencies, and enhanced collaboration, are not fully realised. At the same time, the challenges that range from market cannibalisation to environmental concerns related to energy consumption are not well understood. Identifying and addressing these challenges, while also exploring the opportunities, is crucial for effectively managing sustainability in the Metaverse. Research Objective 2 (RO2) will investigate these aspects, focusing on both the opportunities and difficulties that companies face in integrating sustainability into Metaverse development.

The third gap lies in the lack of established practices, strategies, and metrics to manage sustainability within the Metaverse. Traditional sustainability frameworks, such as the triple bottom line (TBL) or ESG criteria, have not been fully adapted for the unique environment of the Metaverse. While metrics for sustainability, such as energy consumption, emissions, and social impacts, are well-established in other industries, their application to the Metaverse remains speculative. This research aims to examine current practices and strategies used by Metaverse developers, and identify what frameworks or tools are being employed to manage sustainability. Research Objective 3 (RO3) will address this gap by investigating the practices and metrics currently being used and exploring how they can align with broader sustainability standards.

Lastly, the role of regional developers, particularly Finnish Metaverse developers, in shaping the sustainability landscape of the Metaverse has not been sufficiently explored. Finland is one of the first countries to develop a national Metaverse strategy, and its approach to sustainability may offer valuable insights for global practices. By examining the sustainability practices of Finnish developers, this study aims to extract lessons that can inform broader, global frameworks for sustainability management in the Metaverse. Research Objective 4 (RO4) will explore how the practices of Finnish Metaverse developers can inform global sustainability strategies.

In conclusion, this research seeks to address critical gaps in the literature by conceptualising sustainability in the context of the Metaverse, exploring its integration within the frameworks of Industry 4.0 and 5.0, and identifying both the opportunities and challenges in managing sustainability in this digital space. By focusing on the Finnish Metaverse development landscape, the study will provide valuable insights that contribute to the development of future sustainability frameworks in digital environments. The study will also offer contributions to the conceptualisation of the Metaverse, providing a deeper understanding of its evolving role in the broader technological and sustainability landscape.

1.3 Research question and objectives

The purpose of this dissertation is to explore the role of sustainability in the Metaverse, with a specific focus on how sustainability is managed within this emerging digital space. The central research question (RQ) guiding this study is:

RQ: How is sustainability managed in the Metaverse?

This question will be addressed through a series of research objectives (ROs), which will guide the investigation of the Metaverse in relation to sustainability. As the Metaverse is an emerging concept and existing literature is limited, it is essential to explore how the Metaverse is positioned within the broader technological landscape and to identify the challenges and opportunities it presents. Given that the Metaverse is still in its conceptual phase and the full impact of Industry 5.0 on its development remains uncertain, the objectives of this study aim to provide a comprehensive understanding of the sustainability aspects of the Metaverse.

RO1: What is the conceptualisation of sustainability in the Metaverse, and how is it positioned within Industry 4.0 and Industry 5.0?

This objective aims to explore how sustainability is defined and understood in the context of the Metaverse, and how it aligns with the broader technological shifts in Industry 4.0 and 5.0.

RO2: What are the opportunities and challenges in managing sustainability in the Metaverse?
This objective focuses on identifying both the potential benefits and the difficulties faced by organisations in integrating sustainability within the Metaverse.

RO3: What are the practices, strategies, and metrics used to manage sustainability in the Metaverse?
This objective will investigate the approaches and tools currently employed to manage sustainability in the Metaverse, including any existing frameworks, best practices, and performance indicators.

RO4: How are Finnish Metaverse developers managing sustainability, and how can these practices inform general frameworks for sustainability in the Metaverse?
This objective examines the practices of Finnish Metaverse developers, with the goal of extracting insights that could inform global strategies for sustainability management within the Metaverse.

In conclusion, this study aims to contribute to the expanding body of knowledge at the intersection of digital innovation and sustainability, particularly within the context of the Metaverse. By focusing on the Finnish Metaverse development landscape, this research provides practical insights that can inform the creation of future frameworks for sustainability in digital environments. Additionally, this study contributes to the field by conceptualising an emerging phenomenon, offering a deeper understanding of how sustainability is integrated into the Metaverse and its evolving role in the broader technological landscape.

1.4 Structure

This thesis is structured into eight chapters. Chapter One introduces the research topic, outlines the research objectives and questions, and presents the structure of the study. Chapter Two defines key concepts focusing on Industry 5.0 and the Metaverse and reviews the literature on Metaverse technologies, including their drivers, barriers, and underlying technological components.

Chapter Three examines sustainability as a multidimensional concept, discussing its significance and relevance within both academic and business contexts. Moreover, it assesses sustainability in the specific context of the Metaverse, identifying opportunities, challenges, and gaps in the current research and practice. Chapter Four concludes the literature review.

Chapter Five presents the research methodology, including the case study design, data collection, and analysis process. Chapter Six reports the empirical findings, organised thematically around strategies, practices, and metrics of sustainability management in the Finnish Metaverse Initiative. Chapter Seven provides a discussion of the findings in relation to the literature, outlines the theoretical and managerial contributions, and concludes with recommendations for future research and practice.

2 The Metaverse: A Continuation of Industry 4.0 and 5.0

This chapter outlines the technological and industrial context in which the Metaverse has emerged, focusing on the transition from Industry 4.0 to Industry 5.0 and their implications for digital transformation and sustainability.

2.1 The Progression from Industry 4.0 to Industry 5.0

The following section provides an overview of Industry 4.0 and Industry 5.0, discussing their defining characteristics, the differences between them, and the technologies associated with each. It also considers the current stage of this industrial transition and examines how these evolving paradigms contribute to the development of digital ecosystems such as the Metaverse. By exploring both technological advancements and broader strategic objectives, this section aims to contextualise the Metaverse as an emergent phenomenon shaped by successive waves of industrial innovation.

2.1.1 Industry 4.0

The Fourth Industrial Revolution is a 21st-century phenomenon that began with the German government's high-tech strategy in 2011, aimed at automating the manufacturing sector (Xu et al., 2021, p. 530; Gordan, 2023, p. 2; Varriale et al., 2023, p. 1). It represents a continuation of the previous three industrial revolutions. The First Industrial Revolution saw the transition from manual labour to water and steam-powered machinery. The Second Industrial Revolution introduced electricity, transforming factories into high-productivity production lines. The Third Industrial Revolution, in turn, brought about automation through the advent of computers and communication technology (Xu et al., 2021, p. 530). Building on these earlier revolutions, the Fourth Industrial Revolution aims to achieve mass efficiency in producing high-quality, personalised products (Xu et al., 2021, p. 530). Originally conceptualised as Industry 4.0, it seeks to enhance technological competitiveness among companies, thereby ensuring their survival both in the present and future (Varriale et al., 2023, p. 1).

Xu et al. (2021, p. 532) emphasize that Industry 4.0 is a technology-driven revolution which aims to achieve high efficiency and productivity. Hence, Industry 4.0 introduced technologies such as Big Data and analytics, Cloud, Internet of Things (IoT), Augmented Reality (AR), Simulation as well as horizontal and vertical system integration and autonomous robots. Despite the development of such technologies, some argue that Industry 4.0 is still unfolding and has not yet reached its full potential due to difficulties in implementing Industry 4.0 technologies in classic supply chains and smaller businesses (Ghobakhloo et al., 2023, p. 1474).

2.1.2 Industry 5.0

Xu et al. (2021, p. 532) explain that the interest to Industry 5.0 has steadily risen since 2017. In 2021 the European Commission released a paper called "Industry 5.0: Towards a Sustainable, Human-centric, and Resilient European Industry ", which called for the Fifth Industrial Revolution (Xu et al., 2021, p. 532; European Commission, 2021, p. 3). The paper (European Commission, 2021, p. 3) describes Industry 5.0 a resilient provider of prosperity which compelements the existing Industry 4.0.

Aslam et al. (2020, p. 9) note that although businesses struggle with the challenges of Industry 4.0, the rapid advancements in IoT and information technology signal the impending arrival of Industry 5.0. Aslam et al. (2020, p. 9) continue that while opinions differ on when the next industrial revolution, Industry 5.0, will commence, its rapid technological evolution suggests an earlier arrival than expected. Hence, businesses must adapt now to thrive in this impending revolution.

On the contrary to Aslam et al. (2020, p. 9), some argue that Industry 5.0 is not a continuum of Industry 4.0 nor a replacement to it. Rather, it can be explained by technological Industry 4.0 and value-centric Industry 5.0 coexisting together (Narkhede et al., 2024, p. 9; Valette et al., 2023, p. 1–2). Awouda et al. (2024, p. 2) enhance that the notable difference is that Industry 5.0 have principles which are built on the technologies of

Industry 4.0. Moreover, Xu et al. (2021, p. 530) describe that “Age of Augmentation” wherein humans and machines collaborate symbiotically, have been a discussion in Industry 5.0. Aslam et al. (2020, p. 9) stress that despite the impacts of Industry 5.0 being uncertain, it is evident that it will dissolve the boundaries between the physical and virtual realms.

Whereas Industry 4.0 focuses on technological development, The fifth industrial revolution is characterized by human-robot collaboration (cobot) and advanced technologies that are driven by an ideology: Industry 5.0 will fill the requirements of current generation without restricting the ability of future generations to fulfil their needs (Narkhede et al., 2024, p. 2). The emphasis is on complex technological systems that combine smart materials, bio-inspired sensors, and integrating human safety and wellbeing to the design with cobots, Augmented Reality (AR) and Virtual Reality (VR), Digital Twins (DT), Data transmission and storage as well as technologies for energy efficiency and renewable energy sources (Valette et al., 2023, p. 9–12; Xu et al., 2021, p. 533). Further, Industry 5.0 aims to meet the sustainability standards that were set to Industry 4.0 but were failed to implement (Ghobakhloo et al., 2023, p. 432).

According to Awouda et al. (2024, p. 2–3) and European Commission (2021, p. 3) Industry 5.0’s sustainability standards can be divided into three: human-centricity, sustainability, and resilience. As these concepts are complex by nature, they can have perceptions depending on the scientific discipline, the field of application or time/industry scale (Valette et al., 2023, p. 2). Ghobakhloo et al. (2023, p. 1474) describe that some of the micro and macro sustainability concerns that are expected of Industry 5.0 to tackle are employment disruption and autonomy in workplaces, overconsumption, digital divide, and unequal regional development. Moreover, Narkhede et al. (2024, p. 21) predict that the Triple-Bottom-Line of sustainability will be a driver to the adoption of Industry 5.0.

Interestingly, Industry 5.0 differs from other industrial revolutions due to not having a technological pulling power (Ghobakhloo et al., 2023, p. 1474). Hence, Industry 5.0 is defined as technopolitical phenomenon. Industry 5.0 employs technology to reach its values, however, needs regulatory and governance to shift the transformation towards human and environmental values (Ghobakhloo et al., 2023, p. 1474–1477). Moreover, Industry 5.0 prioritizes long-term socio-environmental sustainability and stakeholder value over shareholder value and short-term profitability which characterize Industry 4.0. Ghobakhloo et al. (2023, p. 1477) describe Industry 4.0 is productivity driven which causes maximising shareholder value to be the driver for technological innovation and transformation to Industry 4.0. Contrary to Industry 4.0, Industry 5.0's agenda emphasizes the crucial role of stakeholders' participation in overseeing and managing the digital industrial transformation, highlighting its indispensability in achieving sustainability goals (Ghobakhloo et al., 2023, p. 1477).

According to Leng et al. (2022, p. 289), the strategies adopted by various countries toward Industry 5.0 reflect their diverse approaches and priorities. In the USA, initiatives like the "Advanced Manufacturing Partnership" aim to revitalize the manufacturing sector amid economic challenges. Germany focuses on establishing a comprehensive ecosystem for transitioning from Industry 4.0 to Industry 5.0 through initiatives like the "Smart Factory" concept. The UK's "UK Industry 2050 Strategy" seeks to counter the effects of decentralization strategies and foster modern industrialization. France aims to promote economic recovery and prepare for Industry 5.0 with initiatives like the "New Industrial France" program. Japan emphasizes human-centric development through concepts like "Society 5.0" alongside strategies such as the "New Industrial Structure Blueprint." Meanwhile, China's focus is on accelerating the transformation of its manufacturing industry toward intelligence, greenness, and service-oriented upgrades, as outlined in initiatives like the "14th Five-Year Plan” (Leng et al., 2022, p. 289).

Furthermore, the current technological landscape highlights the role of human-centric technologies as both supportive and enabling tools for addressing human variability, including physical and cognitive conditions (Valette et al., 2023, p. 13). The widespread use of embedded internet-connected devices, along with advancements in technologies like causal AI, explainable AI, Digital Twins, and Augmented/Virtual/Mixed reality, serves as tangible vectors which contribute to making systems more understandable and thereby more acceptable.

2.2 Understanding the Concept of the Metaverse

This section provides an overview of the Metaverse concept, tracing its historical development, defining its ideology and core features, and examining how it differs from related technologies such as virtual reality and augmented reality. By exploring both its technological foundations and its socio-economic aspirations, the section positions the Metaverse as a key evolution of digital ecosystems shaped by Industry 4.0 and potentially aligned with Industry 5.0 principles.

2.2.1 The Historical Development of the Metaverse Concept

The term Metaverse was first introduced in Neal Stephenson's 1992 science fiction novel Snow Crash, where it described a virtual universe parallel to the physical world (Uddin et al., 2023, p. 87089; Schöbel & Leimeister, 2023, p. 2). The word combines meta (meaning "beyond" or "transcending") and verse (from "universe"). Inspired by this vision, early virtual environments emerged, such as Alpha World in 1995, where users could build virtual structures using prefabricated objects (Johri et al., 2024, p. 2). This laid the groundwork for platforms like Habbo Hotel and Second Life, which popularised digital avatars and social interactions in three-dimensional virtual worlds (Johri et al., 2024, p. 2).

A pivotal moment occurred in 2021 when Facebook rebranded as Meta, signalling a renewed corporate focus on building interconnected virtual environments (Uddin et al., 2023, p. 87089). Since then, the Metaverse has gained widespread attention, with organisations investing in its development and exploring its potential applications (Tlili et al., 2023, p. 266).

Over time, the Metaverse concept has expanded beyond early interpretations as a virtual reality space for interaction. It now encompasses a broad range of digital platforms, each functioning as a distinct ecosystem with its own actors, resources, and operational logics (Schöbel & Leimeister, 2023, p. 1). Uddin et al. (2023, p. 87089) describe it as the fifth generation of the internet, where avatars engage in political, economic, social, and cultural activities within immersive three-dimensional environments.

Johri et al. (2024, p. 2) outline three evolutionary phases of Metaverse development: (1) Digital twins replicating real-world objects, with scalability but lacking emotional or cognitive layers, (2) Avatars and infrastructure, allowing creative representation and expanded capabilities in virtual spaces, (3) Mature convergence, where virtual creations surpass physical-world counterparts and avatars bridge digital and physical realities.

Similarly, Wang et al. (2023, p. 323) highlight three defining characteristics: avatars representing users, virtual environments simulating diverse spaces, and digital trade enabling the exchange of virtual goods and services. Njoku et al. (2023, p. 7) emphasise that this embedded transactional dimension distinguishes the Metaverse from earlier virtual environments.

2.2.2 Ideology and Defining Features of the Metaverse

Described as meta, the Metaverse aspires to be an ultra-realistic, accessible, pervasive, and potentially decentralised digital universe (Leng et al., 2022, p. 288). While some interpretations define it narrowly as Persistent Virtual Reality (PVR), broader perspectives see it as the culmination of digital transformation trajectories.

According to Rosenstand et al. (2023, p. 63), three experiential features define the Metaverse: immersion, real-time interactivity, and user agency. These are enabled by artificial intelligence (AI), virtual reality (VR), augmented reality (AR), digital twins, and blockchain (Hwang & Chien, 2022, p. 1; Mourtzis, 2023, p. 1105; Wang et al., 2023, p. 323). Leng et al. (2022, p. 288) summarise the Metaverse as an experience in which users—human or otherwise—perceive the world as a digital universe, whether via virtual, augmented, or mirrored digital realities. Martínez-Gutiérrez et al. (2024, p. 4) highlight the critical role of digital twins in bridging industrial and virtual domains within an industrial Metaverse context.

However, Park and Kim (2022, p. 4210) caution that VR and AR should not be conflated with the Metaverse. While VR/AR are important tools, the Metaverse represents a more expansive platform that enables content creation, service provision, and large-scale social interaction—potentially independent of immersive hardware. Achieving a functional Metaverse requires technological advances such as improved GPU capacity, 5G connectivity, and enhanced recognition and expression models to sustain user participation (Park & Kim, 2022, p. 4210).

Schöbel and Leimeister (2023, p. 1) further conceptualise Metaverse platforms across four perspectives: innovation, production, transaction, and social interaction. Anshari et al. (2022, p. 2) suggest that this multifaceted nature offers opportunities for co-creation, fostering innovation, productivity, and creativity. Business applications span remote work, virtual collaboration, healthcare (e.g., remote surgeries), and immersive learning (Uddin et al., 2023, p. 87087). Despite these opportunities, ethical challenges persist. Sustainability research points to unresolved concerns about data ownership, transparency, and responsible use of big data in Metaverse environments (Anshari et al., 2022, p. 2).

From a sustainability perspective, the Metaverse, as part of Industry 5.0 technological evolution, holds both promise and risk. De Giovanni (2023, p. 2) argues that while the Metaverse may align with Industry 5.0 principles of responsibility and human-centricity, it also introduces social challenges such as shifting work patterns, job displacement, and reduced physical interaction. Similarly, the environmental impacts of data infrastructure and particularly data centres and ICT energy demands, raise concerns about growing carbon emissions (De Giovanni, 2023, p. 2; Chiaroni et al., 2023, p. 258; Uddin et al., 2023, p. 87094). Nonetheless, De Giovanni (2023, p. 27) stresses that the Metaverse's early-stage development still offers opportunities for responsible design and implementation. Proactive sustainability measures are critical to mitigating negative externalities and realising the Metaverse's transformative potential.

2.3 Technologies within the Metaverse

This section introduces the core technologies that underpin the Metaverse, including artificial intelligence, virtual reality, augmented reality, blockchain, and digital twins. It explains how these technologies interact to create immersive, interactive, and persistent virtual environments. By mapping the technological foundations of the Metaverse, this section provides essential context for understanding its potential applications, opportunities, and challenges within the framework of Industry 4.0 and Industry 5.0.

The Metaverse is founded on a selection of technologies that support immersive experiences with digital avatars, virtual environments, and goods and services (Wang et al., 2023, p. 323). Key enabling technologies include AI (artificial intelligence), VR (virtual reality), Digital Twins, and Blockchain (Hwang & Chien, 2022, p. 1; Mourtzis, 2023, p. 1105; Wang et al., 2023, p. 323). These technologies are supported by the IoT (Internet of Things), which connects objects across virtual and physical realms (Valette et al., 2023, p. 2). The scope of the Metaverse extends to wearable devices and human-robot collaboration, such as Cobots3, which are deemed crucial for adoption and immersion, thereby enhancing the primary value of the Metaverse (Hwang & Chien, 2022, p. 1–2; Leng et al., 2022, p. 288). Furthermore, the development of energy-efficient technologies is essential to address sustainability concerns associated with increasing energy consumption in the Metaverse (Jauhiainen et al., 2023, p. 4).

According to Awouda et al. (2024, p. 2) **Internet of Things (IoT)** and digital twins have a symbiotic relationship where the data is contributed by IoT, and digital twin uses the data to build dynamic models of their physical twin. Valette et al. (2023, p. 2) describe IoT as an open and comprehensive network of things that is connected to physical objects in a set of a system that is simultaneously connected to multiple objects. Martínez-Gutiérrez et al. (2024, p. 2) describe IoT one of the main enabling technologies of metaverse.

Under Industry 5.0, **Artificial Intelligence (AI)** is focusing on advanced learning technologies and data analysis (Valette et al., 2023, p. 11). Further, with AI, causality- and correlation-based relation in network systems (human or artefactual) can be analysed and converted to data sets. For learning technologies, Deep Learning has become an important field of study (Valette et al., 2023, p. 11–12). However, Ghobakhloo et al. (2023, p. 435) describe the current AI variants uncapable to reach their full potential which would be Cognitive Artificial Intelligence (CAI). Cognitive Artificial Intelligence (CAI), formed by integrating AI and artificial consciousness, aims to surpass current AI limitations, particularly pivotal in Critical Cyber-Physical (C-CCP) systems. Envisioned as a vital technology in Industry 5.0, CAI's potential lies in enhancing decision-making, reducing errors, and fostering self-healing AI through the integration of sensory information and advanced learning mechanisms. Hwang and Chien (2022, p. 1–2) enhance the role of AI in decision-making in metaverse platforms. AI based arbitration and simulation enable the use of metaverse in education, military training, language learning, and manufacturing.

Further, **Dynamic Simulation and Digital Twin (DSDT) technologies** are data-driven and built on AI, the Internet of Everything (IoE), big data, and adaptive analytics constructing a complex virtual model by integrating historical and real-time data (Awouda et al., 2024, p. 22; Valette et al., 2023, p. 2-10; Ghobakhloo et al., 2023, p. 436). Due to enabling the bridging of virtual and physical worlds, Digital Twin technologies are crucial to the development of metaverse (Martínez-Gutiérrez et al., 2024, p. 2). Dynamic Simulation and Digital Twin (DSDT) technologies, as described by Ghobakhloo et al. (2023, p. 436), merge physical and virtual realms, enabling proactive data analysis and monitoring of complex systems. Digital twins are virtual replicas of physical objects and processes which support complex systems monitoring, data-driven decision-making, and product validation by integrating data between physical objects and virtual environments (Awouda et al., 2024, p. 1). This connection enables remote management, real-time monitoring, and simulation, allowing for virtual scenario planning before implementing decisions in real life. The synergy between the physical and cyber worlds forms a Cyber-Physical System (CPS) (Valette et al., 2023, p. 2). Notably, the development of CPS in an industrial setting relies heavily on the integration of Digital Twins (Awouda et al., 2024, p. 6).

Moreover, Ghobakhloo et al. (2023, p. 435) explain that Cognitive Cyber-Physical Systems (C-CCP) is an upgrade from the Cyber-Physical-System. Cognitive Cyber-Physical Systems (C-CCP) enhances human-machine interaction through a sense-analyse-compute-act cycle, incorporating self-awareness and proactive responses. Using components like sensors, robotics, and advanced communication technologies, C-CCP excels in pattern detection, failure correction, and informed decision-making in ongoing operations (Ghobakhloo et al., 2023. p. 435).

Similarly to the concept of Digital Twin, Park and Kim (2022, p. 4211) describe Mirror World as a digital copy of our current world. More specifically, Mirror World replicates real-world information in a digital space, adding extra simulation data. For example, Google Earth creates a digital replica of reality with its own unique properties and functions. Park and Kim (2022, p. 4211) note that while similar concepts like Metaverse, multiverse and mirror world exist, they may have slight variations depending on context but share common underlying principles.

According to Ghobakhloo et al. (2023, p. 435–436) **Extended Reality (XR)** includes immersive technologies, including Augmented, Virtual, and Mixed Reality. Park and Kim (2022, p. 4216) continue that Mixed Reality (MR) combines Virtual Reality (VR) and Augmented Reality (AR), allowing users to interact with virtual objects in a 3D environment. AR provides a realistic experience with simple hardware like glasses, suitable for short content, while VR offers full immersion but may cause fatigue, suitable for longer content.

Mixed Reality (MR) leverages both AR and VR advantages, offering a versatile solution with a single device. Extended Reality (XR) includes VR, AR, and MR, used in virtual commerce (v-commerce) to create computer-mediated indirect experiences (Park & Kim, 2022, p. 4216).

XR technologies offer benefits like enhanced customer experience, advanced training, real-time fault diagnostics, and improved safety in industrial processes. Although the extended reality (XR) market is experiencing rapid growth, the adoption of XR technologies presents challenges such as data processing, motion tracking, and connectivity (Ghobakhloo et al., 2023, p. 435–436). However, Ghobakhloo et al. (2023, p. 435–436) anticipate that the challenges will be addressed through advancements in big data, edge computing, 6G, and AI.

Further, Tlili et al. (2023, p. 261) explain that **blockchain technology** emerged as a solution to address privacy and security concerns in data exchanges and task automation providing a decentralized and encrypted option for both monetary transactions and data exchange. Hence, blockchain enables the creation of new and secure currencies within Metaverse ecosystems, such as non-fungible tokens (NFTs), which can function as trusted agents in monetary transactions. These technologies also support the development of interconnected digital environments, referred to as "ecospheres", which may reduce customer lock-in effects (Rosenstand, Brix, & Nielsen, 2023, p. 72). Moreover, Njoku et al. (2023, p. 7) highlight that NFT's make metaverse a creator economy where one can make use of Metaverse technologies to create experiences or assets and trade with them. As a result, the incorporation of cryptocurrencies into the metaverse holds social significance for individuals, thereby creating a key distinction between the metaverse and other virtual environments (Park & Kim, 2022, p. 4210; Njoku et al., 2023, p. 7). Despite the decentralisation and encryption of data, concerns about money laundering and financial scams persist with blockchain-based digital wallets in the metaverse, as emphasised by Tlili et al. (2023, p. 279).

Valette et al. (2023, p. 9–10) note that **bio-inspired technologies** can have green properties such as recyclability, reusability, self-healing, or self-repairing. Additionally, bio-inspired technologies can have properties that are either adapted or inspired by biological systems such as embedded sensors, ergonomics, living and traceable materials. Valette et al. (2023, p. 9–10) describe Human-System-Integration the most represented research subject in bio-inspired technologies. Human-System-Integration aims to enhance humans physical and cognitive abilities with embedded bio-sensor technology. Moreover, pervasive **smart materials** such as objects, sensors, and actuators form the foundational sensing and control infrastructure essential for the metaverse. These elements allow for a wide range of information to be collected from both surroundings and human bodies, making it easier to control devices with high precision (Wang et al., 2023, p. 322).

Similarly, **Industrial Smart Wearables (ISW)** and other wearable devices play a crucial role in Industry 5.0 and the metaverse by facilitating human-centricity. These technologies, as highlighted by Ghobakhloo et al. (2023, p. 436) and Wang et al. (2023, p. 322), empower users to engage more actively in virtual environments, bridging the gap between the physical and digital worlds. Advanced Industrial Smart Wearables (ISW) offer enhancements in worker safety, speed, and productivity. For example, bio-inspired protective gears, exoskeletons, and head-worn ISWs improve users' capabilities and navigation, while clothing ISWs utilise sensors to monitor vital signs (Ghobakhloo et al., 2023, p. 436). In the context of Industry 5.0, ISWs operate within the Cognitive Cyber-Physical Systems (C-CCP) framework, leveraging Cognitive Artificial Intelligence (CAI) and the Industrial Internet of Things (IIoT). These technologies enable ISWs to interact seamlessly with other advanced tools such as 3D printers, collaborative robots, and autonomous vehicles (Ghobakhloo et al., 2023, p. 436).

Additionally, **wearable devices** such as head-mounted display (HDM) and brain-computer interfaces (BCI) are crucial for metaverse adoption (Hwang & Chien., 2022, p. 1–2). Wang et al. (2023, p. 322) explain that VR/AR helmets enable users to control digital avatars in various activities within metaverse such as gaming, work, socializing, and interaction. The wearables rely on human-computer interaction (HCI) and extended reality (XR) technologies. However, prolonged use of head-mounted displays can lead to issues such as motion sickness, dizziness, and discomfort due to problems in data processing and motion tracking (Park & Kim, 2022, p. 4210; Ghobakhloo et al., 2023, p. 435–436).

Leng et al. (2022, p. 288) argue that metaverse's primary value lies in enhancing immersion and presence within **Human-Robot Collaboration (HRC)**. Accordingly, Leng et al. (2022, p. 287) finds four collaborative robot fields: Human-Robot Collaboration (HRC) and Human-Robot Interaction (HRI). Human-Robot Interaction (HRI) focuses on improving the user experience with robots by making them more user-friendly and convenient through various interaction methods like speech recognition and eye detection. The other, Human-Robot Collaboration (HRC) involves robots and humans working together on tasks within the same workspace, without any physical barriers separating them. Leng et al. (2022, p. 287) emphasize that in HRC, workers can work alongside robots, combining the strengths of both: the strength, endurance, and accuracy of robots with the intuition, flexibility, and problem-solving skills of humans. This collaboration aims to create user-centred products and services by combining human intelligence with cognitive computing. Hence, HRC aligns with the human-centric and resilient vision of Industry 5.0 and can improve productivity and worker well-being by enhancing flexibility and reconfigurability while reducing the potential errors of manual or robotic manufacturing (Leng et al., 2022 p. 287).

Moreover, Symbiotic Human-Robot Collaboration (HRC) creates a system where humans and robots interact together in a connected environment to complete complex tasks (Leng et al., 2022, p. 287). This differs from traditional HRC by giving the system advanced skills like perception, reasoning, decision-making, and learning through real-time communication. Proactive HRC goes further, enabling not only physical assistance but also cognitive understanding and empathy between humans and robots. This enhances collaboration, with humans adjusting actions for productivity while robots learn human intentions. Examples of Proactive HRC, include visual reasoning-based approaches and multimodal learning methods (Leng et al., 2022, p. 287).

On the contrary to Leng et al. (2022, p. 287), a more recent article of Ghobakhloo et al. (2023, p. 436) use terms of Intelligent or Adaptive Robots to describe the next generation of industrial robots in Industry 5.0. Adaptive Robots offer a higher level of human-centric automation, combining high productivity with the ability to adapt to complex environments. Possible application scenarios for Adaptive robots include precision assembly, part transportation, advanced assembly, and soft-material surface processing. These robots rely on advancements in computer vision, machine cognition, edge computing, and AI technologies. Similarly to HRC, Adaptive robots combine high productivity with the ability to adapt to complex environments. (Ghobakhloo et al., 2023, p. 436).

To address the high energy consumption of Industry 5.0 technologies, Ghobakhloo et al. (2023, p. 436), present **Intelligent Energy Management System (IEMS)** as the solution to energy efficiency and sustainability. Despite Industry 5.0's focus on energy efficiency for industrial productivity, the ongoing digitalization, smart products, and overconsumption has increased the energy demand. IEMS addresses this by enabling real-time monitoring and control of energy systems, improving technical and commercial efficiency in energy production, assessing energy quality, and enhancing overall system reliability (Ghobakhloo et al., 2023, p. 436). IEMS uses technologies like cloud demand response systems, smart storage, intelligent charging, microgrids, and blockchain-based peer-to-peer electricity trade. With this, it bridges the gap in developing renewable energy resources and integrating them into industrial and commercial operations (Ghobakhloo et al., 2023, p. 436). Given the high energy consumption of metaverse technologies, sustainability initiatives within the metaverse prioritize energy-efficient solutions to address this issue (Jauhiainen et al., 2023, p. 4).

2.4 Opportunities and Applications of Metaverse

This section introduces the diverse opportunities and practical applications of the Metaverse across sectors such as gaming, education, healthcare, tourism, transportation, and industry. Drawing on recent research, it highlights how the Metaverse is reshaping industries, while also discussing emerging ethical and sustainability considerations associated with its use.

The Metaverse industry is projected to grow at an impressive annual rate of 37.43 per cent, reaching an estimated market volume of USD 507 billion by 2030 (Statista, 2025). This expansion is expected to be largely driven by online gaming, which is forecasted to contribute nearly half of the total Metaverse revenue (Uddin et al., 2023, p. 87095). Leading technology companies, including NVIDIA, Tencent, Microsoft, Meta (formerly Facebook), and Unity, have expressed strong interest in developing Metaverse technologies, further intensifying research and innovation across multiple sectors. Notably, the fields of education, healthcare, and tourism have emerged as prominent areas for early Metaverse applications (Tlili et al., 2023, p. 270).

According to Uddin et al. (2023, p. 87095), gaming plays a pivotal role in the growth of the Metaverse, offering not only entertainment but also innovative platforms for addressing complex challenges. Games like Second Life, Roblox, and Fortnite exemplify how the Metaverse integrates into gaming environments, fostering social interaction, creativity, and immersive experiences. Furthermore, gaming-based Metaverse tools have been successfully applied in fields such as neurorehabilitation to assist patients' recovery (Uddin et al., 2023, p. 87095).

In education, the Metaverse has been adopted within Problem-Based Learning (PBL) frameworks, enabling immersive and interactive approaches to real-world problem-solving (Uddin et al., 2023, p. 87096). Hwang and Chien (2022, p. 3–5) identify three roles for non-player characters (NPCs) in educational Metaverse platforms: as tutors, providing guidance during learning; as students, allowing pre-service teachers to practice; and as peers, facilitating social constructivist learning. However, the adoption of Metaverse technologies in education also raises ethical concerns, including risks of bullying, privacy violations, academic dishonesty, and discriminatory practices (Hwang & Chien, 2022, p. 5).

In the tourism sector, the Metaverse integrates real-world destinations with virtual reality technologies to create more immersive and interactive travel experiences (Go & Kang, 2023, p. 383–384). This approach not only enhances visitor engagement but also offers opportunities for sustainable tourism development, particularly in targeting future digitally native generations such as Generation Alpha and Zeta. Existing applications include virtual exhibitions and escape rooms, which demonstrate how the Metaverse can augment traditional tourism activities (Go & Kang, 2023, p. 385–387).

The Metaverse is also anticipated to transform social experiences, encompassing virtual lifestyles, shopping, communication, and global travel, thereby reshaping social norms (Uddin et al., 2023, p. 87095). Wang et al. (2023, p. 326) highlight various applications, including virtual concerts with digital merchandise stores, virtual graduation ceremonies during the Covid-19 pandemic, and the establishment of virtual museums, showing how the Metaverse facilitates innovative forms of cultural and social interaction.

In the field of healthcare, the term MEDverse describes the integration of Metaverse technologies into medical applications (Uddin et al., 2023, p. 87097). Within virtual healthcare environments, patients can preview potential outcomes, such as plastic surgery results, enhancing communication and informed decision-making. Healthcare professionals use these platforms for knowledge sharing, teaching, and patient monitoring via digital twin technologies, facilitating more personalised care (Uddin et al., 2023, p. 87097).

Beyond these sectors, the Metaverse is also being explored in intelligent transportation systems, supporting applications such as fault detection, driver assistance, autonomous vehicles, automated traffic management, and simulation testing (Njoku et al., 2023, p. 7). These innovations contribute to sustainable transportation by enhancing safety, improving efficiency, and reducing environmental impacts (Johri et al., 2024, p. 10).

Salminen and Aromaa (2024, pp. 2110–2111) examine Finnish industrial Metaverse organisations and identify key applications including remote operations, design and planning, guidance, collaboration, training, and sales. Among these, remote maintenance emerged as the most prominent use case, enabling the supervision and operation of multiple terminals from a single location. Similarly, Leng et al. (2022, p. 288) and Guo et al. (2024, pp. 29–36) highlight the critical role of human-robot collaboration in achieving optimisation goals within industrial Metaverse environments. Although the industrial Metaverse remains at an early stage, it offers considerable potential for innovation, with a broad imaginative space for future applications. To fully realise this potential, Guo et al. (2024, pp. 36–37) propose optimising the entire product lifecycle through predictive AI models, product quality certification systems, and analytics-driven risk management frameworks.

2.5 Challenges of Managing the Metaverse

This section explores the multifaceted challenges associated with managing the Metaverse, drawing attention to technological, ethical, regulatory, environmental, and social dimensions. Despite the transformative potential of the Metaverse, its implementation and governance raise critical concerns related to inclusivity, sustainability, security, and fairness.

The Metaverse faces significant challenges that cut across accessibility, pricing, regulation, sustainability, energy efficiency, and security. Security risks are particularly relevant, encompassing identity theft, impersonation attacks, verification issues, data breaches, and social engineering tactics (Uddin et al., 2023, pp. 87097–87100; Wang et al., 2023, pp. 327–330). Widespread adoption may also be hindered by high costs, lengthy implementation processes, and public concerns over privacy, surveillance, and the need for robust regulation. Moreover, the immersive nature of the Metaverse raises additional questions about its influence on democratic spaces, requiring safeguards to protect civic participation (Allam et al., 2022, p. 792).

From a legal perspective, challenges arise regarding intellectual property rights, such as copyright infringements when replicating real-world artworks in virtual environments or transferring assets across platforms. These concerns underline the need for stronger judicial enforcement and standardisation of legal frameworks governing virtual spaces (Kaddoura & Al Husseiny, 2023, pp. 23–24). Regulatory challenges become even more difficult to address due to emerging ideas like the Darkverse, which, unlike the dark web, is not included in searchable databases and is extremely hard to monitor (Uddin et al., 2023, p. 87099). Establishing clear legislative frameworks will be essential to prevent conflicts among businesses, technologies, and society (Nahavandi, 2019, p. 11). The absence of regulations and standards is thus regarded as a major barrier to the large-scale adoption of the Metaverse (Uddin et al., 2023, p. 87099).

The Metaverse also presents health and wellbeing risks. Prolonged use of immersive technologies may contribute to addiction, physical inactivity, and strain-related health issues, including obesity (Tlili et al., 2023, p. 280). Accessibility remains a critical challenge, especially for individuals with visual impairments or other disabilities, raising concerns about inclusivity and equitable access (Allam et al., 2022, p. 793). Limited awareness and understanding of Metaverse technologies may further hinder adoption in sectors such as healthcare (Tlili et al., 2023, p. 280). Social inequalities risk being deepened, as marginalised groups—due to disparities in education, socioeconomic status, cultural background, or age—are more likely to be excluded from meaningful participation in the Metaverse (Kaddoura & Al Husseiny, 2023, p. 18; Mourtzis, 2022, p. 1117; Nahavandi, 2019, p. 11). Addressing inclusivity and accessibility will therefore be central to equitable Metaverse design and implementation.

The sustainability of the Metaverse is similarly under scrutiny. Growing adoption is expected to drive substantial increases in energy consumption, necessitating further research into energy efficiency (Wang et al., 2023, p. 347; De Giovanni, 2023, p. 2; Allam et al., 2022, p. 793). Technologies that underpin the Metaverse such as blockchain, artificial intelligence and cloud computing produce vast amounts of data, which are stored in data centres. These centres can account for up to one fifth of a country's total energy consumption (Asif et al., 2023, p. 423; The Economist, 2025). Moreover, the production and disposal of related technologies generate significant electronic waste, raising environmental and health concerns (Nahavandi, 2019, p. 11). Rapid and large-scale manufacturing may further contribute to overproduction and unsustainable consumption patterns. Consequently, future Metaverse designs must align with human-centric and sustainable principles, as advocated by Industry 5.0 (Wang et al., 2023, p. 347).

Privacy and ethical concerns are also prominent. The Metaverse raises risks related to the exploitation of user digital footprints for profiling and data monetisation (Anshari et al., 2022, p. 9). Data collected in the Metaverse may surpass social media in sensitivity and potential for misuse, underscoring the need for stronger ethical safeguards. Anshari et al. (2022, p. 11) observe that users are often given insufficient information about how their data are collected, stored, and shared. The verification and validation of ethical principles in autonomous systems must therefore be prioritised in Metaverse governance (Nahavandi, 2019, p. 11).

The governance and ownership structure of the Metaverse introduces further complexity. Schöbel and Leimeister (2023, p. 7) propose two likely scenarios: one in which a single dominant company, such as Meta, consolidates smaller platforms to monopolise the Metaverse; and another in which multiple competing Metaverses emerge, allowing consumers to choose among proprietary ecosystems. Both models raise questions about market concentration, interoperability, and fairness.

At a geopolitical level, the Metaverse could shift global power relations, exposing vulnerabilities such as biometric data theft, financial fraud, and critical infrastructure sabotage. It may even create a new frontier for cyber warfare (Kshetri, 2022, p. 5). Al-Amoudi (2023, pp. 1241–1242) calls for critical engagement from management studies to investigate how post-human technologies like VR, AI, and robotics reshape power dynamics, human solidarity, and the institutional structures necessary to uphold democratic values.

Finally, technological acceptance and adaptation represent significant barriers. Salminen and Aromaa (2024, pp. 2112–2113) highlight that developers perceive low user familiarity, complex interfaces, and a lack of mass-market readiness as major challenges. The Metaverse is often viewed as "science fiction," leading to hesitancy in investing or adopting these technologies. Changing existing processes and mindsets would require not only significant training but also substantial financial investment—both of which may be viewed as obstacles to development.

3 Managing Sustainability in the Metaverse

This chapter explores how sustainability is managed within the emerging ecosystem of the Metaverse. It situates this exploration within the broader technological shifts of Industry 4.0 and Industry 5.0, addressing definitions, strategies, practices, and current challenges identified in the literature.

3.1 Framing Sustainability through Industry 4.0 and 5.0

This section examines how sustainability is conceptualised and operationalised within the frameworks of Industry 4.0 and Industry 5.0. It sets the stage for understanding how these broader industrial transformations influence sustainability management in the Metaverse.

3.1.1 Challenges in Defining Sustainability

The concept of sustainable development was first established in the report “Our common future” that was published by the by the United Nations Brundtland Commission in 1987 (Ruggerio, 2021, p. 3). The report states that sustainable development should “meet the needs of the present without compromising the ability of future generations to meet their needs” (Brundtland Commission, 1987, p. 16). Moreover, the report distinct three characteristics of sustainable development; economic, social, and environmental.

Ruggerio (2021, p. 2) notes that the terms sustainable development and sustainability are often used as synonyms in literature. However, some argue that the concept of sustainable development is contradictory, as it suggests the possibility of sustaining infinite economic growth. Additionally, the definition of sustainable development is criticised for its lack of precision and ideological influences, leading to an unsolvable debate over its meaning (Ruggerio, 2021, p. 4).

In 2015, The United Nations (UN) created a blueprint of their vision of sustainable development (United Nations, 2023). Thus, **The UN's Sustainable Development Agenda 2030** has 17 goals to target the sustainable development. The goals are No poverty (SDG 1), Zero Hunger (SDG 2), Good Health and Well-Being (SDG 3), Quality Education (SDG 4), Gender Equality (SDG 5), Clean Water and Sanitation (SDG 6), Affordable and Clean Energy (SDG 7), Decent Work and Economic Growth (SDG 8), Industry, Innovation and Infrastructure (SDG 9), Reduced Inequalities (SDG 10), Sustainable Cities and Communities (SDG 11), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), Life Below Water (SDG 14), Life on Land (SDG 15), Peace, Justice and Strong Institutions (SDG 16), Partnerships (SDG 17). The most recent Sustainable Development Goals report (2023) highlights the challenges presented by Covid-19 and inflation, which have impacted countries' abilities to bridge the global economic and geopolitical divide. A primary focus for 2024 is enhancing digital inclusion, which necessitates support from national institutions, increased accountability, and effective regulation. Furthermore, the report underscores the need for improved digital infrastructure and greater data capacity (United Nations, 2023).

The concept of **the Triple Bottom Line (TBL)**, coined by J. Elkington in 1999, defines a sustainable company as one that addresses economic prosperity, environmental quality, and social justice (Jeurissen, 2000, p. 229). However, Rahman et al. (2010, p. 1353) note that the understanding of different stakeholder groups has evolved since then. Primary stakeholders directly affected by a company's decisions and actions include suppliers, customers, employees, and investors. In contrast, secondary stakeholders are indirectly affected and encompass local communities, social activist groups, the public, media, business groups, and government entities (Rahman et al., 2010, p. 1353). Each of these groups may have overlapping interests and expectations of the company. The corporate performance that addresses these varied interests can be measured through the responsibilities of economic performance (profit), social care (people), and environmental stewardship (planet). These three Ps form the foundation of the Triple Bottom Line. However, Varriale et al. (2023, p. 19) note that for novel technologies, such as immersive technology, the definitions of the three Ps can be challenging. Particularly environmental and social impacts require time to be properly evaluated.

The concept of **the Bottom of the Pyramid (BOP)** was introduced by Prahalad et al. in 1998 (Kolk et al., 2014, p. 339). BOP is based on the idea of multinational enterprises (MNEs) engaging in business with the poorer segments of the global population (Kolk et al., 2014, p. 339). The poor are described as the “bottom” of the economic pyramid; however, the concept has faced criticism for its lack of precision in defining "the poor." Common indicators used in BOP literature to identify the “bottom” include purchasing power and income levels, positioning this segment as the largest section of the wealth pyramid (Kolk et al., 2014, p. 351).

To generate profit from the BOP market segment, Kolk et al. (2014, p. 356) explain that many successful business models have modified the functionalities or technologies behind their products to meet lower price points. Moreover, to assess the sustainability of BOP initiatives, many articles in BOP literature reference the Triple Bottom Line (Kolk et al., 2014, p. 357–359). However, it is crucial to conduct more in-depth research into BOP initiatives to identify which business models generate profit and to explore the relationship between profit and poverty alleviation. The impact of different types of organisations on BOP initiatives is less studied, but it has been noted that BOP initiatives positively affect social aspects such as education, health, and employment.

From an economic perspective, BOP literature categorises consumption into several categories: (1) basic needs, such as water and food; (2) basic infrastructure, including transportation; (3) basic education and skills; (4) information and communication; (5) discretionary purchases, such as televisions, beauty products, and clothing; and (6) either virtual or actual marketplaces for selling products, skills, labour, and production. The environmental aspect of the Triple Bottom Line receives the least attention. Aside from waste generation, a central question remains: will BOP markets adopt the consumption and production levels of the developed world, and what effects will this have on the scarcity of natural resources (Kolk et al., 2014, p. 359)?

The European Commission characterises sustainable finance as a process that integrates **environmental, social, and governance (ESG)** factors into investment decisions to promote sustainable and long-term economic activities. The environmental dimension may address issues such as climate change mitigation and adaptation, the circular economy, biodiversity, and pollution. Social factors can encompass inclusivity, inequality, human rights, and labour relations. Meanwhile, governance considerations highlight the critical role of both public and private organisations in incorporating social and environmental aspects into their decision-making processes (European Commission., n.d. -b). To monitor progress, the EU has introduced new regulations.

The Corporate Sustainability Reporting Directive (CSRD) is a regulation introduced by the European Union that requires all publicly listed companies to report on their risks and opportunities related to environmental and social issues, as well as the broader impact of their operations on people and the environment (European Commission, n.d. - a). This reporting obligation begins with the financial year 2024, meaning that the first reports will be published in 2025. Companies must follow the European Sustainability Reporting Standards (ESRS), which are designed to ensure consistency across sectors and alignment with EU policies. Although reporting was originally planned to become mandatory for non-listed companies in 2025, the EU later adjusted this approach through the Omnibus Directive. As a result, only large companies with more than 1,000 employees are currently required to comply with CSRD reporting requirements (European Commission, n.d. - a).

3.1.2 The Evolution of Sustainability from Industry 4.0 to Industry 5.0

Industry 5.0 emerges from the premise that Industry 4.0 places greater emphasis on digitalisation and AI technologies at the expense of social fairness and sustainability principles, focusing predominantly on efficiency and production flexibility instead (Xu et al., 2021, p. 530). However, Industry 4.0 does address societal needs for sustainability and human-centricity. Efforts towards sustainability aim to enhance resource efficiency through modifications in manufacturing processes and machinery design. Human-centricity is supported by socio-technical infrastructures, such as worker upskilling and flexible work arrangements. Smart factories strive to create "better, not cheaper" work environments and to empower employees as decision-makers (Xu et al., 2021, p. 532). Industry 5.0 distinguishes itself from Industry 4.0 by adopting a systematic approach rather than a purely technological one (Ivanov, 2023, p. 1683). While Industry 4.0 addresses human-centricity, sustainability, and resilience through a consequential lens and technological advancements, Industry 5.0 focuses on achieving broader societal goals and prioritising the well-being of industry workers (Xu et al., 2021, p. 534). As Varriale et al. (2023, p. 2) explain, Industry 5.0 builds on the Industry 4.0's approach by enhancing sustainability through digital technologies, thus advancing towards more sustainable, human-centric, and resilient development.

As the solely profit-driven approach to business becomes increasingly untenable, the European Commission (2021, p. 13–14) argues that businesses aiming to be agents of prosperity should integrate social, environmental, and societal objectives to achieve broader prosperity for stakeholders beyond mere profit and cost-efficiency. These stakeholders include the environment, society, workers, and investors. The European Commission identifies three key features of Industry 5.0: a human-centric approach, sustainability, and resilience (European Commission, 2021, p. 13–14). Additionally, resilient value creation, human well-being, and a sustainable society represent the new triple bottom line of Industry 5.0 (Ivanov, 2023, p. 1692). Piccarozzi et al. (2024, p. 1840) argue that the transition from Industry 4.0 to Industry 5.0 signifies a significant evolution, with the Metaverse playing a pivotal role in enhancing collaboration between humans and machines while emphasising sustainability and human centrality as core principles.

Human centric approach strives to put human in the centre of production processes rather than developing technologies to enhance efficiency (European Commission, 2021,

p. 14). Furthermore, new technologies should be developed to meet human needs, rather than requiring humans to adapt to them unnecessarily. This includes that the development notes workers' fundamental rights of privacy, human dignity, and autonomy.

Sustainable technology development in Industry 5.0 respects the planetary boundaries (European Commission, 2021, p. 14). Resource-efficiency and waste management are important aspects of circular development that encompasses re-using, re-purposing, recycling, and reducing natural resources. Further, the development should be in line with UN's Sustainable Development Goals and the meaning of sustainability which was defined in 1987 by the United Nations Brundtland Commission (1987, p. 16) "meet the needs of the present without compromising the ability of future generations to meet their own needs".

Resilience is characterized by the necessity to develop strong industrial production systems capable of averting disruptions in globalized production, which are vulnerable to geopolitical shifts and natural crises (European Commission, 2021, p. 14). Protecting critical infrastructure involves developing resilient strategic value chains, fostering flexibility in business processes, and maintaining adaptable production capacities. These measures are particularly crucial in industries that serve to fundamental human needs, such as healthcare and security.

3.2 Unique Challenges in Managing Sustainability in the Metaverse

This section is divided into three subsections, strategies, practices, and metrics of managing sustainability in the Metaverse, and examines the distinctive characteristics, challenges, and opportunities that shape sustainability management in this context. It highlights how the virtual, decentralised, and rapidly evolving nature of the Metaverse introduces unique complexities compared to traditional industries. In doing so, it situates these challenges within the broader transition from Industry 4.0 to Industry 5.0, reflecting shifts towards more human centric, sustainable, and resilient approaches.

The management of sustainability within the Metaverse presents a complex and evolving challenge, shaped by the intersection of emerging technologies and sustainability imperatives across environmental, economic, and social dimensions. As Industry 5.0 advances, sustainability has gained renewed prominence, accompanied by efforts to align with the standards initially introduced under Industry 4.0 but not yet fully realised (Ghobakhloo et al., 2023, p. 432). In this context, the Metaverse has been identified as a promising arena for advancing sustainable development goals, prompting growing scholarly interest in its sustainability potential (Johri et al., 2024, p. 1–4).

Despite this increasing attention, academic research on sustainability in the Metaverse remains limited, with a disproportionate focus on computer science and engineering disciplines (Anshari et al., 2022, p. 7). Only recently have scholars begun to explore its broader business, management, and social implications, particularly in relation to Industry 5.0 (Piccarozzi et al., 2024, p. 1840). However, significant gaps persist in understanding how sustainability strategies, practices, and metrics can be conceptualised and operationalised in this emerging domain (Jauhiainen et al., 2023, p. 5–15).

The following subsections explore these three dimensions, strategies, practices, and metrics, by synthesising the key insights identified in the literature on sustainability management in the Metaverse.

3.2.1 Strategies to Manage Sustainability in Metaverse

Recent literature increasingly acknowledges the need for strategic approaches to ensure that the development of the Metaverse aligns with sustainability principles. The Metaverse is considered a promising platform for advancing the United Nations Sustainable Development Goals (SDGs), particularly across environmental, economic, and social domains (Johri et al., 2024, p. 1–4). However, many studies have noted that sustainability remains a secondary concern in current Metaverse development efforts, with a greater focus on technological innovation than on long-term social and environmental impacts (Piccarozzi et al., 2024, p. 1840).

One key challenge lies in embedding sustainability into strategic decision-making from the outset. Piccarozzi et al. (2024, p. 1845) caution that the lack of responsible development frameworks may lead to adverse social outcomes. They also highlight a broader uncertainty regarding the Metaverse's tangible contributions to sustainability in real-world contexts. At present, the Metaverse has largely been used for entertainment purposes, with its wider sustainability potential remaining speculative.

Jauhiainen et al. (2023, p. 17) add that academic discussions around Metaverse sustainability are often fragmented, partly due to linguistic diversity and the diffusion of dialogue across non-academic platforms. These findings indicate that although strategic interest in sustainability is increasing, the integration of sustainability principles into Metaverse development strategies remains underdeveloped and inconsistent.

3.2.2 Practices to Manage Sustainability in Metaverse

The Metaverse is believed to support sustainability objectives through frameworks such as the SDGs and environmental, social, and governance (ESG) standards (Jauhiainen et al., 2023, p. 4; De Giovanni, 2023, p. 4). However, translating these frameworks into actionable practices presents ongoing difficulties. De Giovanni (2023, p. 4) calls for further research on how SDG targets can be operationalised in Metaverse projects to support a responsible digital transition in the era of Industry 5.0. Moreover, successful implementation will require professionals who possess both technical expertise and a deep understanding of sustainable development (Piccarozzi et al., 2024, p. 1846).

Several scholars have identified trade-offs that may arise in Metaverse development. These include tensions between efficiency and authenticity, and between inclusivity and safety (Asif et al., 2023, p. 423; Mourtzis, 2023, p. 1117). Kaddoura and Al Husseiny (2023, p. 19) stress that social acceptance is critical for achieving sustainability in virtual environments. Sustainability in this context will rely not only on technical design, but also on ethical considerations such as preventing cyberbullying, ensuring data privacy, and supporting diversity in avatars and virtual spaces.

Varriale et al. (2023, p. 19) also highlight that regulatory uncertainty and ethical dilemmas must be addressed before immersive technologies can fully contribute to sustainable development. Despite the potential, the future trajectory of the Metaverse remains unclear, with some scholars questioning whether it will continue to grow or begin to decline in relevance (De Giovanni, 2023; Piccarozzi et al., 2024, p. 1846).

3.2.3 Metrics to Manage Sustainability in Metaverse

While sustainability has received increasing attention, there remains a lack of standardised metrics for measuring sustainability performance in the Metaverse (Piccarozzi et al., 2024, p. 1840; Jauhiainen et al., 2023, p. 5–15). Although frameworks such as the SDGs, ESG principles, and the triple bottom line are often referenced, their concrete application in Metaverse contexts is still limited (De Giovanni, 2023, p. 4; Piccarozzi et al., 2024, p. 1844).

Jauhiainen et al. (2023, p. 15) suggest that the Metaverse can contribute to sustainability across domains such as education, innovation, infrastructure, renewable energy, responsible consumption, and biodiversity. They advocate for comprehensive assessments to determine the ethical and developmental impacts of Metaverse applications (Jauhiainen et al., 2023, p. 16). Similarly, De Giovanni (2023, p. 4) highlights the importance of evaluating the trade-offs associated with Metaverse adoption through a triple bottom line lens. However, Varriale et al. (2023, p. 19) observe that this framework has not yet been thoroughly applied in immersive technology research, resulting in limited understanding of its broader implications.

Economically, the Metaverse offers new opportunities, including the development of digital markets, non-fungible tokens (NFTs), enhanced brand visibility, and improved operational efficiency. Nonetheless, risks include the potential disruption of traditional markets, increased investment demands for infrastructure, and possible strain on existing production systems (De Giovanni, 2023, p. 4; Piccarozzi et al., 2024, p. 1844). The novelty of the Metaverse also raises questions about its long-term economic sustainability (Varriale et al., 2023, p. 19).

Environmentally, the Metaverse is viewed as a platform capable of reducing physical space and energy use, alleviating transport needs, and reducing resource exploitation, while also enabling sustainable urban development. However, increased energy demands, growing electronic waste, and challenges in recycling technology components present significant environmental risks (De Giovanni, 2023, p. 4; Piccarozzi et al., 2024, p. 1844; Varriale et al., 2023, p. 19).

Socially, the Metaverse may foster cultural exchange, creativity, collaboration, and enhanced virtual experiences, yet concerns remain about potential declines in physical social interaction, worsening mental health issues, and unequal access to technologies across populations (De Giovanni, 2023, p. 4; Piccarozzi et al., 2024, p. 1844; Varriale et al., 2023, p. 19).

De Giovanni (2023, p. 11–12) argues that responsible strategies for implementing the Metaverse should be evaluated using ESG principles. From an environmental perspective, the Metaverse may reduce emissions and waste in production and logistics, while increasing energy demands. From a social perspective, it may enhance transparency and product diversity but also create pressures on suppliers and employment. From a governance perspective, it offers opportunities for fairness and over-sight, while exposing weaknesses in supply chains and ethical practices.

Rajguru and Brüggemann (2024, pp. 2721–2725) suggest expanding the traditional sustainability model which typically focuses on the social, environmental, and economic pillars by introducing a fourth pillar: the technological dimension. This addition underscores the importance of addressing innovation capacity, interoperability, and the long-term resilience of digital systems. By linking this dimension to Sustainable Development Goals (SDG) 9 (Industry, Innovation and Infrastructure) and SDG 17 (Partnerships for the Goals), they argue that sustainability in the Metaverse must also consider how technologies are designed, maintained, and shared. Without this emphasis, the development of the Metaverse risks increasing resource consumption and failing to meet sustainability objectives. As such, the success or failure of Metaverse initiatives should be evaluated through these broader sustainability lenses, rather than being measured solely by economic growth (Rajguru & Brüggemann, 2024, p. 2725).

4 Conclusions from the Literature Review

This chapter concludes the theoretical review by synthesising key insights from current literature on sustainability management in the Metaverse. Integrating sustainability principles into Metaverse development, particularly within the framework of Industry 5.0, presents both promising opportunities and significant challenges in advancing global sustainable development goals. Scholars consistently emphasise the importance of aligning Metaverse initiatives with international frameworks, notably the United Nations Sustainable Development Goals (SDGs), to address pressing environmental and societal concerns. Areas of alignment include sustainable education, innovation and infrastructure, renewable energy, responsible consumption, and biodiversity. To explore these connections, comprehensive research approaches such as impact assessments are seen as essential for understanding the Metaverse's long-term role in sustainable development.

At the strategic level, the literature advocates for embedding sustainability as a foundational design principle from the outset. This includes prioritising values such as human centricity, resilience, and environmental responsibility, which are central to Industry 5.0. However, a noticeable gap remains between these conceptual ideals and their implementation in practice. While the Metaverse has the potential to support transparency, fairness, and inclusivity, these outcomes rely on deliberate governance strategies. Particular attention is needed in areas such as digital inclusion, data ownership, and the risk of monopolistic control. Without robust oversight, there is a risk that emerging platforms will reproduce or intensify existing sustainability and ethical challenges.

In terms of operational practices, several opportunities are identified for promoting sustainability through the Metaverse. These include using digital twins and immersive technologies to optimise industrial processes, reduce material consumption, and lower carbon emissions through remote collaboration. Although these practices may yield environmental benefits, scholars stress that social sustainability must not be overlooked. Concerns related to accessibility, user safety, and algorithmic bias highlight the need for inclusive design and participatory development. Furthermore, sustainability must extend to supply chain responsibility and labour conditions within digital environments. In many cases, however, sustainability is treated as a secondary objective, introduced only after technological and commercial priorities have been established.

A further limitation in the literature concerns the absence of standardised metrics for assessing sustainability in the Metaverse. While environmental indicators such as emissions reduction and energy efficiency are more clearly defined, social and governance aspects are less systematically measured. Scholars propose the adoption of Environmental, Social, and Governance (ESG) frameworks and the Triple Bottom Line (TBL) model to evaluate trade-offs across economic, environmental, and social dimensions. Nonetheless, applying these frameworks in virtual, decentralised contexts remains limited. For instance, while the Corporate Sustainability Reporting Directive (CSRD) mandates sustainability reporting for companies within the European Union, its relevance and applicability to transnational Metaverse platforms remain unclear.

More recently, scholars have proposed a fourth sustainability pillar: the technological dimension. This addition responds to the need for evaluating the sustainability of the digital infrastructure that underpins the Metaverse. It involves consideration of innovation capacity, system interoperability, and long-term technological resilience. By linking this dimension to SDG 9 (Industry, Innovation and Infrastructure) and SDG 17 (Partnerships for the Goals), researchers argue that sustainability in the Metaverse must also address how technologies are developed, maintained, and shared over time.

Although the conceptual models reviewed in this chapter offer valuable theoretical foundations, they remain largely speculative. What is currently missing from the academic discourse is an empirically grounded understanding of how sustainability is managed in practice, particularly within real-world Metaverse development efforts. This gap underscores the significance of the present study, which aims to provide an empirically informed perspective on sustainability strategies, practices, metrics, and technological enablers.

Figure 1 summarises the key opportunities, risks, and sustainability frameworks discussed throughout the literature. This consolidated overview serves as the analytical basis for the empirical analysis presented in the following chapters.

Sustainability in Metaverse					Bottom of the Pyramid
SDGs	**ESG**		**TBL**		
Affordable and clean energy (SDG 7); Climate Action (SDG 13); Responsible Consumption and Production (SDG 12); Clean Water and Sanitation (SDG 6)	**Environmental Perspective**		**Environmental Performance**		
	Opportunities	Challenges	Opportunities	Risks	
	Holds promise for reducing emissions, resources and waste, alleviating transportation demands, and curbing the exploitation of natural resources, while also contributing to the development of sustainable urban environments.	Increased energy consumption and excess heat due to blockchain and IoT sensors, more material usage due to VR tools, suppliers may not be environmental-friendly, the proliferation of land-intensive infrastructure, which may have adverse environmental impacts.	Reduced space and energy consumption, reduced Co2 emissions, services reduce travel, lower exploitation of natural resources and reduced consumption of polluting materials for production, more physical activities at home, sustainable urban development.	Increased energy consumption, land-intensive infrastructure, use of material to enable metaverse , the need to reengineer circular economy systems to include metaverse flows.	
Quality	**Social Perspective**		**Social Performance**		
	Opportunities	Challenges	Opportunities	Risks	

education (SDG 4); Good Health and Well-being (SDG 3); Gender Equality (SDG 5); Decent Work and Economic Growth (SDG 8); Reduced Inequalities (SDG 10)	The metaverse fosters cultural exchange, facilitates personal development through critical thinking and creativity, promotes collaboration, introduces innovative practices, enhances working conditions, and enriches virtual experiences for users, diversified goods, high levels of quality through constant monitoring, 24/7 and 365 service, customers can try and verify goods before purchasing.	Concerns exist about the potential decline in real-world social interactions, exacerbation of mental health issues, and unequal access to technology among different populations, adjusting purchasing and production outcomes, less need for logistics imply less need for jobs, can distract from serving developing countries without access to metaverse.	New needs, jobs and competences, no corruption, cultural exchange, personal development, collaboration, improved working conditions, increased awareness of purchased goods	Decline in real-world social interactions, mental health issues, unequal access to technology, to avoid criminal acts there is a need for improvised protocols, violence, prostitution, money laundering, need for respect towards other cultures and religions, decrease in outdoor activities.	
Industry, innovation & infrastructure (SDG 9); Peace, Justice, and Strong	**Governmental Perspective (Economic + Stakeholder)**		**Economic Performance**		
	Opportunities	Challenges	Opportunities	Risks	
	Raw-material savings, more e-commerce, more trustable and transparent supply chain partnerships, less inventory, metaverse promises enhanced visibility and fairness, need to communicate Total Quality Management orientation to enhance transparent reputation	Integrating digital and physical goods: inefficiencies, part of traditional market may not be served, e-commerce and sunken costs, disrupted supply channels, easy access for competitors, need for plan	Novel digital markets and services, enhanced brand visibility, increased operational efficiency (resources, costs, materials, production cycles),	Cannibalisation of physical goods markets, strain on existing production systems, pressure on a-	

Institutions (SDG 6); Partnerships for the Goals (SDG 17)		to reallocate, reeducate and reintegrate workers to metaverse, may reveal unfair practices leading to lower reputation.	efficient transactions, faster product development and overall improvement in product life cycle monitoring.	typical production systems (just-in-time), substantial investments in new infrastructure with limited government funding (cloud and computing power, data centres, storage systems).	
Technological dimension					

Table 1. Summary of sustainability strategies, practices, and metrics in the Metaverse (Varriale et al., 2023; De Giovanni, 2023; Piccarozzi et al., 2024; Jauhiainen et al., 2023; Kolk et al., 2014; Rajguru & Brüggemann, 2024).

5 Methodology

This chapter outlines the research methodology used in the study, providing a detailed description of the research design, data collection, and analysis processes. The study adopts a qualitative case study approach, focusing on Finnish organisations engaged in Metaverse development. By conducting semi-structured interviews with key stakeholders and applying thematic analysis using the Gioia Methodology, the research seeks to explore how sustainability is conceptualised, practised, and measured within the evolving Metaverse ecosystem. The chapter explains the rationale for case selection, data collection procedures, coding and analysis strategies, and discusses ethical considerations and the trustworthiness of the study. Together, these methodological choices aim to ensure a systematic, transparent, and rigorous approach to addressing the research question and objectives.

5.1 Philosophical assumptions

This section introduces the philosophical foundations of the study, describing how constructivist ontology and interpretivist epistemology shape the research approach. It explains the use of inductive reasoning, qualitative methodology, and semi-structured interviews, and outlines ethical considerations in data collection and analysis.

The philosophical underpinnings of scientific research can be framed through four key concepts: ontology, epistemology, methodology, and methods (Eriksson & Kovalainen, 2015, p. 14). Together, these elements form a research paradigm—a term that may be defined narrowly as a theoretical framework or more broadly as encompassing all scientific practices (Eriksson & Kovalainen, 2015, p. 18; Creswell, 2023, p. 8).

Ontology concerns the nature of reality and how we understand the relationship between individuals, society, and the world (Eriksson & Kovalainen, 2015, p. 14). In qualitative research, reality is seen as socially constructed, shaped by perceptions and experiences rather than existing as a fixed, objective truth. From a constructivist or subjectivist stance, reality emerges through human meaning-making, with individuals interpreting their world in unique ways (Creswell, 2023, p. 8; Eriksson & Kovalainen, 2015, p. 14). In this study, such a view implies that sustainability in the Metaverse is not a singular, objective phenomenon but a reality co-created by the perceptions, practices, and experiences of different stakeholders. For example, businesses, policymakers, and users may interpret and operationalise sustainability differently. Ontology therefore raises questions such as: What constitutes "sustainability" in the Metaverse? What exists within this domain?

Epistemology addresses the nature of knowledge and how it can be acquired (Eriksson & Kovalainen, 2015, p. 15). In research, epistemological positions range from objectivist, which assumes knowledge exists independently of human perception, to subjectivist, where knowledge is shaped by interpretation. Interpretivism, aligned with subjectivism, assumes that reality is socially constructed and that multiple interpretations of phenomena are both valid and meaningful (Eriksson & Kovalainen, 2015, p. 15, 21). Consequently, this study adopts an interpretivist epistemology, aiming to understand how actors in the Metaverse conceptualise and enact sustainability. Interpretivism values exploring participants' subjective meanings, recognising that sustainability strategies are embedded within organisational and individual sensemaking processes. Reflexivity also plays a key role, acknowledging the researcher's influence in co-constructing knowledge (Eriksson & Kovalainen, 2015, p. 21).

Reasoning in research typically follows a deductive or inductive approach (Eriksson & Kovalainen, 2015, p. 23). Deductive reasoning derives hypotheses from existing theory, testing them through empirical data in a linear process. In contrast, inductive reasoning begins with empirical data to generate theoretical insights. This study adopts an inductive approach, building conceptual understanding from qualitative data. To enhance analytical rigour, triangulation was employed, incorporating multiple data sources (Eisenhardt, 1989, p. 538). In this study, epistemology prompts questions such as: How can knowledge about sustainability in the Metaverse be acquired? What processes allow meaningful interpretation of participants' perspectives?

Methodology refers to the overall approach for conducting research and answering research questions (Eriksson & Kovalainen, 2015, p. 17). Qualitative methodology was selected for this study, as it allows an in-depth exploration of sustainability within the relatively under-researched and emergent context of the Metaverse. Specifically, semi-structured interviews were used as the primary data collection method, offering flexibility for participants to share their interpretations while enabling probing and clarification. This format also allowed for adaptive questioning, fostering richer and more nuanced data.

Secondary data were also collected from case organisation publications and websites to contextualise and support the interview findings. Methodology thus covers both the approach to understanding reality and the processes used to generate knowledge. In this study, methods are divided into data collection—through interviews and secondary sources—and data analysis, which involved thematic coding.

Research design, as described by Eriksson and Kovalainen (2015, p. 28–29), structures the inquiry by guiding data collection, analysis, and interpretation. The design process involved selecting the research area, refining research questions, choosing appropriate methods, identifying theoretical lenses, and planning data collection. A key feature of qualitative research is its iterative and circular nature, allowing continuous reflection and refinement throughout the study.

Ethical considerations were carefully addressed to ensure research integrity and uphold participants' rights (Eriksson & Kovalainen, 2015, p. 63–73). This study followed the ethical guidelines of the University of Vaasa (University of Vaasa, n.d.). All participants were voluntary, provided informed consent prior to interviews, and agreed to audio recording. Personal information was kept confidential, and video recordings were deleted after transcription. To protect participant anonymity, organisations and individuals were anonymised in the reporting of findings.

5.2 Research Method and Design

This section outlines the chosen research method and design, explaining why a qualitative, case study approach was selected to explore sustainability management in the Metaverse. It describes the rationale for using semi-structured interviews, the process of case selection, and the application of thematic analysis to interpret the data.

5.2.1 Research Strategy: Case study

The popularity of case study research lies in its ability to present complex business problems in an accessible manner (Eriksson & Kovalainen, 2015, p. 133–137). However, it has been critiqued for its perceived lack of scientific rigour. In extensive case studies, the objective is to explain the phenomenon under investigation and further develop theoretical constructs. This study aims to contribute to sustainability theories by providing a deeper understanding of the Metaverse phenomenon in Finland. Case study research is particularly effective for exploring complex, emerging topics within their real-life context, making it a valuable approach for detailed examination.

Extensive multiple case study research examines cases more broadly or is guided by predefined theoretical interests or planned deductions from prior research. Due to the focused nature of such studies, they are often referred to as "mini cases." Eisenhardt (1989, p. 537) recommends limiting the number of cases in this type of research to between four and ten, as additional cases tend to provide only marginal additional insights. Consequently, this study includes six interviews from five case organisations involved with the Metaverse. By focusing on a select number of cases, this research provides an in-depth understanding of the sustainability management strategies, practices, and metrics of companies involved in the Finnish Metaverse Initiative, while maintaining the analytical depth necessary to uncover meaningful insights into sustainability.

Cross-case analysis enables the identification of patterns across different cases, which is crucial for generalising findings and drawing broader conclusions about sustainability in the Metaverse. Creswell (2023, p. 230) notes that it is typical to gather both qualitative and quantitative data simultaneously in case study research. This approach is particularly beneficial for identifying overarching trends and drawing generalisable conclusions across the studied cases.

Furthermore, case study research typically involves collaboration with participants to create an agenda for reform or change through the analysis of textual data (Creswell, 2023, p. 18). This research adheres to that principle by sharing an analysis of the interviews and examining the current state of sustainability in the Metaverse in Finland. Moreover, Gillham (2000, p. 18) highlights the importance of "keeping an open mind" when collecting data in case study research. Additionally, the researcher must be aware of their own biases and ensure that preconceived assumptions do not influence the research process.

5.2.2 Case Selection and Research Design

This study employed a multiple case study design as outlined by Yin (2014), selecting five organisations as case units to examine how sustainability is managed within the Finnish Metaverse Initiative. The selection process followed Yin's replication logic. Two of the cases (Business Finland) were selected as literal replications and were expected to produce similar findings. The other three cases, drawn from the gaming industry, the industrial Metaverse sector, and a government agency, were chosen as theoretical replications. These were anticipated to yield contrasting insights due to the distinct institutional roles and sectoral circumstances involved (Yin, 2014, pp. 54–55).

All five case organisations, including six interviewees, were identified and accessed through the Business Finland Metaverse Initiative. Each interviewee either contributed directly to the national Metaverse strategy or was actively involved in the internal development of Metaverse-related projects within their respective organisations. Relevant literature and publicly available sources were reviewed to support the case selection and to ensure that each organisation would offer valuable and diverse insights into the research topic.

The research is grounded in the framework of Industry 5.0 and the European Union's sustainability agenda. Finland provides a particularly interesting setting for this study, as the Finnish government, through Business Finland, has played a significant and coordinated role in Metaverse development. This differs from global Metaverse development, where Metaverse initiatives are largely driven by the private sector. To reflect this unique dynamic, the selected organisations were categorised into three sectors: government agencies, industrial Metaverse actors, and gaming industry stakeholders.

This classification allowed for the comparison of sustainability strategies, practices, and metrics across organisations operating in different institutional environments. Each case was first examined independently to identify its specific sustainability approaches. Following this, a cross-case analysis was undertaken to identify common patterns and differences. This approach aligns with Yin's (2014) recommendation for systematic cross-case comparisons to enhance analytical generalisation (Yin, 2014, p. 196–198).

The combination of detailed individual case studies and cross-case analysis allowed the research to achieve both depth and breadth. A deeper understanding of each organisation's sustainability practices was gained, while broader trends and challenges across the Finnish Metaverse ecosystem were also identified. This two-level analysis is particularly well-suited for studying emerging fields such as the Metaverse, where empirical research remains limited (Creswell, 2023, p. 229–237).

To bring together the findings from the different cases, a thematic analysis was applied after the cross-case comparison. Thematic analysis is widely recognised as a robust and flexible method for identifying patterns within qualitative data (MacQueen and Namey, 2011, p. 11). This approach enabled the integration of findings across the interviews and supported the development of an empirically grounded understanding of how sustainability is currently managed in the Finnish Metaverse context.

Table 2 presents a summary of the selected case organisations, including their sector classification and their specific involvement in the Finnish Metaverse Initiative.

Case	Operating Countries	Employees	Company Revenue (MEUR)	Industry
Business Finland	38	760	-	Government Agency
Cybrid Authority	1	1000	137,6	Government Agency
Vertigo Innovations	>60	>60 000	10,5	Industrial
PulpFiction Technologies	>100	>19 000	5,4	Industrial
Game Industry Association	1	4	-	Gaming

Table 2. Case Organisations by Sector and Role in the Finnish Metaverse Initiative.

5.3 Data collection and analysis

This chapter presents the methodology employed in this study to explore sustainability in the Metaverse. It provides a detailed explanation of the research design, the data collection methods using semi-structured interviews, and the analysis techniques involving thematic grouping. These elements are outlined to ensure the research process is transparent, reliable, and consistent with the study's objectives.

5.3.1 Primary Data Collection

Semi-structured interviews served as the primary data source due to their alignment with interpretivist epistemology and explorative research, as they facilitate in-depth exploration of participants' perspectives and experiences. These interviews follow a predesigned outline of questions and topics that address inquiries such as “what” and “how” (Eriksson & Kovalainen, 2015, p. 95). Therefore, all interview questions were open-ended to ensure participants' views were fully captured.

Additionally, semi-structured interviews allow the interviewer to adjust the wording of questions and explore emerging topics during the conversation (Eisenhardt, 1989, p. 539). The tone of the interview is informal and conversational, which encourages participants to express their thoughts freely. This flexibility was utilised during the interviews, making each one unique, as some questions were added that were not in the original research questions draft. The initial draft included 18 questions. However, Eriksson and Kovalainen (2015, p. 95) note that this interview format has been critiqued for its challenges in subsequent analysis and comparison of responses, as the variability in topics raised by different interviewees can lead to inconsistent results.

The interviewees came from different organisational backgrounds, but all held roles in either technology development or strategic work related to Metaverse initiatives or were part of the initial Finnish Metaverse Initiative launched by Business Finland in 2023. The interviews were conducted in Finnish, as it was the native language of all participants, and were subsequently translated into English for analysis and to utilise the quotes. The interview questions followed the thematic structure of the thesis and research questions (RQ1–RQ3), beginning with descriptions of the Metaverse and its technologies, and progressing to understanding the sustainability aspects and Industry 5.0 principles connected to it.

Organisation	Title	Interview Duration	Pages of transcribed data	Number of Codes
Business Finland	Mission Lead for Immersive Digital Life	52:48	15	96
Business Finland	Senior Advisor and Key Account Manager in ICT	1:27:44	18	155
Vertigo Innovations	Digital Lead	1:08:34	16	92
PulpFiction Technologies	Automatic Systems Lead	1:04:40	21	98
Game Industry Association	Executive	1:00:37	15	89
Cybrid Authority	Head of the Technology Department	1:05:34	14	149

Table 3. Summary of Primary Interview Data Collection.

The six interviews generated a total of 6 hours and 40 minutes of material, with individual interview lengths ranging from 52 minutes to 1 hour and 28 minutes (see table 3). All interviews were conducted via Microsoft Teams, a platform provided by the University of Vaasa, and subsequently transcribed into 99 pages of text using the Copilot tool. The decision to conduct interviews online was shaped by both practical and contextual factors. As Karimi-Maleh et al. (2023, p. 2473) note, the COVID-19 pandemic accelerated the adoption of virtual platforms such as Teams, Zoom, and Google Meet for academic research, conferences, and workshops, offering benefits including global accessibility, reduced environmental impact, and lower organisational costs. However, they also highlight limitations, particularly in relation to diminished opportunities for informal networking and social interaction, suggesting a hybrid approach for future research settings.

Video recordings of the interviews were securely archived until transcription and translation were completed, ensuring the accuracy, traceability, and integrity of the data. The transcripts included detailed timestamps, generated by Copilot, to enhance precision and to clearly differentiate between interviewer and participant contributions. To protect participant confidentiality, the transcripts were anonymised; interviewees are later referred to by their professional titles, while the names of the participating organisations have been replaced with pseudonyms. An exception was made for Business Finland, whose name is retained due to its publicly known role as a coordinating body and primary contact point within Finland's Metaverse initiative.

Following transcription, the anonymised interview data were imported into Atlas.ti software to facilitate a systematic coding and analysis process. The analysis followed the principles of the Gioia Methodology (Gioia et al., 2013), which emphasises capturing participants' voices through first-order coding before progressing to more abstract theoretical interpretations. The coding process began inductively, identifying key terms and expressions in the participants' own language. These first-order codes were then iteratively refined and consolidated into second-order themes, representing emergent conceptual patterns. Finally, the second-order themes were synthesised into aggregate dimensions, capturing higher-level theoretical constructs.

Through this process, a total of 40 first-order codes were developed, encompassing 346 supporting quotations. These codes and themes formed the basis of the data structure diagram presented in the Findings chapter, visually illustrating the pathway from raw data to theoretical insights (Gioia et al., 2013, p. 20). Selected visualisations, including coding distributions and theme frequencies, are also provided to support transparency and rigour in the analytic process.

The analysis remained data-driven and inductive, avoiding preconceived theoretical impositions and instead allowing patterns to emerge organically from the participants' accounts. As Fainshmidt et al. (2021, p. 1417–1418) suggest, the integration of digital tools such as Atlas.ti reflects a broader trend toward agile, technology-enabled research designs, enhancing both the transparency and adaptability of qualitative inquiry. By combining virtual interview methods with computer-assisted qualitative analysis, this study leveraged both practical and technological advances to produce a rigorous and grounded analysis.

5.3.2 Secondary Data Collection

To further enhance validity, the researcher can apply triangulation in data collection (Eriksson & Kovalainen, 2015, p. 306). Triangulation involves using multiple perspectives to analyse and refine findings. For instance, this can include employing various theories to analyse the case, gathering evidence from multiple empirical sources, utilising different methods to validate findings, and combining qualitative and quantitative data to explain the phenomenon of sustainability in the Metaverse. This research utilises triangulation to validate its findings; several theoretical models are discussed in the literature review, and the case organisations are based on interviews corroborated by public records of the organisations' actions and initiatives related to digitalisation, Metaverse and sustainability.

Theory
Sustainability management in Metaverse
Research Design
Multiple cases
Exploratory cross-case study
Data Collection
Primary Data Collection, semi-structured interviews
Government agencies
Industrial Metaverse
Game Industry
Secondary Data Collection

Publicly available information: reports, news, interviews, articles

Figure 1. Research Design.

5.3.3 Data Analysis: Gioia method

This study employed the Gioia Methodology (Gioia et al., 2013) as the principal analytical framework to ensure qualitative rigor in inductive research. The methodology was selected because it enables systematic theorising from qualitative data while maintaining a clear audit trail from empirical material to conceptual insights. It is particularly well-suited for emerging, under-theorised contexts such as sustainability management in the Metaverse, where existing frameworks are fragmented or absent (Magnani & Gioia, 2023, p. 2).

The Gioia Methodology is grounded in an interpretivist epistemology, assuming that organisational and technological realities are socially constructed and shaped through iterative interaction (Gioia et al., 2013, p. 17; Magnani & Gioia, 2023, p. 3). Participants are viewed as "knowledgeable agents" (Gioia et al., 2013, p. 18), capable of articulating their own experiences, meanings, and interpretations. This perspective justified the reliance on expert interviews as primary data.

The coding process of the analysis followed the three core steps of the Gioia Methodology: first-order coding, second-order thematizing, and development of aggregate dimensions (Gioia et al., 2013, p. 20). The initial phase involved reading and coding interview transcripts in Atlas.ti software, staying close to participants' own language and expressions. This produced a wide range of first-order codes reflecting their descriptions of technological development, governance issues, sustainability challenges, and institutional roles.

In the second phase, these first-order codes were iteratively compared and clustered into second-order themes, representing higher-level concepts that abstracted and organized informant accounts. Here, abductive reasoning played an important role: I incorporated existing theoretical concepts from sustainability literature, particularly the categories of strategy, practice, and metrics, as interpretive lenses to organize emerging themes. This process followed Gioia et al.'s (2013, p. 21) recommendation to balance inductive coding with theoretical sensitivity, while engaging in abductive inference to bridge empirical patterns with existing frameworks (Magnani & Gioia, 2023, p. 4).

For example, statements describing reduced emissions through remote work were categorised under "sustainability practices," while descriptions of Finland's resilience-driven approach were grouped under "strategic sustainability approaches." Themes related to the absence of measurement tools were organised under "sustainability metrics." This approach allowed the findings to emerge inductively while being conceptually structured through theoretically informed categories.

Finally, the second-order themes were distilled into aggregate dimensions representing the most abstract conceptual categories. The process culminated in the construction of a data structure diagram (see Table 4), visually representing the pathway from raw data to theoretical insights (Gioia et al., 2013, p. 20). The data structure also served as a scaffolding for developing a grounded model in the discussion chapter, moving from static coding structures to dynamic theoretical relationships (Gioia et al., 2013, p. 23).

1st Order Concepts	2nd Order Themes	Aggregate Dimensions
"--suggested that Finland should develop a national metaverse strategy"	Resilience	Sustainability Strategies
"In Finland, we don't aim to be the first to push technological progress alone. -- we do have a lot	Finnish Metaverse Characteristics	Sustainability Strategies

to offer in human-centred thinking”		
“We replaced prototypes with digital twins”	Digital design reduces materials	Sustainability Practices
“--Most likely, we will use the same operational models and calculation methods for aspects such as emissions as we do now.”	Environmental Metrics	Sustainability Metrics
“Yeah. There's really nothing yet in place. Right now, the focus is just on getting the software to work and getting the features right.”	Lack of social sustainability metrics	Sustainability Metrics

Table 4. Data Structure Illustrating First-Order Concepts, Second-Order Themes, and Aggregate Dimensions.

The use of the Gioia Methodology contributed to the study’s qualitative rigor by enabling credibility, transparency, and traceability from data to findings (Gioia et al., 2013, p. 17). The iterative coding process was documented through memos and coding histories in Atlas.ti, ensuring an auditable chain of evidence. Representative participant quotations were integrated throughout the findings to demonstrate alignment between informant voices and analytical claims, reinforcing what Gioia et al. (2013, p. 17) describe as maintaining the “voice of the informants.”

Moreover, by combining inductive coding with abductive reasoning, the analysis moves beyond purely descriptive accounts to develop conceptually grounded but analytically generalizable insights (Magnani & Gioia, 2023, p. 5). This integration of empirical data with theoretical constructs enabled the articulation of sustainability management in the

Metaverse as a multi-level phenomenon encompassing strategy, practice, and metrics—while simultaneously highlighting the gaps and tensions in current approaches.

In summary, the Gioia Methodology provided a structured yet flexible analytical pathway for translating rich, contextualized interview data into theoretically informed contributions, aligning with the study's objective to explore how sustainability is managed in the Metaverse and how these practices reflect broader technological and institutional dynamics.

5.4 Reliability and Validity

This section discusses the steps taken to ensure the research findings are trustworthy and credible, including measures for reliability, validity, and qualitative research rigour.

Reliability in research refers to the replicability of the findings (Stebbins, 2001, p. 49). For a study to be deemed reliable, another researcher employing similar methods should be able to make comparable observations. In exploratory research, reliability is heightened when multiple researchers participate in the same study and can identify similar patterns. To enhance the reliability of this research, utmost transparency is maintained. All interview questions and methods are thoroughly documented, and the literature is referenced according to the academic guidelines of the University of Vaasa.

Validity presents challenges in three keyways: first, the presence or activities of the researcher may influence the phenomenon being studied; second, the researcher may exhibit selective perception and interpretation; and third, the researcher may only observe limited aspects of the phenomenon (Stebbins, 2001, p. 48). To address these concerns, the exploratory researcher should engage with participants to discuss potential generalisations and mitigate personal bias. Additionally, the researcher must be aware of their own biases and actively seek evidence that contradicts their assumptions. It is also crucial to question whether the observed process can be generalised, as this is necessary for validation. Stebbins (2001, p. 49) notes that exploratory research lacks finality, and only future studies will provide the validity needed to establish an exploratory-confirmatory link.

Eriksson and Kovalainen (2015, p. 306) highlight the controversy surrounding the applicability of validity as a method for evaluating qualitative research. In this context, the validity of qualitative research refers to the accuracy of the report through analytic induction and reflexivity. To enhance generalisability, this research employs analytic generalisation. Eriksson and Kovalainen (2015, p. 307) explain that the empirical results are compared to previously developed theories in analytic generalisation. Replicability is achieved when two or more cases support the theory.

As discussed in the previous chapter, triangulation was employed in this research to further enhance validity (Eriksson & Kovalainen, 2015, p. 306). Furthermore, to strengthen the validity, the sample of interviewees was intentionally diverse in terms of age, gender, cultural background, organisational position, and various functional roles within the organisation.

Finally, traditional notions of reliability and validity in research have been superseded by a new set of trustworthiness criteria, which include dependability, transferability, credibility, and confirmability, alongside concepts of coherence, consistency, plausibility, and usefulness (Eriksson & Kovalainen, 2015, p. 308). The application of these factors in this research is outlined in Table 5.

1	Preunderstanding	The researcher gained pre-understanding through extensive literature reviews of Industry 4.0, Industry 5.0, sustainability frameworks, and Metaverse development. Additionally, familiarity with Finnish innovation policy and funding systems, including Business Finland, was developed through preliminary document analysis.
2	Creditability	

		Credibility was enhanced by triangulating interview data with secondary data from company reports, government strategies, and academic literature. The use of the Gioia method further ensured close adherence to participants' own language in coding and analysis.
3	Transferability	Transferability was supported by interviewing organisations across three key sectors of Finnish Metaverse development: gaming, industrial Metaverse, and public sector actors. Although specific to Finland, the insights are relevant to similar small innovation economies or public-private ecosystems prioritising human-centric digital strategies.
4	Dependability	Dependability was ensured by maintaining a detailed research log, documenting decisions, coding processes, and analysis steps. Interviews were transcribed verbatim with timestamps; coding decisions were reviewed iteratively, and an audit trail was kept through Atlas.ti software.
5	Confirmability	Confirmability was enhanced by using first-order codes based directly on participants' wording before progressing to higher-order themes, following the Gioia method. Selected quotations were presented in the findings to support interpretations.
6	Coherence	Integrity was supported by interviewing participants across different roles and sectors, reducing overreliance on a single organisational perspective. Interviews were confidential and anonymised to promote open disclosure without reputational concerns.
7	Plausibility	Participants were invited to review initial thematic summaries, and feedback was incorporated where clarification was needed. Multiple participants expressed that the findings accurately captured their perspectives.

8	Usefulness	Findings provide actionable insights for participating organisations by identifying gaps in sustainability practices, potential governance improvements, and opportunities for cross-sector collaboration. Interviewees were provided with a summary of implications to inform internal discussions.

Table 5. Trustworthiness Evaluation of the Study (Modified from Eriksson and Kovalainen, 2015, p. 308).

6 Findings

This chapter presents the empirical findings of the study. It begins by providing an overview of the Finnish Metaverse Initiative to contextualise the research setting. This is followed by a description of the selected case organisations and their respective roles within the initiative. The chapter then proceeds to a thematic presentation of the interview material, organised around the key dimensions of sustainability management identified in the analysis: strategies, practices, and metrics. Each theme is illustrated with supporting evidence from the interviews, highlighting both shared patterns and sector-specific differences across the cases.

6.1 Metaverse in Finland: Business Finland Initiatives for Metaverse

Business Finland is an official Finnish government agency that promotes trade, investment, innovation, funding, travel, and talent attraction. Its primary aim is to generate prosperity for Finland through sustainable growth and success for its customers. Business Finland supports the creation of solutions and the development of future ecosystems. As part of its initiatives, the agency launched the Finnish Metaverse Initiative, which includes over 250 companies, making Finland the first European nation to develop a dedicated Metaverse strategy. The interviewees were actively involved in the development of this initiative serving as a Senior Advisor and Key Account Manager in ICT and as the Mission Lead for Immersive Digital Life.

Launched in 2023, the Finnish Metaverse Initiative aims to bring together players from the Metaverse industry to collaboratively develop their own strategy. The vision of the initiative is to position Finland as the global leader and enabler in Metaverse development. The strategy will be updated annually and will be realised through five Metaverse in Action (MIA) programs starting in 2024. These programs include: (1) Technology Enablers, (2) Metaverse Society Program, (3) Metaverse Health Program, (4) Industrial Metaverse Program, and (5) Business Networks. According to the strategy paper, "We aim to create a Metaverse that is inclusive, accessible, ethical, and sustainable for all.

Sustainability refers to the Metaverse's value from environmental, social, and economic perspectives." Before the Finnish Metaverse initiative, Business Finland had other initiatives regarding the use of augmented reality, however, this initiative brings together different industry players – such as industrial metaverse developers as well as gaming and health industries. Despite this, the role of government funded VTT Technical Research Centre, Business Finland, agencies and universities is vital for the development of metaverse ecosystems in Finland. The case organisations are all part of the initiative and present different industries that take part in Metaverse. The comparative Table 2 in the case selection section consolidates information from the case organisations into a single overview.

6.2 Short Introductions to Case Organisations

6.2.1 Vertigo Innovations

Vertigo Innovations operates across more than 60 countries, serving nearly 600,000 customers globally. The interviewee holds the position of Digital Lead within the company's technology development unit in Finland. With ten years of tenure at Vertigo Innovations, she currently focuses on advancing digital distribution channels as part of the organisation's broader digital transformation efforts.

Vertigo Innovations has set an ambitious six-year strategy aiming to lead the industry across three core domains: becoming the number one choice for customers and employees, establishing leadership in sustainability and innovation, and achieving growth alongside profitability. To realise these ambitions, the company has articulated four strategic priorities: accelerating digital transformation to fundamentally reshape service delivery; driving growth by leveraging modernisation opportunities; securing a leadership position within the residential sector, the industry's largest segment; and reducing carbon emissions to enhance customer value and differentiate itself in the market.

In response to global megatrends such as sustainability, urbanisation, and technological advancement, the company focuses on delivering smart services and sustainable solutions that enhance user experience, safety, and accessibility. Key sustainability goals centre on achieving carbon neutrality and advancing diversity, equity, and inclusion (DEI). Vertigo Innovations actively promotes co-creation within partner ecosystems and champions integrated smart connectivity and intelligent maintenance solutions powered by IoT and AI technologies. Although the term Metaverse does not explicitly appear in the company's 2023 reports, the broader concept of digitalisation is repeatedly referenced as a strategic driver.

The company recognises several key risks associated with its digital ambitions. These include cybersecurity threats, operational vulnerabilities stemming from gaps in employees' digital competencies, and disruptions linked to geopolitical instability. Such risks are acknowledged as potential barriers to the successful digitalisation of services.

6.2.2 PulpFiction Technologies

This Finnish company specialises in the development and supply of process technologies, automation systems, and services for the pulp, paper, and energy industries. With a history spanning over 200 years, it has established itself as a global leader in these sectors. It operates in over 30 countries, employing approximately 19,000 professionals worldwide. The interviewee works as a lead in automatic systems and has been researching and working in the field of virtual reality since 2016. Recently the interviewee has been nominated as the Professor of Practice at a Finnish University. This is one of the ways the company seeks to strengthen their collaboration in areas of generative AI and green transition.

PulpFiction Technologies integrates the creation of sustainable outcomes into its core mission. To achieve this, the company aims to become an industry leader in innovation and technology. They believe that new technologies can drive growth and carbon neutrality. In terms of supply chains and operations, the company seeks to enhance sustainability, cost savings, and flexibility. These objectives are supported by a sustainability agenda grounded in Environmental, Social, and Governance (ESG) principles.

The environmental focus includes promoting material circularity, reducing CO2 emissions, and improving process efficiency. Social aspects centre on employee well-being, fostering a safety culture, and collaborating with universities and local initiatives working towards a better future. Governance is reflected in ethical business practices, including a systematic approach to sustainability management. Additional priorities include improving the transparency and sustainability of their supply chain and enhancing sustainability reporting.

6.2.3 Game Industry Association

The interviewee has served as the Executive of Game Industry Association, the hub of the Finnish game industry, for 13 years. The organisation's mission is to advocate for the game industry and unite key stakeholders in the field. Game Industry Association works to promote the shared interests of the industry, striving to provide a sustainable and growth-enabling working environment for Finnish game companies. With these goals in mind, the interviewee was part of the core group that established the Finnish Metaverse Initiative. While he no longer works directly with the Metaverse, he retains an overview of its role within the gaming industry.

Game Industry Association's strategy for 2024–2026 emphasises the sustainability challenges emerging within the gaming industry. Their role is to assess, facilitate, and support game companies in adapting to changes related to sustainability reporting, climate action, and other sustainability initiatives. Additionally, the association focuses on tracking and facilitating the impact of regulations such as the Digital Markets Act (DMA) and AI regulations on the gaming sector, as well as other technological advancements, including AI, that are transforming the industry. Social factors, such as attracting and retaining talent within the gaming industry, are also a key priority. Furthermore, supporting start-ups and enhancing communication within the gaming sector are central to the strategy for the coming years.

6.2.4 Cybrid Authority

Cybrid Authority is a government agency dedicated to ensuring smooth, sustainable, safe, and secure transport and communication services. The agency also plays a key role in promoting cybersecurity in Finland and provides licenses and registrations for businesses and individuals. The interviewee is the head of the Technology Department, with over 20 years of experience at the agency. Prior to her current role, she served as the head of Cybrid Authority.

The agency aims to be a leader and guiding force for Finnish public sector organisations in adopting a safe transition to the cloud and utilising AI. They recognise that digitalisation, security, and knowledge management will be key competitive advantages in the future. The Finnish government recommends that all public sector organisations prepare an annual sustainability report, addressing their activities in relation to the environment, people, and the economy. The Cybrid Agency has chosen three dimensions from the UN’s Agenda 2030 to focus on: Good Health and Well-being, Climate Action, and Sustainable Cities and Communities.

6.3 Concept of metaverse in practice

To understand the concept of the Metaverse, the case organisations were asked to explain their perceptions of what it is. The common conception of the Metaverse is that it represents something revolutionary, yet parallel to our everyday life, and inherently collaborative. However, it can be difficult to define due to its broad nature and the lack of a formal, universally accepted definition. The Metaverse is often described as a platform like Habbo Hotel, a fifth-generation internet world, or a collaborative ecosystem:

"At its simplest, the metaverse could be an internet add-on, something built on top of the internet. At the other extreme, it could be something that completely replaces the internet. -- The idea of what the metaverse is has become extremely broad—essentially, the metaverse can be anything from Habbo Hotel to The Matrix and everything in between." (Executive, Game Industry Association)

"The metaverse is, on one hand, a digital twin of reality, and on the other, the next evolution of the internet." (Senior Advisor and Key Account Manager, Business Finland)

"Well, I see that the metaverse is not any single technology but rather a kind of rendition of normal, real life. -- Instead of being human or machine, it's about what this co-existence means, and that's essentially what the metaverse is about—it's a large amount of data and how humans can utilize it." (Vertigo Innovations, Digital Lead)

"--community and social interaction play a major role in the metaverse-- (Head of the Technology Department, Cybrid Authority)

It is important to note, however, that the development of the Metaverse is still in its infancy, and the ecosystem has not yet matured to offer a unified experience. Despite this, it is already being utilised by industries:

"However, its business value has not yet fully materialized. Right now, training and remote support are the main business applications that work well." (Automatic Systems Lead, PulpFiction Technologies)

"On the industrial side, a company may have a virtual environment for product development, but that alone is not yet a metaverse." (Mission Lead for Immersive Digital Life, Business Finland)

"-- metaverse is mainly used by early adopters and industry." (Head of Technology Department, Cybrid Authority)

Interviewees identified several technologies currently shaping the Metaverse. These technologies include virtual reality (VR), augmented reality (AR), extended reality (XR), digital twins, simulations, and artificial intelligence (AI). The integration of these technologies supports immersive virtual worlds, facilitating interactive and engaging user experiences. Additionally, data sharing and partner collaborations play significant roles in defining how these technologies are employed:

> *"I always say that the Metaverse is a circle, with 3D models and data at its core, which we produce. On the outer ring, there are various technologies, some of which we don't even know yet, but are being developed. Currently, these include VR, AR, Digital Twin, various simulations, and AI, which enables many things. The outer ring also includes partners, with open connection points where only a specific layer of relevant data is shared with them. With one company, we share one set of data. With another company, we exchange a different set of data." (Digital Lead, Vertigo Innovations)*

> *"The European Commission refers to "immersive virtual worlds", where immersion is a key concept and one group of technologies. This includes VR/AR/XR technologies, which provide an engaging, immersive experience where the user is placed in another environment. The second major area involves virtual worlds and virtual platforms." (Senior Advisor and Key Account Manager, Business Finland)*

Interviewees also emphasised the necessity of explicitly linking technological choices to sustainability. They suggested that technology must not only be functional and immersive but also socially acceptable, accessible, safe, and inherently sustainable by design. This holistic perspective underscores the importance of embedding sustainability considerations into technological development from the outset, rather than treating sustainability as an afterthought:

> *"--must be easy to use, accessible, and socially accepted. The tools and technologies must also be safe." (Head of Technology Department, Cybrid Authority)*

> *"Technology choices are linked to sustainability." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

> *"But let's put it this way: the way this should be done is with a sustainability by design approach. That should be one of the fundamental principles in metaverse development, because otherwise, sustainability is just something that gets pasted on afterward." (Executive, Game Industry Association)*

However, some experts argue that sustainability has not been fully integrated into the development of the Metaverse from its inception. According to interviewees, sustainability considerations often appear secondary, introduced only after core technological and experiential goals have already been pursued:

> *"It depends a lot on the developer. I think sustainability hasn't really been integrated into the development process from the beginning. Instead, the focus has been on creating a metaverse or XR experience first, and only later thinking about how to incorporate sustainability. Right now, many projects seem to have been developed without sustainability in mind from the start." (Mission Lead for Immersive Digital Life, Business Finland)*

> *"User experience and human-centric design will become a bigger focus later as the whole ecosystem develops." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

> *"No, it hasn't [been integrated to the development of Metaverse]. Not at all. -- Meanwhile, my focus is heavily on technology, its limitations, and all the requirements that come with it." (Automatic Systems Lead, PulpFiction Technologies)*

> *"I think there has been so much new learning just in the technology itself and its use. Unfortunately, these softer values always tend to come in a little later." (Mission Lead for Immersive Digital Life, Business Finland)*

Additionally, the inherent characteristics of Metaverse technologies, such as rapid obsolescence, high initial investment costs, and challenges associated with electronic waste, may negatively influence their overall sustainability. Experts highlight concerns regarding both financial and ecological debts resulting from quickly evolving technologies:

> *"I think about the debt left when investing in certain technologies, and suddenly a better one comes along, requiring investment in that. Debt accumulates both financially and in terms of knowledge. So, what have people invested in: what have they decided to study, and if technology becomes obsolete, what does that mean? I see the biggest challenge being that the development is so vast, and no one knows what to expect in the end and how to plan for the future. On the other hand, if nothing is done right now, one will be late in development at some point." (Digital Lead, Vertigo Innovations)*

"This is what worries me the most right now. Many of these devices have a cycle too fast, they become obsolete quickly, and then what happens to them? They contain lithium and other materials. It's interesting to think about whether they just end up in mixed waste, whether they are crushed or emptied, but their recycling hasn't really been considered at all, even though they are high-end electronics." (Automatic Systems Lead, PulpFiction Technologies)

"Sustainability is also affected by development and maintenance costs." (Automatic Systems Lead, PulpFiction Technologies)

Nevertheless, interviewees suggest that sustainability considerations may become more prominent as Metaverse technologies become mainstream, economically viable, and practically integrated into daily life. This stage of adoption would enable greater focus on long-term sustainability:

"-- once the price, usability, and comfort of metaverse devices reach a level that aligns with people's everyday consumption habits—similar to smartphones—then sustainability will receive more attention." (Senior Advisor and Key Account Manager in ICT, Business Finland)

"Once smart glasses are developed to the level where they replace regular eyeglasses, we will probably be able to create more sustainable solutions and assess their cost-effectiveness." (Head of the Technology Department, Cybrid Authority)

These perspectives indicate that while current integration of sustainability is limited, future technological maturity and market acceptance could enhance sustainability's role in Metaverse development.

6.4 Sustainability strategies in the Metaverse

6.4.1 How economic sustainability and resilience sparked Metaverse initiatives in Finland

The request for the government-owned Business Finland to initiate a Metaverse project stemmed from a privately owned technology company. One of the key drivers behind coordinated Metaverse development in Finland is resilience, which aligns with the principles of Industry 5.0 outlined by the EU:

> *"The whole initiative started when we received interest from the global network and Nokia, which suggested that Finland should develop a national metaverse strategy—since China and the UAE had already done so at that time." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

> *"Finland has stronger expertise in immersive technologies, while platform development is happening primarily in East Asia and the U.S." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

> *"If, in ten years, the metaverse becomes the next stage of the internet, and business, commerce, personal lives, and communication all take place within that ecosystem, there is a clear risk if those platforms and ecosystems are controlled by China while Europe has no say in their governance. That is why I see Europe's metaverse development as a resilience factor. To remain resilient in the face of geopolitical shifts, we must keep pace with technological advancements." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

> *"When it comes to resilience, one major question regarding these virtual platforms is who provides the platforms, and which platforms will remain in operation." (Mission Lead for Immersive Digital Life, Business Finland)*

> *"Finland wants to promote the idea that the metaverse will become a positive development rather than a dystopia. The goal is to actively work to avoid negative consequences and strive toward a positive future." (Mission Lead for Immersive Digital Life, Business Finland)*

In Finland, expertise in the Metaverse field has been somewhat siloed, with different regions and organisations focusing on their own initiatives. As a result, one of the key roles of Finnish government agencies has been to unite these stakeholders, providing support and funding to foster collaboration:

> *"--and in Finland, you can see a similar pattern where Helsinki has its XR centre and considers itself strong, Turku has its own initiatives and thinks they are good, Tampere has a few strong players, and Nokia sees itself as a leader. However, no one has a comprehensive overview. -- when looking at the broader Metaverse as a*

whole, the expertise in Finland is also siloed into specific areas." (Automatic Systems Lead, PulpFiction Technologies)

"Since the industry is still in its early development phase, there has been a need for leadership to bring stakeholders together—and that role has so far been carried out by Business Finland." (Senior Advisor and Key Account Manager in ICT, Business Finland)

"I see Business Finland as a key player in advancing innovation and R&D projects. In fact, we distribute funding for cybersecurity-related innovation projects, and various government agencies provide financial support as well." (Head of the Technology Department, Cybrid Authority)

Another significant concern is the potential for Metaverse ecosystems to become closed-off, preventing Finnish organisations from participating. To address this, Finland has positioned itself as an architect and enabler for the emerging Metaverse:

"From an economic sustainability perspective, a major concern is that these platforms could become fully closed ecosystems—requiring entry fees or other restrictions, making it difficult for Finnish SMEs to access these markets." (Senior Advisor and Key Account Manager in ICT, Business Finland)

"Since we had to focus our efforts, we have chosen to position ourselves as an enabler or architect for the emerging metaverse platform." (Senior Advisor and Key Account Manager in ICT, Business Finland)

Interviewees illustrate how Finland is actively shaping the development of the Metaverse by focusing on resilience, fostering collaboration, and ensuring accessibility for its organisations, all while addressing the risk of platform monopolies and closed ecosystems.

6.4.2 Characteristics of Finnish Metaverse

Resilience is regarded as the primary driver of Metaverse development in Finland, though other guiding principles, such as sustainability and human-centricity, also play a crucial role in shaping technological development. These principles are considered essential to ensuring that technological progress aligns with broader societal and environmental goals. As one expert from Vertigo Innovations explains:

> *"In Finland, we don't aim to be the first to push technological progress alone. As a small country, we don't have the same capacity to compete in pure technological innovation. However, we do have a lot to offer in human-centred thinking." (Digital Lead, Vertigo Innovations)*

The emphasis on human-centric thinking reflects Finland's strategy of leveraging its strengths in areas like user experience and ethical technology design, rather than attempting to compete with larger countries in raw technological innovation. Further, the expert highlights a key aspect of sustainability from a social perspective:

> *"I think it's an interesting thought how people will accept new technologies into their use. Everyone knows that technologies might partially replace the work they do. Job roles are changing, and how people adapt to that is a key issue. That's a kind of sustainability perspective – how people can adjust to change, leverage it, and benefit from it. Do new technologies free up people's potential for innovation and help us focus on the areas where we excel, areas where machines cannot perform?" (Digital Lead, Vertigo Innovations)*

This statement points to the adaptability of the workforce in Finland, considering how technological advancements can facilitate personal and professional growth while ensuring that people are not displaced but empowered to focus on tasks where human skills are irreplaceable. Additionally, the Finnish government is prioritising the development of digital skills, particularly in areas such as cybersecurity, to support this transition. As noted by a representative from the Cybrid Authority:

> *"The Commission is also advancing digital skills development, particularly in cybersecurity expertise. "(Head of the Technology Department, Cybrid Authority)*

This effort aims to ensure that the workforce is well-equipped to engage with emerging technologies and secure the digital infrastructure necessary for Metaverse development. Finland is also positioned as a leader in Metaverse development within Europe. As one expert from the Cybrid Authority explains:

“Finland was the first European country to create a metaverse strategy. The Finnish metaverse community is quite active, and no other European country is at the same level yet. So, one could almost say that in terms of sustainability, Finland is also at the forefront.” (Head of the Technology Department, Cybrid Authority)

This highlights Finland’s pioneering role in the Metaverse space, particularly in terms of aligning technological development with sustainable practices. Moreover, Finnish stakeholders have consciously differentiated themselves by positioning Finland as a fair-trade-based Metaverse developer:

“In Finland, we have tried to differentiate ourselves from others by positioning ourselves as a country that develops a fair-trade-based metaverse.” (Senior Advisor and Key Account Manager ICT, Business Finland)

The Finnish reputation for trustworthiness also provides a competitive edge in developing critical applications. As noted by another expert:

“Finns are well-known for being trustworthy, and this reputation gives Finnish companies a competitive advantage in developing critical applications. For example, the Finnish company Varjo makes smart glasses for the U.S. defence industry, and these glasses have no data transfer capabilities at all. This kind of data security focus makes Finnish companies particularly well-positioned in certain fields.” (Mission Lead for Immersive Digital Life, Business Finland)

The emphasis on trustworthiness aligns with the broader ethical stance Finland takes towards technology and its applications, reinforcing the human-centric and responsible approach. Finally, one expert pointed out that Finnish companies share a common set of values, which fosters collaboration and sets them apart from other regions in the world:

“Another reason is that Finnish companies generally share similar values, making cooperation easier. For example, we don’t automatically consider cutting down all tropical rainforests acceptable. We also don’t view technology and business as the only priorities. In Finland, sustainability is highly valued, and there is a strong sense of responsibility toward both the environment and employees, which is not necessarily the case everywhere in the world.” (Digital Lead, Vertigo Innovations)

These quotes illustrate Finland's strong commitment to sustainability, not just in technology development, but across all sectors, underlining the country's collective responsibility toward environmental and social sustainability.

6.4.3 Institutional Dependencies in Digital Infrastructure Development

The involvement of the government and the European Union (EU) is regarded as crucial for organisations, as the development of the Metaverse heavily depends on robust infrastructure and economic growth. Experts highlight that establishing the necessary foundation for the Metaverse requires more than just technological expertise; it also necessitates significant investment and reliable, high-speed internet infrastructure:

> *"It requires expertise, money, and a stable, high-speed internet infrastructure." (Automatic Systems Lead, PulpFiction Technologies)*

> *"Nokia can provide network infrastructure and likely contribute something to the metaverse, but they can't do it alone -- the metaverse requires more than that." (Automatic Systems Lead, PulpFiction Technologies)*

> *"When we talk about digital services, resilience is only as strong as our digital infrastructure's resilience." (Executive, Game Industry Association)*

As one expert from Business Finland states, public sector involvement is essential to ensure that the Metaverse does not rely solely on private companies:

> *"-- public sector involvement is essential—it cannot rely solely on companies." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

Furthermore, the importance of European collaboration is stressed due to the vast financial resources of global competitors:

> *"We see European collaboration as essential because global competitors are massive and have deep financial resources." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

The EU and national actors in Finland are also promoting critical aspects of digital infrastructure, such as the development of cloud services:

> *"Similarly, the Commission—along with national actors in Finland—promotes cloud service development, which is also a critical part of the digital infrastructure." (Head of the Technology Department, Cybrid Authority)*

However, there are challenges related to economic sustainability. The EU suggests that member states should take action to ensure infrastructure development, but economic barriers, such as cost-saving concerns, may lead to the privatisation of the Metaverse. One expert from the Cybrid Authority explains:

> *"Yes, exactly. In fact, the EU Commission has published a white paper on infrastructure, in which it suggests that member states should own and control the infrastructure. The idea is to create a larger European entity, but all EU member states oppose this plan. The key concern is that the system needs to be economically sustainable and financially supported, so it is quite likely that we will see the emergence of large corporate players. Otherwise, we won't be able to achieve the benefits or cost savings that are necessary for success." (Head of the Technology Department, Cybrid Authority)*

Concerns over corporate dominance in the Metaverse are also raised, particularly in terms of competition and sustainability:

> *"And what happens if a major tech company buys out the platforms? Staying in the competition is a big challenge for Europe, and this also ties into sustainability—how sustainability issues are addressed will play a key role." (Head of the Technology Department, Cybrid Authority)*

Finally, it is essential for Finnish stakeholders to ensure that market access barriers are not embedded in platform development, as this could hinder sustainable progress:

> *"Finnish stakeholders must stay vigilant to ensure that market access barriers are not embedded into platform development—as these could also hinder the progress of sustainable development." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

These observations highlight the intricate connections between infrastructure development, economic sustainability, and the role of government and EU collaboration in shaping the future of the Metaverse in Finland.

6.4.4 The Growing Demand for Standardisation and Regulation

The European Union (EU) plays a crucial role in the development of the Metaverse, with its Industry 4.0 strategy paper and the Industry 5.0 principles of resilience, sustainability, and human-centricity influencing strategy development in Finland. These EU perspectives have been integrated into Finland's own Metaverse strategy, as noted by a Senior Advisor from Business Finland:

> *"The EU Commission released its Internet 4.0 strategy paper last year, which includes many of the same themes that we have incorporated into our own metaverse strategy work. -- Those three EU perspectives have been incorporated into our metaverse strategy work, which was published last November." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

In addition to orchestrating the Metaverse initiative, the Finnish government and its agencies are instrumental in shaping the strategy for the Metaverse, particularly in areas such as regulation and standardisation. These are areas where case organisations anticipate significant guidance from both Finnish government agencies and the EU:

> *"The public sector also plays a role—the state, through various strategies, guidelines, and regulations, provides incentives for development." (Head of the Technology Department, Cybrid Authority)*

> *"On the other hand, resilience is more about standards and how the technology is maintained and kept stable." (Mission Lead for Immersive Digital Life, Business Finland)*

However, global companies face significant challenges in competing with international players, particularly when standards vary widely across regions. This disparity in regulations complicates efforts to establish global agreements and harmonised approaches to technology development. As the Digital Content Lead at Vertigo Innovations points out:

"Perhaps the biggest global challenge is that legislation varies significantly between different countries. For example, if we consider China, its laws are very different from European regulations, making it extremely difficult to establish global agreements or get companies to commit to specific rules." (Digital Lead, Vertigo Innovations)

This comment highlights the difficulty in creating a unified global framework for technology and digital practices, as differing regulations across countries create barriers to consistent international cooperation and business operations. Moreover, it is noted that regulation and innovation are sometimes at odds:

"No, the EU couldn't lead it [establish itself in driver's seat in Metaverse development], but it could create a reference framework. The problem with EU regulation, or regulation in general, is that when things are regulated too strictly, it can negatively impact the market's ability to innovate because everything becomes too controlled. Meanwhile, in places where there is less regulation, the freedom to innovate is much greater. They can develop things that later arrive at us as a given because our regulations have prevented us from doing them ourselves. That is the downside of regulation." (Executive, Game Industry Association)

Additionally, the development of metaverse raises concerns about the future trajectory of digital capabilities, particularly regarding whether the gap between developed and developing regions will widen or narrow as the Metaverse continues to evolve:

"The big question is whether the gap in digital capabilities will widen or narrow as development continues. It's really difficult to address this through legislation because it comes from completely different starting points. However, I think the situation in Finland is good." (Digital Lead, Vertigo Innovations)

Here, the focus is on the challenge of addressing the digital divide, with legislation being an imperfect tool to close this gap, especially when countries are starting from different technological baselines. The reference to Finland's positive position suggests that it may have a unique opportunity to lead in this space. These reflections underscore the critical role of government involvement in developing standardised regulations that can ensure fair competition and alignment in the rapidly evolving Metaverse landscape. The importance of coordinated policymaking at both the national and international levels is evident, as without it, companies may face difficulty in navigating varying legislative frameworks across regions.

6.4.5 The Absence of Established Sustainability Frameworks

Sustainability is recognised as a key consideration within the case organisations; however, there is a notable lack of established frameworks to guide the development of strategies that address the economic, environmental, and social dimensions of sustainability. This gap is primarily attributed to the absence of clear regulations that direct organisations in these areas. As a result, there is uncertainty regarding the relevance of existing sustainability frameworks, particularly as current developments may not align with future needs. While efforts are made to comply with existing legislation, the frameworks and strategies being developed today may become outdated as the technological landscape evolves, complicating efforts to assess long-term impacts:

> *"These have become distant. It's difficult to see if these sustainability frameworks will still be relevant in 2030 when the things developed now are in production. At times, it's hard to place these issues on a timeline. A lot of work must be done in a vacuum in terms of conceptualizing and thinking, as we consider future issues, today's reality, and not tomorrow. If we base the development of something new solely on certain standards, it somewhat takes away from the cutting edge of innovation. Before anything goes into production, however, it is ensured that legislation is in place and other restrictions are considered. Except for a few small pieces, this is not very relevant at the moment." (Digital Lead, Vertigo Innovations)*

One reason for the lack of clear sustainability frameworks may be the lag between technological advancements and regulatory frameworks, which forces companies to navigate issues without clear guidance from existing laws:

> *"I think [EU's Digital Agenda] create a framework within which we operate, and they guide companies and countries to move in a certain direction. The problem is that legislation constantly lags behind. This means we often have to do things and consider issues for which there are no existing laws yet." (Digital Lead, Vertigo Innovations)*

Moreover, profitability plays a significant role in determining which sustainability frameworks companies adopt. The calculation of costs and benefits often leads companies to choose frameworks that align with their business goals rather than being driven solely by regulatory requirements:

> *“Business-driven decision-making plays a role in which frameworks and standards are deemed reasonable for companies to adopt. Costs and benefits are calculated, and based on that analysis, companies choose what is most profitable. So, as you mentioned, there are many frameworks available, but ultimately, each company makes its own choice.” (Head of the Technology Department, Cybrid Authority)*

As a result, there is a constant tension between sustainability and profitability within companies. While sustainability is often regarded as a key objective, financial factors frequently take precedence in decision-making. This dynamic underscore the challenge many companies face in driving sustainability efforts independently unless they can also demonstrate financial benefits:

> *“One thing I sometimes think about is the valuation of sustainability matters. The purpose of companies is to make a profit, and if profit and sustainability come into conflict, which one is chosen? Although many companies want to say that sustainability is really important, ultimately financial factors decide. In the best case, these can benefit each other. For example, it's much easier to justify a sustainability initiative when it simultaneously saves something. In many companies, it is difficult to drive sustainability efforts alone.” (Digital Lead, Vertigo Innovations)*

To conclude, sustainability in the Metaverse is shaped by a combination of industrial, technological, and societal factors. This highlights the need for a holistic approach to sustainability within the sector:

> *“This is a very broad topic, but in my view, sustainability in the metaverse emerges through the industrial, technological, and societal framework of the sector driving it.” (Executive, Game Industry Association)*

6.5 Sustainability practices in the Metaverse

6.5.1 Environmental Sustainability Practices in the Metaverse

Interviewees identified clear environmental sustainability benefits associated with the Metaverse, particularly highlighting reduced travel and transportation. The technologies enabling remote work, virtual collaboration, and remote operations significantly contribute to lowering carbon emissions. Such applications include remote operation of machinery, virtual workspaces facilitating global teamwork, and remote educational laboratories, all of which minimise the need for physical mobility:

> *"One major sustainability benefit is remote work and remote operations. Examples include: Remote operation of machinery, Virtual workspaces for global teams, Remote educational labs. These reduce travel, which has a significant impact on carbon footprints. -- In summary, the biggest environmental impact of the metaverse comes from reducing travel. For both personal and professional reasons, travel is one of the biggest contributors to an individual's carbon footprint. Thus, metaverse technologies can play a key role in making work and social interactions more sustainable." (Mission Lead for Immersive Digital Life, Business Finland)*

Similarly, the gaming industry has actively addressed sustainability challenges by developing various calculation and compensation models for climate emissions. Over recent years, significant progress has been made in this field, though experts acknowledge that such initiatives are continuously evolving and are unlikely ever to be fully completed:

> *"Well, let's put it this way—I don't know much about the metaverse in the field of medicine, but in the gaming industry, discussions about various sustainability gaps have been ongoing for the past 4–5 years. A lot of work has been done to address them, and different activity models, climate emission compensation models, and calculation models have been developed. This has actually been quite a big issue in the gaming industry over the past few years. It has evolved tremendously since we first started addressing it in 2019, before the Covid-19 pandemic. Since then, many new players have entered the space. It's not fully developed yet, and it probably never will be completely finished." (Executive, Game Industry Association)*

Furthermore, digitalisation and the Metaverse are noted as directly supporting sustainability through reducing the necessity for physical meetings and transport of goods, resulting in lower CO_2 emissions:

> *"Digitalization and the metaverse enable remote meetings and interactions, reducing the need for physical travel and transportation of goods. This directly contributes to reducing CO2 emissions." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

Hence, Metaverse has the potential to significantly contribute to environmental sustainability by reducing physical travel and transportation, suggesting broader implications for both individual and organisational carbon footprints.

6.5.2 Promoting Social Sustainability and Ethical AI

Interviewees highlighted several social sustainability concerns related to Metaverse technologies. These concerns primarily revolve around ergonomic challenges, inclusivity, accessibility, and broader societal implications such as digital inequality and social isolation. The physical usability of devices such as VR headsets is identified as problematic, potentially limiting prolonged usage:

> *"Yes, but it's also a problem for people because no one can wear headsets all day—they cause sweating, they are heavy, and they lack ergonomics." (Automatic Systems Lead, PulpFiction Technologies)*

Interviewees highlighted several social sustainability concerns related to Metaverse technologies. These concerns primarily revolve around ergonomic challenges, inclusivity, accessibility, and broader societal implications such as digital inequality and social isolation. The physical usability of devices such as VR headsets is identified as problematic, potentially limiting prolonged usage:

> *"Inclusivity and accessibility are critical. There is extensive research on how XR and metaverse environments can be used in product and service development to improve accessibility and inclusivity. This is particularly relevant in industrial*

maintenance, where most technicians are tall men. The ergonomics and usability of machines are often designed for their proportions, which excludes shorter individuals, such as women in the field." (Mission Lead for Immersive Digital Life, Business Finland)

Interviewees also expressed concern about the digital divide created by the high cost of Metaverse-related technologies, potentially exacerbating social inequalities:

"The cost is another factor, as poorer people may not be able to afford VR glasses, which in turn creates inequality in access to the metaverse." (Mission Lead for Immersive Digital Life, Business Finland)

"One possible solution to bridge this digital divide is to offer metaverse access points in public spaces, like libraries, where people could experience it firsthand." (Senior Advisor and Key Account Manager in ICT, Business Finland)

Additionally, interviewees pointed out initiatives designed specifically to address global digital divides and enhance social sustainability by fostering connectivity and employment opportunities in developing regions:

"There was an initiative called "5G Cottage", which is quite old now, but it involved several credible stakeholders. The idea was to provide connectivity and devices to developing countries, which could also create local job opportunities in those regions." (Senior Advisor and Key Account Manager in ICT, Business Finland)

Moreover, Metaverse initiatives are viewed as having positive potential for social sustainability, addressing issues like loneliness and improving social engagement among different demographics:

"Loneliness is a major and growing issue in Finland and many developed countries. The metaverse aims to reduce loneliness by creating new ways to connect. It also enhances democratic processes, allowing for broader citizen engagement and participation." (Senior Advisor and Key Account Manager in ICT, Business Finland)

"-- elderly people using smart glasses in rehabilitation have enjoyed the experience." (Senior Advisor and Key Account Manager in ICT, Business Finland)

6.5.3 Governance Practices in the Metaverse

Regarding governance and regulatory compliance, particularly around ethical AI use within the Metaverse, interviewees emphasised the importance of embedding regulatory compliance into the software design process from the outset, reflecting a proactive approach to governance:

> *"Since AI models are trained by humans, software design must account for these regulatory concerns from the start. Additionally, when launching software for public use, further regulatory compliance checks are necessary to avoid any legal violations under EU regulations." (Automatic Systems Lead, PulpFiction Technologies)*

Furthermore, there is recognition of the value of anticipatory governance, where strategic foresight guides the development of technology, rather than strictly adhering to current legislation, which might become quickly outdated:

> *"That's why I appreciate the fact that Finland approaches development rationally. We aim to conceptualize something that is not yet strictly regulated by current legislation. Here, the focus is on what work will look like in 2030, rather than getting stuck in what the laws say today." (Digital Lead, Vertigo Innovations)*

6.5.4 Economic Practices in the Metaverse

Economic sustainability practices identified by the interviewees relate primarily to cost optimisation, business development, and potential revenue generation through Metaverse technologies. Virtual models, for instance, can yield substantial cost savings in design processes and environmental compliance:

> *"We also used them to meet environmental board requirements and to visualize internal layouts, like movement areas. These virtual models save design costs." (Automatic Systems Lead, PulpFiction Technologies)*

The potential for the Metaverse to foster new export opportunities and enhance existing services, particularly in healthcare, was also emphasised:

> *"The goal is to develop new export-driven business opportunities for Finland, generating revenue and helping maintain the welfare state. The metaverse can also enhance existing processes, for example, in healthcare, by enabling remote digital services. At Business Finland, our focus is strongly on export promotion." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

Interviewees indicated that economic objectives, such as process optimisation, often indirectly contribute to sustainability by reducing emissions:

> *"Certain industries prioritize the business perspective and economic sustainability, such as process optimization. Often, when industrial processes are optimized, it indirectly leads to a reduction in CO2 emissions as well." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

Additionally, regulatory bodies such as tax authorities are exploring economic implications within the Metaverse context:

> *"For example, the Tax Administration is already investigating what taxation will mean in the metaverse." (Head of the Technology Department, Cybrid Authority)*

Innovative business models like 'play-to-earn', linked to NFTs and digital ownership, were also highlighted, alongside awareness of associated sustainability challenges:

> *"Back in the day, we developed a play-to-earn model, which at the time was one of those buzzwords that was linked to the NFT side of the metaverse. Essentially, it involved how NFTs become part of the metaverse and how ownership becomes a part of gaming. At the same time, we also touched upon the social and environmental challenges or other issues that might be associated with it." (Executive, Game Industry Association)*

Finally, the integration of sustainability into the broader value chain was recognised as becoming increasingly relevant as technological and economic activities mature:

> *"--the further we move along the value chain, the more sustainability perspectives come into focus." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

However, interviewees noted a significant lack of cross-industry collaboration and visibility regarding sustainability practices:

> *"There isn't [differences in sustainability practices between industries]. I am involved in the Metaverse in Action group, which focuses on technology companies, but we do very little collaboration with healthcare companies. So, the visibility between different industries is really poor. It feels like each player only has a view of their own sector, and in a way, a lot of work is still being done in silos. The metaverse should connect all these together, but we are not that far along yet." (Digital Lead, Vertigo Innovations)*

6.6 Sustainability metrics in the Metaverse

6.6.1 Current Gaps in Sustainability Metrics

The consensus among stakeholders is that sustainability metrics are either largely absent or still in development. Many experts in the field acknowledge that they have yet to encounter established metrics for sustainability:

> *"I haven't seen any. If you find any metrics, please share them with me as well." (Mission Lead for Immersive Digital Life, Business Finland)*

> *"We are not yet at a stage where we have specific metrics in place for this. -- It's a good thought and idea for future development." (Senior Advisor and Key Account Manager in ICT, Business Finland)*

> *"Yeah. There's really nothing yet in place. Right now, the focus is just on getting the software to work and getting the features right. I think sustainability is still in its early stages in this field." (Automatic Systems Lead, PulpFiction Technologies)*

> *"I don't really know if any metrics are being used yet. I'm not sure if we are using metrics at the Finnish level." (Digital Lead, Vertigo Innovations)*

Despite this, some sectors, particularly those focused on environmental impact, have already adopted emissions as a key metric for environmental sustainability. However, the broader issue remains the absence of comprehensive and standardised measurement systems:

> *"--Most likely, we will use the same operational models and calculation methods for aspects such as emissions as we do now." (Executive, Game Industry Association)*

> *"However, I have seen companies researching how much travel time and costs are saved and how much CO_2 emissions decrease when shifting to remote work." (Mission Lead for Immersive Digital Life, Business Finland)*

> *"-- Or could we lack proper metrics or standards?" (Head of the Technology Department, Cybrid Authority)*

Additionally, social sustainability metrics remain difficult to define, as they often involve qualitative aspects. The challenge of measuring concepts such as employee satisfaction and societal impact is highlighted by several experts:

> *"First, we need to know what we want to measure and how to measure it. Sustainable development cannot be measured with indicators; there are a lot of qualitative aspects involved. For example, if we consider an employee's satisfaction with their day, we can't directly say: "OK, today it was 8, and then it's 10." We can do self-assessments, but measuring qualitative data is more difficult." (Digital Lead, Vertigo Innovations)*

> *"Social metrics are harder to define. How do we measure working conditions and employee experience? Or assess the societal impact of digital developments? What does digital inclusion truly mean?" (Head of the Technology Department, Cybrid Authority)*

Above insights highlight the complexity and ongoing challenges in developing comprehensive sustainability metrics for both the environmental and social dimensions within the Metaverse and related industries.

6.6.2 Emerging Ethical, Cultural, and Regulatory Metrics

The interviews revealed diverse perspectives on the development and future integration of sustainability metrics into industry practices. A common theme was the increasing importance of regulation and self-reflection for companies on issues like emissions, diversity, and carbon footprint. As the executive from Game Industry Association noted, regulation is expected to gradually expand to include smaller companies in Europe, with a focus on metrics related to pay equality, emissions, and diversity. This would encourage companies to reflect on aspects they may not have considered before. However, the global adoption of such standards may be slower, particularly outside Europe:

> *"I believe regulation will move in a direction where it will gradually be extended—perhaps in a lighter form—to smaller and smaller companies. At some point in the future, the metrics will cover things like pay equality, emissions, carbon footprint, and diversity. At least European companies will comply with these regulations, but I don't think other countries around the world will be as eager to follow suit. The idea is to force companies to engage in self-reflection on issues they might not have previously considered. For example, in the gaming industry, some companies have been tracking their climate emissions for years, but certainly not all of them." (Executive, Game Industry Association)*

Another significant discussion point was the need for specific, actionable sustainability metrics. While experts agreed that metrics such as total energy consumption, energy efficiency, carbon footprint, digital waste generation, and recycling rates could be valuable, they also emphasised that political decisions and long-term guidelines are necessary for ensuring these metrics' relevance and consistency across industries. The Head of the Technology and Strategy Department at Cybrid Authority noted that while sustainability certifications are already in place, companies currently have the discretion to decide which metrics to follow, presenting an opportunity for these metrics to act as competitive advantages:

> *"So why not use total energy consumption as a metric? Or an energy efficiency index? Why not measure the carbon footprint? Should we consider the share of renewable energy used? Should digital waste generation be measured—or how much of it is produced? Why not track recycling rates? These are all metrics that already exist, but they would require political decisions and long-term guidelines to ensure their relevance in the future. There are already various sustainability programs and certifications, but currently, it is largely up to companies themselves to decide what they follow. However, these could also serve as competitive advantages." (Head of the Technology Department, Cybrid Authority)*

The ethical dimension of sustainability in digital spaces, such as the Metaverse, was also emphasised. One expert suggested that European standards, such as the GDPR, might be adopted globally in the future. However, the future of sustainability will also be influenced by cultural values and attitudes towards digital living. The Head of the Technology and Strategy Department raised the issue of transparency, particularly in terms of algorithmic transparency in the Metaverse, suggesting that societal values and cultural shifts will shape how sustainability is approached:

> *"I believe that at some point, the rest of the world will adopt Europe's GDPR requirements, forcing tech giants to comply. But we should also ask: What ethical standards will exist in the future? What will transparency requirements look like in the metaverse? Should algorithmic transparency be mandatory? In a way, the importance of transparency could even increase. Future attitudes and cultural values will also play a role—will people actually want to live in a digital world? I see this as a question of values and culture, which will heavily influence the future of ecological sustainability." (Head of the Technology Department, Cybrid Authority)*

Another expert emphasised the importance of reflecting on the added value and practical benefits of the Metaverse, questioning whether it truly enhances human well-being and quality of life. This perspective ties closely to sustainability, as the impact of the Metaverse on daily life and well-being is a central concern:

> *"What sometimes frustrates me in discussions about the metaverse is that has anyone really thought about what the metaverse actually gives us? What is its added value? Why do we need it? What will we do there? Sometimes, it would be good to ask whether we actually need it or not, and in what ways the metaverse improves our quality of life. This, again, is strongly connected to the idea of sustainability: in what ways does the metaverse enhance human well-being, daily life, and overall quality of life?" (Executive, Game Industry Association)*

These insights suggest that the future of sustainability in the Metaverse will not only rely on the development of standardised metrics but also on addressing ethical considerations, regulatory developments, and cultural shifts that influence how technology companies approach sustainability.

6.7 Summary of Findings

This chapter has explored how the Metaverse is conceptualised, developed, and managed by Finnish organisations, with particular emphasis on sustainability considerations, strategies, practices, and metrics. The findings illustrate that while there is broad recognition of the Metaverse as revolutionary and inherently collaborative, no universally accepted definition yet exists. This aligns closely with RO1, highlighting diverse interpretations of sustainability within the Metaverse and its alignment with Industry 4.0 and 5.0 principles, particularly emphasising resilience, human-centricity, and environmental responsibility.

Experts commonly perceive the Metaverse as an advanced digital ecosystem integrating immersive technologies such as VR, AR, XR, digital twins, simulations, and AI. However, practical adoption remains limited primarily to industry-specific applications, such as training, remote operations, and virtual collaboration. This early-stage development presents clear opportunities for enhanced sustainability but also significant challenges, notably the lack of standardised sustainability frameworks and metrics—addressing RO2. Key opportunities identified include reduced carbon emissions from decreased travel, improved inclusivity through technology design, and new economic and social engagement models. Challenges, meanwhile, stem from rapid technological obsolescence, high initial costs, digital inequality, ergonomic limitations, and insufficient cross-industry collaboration.

Sustainability strategies in Finland have been driven notably by economic resilience and geopolitical considerations, ensuring national competitiveness and independence from global platform monopolies. The Finnish approach emphasises sustainability by design, suggesting a proactive rather than reactive integration of sustainability. However, in practice, sustainability is often introduced as a secondary consideration once foundational technological goals have been established, highlighting gaps in current management practices—addressing RO3. Notably, sustainability metrics remain underdeveloped, with current efforts largely centred around measurable environmental impacts such as emissions, but lacking clear qualitative indicators for social dimensions.

Finnish organisations actively seek guidance from the EU and national institutions for developing standardised sustainability frameworks, illustrating strong institutional reliance in governance and infrastructure—addressing RO4. These organisations have positioned Finland as a leader within Europe, focusing on resilience, human-centricity, and ethical technology use. Nevertheless, substantial efforts remain to be made in defining consistent sustainability metrics and frameworks that can adapt to the evolving technological landscape.

Ultimately, these findings establish a foundation for the subsequent analysis and discussion chapter, which will critically evaluate how the empirical insights gathered here intersect with existing literature. The forthcoming discussion will specifically address how Finnish sustainability practices, strategies, and emerging metrics can inform broader frameworks for sustainability management in the global Metaverse landscape.

7 Discussion

This chapter critically discusses the findings presented in the previous chapter in relation to existing literature on sustainability management and Metaverse development. The aim is to interpret the results, evaluate their implications, and address the research question: How is sustainability managed in the Metaverse?

The importance of this study lies in its contribution to an emerging and underexplored field. While the Metaverse is gaining significant attention, limited research has examined how sustainability considerations are integrated into its development and management. By focusing specifically on the Finnish Metaverse initiative, this study offers early insights into how a technologically advanced, socially oriented country approaches sustainability within immersive digital ecosystems.

To achieve this, a qualitative case study approach was employed. Interviews were conducted with a range of organisations connected to the Finnish Metaverse initiative, including government agencies, industrial Metaverse developers, and gaming industry actors. Thematic analysis was applied to the interview data using Atlas.ti software, and the Gioia method was used to systematically code and structure emerging themes. This approach enabled a detailed understanding of how sustainability is conceptualised, strategized, and operationalised in this early stage of Metaverse development.

The discussion is structured around the four research objectives. First, it examines how sustainability is conceptualised within the Metaverse and how it is positioned within Industry 4.0 and Industry 5.0 frameworks (RO1). Second, it explores the opportunities and challenges associated with managing sustainability in the Metaverse (RO2). Third, it discusses the practices, strategies, and emerging metrics identified (RO3). Finally, it reflects on how the Finnish case can inform the development of general sustainability frameworks for the Metaverse globally (RO4).

By comparing the empirical findings with the existing body of knowledge, this chapter highlights areas of convergence and divergence, identifies research gaps, and offers new insights for advancing sustainable Metaverse development.

7.1 Conceptualisation of Sustainability in the Metaverse (RO1)

This section discusses how sustainability is conceptualised within the Metaverse by Finnish organisations and how these conceptualisations align with the broader frameworks of Industry 4.0 and Industry 5.0.

The findings showed that the Metaverse is generally perceived not as a single technology, but as an evolving ecosystem of interconnected technologies layered upon existing internet infrastructure. These technologies are such as VR, AR, XR, digital twins, and AI. This broad and somewhat fragmented understanding mirrors the challenges noted in the literature, where the Metaverse lacks a universally agreed definition (Uddin et al., 2023, p. 87089; Park & Kim, 2022, p. 4211; Schöbel & Leimeister, 2023, p. 1; Leng et al., 2022, p. 288).

Based on the findings, the technological structure of the Metaverse ecosystem can be conceptualised through a layered model. This model reflects how different technological and organisational elements interact to support immersive virtual environments (see Figure 2). The outermost layer represents the ecosystem of organisations, businesses, and stakeholders involved in the development, implementation, or use of these technologies. This includes tech companies, research institutions, governments, and other key actors essential for advancing and integrating these technologies into society.

The second layer encompasses the foundational technologies that support the operation of immersive and virtual systems. These technologies are crucial for providing the computational power, data security, and connectivity required for advanced technologies such as AI, VR, and 3D models. These infrastructure elements are necessary for the efficient functioning of more complex systems, particularly at scale.

The third layer includes the immersive technologies that allow users to access virtual worlds and interact with enhanced realities. These technologies build upon the foundational systems mentioned in the previous layer, enabling user engagement with virtual environments. The innermost layer consists of the virtual worlds and 3D models created using the technologies described in the previous layers

However, it is important to note that at this stage, sustainability and ethical governance layers are not yet explicitly integrated into the infrastructure model, highlighting an important gap in current Metaverse development.

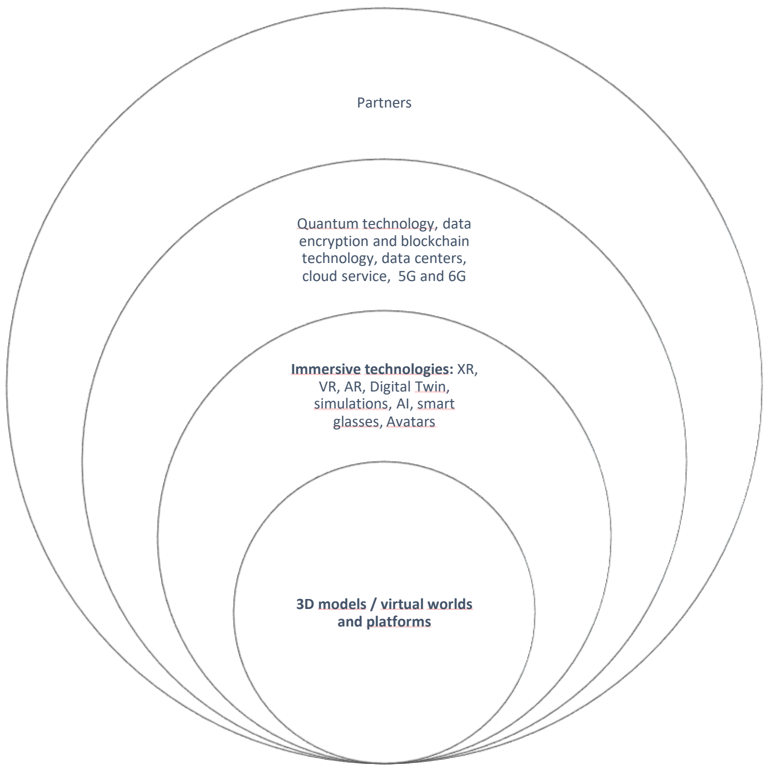

Figure 2. Conceptual Model of the Digital Infrastructure of the Metaverse.

Sustainability, within this evolving concept, is primarily positioned in relation to Industry 5.0 principles, particularly resilience, human-centricity, and environmental consciousness. This reflects the broader shift from Industry 4.0 to Industry 5.0, where sustainability moves from a secondary business goal towards a core strategic element (Ivanov, 2023, p. 1683; Xu et al., 2021, pp. 530–532). Finnish organisations in the study conceptualised sustainability not only in terms of reducing environmental impact, for instance, through virtual collaboration to reduce travel emissions but also as a human-centric challenge, emphasising inclusivity, accessibility, and ethical governance.

However, the findings also reveal that, in practice, sustainability is frequently introduced at later stages of development, rather than being embedded from the outset. This observation contrasts with the principle of ‘sustainability by design’ advocated in recent Metaverse scholarship (Wang et al., 2023, p. 347; Varriale et al., 2023, p. 19), suggesting a disconnect between strategic aspirations and operational realities. Piccarozzi et al. (2024, p. 1840) similarly note that sustainability considerations have often been secondary in the development of the Metaverse.

Moreover, this divergence calls into question the assumption that the Metaverse inherently reflects Industry 5.0 principles. Although the technologies underpinning the Metaverse are commonly associated with Industry 5.0, the development practices observed in this study appear more closely aligned with Industry 4.0 paradigms, where efficiency and technological advancement are prioritised over sustainability and human-centricity. This finding contrasts with Piccarozzi et al.’s (2024, p. 1840) argument that the Metaverse plays a pivotal role in facilitating the transition from Industry 4.0 to Industry 5.0 by enhancing human–machine collaboration and embedding sustainability and human-centred values as core principles. At the same time, Piccarozzi et al. (2024, p. 1845) warn that without responsible development processes, the Metaverse risks worsening negative outcomes, particularly in relation to social sustainability.

Thus, while the conceptual alignment with Industry 5.0 appears clear at a strategic level, practical implementation remains incomplete and fragmented. This highlights the need for clearer frameworks, earlier integration of sustainability considerations, and a stronger alignment between technological development and ethical, human-centric values.

7.2 Opportunities and Challenges in Managing Sustainability

This section critically examines the opportunities and challenges identified in managing sustainability within the Metaverse, drawing connections between the empirical findings and existing literature. It explores how technological, economic, environmental, social, and ethical factors shape sustainability management and highlights the broader systemic risks that could affect sustainable development in this emerging ecosystem.

The findings reveal that the Metaverse presents notable opportunities for advancing sustainability, even at this early stage of adoption. Organisations are already leveraging Metaverse technologies to reduce travel-related emissions through remote work, streamline industrial processes using digital design models, and reduce the need for physical business travel. These findings align with the literature, which suggests that the Metaverse could contribute to reducing spatial and energy consumption, as well as alleviating transportation demands (De Giovanni, 2023, p. 4; Piccarozzi et al., 2024, p. 1844). However, the literature also raises concerns regarding the substantial energy demands of enabling technologies such as blockchain, artificial intelligence data centres, and cloud computing (Asif et al., 2023, p. 9). Moreover, the production and disposal of hardware supporting the Metaverse contribute to growing volumes of electronic waste, posing environmental and health risks if sustainable recycling systems are not established (Nahavandi, 2019, p. 11).

Furthermore, when inclusivity is prioritised in its design, the Metaverse holds potential to support new economic and social models by expanding accessibility and creating opportunities for diverse user groups. An example of this is PulpFiction Technologies, which actively collaborates with universities in research, environmental protection, and youth initiatives.

Nevertheless, the findings also highlight significant challenges and global risks that could hinder the sustainable development of the Metaverse. First, interviewees consistently emphasised the high costs associated with developing, deploying, and maintaining Metaverse technologies. These costs create barriers not only for users, particularly individuals and small firms, but also for developers, thereby limiting large-scale adoption and exacerbating the digital divide. In addition, the rapid obsolescence of devices such as virtual reality headsets and smart glasses heightens concerns regarding electronic waste. Devices quickly become outdated, yet recycling systems for high-end electronics containing critical raw materials such as lithium are not yet adequately established. While ethical concerns about digital profiling and data extraction are widely discussed in the literature (Anshari et al., 2022, p. 9), the interviewees placed less emphasis on data ethics, instead prioritising economic and technological risks.

In contrast to the interviewees' emphasis, the literature highlights growing concerns about privacy, data extraction, and user profiling in the Metaverse (Anshari et al., 2022, p. 9; Wang et al., 2023, pp. 327–330). Anshari et al. (2022, p. 9) note that the data generated within immersive environments may be even more valuable and potentially more exploitable than traditional social media data. This highlights the need for sustainability management to encompass not only environmental and economic dimensions but also ethical and governance considerations within digital ecosystems.

A second major challenge identified was the fragmented nature of industry collaboration. Different sectors, including industrial, healthcare, and gaming, tend to operate in isolation with limited cross-sector visibility or cooperation. This fragmentation risks slowing innovation and impeding the development of shared sustainability standards and best practices.

Moreover, the findings indicate that sustainability is often treated as a secondary consideration, addressed only after core technological and experiential goals have been achieved. Several interviewees noted that organisations prioritised making the technology work, while issues such as accessibility, inclusivity, and environmental impact were addressed retrospectively. This observation is consistent with research, which suggests that sustainability by design approaches remain more aspirational than operational (Varriale et al., 2023, p. 19).

The literature further highlights that without explicit inclusion strategies, marginalised groups, such as individuals with disabilities, older adults, and those from disadvantaged socioeconomic backgrounds, face heightened risks of exclusion from Metaverse participation (Allam et al., 2022, p. 793; Kaddoura and Al Husseiny, 2023, p. 18; Nahavandi, 2019, p. 11). Although the interviewees acknowledged access challenges, their focus remained more on technological obsolescence than on issues of equity and inclusion. Yet a notable contrast emerged: while the case organisations identified sustainability as part of their core mission, their technological development activities remained disconnected from broader corporate sustainability initiatives. For example, Vertigo Innovations sustainability report describes their sustainability ambitions as very ambitious, while Pulp-Fiction Technologies reported addressing sustainability across their value chain, operations, and client technologies. This contrast underscores the persistence of silos between technological development and wider organisational strategies.

The digital divide also emerged as a significant challenge. High device costs and uneven digital skills across regions and social groups risk excluding disadvantaged populations from meaningful participation in Metaverse environments. Without deliberate strategies to promote digital inclusion, the Metaverse could reinforce, rather than mitigate, existing inequalities. This observation aligns with Kaddoura and Al Husseiny (2023, p. 18), who identified accessibility, particularly the affordability of virtual reality equipment, as a key barrier to equitable participation. However, the interviewees in this study perceived technological obsolescence as a greater obstacle than formal legal or regulatory exclusion.

Beyond these technological and social barriers, the findings also pointed to broader systemic global risks. Interviewees expressed concerns about the emergence of platform monopolies, whereby a few dominant corporations could control access, content, and participation in the Metaverse. Such monopolisation could significantly constrain opportunities for sustainable and inclusive governance. Additionally, regulatory fragmentation, particularly between the European Union, China, and the United States, complicates the development of consistent international standards. Divergent regulatory approaches may impede sustainable innovation while increasing competitive imbalances and geopolitical tensions.

Another critical concern identified was the potential subordination of sustainability principles to economic imperatives. As profitability continues to drive corporate decision-making, there is a tangible risk that sustainability initiatives will be deprioritised unless they can demonstrate immediate economic value. This economic imperative also intersects with ethical risks identified in the literature, including the monetisation of user data and digital footprints within immersive platforms (Anshari et al., 2022, p. 9), raising concerns about privacy, profiling, and data exploitation that are yet to be fully addressed within sustainability frameworks.

Finally, interviewees raised concerns about the risk of future inequality, whereby closed Metaverse ecosystems with high entry costs and proprietary platforms could exclude smaller actors, including small and medium-sized enterprises and organisations from developing regions, from participating fully in the digital economy. These risks directly impact sustainability management because if access to the Metaverse becomes restricted by monopolistic control or fragmented governance, the capacity to implement sustainable practices across the sector will be severely constrained.

These empirical findings align with broader concerns raised by the European Commission's resilience framework, which accentuates the need to build strong and adaptable strategic value chains capable of withstanding geopolitical disruptions and natural crises (European Commission, 2021, p. 14). Protecting critical infrastructure and maintaining flexible, sustainable production systems are particularly vital in sectors that address fundamental human needs, such as healthcare and security.

In conclusion, managing sustainability within the Metaverse must extend beyond technical solutions to address these broader systemic risks. Coordinated action among governments, industries, and civil society will be essential to develop inclusive governance structures, foster cross-sector collaboration, and ensure that sustainability remains a core principle rather than an optional consideration.

Table 1 summarises the key opportunities and challenges identified by the interviewees in managing sustainability within the evolving Metaverse ecosystem.

Opportunities	**Risks and Challenges**
Reduced travel & emissions	High technological costs
Enhanced inclusivity (if designed well)	Sustainability as a secondary priority
New economic opportunities	Electronic waste concerns
Digital prototypes and simulations	Rapid obsolescence of devices
Social benefits (e.g., reducing loneliness)	Digital divide and access inequality
Improved resilience (national and EU)	Platform monopolisation risks
Proactive positioning globally	Fragmented regulation globally
	Poor cross-industry collaboration
	Absence of sustainability metrics
	Unpredictability of societal impacts

Table 6. Opportunities, Risks and Challenges in Managing Sustainability in the Metaverse.

7.3 Practices, Strategies, and Metrics Used

While the opportunities and challenges outlined above provide a broad context for sustainability management in the Metaverse, it is equally important to examine the concrete practices, strategies, and emerging metrics that Finnish organisations are employing. The following section discusses these operational dimensions, offering insights into how sustainability is being translated from conceptual ideals into practical actions within the developing Metaverse ecosystem.

7.3.1 Sustainability Practices

The findings reveal that a range of practical actions are being undertaken to enhance sustainability within the Metaverse ecosystem. Organisations are primarily focusing on initiatives aimed at reducing environmental impact through technological applications.

One of the most frequently cited practices was the use of digital models to replace physical prototypes, thereby reducing both material consumption and the need for business travel. Interviewees also highlighted the adoption of remote operational technologies, enabling industrial processes to be managed without physical presence, thus contributing to lower emissions.

These practices align with the aspirations outlined in the Industry 5.0 framework, which emphasises operational resilience and resource efficiency (European Commission, 2021, p. 14). From an environmental standpoint, the literature similarly suggests that Metaverse adoption holds potential for reducing emissions and waste in production and logistics, although it may also lead to increased overall energy consumption (De Giovanni, 2023, pp. 11–12). The concern of rising energy consumption was also raised by Cybrid Authority, which has adopted the United Nations Sustainable Development Goal (SDG) 13, “Climate Action,” as one of its strategic objectives. The organisation collects annual data on the ICT industry’s energy use and contributes this information to EU-level collaboration initiatives aimed at developing shared environmental impact monitoring indicators.

Furthermore, although inclusivity and accessibility were frequently mentioned in the findings, they were primarily framed as aspirational goals rather than being implemented through specific practices at this stage. In practice, efforts to broaden inclusivity appear to have been driven mainly by Business Finland, which has facilitated collaboration with universities, non-governmental organisations, and other societal actors. These partnerships have aimed to integrate diverse perspectives beyond purely technological viewpoints, although concrete measures for inclusivity remain limited in implementation.

7.3.2 Strategic Approaches to Sustainability

Beyond individual practices, Finnish organisations have adopted broader strategic approaches to integrate sustainability into Metaverse development. The findings indicate that strategy formation has been heavily influenced by national resilience goals and the drive to maintain technological sovereignty. Also, the literature raises critical concerns about the Metaverse's potential to erode democratic spaces and civic participation if governance structures privilege corporate control over public accountability (Allam et al., 2022, p. 792; Al-Amoudi, 2023, pp. 1241–1242). These risks further emphasise the need to embed principles of transparency, inclusion, and democratic oversight within Metaverse governance to ensure its alignment with broader sustainability and societal goals.

A key strategic initiative involves the coordination efforts led by Business Finland, aiming to consolidate siloed expertise across regions and sectors. Furthermore, Finnish companies have sought to differentiate themselves from global competitors by emphasising ethical and human-centric design principles, particularly in areas such as cybersecurity and data protection. Nevertheless, the findings also suggest that sustainability remains more of an aspirational goal than a fully embedded practice within current strategic planning processes.

7.3.3 Sustainability Metrics: Current Gaps and Emerging Ideas

The development and application of sustainability metrics within the Metaverse remain at an early and uneven stage. Most interviewees acknowledged a notable absence of formalised metrics, particularly in relation to the social and ethical dimensions of sustainability. Environmental indicators such as reductions in travel-related emissions were among the few quantifiable measures currently in use. Some organisations have begun tracking factors such as time savings from virtual operations and the corresponding reduction in carbon dioxide emissions.

In addition to the traditional pillars of sustainability that include economic, environmental, and social, some case organisations reflected emerging attention to a technological dimension (Rajguru & Brüggemann, 2024). However, this aspect appeared largely aspirational, with limited evidence of concrete strategies or metrics to evaluate long-term technological resilience, interoperability, or innovation capacity. Nonetheless, the conceptual inclusion of this dimension in the literature presents a compelling argument. It aligns with the broader objectives of Industry 5.0, which shifts focus from economic growth alone to more values-based, sustainable progress. From this perspective, the success of the Metaverse should be assessed not solely through growth metrics, but by its contribution to sustainable development. This reframing suggests that technological development itself must become a core component of sustainability evaluation. While this offers a more holistic lens for assessment, the operationalisation of the technological dimension remains a clear area for future development.

These findings are consistent with concerns in the academic literature, which note that emerging technologies often face measurement challenges due to the absence of standardised frameworks (Wang et al., 2023, p. 247). A notable exception emerged in the gaming sector, where one interviewee reported that sustainability had been actively addressed for several years: “In the gaming industry, discussions about various sustainability gaps have been ongoing for the past 4–5 years. A lot of work has been done to address them, and different activity models, climate emission compensation models, and calculation models have been developed. This has actually been quite a big issue in the gaming industry over the past few years.” This indicates that while most sectors involved in Metaverse development are still in the early stages of developing sustainability metrics, but others like gaming—may offer valuable precedents and practical models for wider application.

The findings also support Piccarozzi et al. (2024, p. 1840), who observe that although interest in sustainability is growing, it remains underexplored within the context of the Metaverse—especially in terms of identifying concrete opportunities, addressing challenges, and defining suitable metrics. This reinforces the need for continued research and the development of robust, standardised frameworks for evaluating sustainability in immersive digital environments.

In summary, although sustainability practices and strategic intentions are beginning to take shape within Finland’s Metaverse ecosystem, the development of comprehensive and reliable metrics is still in its infancy. As the ecosystem matures, the ability to measure and validate sustainability outcomes across environmental, social, governance, and technological dimensions will be critical for embedding sustainability as a core principle rather than treating it as a secondary or symbolic goal.

7.4 Finnish Approaches and Lessons for Global Sustainability Frameworks

This section discusses how Finnish Metaverse initiatives combine sustainability principles such as human-centricity and resilience and explores how these practices may inform the development of broader sustainability frameworks for the Metaverse at the global level.

7.4.1 Human-centricity and Ethical Design

Human-centricity is consistently emphasised in Finnish Metaverse strategies. Interviewees highlighted the prioritisation of inclusivity, accessibility, and user-centred design, particularly in sectors such as cybersecurity and XR environments. The focus on ethical design, which includes data protection and reducing digital exclusion, was seen as a strategic differentiator when compared to larger, less regulated global competitors. Sustainable design was also reported as one of PulpFiction Technologies' strategic goals. Similarly, Vertigo Innovations' sustainability report mentions ethical standards, indicating a formal commitment to responsible practices. These standards align with regulatory frameworks, reinforcing the importance of guidelines highlighted by Cybrid Authority, whose representative noted: "The public sector also plays a role—the state, through various strategies, guidelines, and regulations, provides incentives for development."

These findings are consistent with the literature, which emphasises the need to align Metaverse development with broader sustainable development goals. Jauhiainen et al. (2023, p. 4) advocate for aligning Metaverse projects with the United Nations Sustainable Development Goals (SDGs) to improve ethical responsibility and long-term sustainability. Furthermore, they stress the importance of conducting systematic impact assessments to evaluate the Metaverse's relationship with sustainable development without undermining economic growth (Jauhiainen et al., 2023, p. 16).

Additionally, the novelty of immersive technologies introduces unpredictability regarding their societal and environmental impacts. As noted by Varriale et al. (2023, p. 19), the triple bottom line perspective, which covers economic, social, and environmental sustainability, has yet to be extensively examined within the Metaverse context. This gap highlights the need for proactive governance and ethical oversight.

7.4.2 Collaboration Between Institutions and Industry

Another distinctive feature of the Finnish approach is the close collaboration between governmental agencies, particularly Business Finland, and private industry stakeholders. Business Finland has played a central role in unifying a previously fragmented national ecosystem, facilitating cross-sector collaboration, and providing critical funding for Metaverse-related innovations.

This collaborative model exemplifies a proactive, resilience-driven strategy, contrasting with the more reactive or fragmented approaches observed in other regions. By fostering early cooperation and strategic alignment, Finland aims to build a Metaverse infrastructure that is resilient to geopolitical and technological disruptions while maintaining a strong focus on ethical and human-centric design principles.

Nonetheless, a notable gap emerges when sustainability objectives have not been systematically embedded within governmental funding criteria or strategic guidance. Although public funding influences which organisations and projects receive support, it does so without explicitly requiring alignment with environmental or social sustainability goals. Consequently, while resilience is prioritised, broader sustainability dimensions risk being overlooked. This raises a critical question for future policy: whether resilience without comprehensive sustainability integration can be considered sufficient, and whether public agencies should introduce sustainability obligations to ensure technological progress also advances environmental and social imperatives.

These interrelated dynamics can be conceptualised through a grounded model, which illustrates the interactions between sustainability strategies, practices, metrics, institutional influences, and systemic challenges within the Finnish Metaverse context (Figure 3).

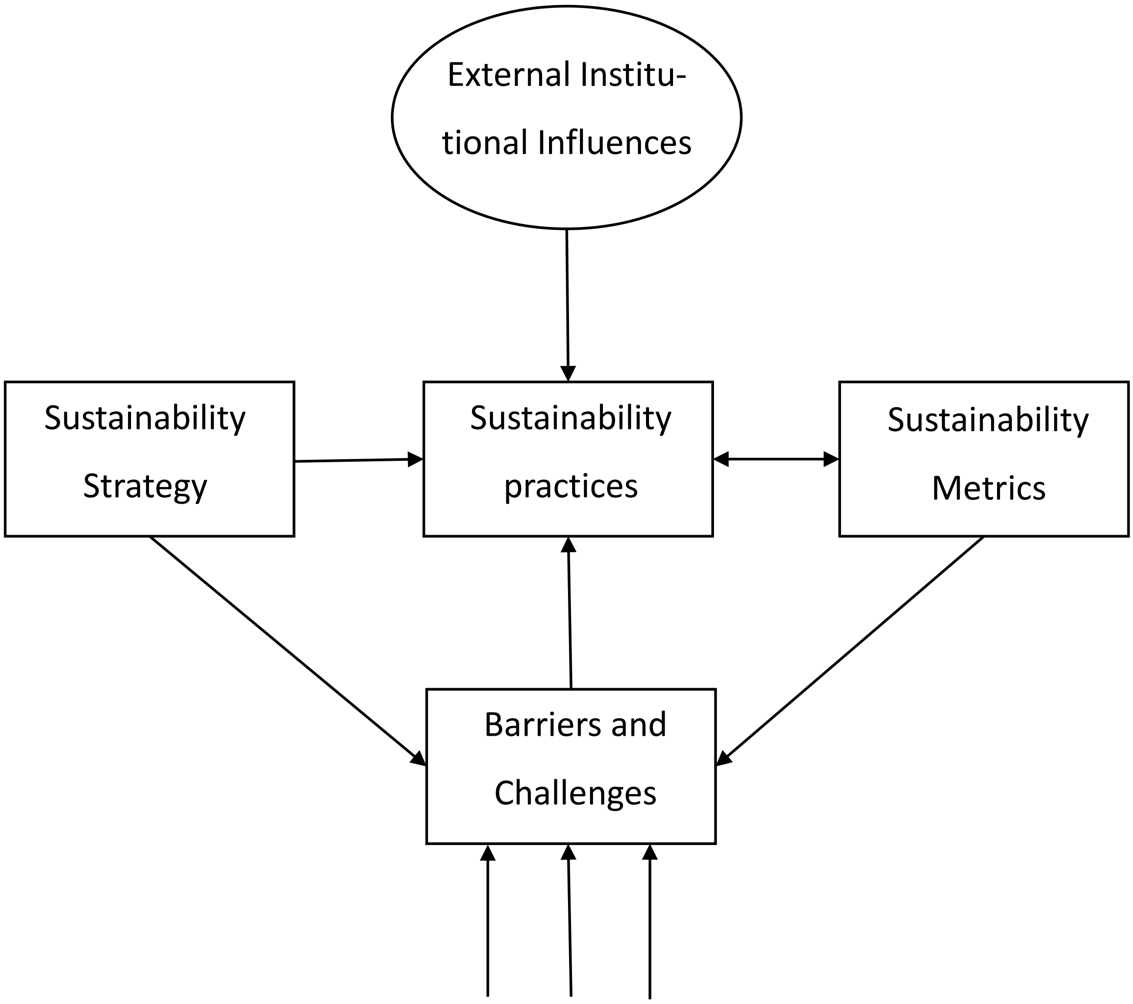

Figure 3. Grounded Model of Sustainability Management in the Finnish Metaverse Context.

7.4.3 Towards Inclusive and Practical Sustainability Frameworks

The findings highlight the need for interdisciplinary approaches that bridge business, sustainability, and engineering disciplines. Currently, Metaverse research and development tends to occur in silos: business studies focus on sustainability implications, while technological and engineering disciplines concentrate on infrastructure development. Therefore, to build effective and future-proof sustainability frameworks for the Metaverse, it is essential to foster dialogue and collaboration across these disciplinary boundaries. Frameworks must not only articulate high-level goals but also address practical implementation realities, considering the perspectives and challenges faced by developers, engineers, and technologists. Moreover, as Kaddoura and Al Husseiny (2023, p. 19) emphasise, achieving sustainability in the Metaverse also requires addressing issues of social acceptance and inclusivity, reinforcing the need for participatory and user-centred approaches in both design and governance.

In this regard, the Finnish experience offers important lessons: although strong conceptual foundations have been laid, the path to operationalising sustainability within Metaverse development remains complex, iterative, and highly dependent on cross-sector cooperation, cultural change within the technology sector, and ongoing efforts to ensure inclusive participation.

7.5 Summary of the Discussion

The aim of this study was to explore how sustainability is managed within the emerging context of the Metaverse. The research was guided by the following Research Question: How is sustainability managed in the Metaverse?

To answer this question, four Research Objectives (ROs) were established:
RO1: To investigate how sustainability is conceptualised in the Metaverse and positioned within the frameworks of Industry 4.0 and Industry 5.0.
RO2: To identify the opportunities and challenges in managing sustainability in the Metaverse.
RO3: To examine the practices, strategies, and metrics used to manage sustainability.
RO4: To analyse how Finnish Metaverse developers manage sustainability and how these practices could inform broader frameworks.

The research adopted a qualitative case study approach, focusing on organisations involved in the Finnish Metaverse initiative. Data were collected through semi-structured interviews with key actors from government agencies, industrial Metaverse sectors, and the gaming industry. The data were analysed using thematic analysis, applying the Gioia method with Atlas.ti software to systematically code and conceptualise findings. The findings were presented and discussed across four main themes in Chapter 7.

Firstly, Section 7.1 examined the conceptualisation of sustainability within the Metaverse. Sustainability was primarily framed through the principles of Industry 5.0, such as resilience, human-centricity, and environmental consciousness. However, the practical implementation of these ideals often lagged the conceptual goals.

Secondly, Section 7.2 explored the opportunities and challenges in managing sustainability. Opportunities such as reduced emissions through remote work and enhanced inclusivity were identified, alongside significant challenges including high costs, technological obsolescence, the digital divide, lack of cross-industry cooperation, and risks of monopolisation.

Thirdly, Section 7.3 examined the practices, strategies, and metrics currently employed by Finnish organisations. While environmental practices, such as travel reduction, were beginning to emerge, social and ethical aspects of sustainability were less systematically addressed. Strategies primarily focused on enhancing resilience and ensuring technological sovereignty, but sustainability considerations largely remained aspirational. Notably, formalised sustainability metrics were largely absent, reinforcing the literature's observations about the early-stage gaps in measurement within this field.

Finally, Section 7.4 examined the Finnish approaches and lessons for global sustainability frameworks. Human-centricity, ethical design, and institutional collaboration were key strengths identified. However, it was also noted that while public agencies such as Business Finland played a central role in shaping the Metaverse ecosystem, sustainability requirements were not yet systematically embedded into funding or strategic frameworks. This raises critical questions about whether resilience-driven development can be sufficient without more explicit integration of sustainability goals. Overall, the findings highlight a dynamic but fragmented landscape, where the aspirations of sustainable Metaverse development have yet to be fully realised in practice.

7.5.1 Key Findings

The Metaverse has been conceptualised by Finnish organisations not as a singular technology, but as a dynamic ecosystem composed of multiple interconnected technologies, such as VR, AR, XR, digital twins, and AI. Sustainability is a central focus within the framework of Industry 5.0, particularly in terms of resilience, human-centricity, and environmental consciousness. However, while these principles are prominently positioned in strategic discussions, they are often viewed more as idealistic aims than as operational imperatives. Despite recognising the importance of sustainability, stakeholders have not systematically integrated it from the outset of Metaverse development. This gap reflects a disconnection between the conceptual alignment with Industry 5.0 and its practical application, a concern that has been highlighted in recent academic critiques.

The study identified several key opportunities for integrating sustainability into Metaverse development. These include reducing carbon emissions by minimising travel, enhancing inclusivity and accessibility through digital platforms, and fostering new economic and social forms of interaction. However, significant challenges also emerged. These challenges include the high technological costs associated with Metaverse development, rapid obsolescence of hardware, the creation of electronic waste, digital inequality due to access barriers, and the risk of monopolisation by dominant platform providers. In addition, regulatory fragmentation at the international level complicates efforts to coordinate sustainability practices. If not adequately addressed, these risks could heighten existing inequalities and undermine the long-term sustainability of the Metaverse.

At a practical level, Finnish organisations have begun to implement measures aimed at enhancing environmental sustainability. This includes the use of digital twins and remote operational technologies to optimise processes and reduce emissions. Strategic approaches in the Metaverse focus on building resilience, promoting ethical design, and fostering collaboration between the public and private sectors, particularly through initiatives such as Business Finland. However, sustainability remains largely aspirational, with few concrete strategies being systematically incorporated into day-to-day operations.

In terms of metrics, the research found a significant gap in the formalisation of systems to measure sustainability impacts. Existing efforts have mainly focused on environmental factors, such as reductions in CO_2 emissions linked to travel reduction. Social and ethical metrics, however, are still largely underdeveloped, indicating a pressing need for standardised and actionable frameworks to measure sustainability effectively.

Finnish organisations have taken a proactive approach, focusing on resilience, ethical development, and early-stage collaboration across various sectors. The integration of human-centric design and cybersecurity into Metaverse development were identified as notable strengths. Despite these efforts, a critical limitation emerged: although the government is heavily involved, sustainability goals have not yet been systematically embedded into funding criteria or development strategies. Overlooking this poses a risk to long-term sustainability, as the goals could become disconnected from practical implementation.

The Finnish approach demonstrates that while national coordination and ethical framing are strong foundations, the development of sustainability frameworks in the Metaverse requires more than top-down policy. It necessitates a collaborative, interdisciplinary effort that includes technological developers and technology users in the conversation. Finland's model provides useful lessons for creating global frameworks but also underpins the considerable challenges involved in operationalising sustainability in an emerging digital ecosystem.

7.5.2 Theoretical Contributions

This chapter defines the theoretical contributions of this study to the growing body of literature on sustainability management within the Metaverse. By combining perspectives from Industry 4.0 and Industry 5.0 frameworks, this research introduces a novel conceptualisation of the Metaverse as an evolving, layered ecosystem, rather than a discrete technological platform. This conceptualisation builds upon existing definitions by emphasising the dynamic interplay between technological infrastructures, organisational ecosystems, and sustainability challenges, marking a significant step in the theoretical understanding of this emerging field.

The study highlights a persistent gap between strategic sustainability aspirations and operational realities, reinforcing recent scholarly calls for the earlier integration of sustainability principles into technological innovation. The findings contribute to the literature by deepening theoretical debates around how key Industry 5.0 ideals, such as human-centricity, resilience, and sustainability, are under-implemented in Metaverse development, despite their prominence in policy and strategy discussions. This directly responds to the literature gap concerning how sustainability is conceptualised and operationalised in the Metaverse.

Furthermore, the research reveals a critical absence of standardised sustainability metrics, particularly regarding social and ethical dimensions. This finding enriches the theoretical understanding by underlining the need for interdisciplinary approaches that integrate sustainability research, business strategy, and technological development. The study advocates for the development of comprehensive frameworks capable of addressing the complex sustainability trade-offs inherent in immersive digital environments, supporting recent calls for more robust, cross-sector frameworks for sustainable development in the Metaverse.

The theoretical contributions also extend to the issue of governance. The research identifies the fragmentation of governance structures in global digital ecosystems, reinforcing concerns about the disjointedness of regulatory approaches. By identifying these governance gaps both empirically and theoretically, the study highlights the need for policy interventions that prioritise cross-sector collaboration and the establishment of ethical standards, which are crucial for ensuring the sustainable and responsible development of the Metaverse.

Finally, the study positions the Metaverse within the broader transition from Industry 4.0 to Industry 5.0. It addresses the gap in research regarding how emerging technologies align with the human-centric and sustainability principles of Industry 5.0, providing empirical evidence that sustainability management remains underdeveloped during this technological shift. By conceptualising sustainability as relationally constructed across organisational, technological, and policy layers, this research introduces a more systemic lens for theorising sustainability governance in immersive digital spaces.

7.5.3 Managerial Implications

This chapter discusses the practical implications of this study for organisations operating within the Metaverse ecosystem. The findings emphasise the importance of integrating sustainability considerations early in the development process, suggesting that organisations should adopt sustainability-by-design principles rather than treating sustainability as a secondary concern or a retrospective add-on. Given the emerging nature of the Metaverse, this approach can help organisations stay ahead of regulatory and reputational risks by proactively addressing environmental, social, and ethical impacts.

One of the key managerial takeaways is the need to develop quantifiable sustainability metrics, such as emissions reductions, energy consumption tracking, and digital inclusion indicators. These metrics would not only enable transparent reporting but also allow for effective benchmarking across projects, helping organisations better assess, and communicate their sustainability performance. The research indicates that the lack of formalised sustainability metrics, especially in social and ethical domains, is a significant gap in current Metaverse development and should be prioritised by organisations.

Moreover, the research highlights the critical role of public agencies, such as Business Finland, play in shaping sustainability outcomes. The study suggests that public agencies should incorporate environmental, social, and governance (ESG) criteria into funding mechanisms and strategic policy guidance. By leveraging their position as funding bodies and ecosystem coordinators, these agencies can help align technological innovation with broader sustainability goals, fostering collaboration between public and private sectors.

For policymakers and practitioners, the study highlights the necessity of fostering interdisciplinary collaboration across technical, business, and sustainability domains. Addressing the complexities of sustainability management in the Metaverse requires going beyond sectoral silos to create shared standards, practices, and metrics. Developing cross-sector partnerships and involving diverse stakeholders early in the innovation process can mitigate fragmentation and ensure more equitable and sustainable outcomes.

The study also indicates that organisations prioritising human-centricity, ethical design, transparency, and inclusivity from the start are likely to gain a competitive advantage in the increasingly sustainability-conscious global market. Aligning strategies with emerging sustainability and ethical expectations will not only reduce future regulatory and reputational risks but also position companies as leaders in responsible digital innovation.

Overall, the research provides actionable insights for organisations within the Metaverse ecosystem, offering a roadmap for integrating sustainability into the heart of technological development. By proactively addressing sustainability issues, organisations can help shape the Metaverse as a more inclusive, responsible, and resilient digital environment.

7.5.4 Limitations of the Study

While this study provides important insights into sustainability management in the context of the Metaverse, it also has several limitations that should be acknowledged.

Firstly, the research was geographically limited to Finland, focusing on organisations involved in the Finnish Metaverse initiative. Although this provides a valuable case study of a proactive national approach, the findings may not be fully generalisable to different socio-economic or regulatory environments, particularly outside Europe.

Secondly, the Metaverse as a technological and social phenomenon remains in an early stage of development. Consequently, the practices, strategies, and conceptualisations identified in this study may evolve rapidly, and some observations may become outdated as the Metaverse ecosystem matures.

Thirdly, the study primarily captured the perspectives of organisational representatives with technological and strategic expertise. While this was appropriate for the study's objectives, it may have limited the depth of insight into how sustainability considerations are perceived and operationalised by broader stakeholder groups, such as end-users or sustainability specialists within organisations.

Finally, given the qualitative and exploratory nature of the research, the findings are based on a thematic analysis of interviews rather than quantitative validation. While the Gioia method ensured systematic coding and interpretation, the results are inherently interpretive and context specific.

These limitations suggest that further research in broader contexts and using mixed-methods approaches would be valuable to build a more comprehensive understanding of sustainability management in emerging digital ecosystems.

7.5.5 Future Research Directions

Given the Metaverse's emerging nature and the current lack of established frameworks for evaluating its sustainability, future research should prioritise the development of standardised, cross-sector indicators. More attention should be given to assessing the social, ethical, and technological dimensions of sustainability, which have so far received less focus compared to environmental, governance, and economic aspects. These indicators would help ensure a more balanced and inclusive approach to evaluating sustainability performance in immersive digital environments.

Additionally, the Metaverse ecosystem would benefit from comparative case studies, especially those that make cross-national comparisons between leading Metaverse-developing countries such as China and the United States. Such studies could investigate how regulatory frameworks, cultural norms, and market maturity affect the integration of sustainability principles into Metaverse development.

Finally, due to the novelty of the Metaverse and the lack of long-term data, longitudinal research is needed to examine how sustainability strategies emerge, adapt, and evolve over time. Tracking these developments would provide valuable insights into whether early-stage sustainability commitments are maintained, expanded, or deprioritised as the ecosystem matures.

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