International Journal of Information Management Data Insights 5 (2025) 100335

Contents lists available at ScienceDirect

International Journal of Information Management Data Insights

journal homepage: www.elsevier.com/locate/jjimei

Transforming business management practices through metaverse technologies: A Machine Learning approach

Raghu Raman [a,*], Santanu Mandal [b], Angappa Gunasekaran [c], Thanos Papadopoulos [d], Prema Nedungadi [e]

[a] Amrita School of Business, Amritapuri, Amrita Vishwa Vidyapeetham, Kerala 690525, India
[b] Amrita School of Business, Amaravati, Amrita Vishwa Vidyapeetham, Andhra Pradesh, India
[c] School of Business Administration, Penn State Harrisburg, Middletown, PA 17057-4898, United States
[d] Kent Business School, University of Kent, Canterbury, CT2 7FS Kent, United Kingdom
[e] Amrita School of Computing, Amritapuri, Amrita Vishwa Vidyapeetham, Kerala 690525, India

ARTICLE INFO

Keywords:
Metaverse
Technology acceptance model
Digital twins
Online retail
Tourism
Human resource management

ABSTRACT

This study critically reviews the literature on metaverse technologies, developing an integrative framework to explore their sector-specific implications and transformative impact on business management. Employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework and machine learning-based BERTopic modeling, the study identifies nine key themes, reflecting the diverse ways augmented reality (AR), virtual reality (VR), extended reality (XR), digital twins, and decentralized finance (DeFi) influence industries. These themes include the metaverse as a tool for economic and environmental policy experiments, navigating financial risk and regulatory dynamics, adapting human resource development to VR-driven environments, Industry 4.0 applications of VR and digital twins, digital twin applications in manufacturing and supply chain optimization, AR and VR in digital marketing and customer experience, AR in enhancing retail and consumer experiences, exploring user interaction and affordances in the metaverse, and VR and AR in tourism experience and engagement. The framework highlights drivers, constraints, and cross-sector linkages, addressing practical challenges such as high implementation costs, regulatory uncertainties, interoperability barriers, cybersecurity risks, and ethical concerns surrounding data privacy and inclusion. The study critically evaluates contradictions in metaverse adoption, such as the tension between sustainability goals and energy-intensive technologies like blockchain, the gap between immersive training potential and workforce adaptation challenges, and the disparity between metaverse-driven economic models and real-world policy implementation hurdles. Research propositions suggest integrating metaverse technologies into business operations while balancing ethical dimensions, psychological impacts, cost limitations, and accessibility barriers. Additionally, the study advocates for expanding theoretical frameworks such as the Resource-Based View (RBV), Technology Acceptance Model (TAM), and experiential learning to account for the dynamic capabilities, risks, and industry-specific constraints of metaverse adoption. Policymakers and practitioners are encouraged to address regulatory and ethical challenges, sectoral disparities, and the unintended consequences of metaverse-driven digital transformation, ensuring operational efficiency, resilience, and consumer engagement while fostering sustainable and inclusive adoption. This research offers actionable insights for strategic implementation, interdisciplinary theoretical expansion, and ethical progress in business management.

1. Introduction

The digital economy is conceived with the concept of metaverse, where physical and digital worlds merge into seamless, immersive, connected spaces (Kumar & Shankar, 2024; Dwivedi et al., 2023). The metaverse—a virtual universe encompassing multiple types of digital experience, including augmented and virtual reality as well as 3D online worlds—is changing the way we work and respond to modern-day

* Corresponding author.
E-mail addresses: raghu@amrita.edu (R. Raman), Santanu.Mandal@av.amrita.edu (S. Mandal), aqg6076@psu.edu (A. Gunasekaran), a.papadopoulos@kent.ac.uk (T. Papadopoulos), prema@amrita.edu (P. Nedungadi).

https://doi.org/10.1016/j.jjimei.2025.100335

Available online 31 March 2025

challenges (Lim et al., 2024). Once merely a fictional concept in Neal Stephenson's 1992 novel Snow Crash, the metaverse has become a thriving digital space fuelled by AR, VR, blockchain, and AI (Mahdikhani & Meena, 2024). A combination of these technologies can help construct strong physical/digital human models, revolutionizing consumer experience and reshaping business practices and economic configurations (Gao et al., 2024). The three decades of rapid progress in AR, VR, blockchain, and AI development have turned the science-fiction metaverse into a technical reality (Saeed et al., 2024; Mahajan et al., 2023), bringing a leap change throughout organizational societies and economies (Aysan et al., 2024; Barrera & Shah, 2023). The metaverse has various use cases — retail, healthcare, education, manufacturing, tourism, and entertainment (Gao et al., 2024; Gursoy et al., 2022). For example, metaverse platforms are used for the development of virtual retail spaces that allow customers to search for and try-on products without leaving their homes. The Roblox experience, 'Nikeland', which was introduced by Nike, must likewise have been a popular store with >21 million participants, demonstrating that immersive commerce can be used to engage and retain customers (Varshney & Chowdhury, 2024; Dwivedi et al., 2022). In the same way, the Metaverse enables open surgeries and remote processes for healthcare, while virtual classrooms and training simulations are integrated into education (Wang et al., 2024; Raman et al., 2024b). In addition, the real estate uses digital twin technologies to conduct virtual property tours (Hou et al., 2024; Ding et al., 2019), and the tourism industry employs VR for sustainable travel through virtual experiences of remote or unvisited destinations (Gursoy et al., 2022; Tussyadiah et al., 2018).

The economic impacts of the metaverse are just as large. By 2030, the number of users in the Metaverse market is expected to reach 2.6bn users, with user penetration predicted to be 14.6 % in 2024, and this figure is expected to increase to 39.7 % by 2030 (Statista Report, Nov 2024). The growth of the metaverse is being fuelled even more by investments from tech behemoths, including Alphabet, Meta, Microsoft, and several others. Nvidia and Qualcomm are driving metaverse innovation through Nvidia Omniverse's advanced 3D workflow capabilities and Qualcomm's $100 million fund to lead in metaverse hardware and mixed-reality development (Krishnan, 2024; Queiroz et al., 2023). In a similar vein, Accenture has onboarded its employees via virtual reality and has also launched metaverse-based consulting practices, whereas Deloitte has launched a series of metaverse services and a study (Ajao, 2022; Weking et al., 2023). The value of this type of technology is undeniably transformative, but mass adoption will be a considerable challenge, requiring an established digital infrastructure, the interconnection of current digital systems, and taking steps to address data privacy concerns and ethical governance (Dwivedi et al., 2022; Vidal-Tomás, 2023).

While the current metaverse literature identifies transformative implications of this innovative technology across multiple business domains, critical gaps remain regarding our collective understanding of its wide-ranging ramifications. First, even though some prior works addressed the effects of metaverse effects on individual functions such as supply chains (Dolgui & Ivanov, 2023; Queiroz et al., 2023), marketing (Barrera & Shah, 2023; Belk et al., 2022; Dwivedi et al., 2023) and human resources (Lim et al., 2024; Saeed et al., 2024) in extended reality environments, we miss frameworks that integrate these developments as they relate to core business processes. For example, supply chains across the world have proven over the years to be strengthened by various metaverse technologies, such as digital twins and blockchain, all while marketing strategies have immersed consumer experiences. Thus, the research has not yet investigated how these emerging technologies can be utilized together to change organizational efficiency, collaboration, and decision-making across multiple domains (Weking et al., 2023; Dwivedi et al., 2022; Mahdikhani & Meena, 2024). Such integrated comprehension hinders organizations from embracing the metaverse as an integrated approach to innovation and competitive edge.

One of the key gaps is in the behavioral and psychological aspects of consumer involvement in metaverse commerce. Despite these studies pointing to the high level of immersed metaverse and social presence that can drive consumer satisfaction (Ribeiro et al., 2024; Dwivedi et al., 2023), there has been little research on whether virtual possession (MP), symbolic meaning (SM) or affection (AR) lead to consumer behavior that is metaverse. Although the move to define ownership in terms of NFTs and cryptocurrencies has been highlighted as an essential metaverse marketing endeavor, its impact on consumer loyalty and purchase intentions over time has not yet been investigated (Vidal-Tomás, 2023; Kumar et al., 2025). In addition, the impact of gamification, avatar personalization, and socialization in digital space on consumer preference is still an open area for further research (Ribeiro et al., 2024; Roh et al., 2024). These gaps need to be addressed if businesses are to determine how the metaverse can best support their customer experiences or brand engagement strategies.

Finally, the metaverse is often presented as a sustainable alternative to traditional practices in industries such as tourism (Gursoy et al., 2022; Raman et al., 2024b) and retail (Kumar & Shankar, 2024; Barrera & Shah, 2023), its environmental and ethical challenges are insufficiently addressed. For example, the inherently energy-intensive nature of blockchain technologies, a key element in metaverse infrastructure, raises concerns related to the environmental costs associated with undertaking operations virtually (Aysan et al., 2024). In the same way, data privacy concerns, the governance of virtual assets, and equitable access to metaverse technologies also raise constraints for this area from being widely accepted (Dwivedi et al., 2023). While extant studies mainly emphasize the possibility that information technologies are offered through metaverses (Mahdikhani & Meena, 2024; Aysan et al., 2024; Gao et al., 2024), they do not offer prescriptive guidance about how entities should leverage these opportunities in alignment with sustainability and ethical responsibility. Closing this gap is key to ensuring that the metaverse evolves as an outlet through which global sustainability objectives are realized and that people-centered economic expansion is achieved.

Such research gaps point to the necessity of systematically investigating how the metaverse influences business management from a multidimensional perspective, thus providing a basis for future empirical inquiries that can advance both theory and practice. To fill these gaps, this study aims to contribute by conducting a systematic review of the metaverse-related literature in business management. By providing an overview of interdisciplinary studies related to marketing, operations, human resource development, finance, and consumer behavior, this review comprises literature to derive a metaverse-impact framework representing the complexity of the effect of the metaverse. In particular, it explores how businesses can harness the metaverse to generate value and derive efficiency both for their operations and for consumer engagement, all while navigating ethical, social, and environmental dilemmas that are part and parcel of this digital transition. The current study, therefore, addresses the research questions that follow a logical progression, beginning with strategic considerations, moving into operational enhancements, and culminating in user-centric innovations, providing a comprehensive framework for understanding the contributions of the metaverse to business and management practices.

- *RQ1: How can metaverse technologies reshape strategic decision-making in economic policy, financial risk management, and workforce development to address the evolving needs of organizations?*
- *RQ2: In what ways do virtual reality, augmented reality, and digital twins enhance operational efficiency, optimize supply chain management, and transform marketing practices within business ecosystems?*
- *RQ3: How do metaverse-enabled interactions, immersive retail experiences, and virtual tourism applications redefine customer engagement and user experience in business contexts?*

The next section discusses the literature associated with the metaverse and its interfaces with different business segments. The subsequent section elaborates on the research methodology, followed by the results and critical discussion of the findings. We then proceed with research propositions with future research directions and implications of our findings.

2. Metaverse technologies

The metaverse represents more than just a technological breakthrough; it compels businesses to rethink and transform their strategies across various domains (Dang Quan et al., 2024; Mahajan et al., 2023). It essentially provides an experience that comes hand-in-hand with a much more personal and interactive level of customer engagement through brand campaigns, as seen in marketing, for instance. Digital twins and blockchain technologies are transforming the landscape of supply chain and operations management (SCOM) by enhancing transparency, improving efficiency, and enabling predictive capabilities (Mahdikhani & Meena, 2024; Dolgui & Ivanov, 2023). Simulations powered by VR are sparking a revolution in the realm of human resource development and bringing carefree and interactive learning experiences to all employees (Lim et al., 2024; Akdere et al., 2022).

Table 1 organizes the literature based on specific metaverse technologies discussed, including Augmented Reality (AR), Virtual Reality (VR), blockchain, and digital twins. It highlights key authors and concisely indicates the contexts in which these technologies are applied, emphasizing their role in transforming business practices and consumer experiences.

Table 2 summarizes the latest research regarding the metaverse and its interfaces with business management domains. Research by Mancuso et al. (2024) emphasizes the necessity of integrating digital assets with organizational adaptation through structured leadership and innovation ecosystems, paving the way for metaverse-ready firms. The supply chain domain has also garnered attention, with Mahdikhani and Meena (2024) demonstrating how metaverse-driven digital technologies enhance global supply chain efficiency, while Dolgui and Ivanov (2023) highlight the integration of digital twins and blockchain for optimizing supply chain processes. Human resource management emerges as another critical area, where Saeed et al. (2024) and Lim et al. (2024) explore the metaverse's potential to revolutionize employee training, reshaping organizational culture and learning methodologies. Financial implications are underscored by Aysan et al. (2024) and Vidal-Tomas (2023),

Table 1
Summary of related studies based on metaverse technologies.

Metaverse Technologies Used	Author(s)	Context
Augmented Reality (AR)	Kumar & Shankar (2024); Dwivedi et al. (2023); Lim et al. (2024); Mahdikhani and Meena (2024); Saeed et al. (2024); Mahajan et al. (2023)	Enhancing immersive experiences and consumer engagement
Virtual Reality (VR)	Varshney & Chowdhury (2024); Wang et al. (2024); Lim et al. (2024); Raman et al. (2024b); Gursoy et al. (2022); Tussyadiah et al. (2018)	Retail, healthcare, education, tourism, and workforce training applications
Blockchain	Kumar et al. (2025); Aysan et al. (2024); Dolgui and Ivanov (2023); Queiroz et al. (2023); Vidal-Tomás (2023)	Ownership, transparency, supply chain management, sustainability, cryptocurrencies
Digital Twins	Hou et al. (2024); Ding et al. (2019); Mahdikhani and Meena (2024); Dolgui and Ivanov (2023)	Virtual real estate tours, predictive supply chain modeling

Table 2
Summary of related studies based on business domains.

Business Domains	Author(s)	Key Contributions	Methods used
Organizational Capabilities	Mancuso et al. (2024)	Firms must integrate digital assets and organizational adaptation via organizational change and innovation ecosystems, guided by a three-stage roadmap and metaverse-ready leadership.	Case Study
Supply Chains	Mahdikhani and Meena (2024)	Metaverse's transformative potential in enhancing global supply chain growth across industries through digital technologies, offering insights for policymakers and industry leaders; diverse applications in sectors like manufacturing, logistics, and retail.	Latent Dirichlet Allocation (LDA) and BERTopic topic-modeling
Human Resources	Saeed et al. (2024)	Metaverse can transform employee training by enhancing interactivity, practicality, and feedback.	SEM of 889 employees' reviews about various training applications
Finance	Aysan et al. (2024)	Financial Institutions are yet to prepare well for technological integration; Metaverse can significantly reshape financial services, thereby having a significant bearing on the economy, key sectors, and prospects.	Conceptual
Human Resources	Lim et al. (2024)	Metaverse can significantly reshape human resource development through reshaping employee training, altering organizational culture, and improving performance.	A narrative review of 34 cases
Emerging Business Models	Mancuso et al. (2023a)	Businesses are innovating metaverse models through phygital transformations (e.g., Gucci's virtual fashion) and fully virtual strategies (e.g., Nike's Nikeland), redefining value creation at the physical-digital intersection.	Case Study
Business Model Innovation	Mancuso et al. (2023b)	This study links macro variables (tech, knowledge, stakeholder readiness) with micro factors (skills, relationships) to explain business model innovation (BMI) in the metaverse.	Case Study

(continued on next page)

Table 2 (*continued*)

Business Domains	Author(s)	Key Contributions	Methods used
Operations	Queiroz et al. (2023)	Metaverse would reshape operations and supply chain management, offering numerous benefits, improving risk mitigation and coordination.	Empirical
Marketing	Barrera and Shah (2023)	Firms can utilize immersiveness, sociability, and environmental fidelity to design and characterize consumer experiences in the metaverse.	A systematic review of 164 articles; viewpoints of 78 business professionals
Finance	Vidal-Tomas (2023)	Economic governance is based on metaverse tokens that cannot be defined as reliable virtual currencies due to their explosive behavior, negative performance, and higher volatility compared to traditional alternatives.	Analyzed 196 metaverse fungible tokens and nonfungible token (NFT) transactions
Entrepreneurship	Weking et al. (2023)	Metaverse acts as a transformative external enabler for entrepreneurship, introducing four distinct virtual-physical pathways—pure virtual, virtual-to-physical, physical-to-virtual, and hybrid—each leveraging specific sociotechnical enablers to shape entrepreneurial ventures, offerings, and processes.	Conceptual
Supply Chains	Dolgui and Ivanov (2023)	Metaverse enables the integration of physical and digital supply chains using advanced technologies like digital twins and blockchain, fostering innovations in processes and performance metrics while enhancing visibility, analytics, and decision-making in SCOM.	SLR of 217 papers and 119 keywords

with the former noting the financial sector's lack of preparedness for metaverse adoption and the latter revealing the volatility of metaverse tokens as economic governance instruments. Business model innovation is also a focal point, with Mancuso et al. (2023a, 2023b) detailing the emergence of phygital transformations and linking macroeconomic and micro-level factors to metaverse-based innovations. Similarly, Weking et al. (2023) conceptualize how the metaverse acts as an external enabler for entrepreneurship through various virtual-physical pathways. The marketing domain benefits from immersive consumer experiences, as detailed by Barrera and Shah (2023), who identify key metaverse features that shape engagement and brand interactions. Lastly, Queiroz et al. (2023) provide empirical insights into how metaverse technologies improve risk mitigation and coordination in operations. Collectively, these studies underscore the metaverse's vast potential to redefine business landscapes, offering theoretical, empirical, and conceptual insights into its evolving role across industries.

When it comes to grasping the business relevance behind the metaverse, several theoretical stances provide helpful perspectives. Dwivedi et al. (2022) emphasize that the theoretical foundations of the metaverse are closely connected to extended reality (XR) as well as Web 3.0. XR includes augmented reality (AR), virtual reality (VR), and mixed reality (MR), which enable interactions in hybrid environments that combine the physical and digital (Kumar et al., 2025). Concurrently, Web 3.0, standardized by decentralization and blockchain technology, promotes interoperable ecosystems and token-based economies that increase digital ownership, security, and governance (Vidal-Tomas, 2023). Collectively, these technologies underpin cyber-physical systems (CPSs), enabling businesses to make real-time adaptations, innovations, and operational efficiencies so that they can span across various industries like manufacturing, healthcare, retail, and entertainment.

The Resource-Based View (RBV) (Barney, 1991, 2001; Wernerfelt, 1984; Huang et al., 2023) offers a lens through which to examine the extent to which firms rely on tangible and intangible resources, including immersive digital assets, AI-driven personalization, and decentralized finance mechanisms, as sources of competitive advantage. Nonetheless, the Technology Acceptance Model (TAM) (Davis, 2024) and Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) have strengthened their utility by recognizing that sensory and emotional engagement are important factors in the likelihood of engaging with an emerging immersive technology (Cummings et al., 2023). Adding to this point, the marketing literature has also pointed out how AR engenders experiential consumption and brand attachment through hyper-personal, affective touchpoints (Huang & Chung, 2024; Zarantonello & Schmitt, 2023). As such, relationship marketing theories are refined by proposing sensory engagement as a key process in creating, maintaining, and developing long-term customer relationships.

More than simply being an avenue to engage with consumers, VR is disruptive to authenticity theory, ushering in what is referred to as 'virtual authenticity' (Sun et al., 2023). Authenticity historically relied heavily on physical manifestations of heritage and real-world interactions. However, VR allows digital spaces to elicit comparable emotional and cognitive responses making virtual tourism a valid pathway for value creation (Rickly & Canavan, 2024). Such an evolution is especially liberating for the retreats limited by ecology or foregone resources since a VR-powered experience allows for an ecologically sustainable alternative that doesn't sacrifice much in terms of experience. Additionally, the highly immersive aspect of the VR environment fits well with situated cognition and experiential learning theories, given that VR can facilitate high-fidelity simulations involving realistic environments (Cobb & Bowers, 1999). Such a functionality seems particularly relevant in the context of remote teaching and professional development, where interaction through simulations assists in understanding the concepts better and applying them in practice (Makransky & Petersen, 2021).

Metaverse technologies facilitate a more sweeping, cross-consumer life adoption of digital interaction — a process of a service ecosystem epoch in a value co-creation sense. As another example, in tourism and hospitality, immersive experiences (VR-based explorations before actual visits) help consumers develop emotional bonds with local sites, thereby deepening their subsequent physical experiences (John & Supramaniam, 2024; Yersüren & Özel, 2024). The proliferation of digital touchpoints fundamentally restructures the traditional notion of service, underscoring the interconnected dimension of value co-creation between virtual and tangible realms in end-user experience.

Additionally, the use of digital twins in cyber-physical systems (CPSs) takes operational theories such as systems dynamics, Just-In-

Time (JIT) production, and lean manufacturing further (Guo & Mantravadi, 2024; Dolgui & Ivanov, 2023). Digital twins allow for continuous monitoring, predictive analytics, and feedback loops, which will help companies move from static operational models to data-driven production systems. Continuous adaptation to market fluctuations and logistical constraints brought by these technological advancements makes supply chain resilience much stronger and helps organizations optimize resource allocation and effectively reduce inefficiencies.

In spite of these theoretical advancements, the metaverse also poses key challenges regarding data privacy, inclusive as well as sustainable economies. Such concerns can be addressed through stakeholder theory: a helpful framework for understanding how to engage responsibly with stakeholders and consider the best approach to governance of metaverse ecosystems. We need to regulate the new generation of decentralized digital infrastructures, taking into account to so it promotes social responsibility, given the increasing dependence on these infrastructures, and also providing fair access and acting against risks related to digital exclusion, surveillance, and environmental impact.

This study builds on these theoretical foundations by systematically exploring the transformative influence of metaverse technologies on business ecosystems. By synthesizing insights from diverse cross-disciplinary literature, it develops an integrative framework of technological affordances, consumer behavior, and ethical considerations. Moving forward, this directionally supports understanding of meta-organizing and how this is emerging through organizations making sense of convergence and divergence, producing new sensitive landscapes, albeit those that require real-time macro-environmental analysis to determine the meta nexus, as well as meta-organization.

3. Methodology

3.1. PRISMA framework

To ensure transparency and rigor, this study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021), a widely accepted methodology for conducting systematic reviews (Raman et al., 2024a). Fig. 1 illustrates the stepwise selection process, ensuring replicability and methodological robustness in identifying and analyzing relevant literature on metaverse applications in business management.

Data Source & Search Strategy: The Scopus database was selected as the primary data source due to its comprehensive coverage of peer-reviewed literature across business, management, and economics (Donthu et al., 2020). A systematic search was conducted on October 6, 2024, covering the years 1992 to 2024, applying precise keywords in titles and abstracts to capture a broad yet relevant set of studies. The search query was designed to encompass diverse terminologies related to metaverse technologies - (metaverse OR multiverse OR "virtual reality" OR "augmented reality" OR "mixed reality" OR "digital twin″ OR "digital human" OR "extended reality" OR "web 3.0″ OR "virtual twin" OR "virtual replica").

To ensure disciplinary relevance and methodological rigor, specific filters were applied, restricting the results to peer-reviewed journal articles and reviews published in English. The focus was on studies explicitly discussing metaverse applications within business, management, accounting, economics, and finance. These refinements helped narrow the scope to literature that is academically rigorous and aligned with the study's objectives.

Selection Process: Following the PRISMA framework, a four-stage

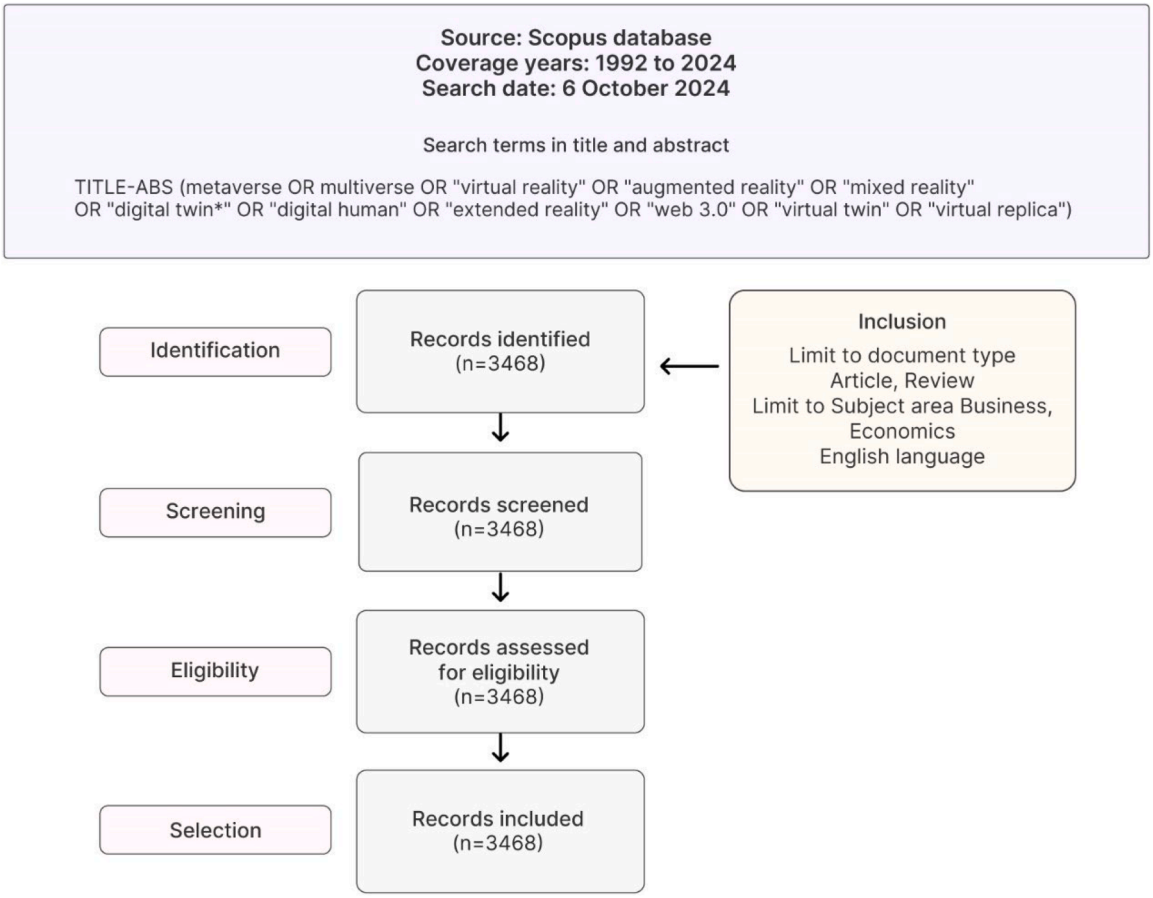

Fig. 1. PRISMA framework.

process was employed to refine the dataset systematically:

1. Identification: The search retrieved 3468 studies from Scopus, encompassing research on metaverse technologies for the business and economics domains. Studies were included if they were documents of the type article and review and published in English. Conversely, non-peer-reviewed works, conference papers, book chapters, and reports were excluded to maintain methodological rigor.
2. Screening: To maintain quality and relevance, studies with missing author details and duplicate records were removed.
3. Eligibility: At this stage, all screened records were deemed eligible, as the initial filtering process ensured that only business-related, peer-reviewed studies were included. The strictly defined search parameters and applied filters effectively eliminated irrelevant research, negating the need for further exclusion.
4. Selection: A final corpus of 3468 eligible publications was established for analysis.

This structured and transparent approach ensured that the final dataset was both comprehensive and focused, providing a solid foundation for thematic analysis using BERTopic modeling to extract key trends and insights from the literature.

3.2. BERTopic modeling

The use of the PRISMA framework to systematically identify and select relevant studies established a strong foundation for applying topic modeling. Unlike techniques such as cocitation analysis, bibliographic coupling, or keyword co-occurrence, topic modeling delves into the semantic content of documents, offering a more nuanced exploration of underlying themes (Raman et al., 2024a). While cocitation and bibliographic coupling focus on historical linkages through shared references, and keyword co-occurrence emphasizes frequently paired terms, topic modeling uncovers latent thematic patterns within the text. This capability makes it particularly suited for analyzing evolving research areas like metaverse technologies, as it provides insights into emerging concepts and their contextual interconnections.

Topic modeling encompasses a variety of approaches, such as nonnegative matrix factorization (NMF), latent Dirichlet allocation (LDA), probabilistic latent semantic analysis (PLSA), and To2Vec. Despite their utility, these methods often fail to capture semantic relationships between words and face challenges when dealing with short text formats (Egger & Yu, 2022). Unlike traditional bag-of-words (BoW) techniques that prioritize term frequency, BERTopic leverages unsupervised machine learning and embeddings for improved performance (Grootendorst, 2022). BERTopic is powered by bidirectional encoder representations from transformers (BERT), a deep learning language model developed by Google (Devlin et al., 2019). Unlike conventional models, BERT maps documents into a lower-dimensional space while preserving semantic nuances, offering a richer and more contextual interpretation of the text (Venugopal et al., 2024; Nedungadi P. et al., 2024; Vaid et al., 2023).

BERTopic modeling enhances insights beyond conventional literature reviews by automating thematic extraction, identifying latent patterns, and quantifying topic-document associations. Unlike traditional reviews, which rely solely on manual coding and subjective interpretation, BERTopic clusters research articles based on semantic similarity, ensuring an unbiased and scalable analysis of large datasets, capturing contextual relationships between terms, and detecting emerging themes that may not be evident through manual analysis. However, to ensure interpretability and validity, we conducted a manual review of the extracted topics and representative publications on each topic. The integration of machine learning with expert validation allowed us to combine computational efficiency with human judgment, ensuring both robustness and contextual accuracy in the thematic analysis.

The modeling process begins with embedding vectorization, which involves transforming input text into numerical representations called embeddings (Fig. 2). The text was preprocessed by lowercasing, tokenization, and removal of special characters and non-alphanumeric symbols to ensure consistency across documents. The next step is dimensionality reduction, which is achieved through unified manifold approximation and projection (UMAP). This method simplifies the numerical data, enabling similar data points to be grouped more effectively and producing clearer topic clusters (Yi et al., 2025). For UMAP, the nearest neighbor parameter (n_neighbors) was set to 15 to balance local and global structure, and the minimum distance was set to 0.05 to ensure adequate separation between points in the reduced-dimensional space. Following dimensionality reduction, the data points are clustered via hierarchical density-based spatial clustering of applications with noise (HDBSCAN). This clustering approach identifies dense regions of data points to form groups while excluding scattered or unrelated points. The minimum cluster size was set at 20 to maintain topic significance while preventing over-fragmentation. To interpret these clusters, the model applies class-based term frequency-inverse document frequency (c-TF-IDF), which extracts the most significant words or phrases for each cluster, providing insights into the main topics within the documents (Oh et al., 2023). The c-TF-IDF calculation was adjusted to smooth term importance across topics, mitigating dominance by frequently occurring words. In our analysis, we utilized the "all-MiniLM-L6-v2″ text representation model, optimized for tasks such as clustering and semantic search in English texts (Kim et al., 2024). This model was selected based on computational efficiency and alignment with short-text clustering tasks. Using these representative terms, the model assigns topics to documents, with probabilities indicating the likelihood of each document belonging to specific topics (Khodeir & Elghannam, 2024).

To optimize the topic modeling results, several key hyperparameters were fine-tuned: the n-gram range, number of topics, minimum topic size, and keywords per topic. The text was tokenized into unigrams and bigrams, with an n-gram range of (1,2), allowing the model to consider both single words and two-word phrases. This approach captures individual terms and meaningful word combinations, improving contextual understanding without introducing excessive complexity. The number of topics was iteratively adjusted between 4 and 20, with coherence scores used as an evaluation metric to ensure a balance between topic distinctiveness and interpretability. The coherence scores were calculated using the normalized pointwise mutual information (NPMI) metric to assess the semantic consistency of terms within each topic. The minimum topic size was set at 20, ensuring that each topic contained enough documents to maintain significance and avoid excessive granularity. Additionally, the number of keywords per topic was fixed at 20, enabling the identification of the most relevant terms for each topic while maintaining clarity and focus. These settings, as recommended by Grootendorst (2022), ensured that the topics generated were both insightful and actionable. Stop words and frequently used generic terms such as "use," "used," "adding," "based," and "related" were removed to reduce noise and improve topic coherence.

For the UMAP algorithm, default parameters were utilized, with "calculate probabilities" enabled to assess the likelihood of document-topic associations, and the language was set to English. The "cosine" metric was employed to measure angular similarity between vectors, ensuring robustness in high-dimensional spaces. A random state of 100 was applied to ensure reproducibility across multiple runs of the model. These parameter choices were based on empirical evaluations and recommendations from prior applications of BERTopic (McInnes et al., 2015). As a result, six major topics were identified, each with 20 representative publications.

Although machine learning techniques are effective in clustering data, the risk of misclassification persists (Lyutov et al., 2021). To enhance the validity and interpretability of the results, a manual review of the topics and their representative publications was undertaken. This process involved five faculty members with over a decade of experience

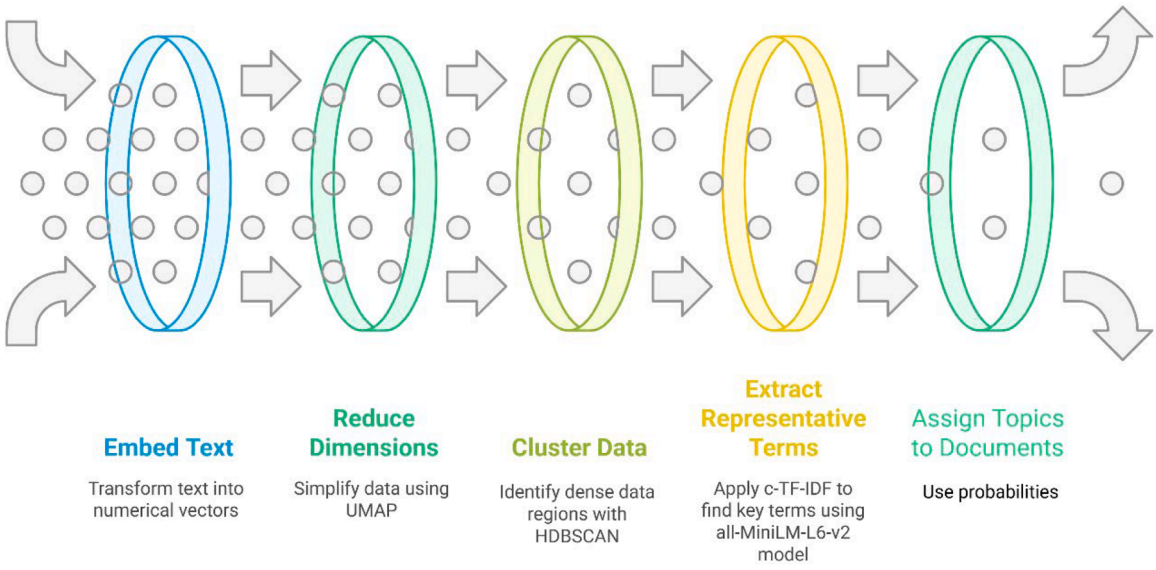

Fig. 2. BERTopic modeling process.

teaching in postgraduate business administration programs. Drawing from recent studies employing BERTopic (Douglas, 2024; Wang et al., 2023), the faculty conducted a qualitative evaluation to ensure that the topics were both meaningful and cohesive. The faculty members assessed the keywords associated with each topic and reviewed the representative publications by analyzing their abstracts, titles, and, where necessary, full texts. Additionally, probability values and citation counts were utilized to select twenty representative articles per topic, resulting in a total of 120 studies across six topics. These studies were further classified to address three research questions and assigned themes on the basis of a full reading of the papers. A scoring system—1 for not relevant, 2 for neutral, and 3 for relevant—was employed to evaluate the relevance of the studies to the topics and research questions. Any disagreements in scoring were resolved through discussion until a consensus was reached. This thorough review process ensured that the unsupervised topic modeling results were both accurate and practical, facilitating the identification of key themes in the dataset.

4. Findings

The findings are discussed in tandem with the research questions and organized into key themes, as indicated below.

4.1. Exploring strategic applications of metaverse technologies

RQ1: How can metaverse technologies reshape strategic decision-making in economic policy, financial risk management, and workforce development to address the evolving needs of business organizations?

Theme 1: metaverse as a tool for economic and environmental policy experiments

This theme illustrates how metaverse technologies, particularly virtual and augmented reality, are reshaping both the methodological approaches and practical applications of policy and economic analysis (Table 3).

The integration of VR technologies has advanced economic and environmental research by providing realistic, ethically sound, and replicable experimental frameworks. De Solla and Martin (2009) demonstrate how VR bridges the gap between controlled laboratory settings and real-world conditions, allowing policymakers to gain more authentic insights into public responses to wildfire management strategies. Building on this, Innocenti (2017) categorizes virtual environments into low-immersive and high-immersive settings, showcasing

Table 3
Publications related to economic and environmental policy experiments.

Author(s)	Key metaverse concepts	Application area
de Solla & Martin (2009)	Virtual experiments, VR, naturalistic decision-making	Application of virtual experiments to environmental policy, wildfire management
Innocenti (2017)	Virtual Reality	Empirical evidence in economics through VR, immersive environments
Olschewski et al. (2012)	VR visualizations, ecosystem services	Valuation of forest ecosystem services, virtual choice experiments

VR's ability to mimic field experiments while maintaining the control of laboratory conditions. This makes VR particularly effective for studying economic behaviors influenced by contextual cues and for capturing decision-making processes that traditional methods may overlook. Similarly, Olschewski et al. (2012) employ VR-enhanced choice experiments to evaluate willingness to pay for ecosystem services, such as avalanche protection, in the Swiss Alps. By creating realistic scenarios, this study addresses hypothetical biases often seen in traditional surveys, providing more accurate valuations of public goods. Collectively, these studies underscore the potential of VR to enhance policy analysis, economic modeling, and environmental valuation, enabling researchers and policymakers to make more informed and sustainable decisions.

Theme 2: navigating financial risk and regulatory dynamics in the metaverse

Exploring the intersection of financial systems, risk management, and regulatory frameworks within the metaverse reveals an evolving landscape, particularly as digital assets, blockchain technology, and DeFi tools become more prominent. Each study offers insights into how these elements both enable and challenge the expansion of financial and economic systems within virtual spaces, as shown in Table 4.

Recent research provides detailed insights into the financial dynamics and risks associated with metaverse-linked digital assets, highlighting their unique role in the broader cryptocurrency market. Vidal-Tomás (2022) explores the economic performance of NFTs, metaverse tokens, and play-to-earn gaming economies, distinguishing these assets from traditional cryptocurrencies. The study identifies unique features, such as lower co-movements with broader crypto markets and bubble-like behaviors, which create both opportunities and challenges for investors exploring niche virtual markets. Expanding on this, Qiao

Table 4
Publications related to **navigating financial risk.**

Author(s)	Key metaverse concepts	Application area
Vidal-Tomás (2022)	NFTs, metaverse tokens, play-to-earn, blockchain	Economic performance, token dynamics, and long-term viability of metaverse assets
Qiao et al. (2023)	Cryptocurrency, DeFi, NFTs, risk spillover	Risk management in cryptocurrency, decentralized finance, and metaverse-related assets
Li et al. (2023)	Altcoins, Bitcoin, metaverse cryptocurrencies	Safe-haven and hedging characteristics of metaverse and other cryptocurrencies

et al. (2023) analyze risk networks among cryptocurrencies, DeFi tokens, and NFTs using a time–frequency approach. Their findings reveal that metaverse-related NFTs dominate upside risk networks but exhibit both short-term volatility and long-term risk reversal, making them valuable for managing depreciation risks in diversified portfolios. Building further, Li et al. (2023) examine the role of altcoins tied to DeFi, NFTs, and the metaverse as hedges or safe havens during market volatility. They find that metaverse-themed coins can act as protective financial instruments, particularly during market bubbles, serving as safe havens for Bitcoin and other assets. Collectively, these studies highlight the intersection of financial systems, economic dynamics, and risk management within the metaverse, offering valuable insights into investment strategies and the evolving role of decentralized finance.

Theme 3: adapting human resource development to VR-driven environments

Table 5 highlights how VR technologies are reshaping human resource development (HRD) and training approaches. This collective exploration demonstrates the different ways in which VR and AI are applied across human resource contexts, impacting employee experiences, skill development, and evaluation methodologies.

The study by Malik et al. (2022) investigated the dual impact of AI and VR on employee well-being and professional demands within Industry 4.0-driven environments. This research reveals that while VR and AI enhance flexibility and innovation at work, they also introduce technostress due to the rapid pace of digital transformation and complexity in job functions. Employees face increased job insecurities and must continuously adapt to new skills, pointing to a need for HR practices that balance technology's positive and challenging aspects. Building on this perspective, Schmid Mast et al. (2018) emphasized the use of immersive VR (IVR) to enhance interpersonal skills training. Here, IVR is presented as an advanced tool that provides an engaging, virtual setting to develop soft skills, which contrasts with Malik et al.'s (2022) focus by emphasizing VR's constructive role in skill enhancement rather than its potential stressors. Extending beyond the immediate application of VR to HR skills, Thite (2022) delves into the strategic alignment of digital capabilities within HR. This paper provides a framework for virtual HR development (VHRD), encompassing current capabilities, future digital needs, and recommendations for an adaptable HR strategy. Thite's (2022) approach to VHRD suggests a forward-looking HR perspective, where virtual technologies play a foundational role in HR strategies. While Malik et al. (2022) and Schmid Mast et al. (2018) focus on specific employee impacts, Thite's (2022) contribution offers a strategic blueprint, emphasizing the importance of HR's role in leveraging digital tools for sustainable growth in organizational capacities. Overall, these studies collectively portray a finer understanding of VR and AI's role in HR. They show how VR and AI can simultaneously enhance skill acquisition and present new challenges, underscoring the importance of structured approaches to VR integration in HR development.

Table 5
Publications related to **adapting to human resource development.**

Author(s)	Key metaverse concepts	Application area
Malik et al. (2022)	Virtual reality (VR), AI, technostress	Impact of AI and VR on employee experiences and skill demands in HRM
Schmid Mast et al. (2018)	Immersive virtual reality (IVR), virtual humans	Interpersonal skills training with IVR in human resource development
Thite (2022)	Digital HR, virtual HRD (VHRD)	Strategic alignment of HR capabilities with digital demands and virtual HR development

4.2. Enhancing operations with immersive and digital tools

RQ2: In what ways do virtual reality, augmented reality, and digital twins enhance operational efficiency, optimize supply chain management, and transform marketing practices within business ecosystems?

Theme 1: Industry 4.0 applications of virtual reality and digital twin technologies

The studies shown in Table 6 highlight the diverse applications of metaverse-driven tools, such as VR and digital twins, within smart manufacturing, remanufacturing, and energy-efficient processes. Each study contributes to the broader understanding of how digital twins and VR technologies are transforming industrial practices under the Industry 4.0 framework.

Zawadzki and Żywicki (2016) introduced the concept of hybrid prototyping, which combines VR with additive manufacturing to create an agile production environment tailored to mass customization. By using VR, manufacturers can visualize and adjust production processes early in the design stages, shorten development timelines, and align with Industry 4.0's emphasis on efficient, personalized production. This focus on integrating virtual and physical production processes resonates with Rodič's (2017) exploration of the digital twin concept as part of a new simulation modeling paradigm. The study examines how digital twin-based simulation modeling is applied in automated industrial processes, emphasizing that the adoption of digital twins offers a more sophisticated approach to managing and optimizing production workflows. In the examined cases, companies of varying sizes adopted digital twin methodologies differently, indicating that the level of digital twin implementation often correlates with company size and resources. This contrasts with Kerin and Pham's (2019) perspective, which presents VR and AR as tools to support remanufacturing within circular economy models. By emphasizing remanufacturing, the study extends the discussion beyond production control and into sustainable practices, showing how VR and AR facilitate remanufacturing processes that align with the goals of Industry 4.0. Together, these studies illustrate the varied applications of VR, AR, and digital twins within Industry 4.0 settings, emphasizing how these technologies can optimize production, support circular economy goals, and enable sustainable manufacturing practices. By integrating virtual and physical systems, these studies collectively outline a vision of a more adaptable, efficient, and resource-conscious manufacturing landscape.

Theme 2: Digital twin applications in manufacturing and supply chain optimization

Table 6
Publications related to **Industry 4.0 applications.**

Author(s)	Key metaverse concepts	Application area
Zawadzki and Żywicki (2016)	Virtual reality, hybrid prototyping	Smart design and production control for mass customization in Industry 4.0
Kerin and Pham (2019)	Virtual reality, augmented reality, IoT	Emerging digital technologies for remanufacturing and circular economy business models
Rodič (2017)	Digital twin, simulation modeling	Adoption of digital twin-based simulation modeling for automated industrial processes

The theme, as seen through the studies in Table 7, captures the role of digital twins in enhancing operational efficiency, supporting resilience, and enabling customized production across various industries. Each study provides a distinct perspective on how digital twins contribute to real-time monitoring, adaptive decision-making, and overall performance improvement in manufacturing and supply chains.

Wang et al. (2019) explore the diagnostic capabilities of digital twins in smart manufacturing by applying a digital twin model for rotating machinery. Their study demonstrates how real-time data feeds into adaptive models to detect faults and predict degradation patterns, enabling precise diagnosis and predictive maintenance. This approach enhances machinery reliability and minimizes downtime, supporting uninterrupted manufacturing operations and aligning with the theme of resilience. Building on this, Ding et al. (2019) investigate the integration of digital twins in autonomous production environments through a digital twin-based cyber-physical production system (DT-CPPS). By leveraging real-time data from physical and cyber environments, this system continuously monitors and simulates shop floor operations, enhancing efficiency and enabling dynamic responses to operational changes. This cyber-physical integration complements Wang et al.'s findings by extending resilience and efficiency to autonomous operational control. Min et al. (2019) add another dimension by integrating digital twins with machine learning and IoT for production optimization in the petrochemical industry. Real-time big data and machine learning algorithms enhance digital twin models, allowing production controls to adapt to shifting demands and market conditions. This dynamic approach aligns with the adaptive and responsive qualities highlighted in earlier studies. Together, these works underscore the versatility of digital twins in manufacturing and supply chain contexts, emphasizing their role in enabling real-time adaptability, predictive maintenance, and enhanced production efficiency through autonomous operations, machine learning, and tailored production design.

Theme 3: Augmented and virtual reality in digital marketing and customer experience

This theme encapsulates how metaverse technologies such as AR, VR, and the metaverse are reshaping customer engagement, service experiences, and marketing strategies. Each study provides insights into the specific affordances and challenges of these technologies in enhancing consumer interaction and perception (Table 8).

Building on the discussion of consumer engagement, Flavián et al. (2019) present the EPI cube model, a taxonomy that classifies VR, AR, and mixed reality technologies according to their psychological and behavioral affordances, including embodiment and interactivity. This framework aims to provide clarity for managers and researchers as they navigate the still-evolving boundaries between different immersive experiences. This classification complements the detailed exploration by Yim et al. (2017), who investigated AR's effectiveness as a tool in e-commerce by comparing AR to traditional web-based presentations. The findings show that AR heightens immersion and interactivity, which leads to greater enjoyment and purchase intentions among customers, thereby supporting Dwivedi et al.'s (2021) observation of AR's potential in digital marketing. In Dwivedi et al.'s (2021) study, digital and social media marketing is evaluated within the context of emerging AR and VR technologies. This research discusses both opportunities and challenges, emphasizing how these tools improve brand awareness, sales, and customer interaction while also acknowledging the potential pitfalls of negative digital interactions, such as intrusive ads and privacy concerns. Collectively, these studies show how AR, VR, and the metaverse are advancing digital marketing and customer experience by enhancing interactivity, presence, and engagement. The various approaches emphasize that while these technologies introduce new layers of complexity, they also offer powerful tools to engage consumers in novel ways and support brand–customer relationships within the evolving digital landscape.

Table 7
Publications related to **digital twin applications in manufacturing.**

Author(s)	Key metaverse concepts	Application area
Wang, J et al. (2019)	Digital Twin, fault diagnosis	Rotating machinery fault diagnosis in smart manufacturing
Ding et al. (2019)	Digital Twin, cyber-physical systems	Autonomous manufacturing through cyber-physical production systems (DT-CPPS)
Min et al. (2019)	Digital Twin, machine learning, IoT	Production optimization in petrochemical manufacturing with machine learning-driven digital twin

Table 8
Publications related to augmented and virtual reality in digital marketing.

Author(s)	Key metaverse concepts	Application area
Flavián et al. (2019)	Virtual Reality, Augmented Reality, Mixed Reality	Customer experience transformation with metaverse technology
Dwivedi et al. (2021)	Augmented Reality, digital content management	Opportunities and challenges in digital and social media marketing
Yim et al. (2017)	Augmented Reality, interactivity, vividness	Effectiveness of AR as a tool in e-commerce

4.3. Redefining user engagement through the metaverse

RQ3: How do metaverse-enabled interactions, immersive retail experiences, and virtual tourism applications redefine customer engagement and the user experience in business contexts?

Theme 1: Augmented reality in enhancing retail and consumer experiences

Studies highlight the impact of AR applications on the retail sector, emphasizing how AR influences consumer engagement, satisfaction, and purchasing behavior. The studies collectively illustrate the transformative role that AR plays in modernizing retail settings, enabling brands to offer interactive and immersive shopping experiences that are aligned with evolving consumer expectations (Table 9).

In Grewal et al.'s (2017) study, the future of retailing is examined through a range of technologies, including augmented reality, virtual reality, and artificial intelligence, which enhance customer decision-making, engagement, and brand interaction. By adopting these technologies, retailers can streamline product offerings, facilitate better customer choices, and improve profitability. Grewal et al.'s (2017) broader view of technological adoption in retail aligns with Dacko's (2017) focus on Mobile AR apps (MARs), which specifically address how AR technology creates a smarter retail environment. Through consumer surveys, the study reveals that MAR apps not only improve the shopping experience but also contribute positively to retailer perception, with early adopters reporting high satisfaction and a preference for retailers incorporating MAR into their shopping options. Extending the discussion to brand perception, Rauschnabel et al. (2019) present AR as a tool that enhances brand engagement by inspiring consumers. In this study, consumer inspiration emerges as a key factor mediating the relationship between AR app quality and brand attitude. The findings indicate that consumers' positive experiences with AR apps improve their perceptions of brands, highlighting how AR can shift traditional marketing strategies

Table 9
Publications related to augmented reality in enhancing retail.

Author(s)	Key metaverse concepts	Application area
Grewal et al. (2017)	Virtual Reality, Augmented Reality	Technological advancements in retail and consumer engagement
Rauschnabel et al. (2019)	Augmented Reality, mobile AR apps	Impact of AR apps on consumer brand perception and inspiration
Dacko (2017)	Mobile Augmented Reality (MAR)	Contributions of MAR apps to smart retail settings and value creation

from information provision to experiential engagement. Together, these studies underscore the role of AR in shaping the retail landscape by making customer experiences more interactive and meaningful. For instance, through MAR apps, mobile AR in e-commerce, or in-store AR applications, retailers can offer personalized and memorable shopping journeys that resonate with modern consumers and encourage positive brand associations.

Theme 2: Exploring user interaction and affordances in the metaverse

Studies within this theme capture how metaverse technologies advance user engagement, presence, and interaction within virtual and augmented environments (Table 10). Furthermore, they offer insights into how users perceive and interact with virtual affordances, particularly through avatars and immersive settings that span various business and personal applications.

Dwivedi et al. (2022) explore the transformative potential of the metaverse across various sectors by examining the social, regulatory, and economic dimensions of a fully immersive, cross-platform virtual world. Their multidisciplinary analysis highlights the metaverse's capacity to blur physical and digital boundaries, reshaping business practices and user experiences in areas such as marketing, healthcare, and education. Central to their discussion is the role of avatars and virtual worlds in redefining interaction norms and economic transactions. Adding to this, Dincelli and Yayla (2022) apply affordance-actualization theory to examine VR's capabilities in organizational contexts, identifying dimensions such as embodiment, interactivity, and navigability as critical for transforming organizational processes. Their work underscores VR's value in environments where user engagement and interaction depth are essential. Expanding on the theme of avatars, Suh et al. (2011) investigate the impact of avatar resemblance on user attitudes and intentions in virtual worlds. Using a dual-congruity framework, they show that personalized avatars, which reflect a user's appearance and identity, significantly enhance engagement and positively influence user intentions, particularly in settings like virtual shopping and services. Together, these studies emphasize the evolving role of user affordances and avatar-based embodiment in shaping both personal and professional interactions within the metaverse. They illustrate how VR, AR, and avatar technologies are redefining engagement, fostering deeper connections between individuals and organizations in virtual environments.

Theme 3: Virtual reality and augmented reality in the tourism experience and engagement

This theme addresses how metaverse technologies, specifically VR and AR, are reshaping consumer engagement, satisfaction, and destination preferences within tourism. Studies explore VR and AR's role in enhancing tourism experiences, focusing on applications such as destination marketing, consumer behavior, value cocreation, and user experience enhancement (Table 11).

In Guttentag's (2010) research, virtual reality is examined across six tourism applications, including planning, management, marketing, heritage preservation, and education. The study emphasized that VR allows tourists to explore and appreciate sites without physical travel, which can be beneficial for promoting sustainable tourism and preserving fragile destinations. This perspective on virtual tourism aligns with that of Kim et al. (2020), who used the stimulus–organism–response (SOR) model to understand consumer behavior in VR tourism. The findings suggest that authentic virtual experiences significantly influence cognitive and affective responses, fostering stronger attachment and greater intentions to visit the showcased destination. This relationship between authenticity and visitor intent highlights VR's potential to motivate travelers and encourage destination interest. Adding depth to the discussion on consumer behavior, Tussyadiah et al. (2018) investigate how a sense of presence in VR experiences can drive attitude change and strengthen the preference for a destination. Through studies in Hong Kong and the United Kingdom, this research illustrates that a heightened feeling of presence in VR leads to greater enjoyment, positive attitude shifts, and stronger visitation intention. The emphasis on presence aligns with the findings of Kim et al. (2020), highlighting that VR's effectiveness in tourism relies on immersive, authentic experiences that engage users at both emotional and cognitive levels. Together, these studies illustrate VR and AR's growing influence on tourism, with applications that span from improving marketing strategies to creating more personalized and accessible travel experiences. Each study emphasized that VR and AR enable immersive interactions that enrich customer engagement, enhance destination appeal, and foster meaningful connections between tourists and locations.

Table 10
Publications related to **exploring user interaction and affordances.**

Author(s)	Key metaverse concepts	Application area
Dwivedi et al. (2022)	Metaverse, avatars, immersive environments	Challenges and opportunities in metaverse adoption across business, social, and regulatory landscapes
Dincelli and Yayla (2022)	Immersive VR, affordance-actualization theory	Organizational applications and affordances of immersive VR in information systems
Suh et al. (2011)	Avatars, self-congruity, functional congruity	User attitudes and intentions in virtual settings with avatars, emphasizing dual-congruity frameworks

Table 11
Publications related to virtual reality and augmented reality in tourism.

Author(s)	Key metaverse concepts	Application area
Guttentag (2010)	Virtual Reality	VR applications in tourism planning, marketing, heritage, and management
Kim et al. (2020)	Virtual Reality, immersive experiences	Impact of VR on tourist behavior and visit intention using SOR model
Tussyadiah et al. (2018)	Virtual Reality, presence, attitude change	Influence of presence in VR on tourist attitude and destination preference

5. Discussion of research findings

The metaverse is poised to revolutionize business management by reshaping traditional practices across key domains, integrating metaverse technologies to address contemporary challenges and unlock new opportunities (Fig. 3). At its core, the metaverse leverages tools such as VR, AR, and digital twins to bridge physical and digital boundaries, enabling businesses to enhance efficiency, engagement, and decision-making (Dwivedi et al., 2022; Dolgui & Ivanov, 2023).

The metaverse is reshaping business management across multiple sectors, including Economics & Policy, Finance, Human Resources, Manufacturing, Supply Chain Management, Marketing & Retail, and Tourism. These industries adopt key metaverse applications such as Digital Twins, Virtual Assets & DeFi, Immersive Training, Policy Simulation, and AR/VR Shopping to drive decision-making, efficiency, and immersive experiences. This framework ensures a clear distinction between sectors (business domains) and applications (functional enablers) while illustrating their cross-sector linkages, creating a holistic representation of metaverse integration. However, while these applications offer significant potential, their practical implementation varies by sector, often facing technological, regulatory, financial, and workforce-related challenges that shape their adoption trajectories.

RQ1: How can metaverse technologies reshape strategic decision-making in economic policy, financial risk management, and workforce development to address the evolving needs of business organizations?

Economics & Policy Sector: Enabling Strategic Business Decision-Making. This sector plays a foundational role in the metaverse by offering controlled experimentation environments that enable business resource optimization and policy simulation. These simulations allow

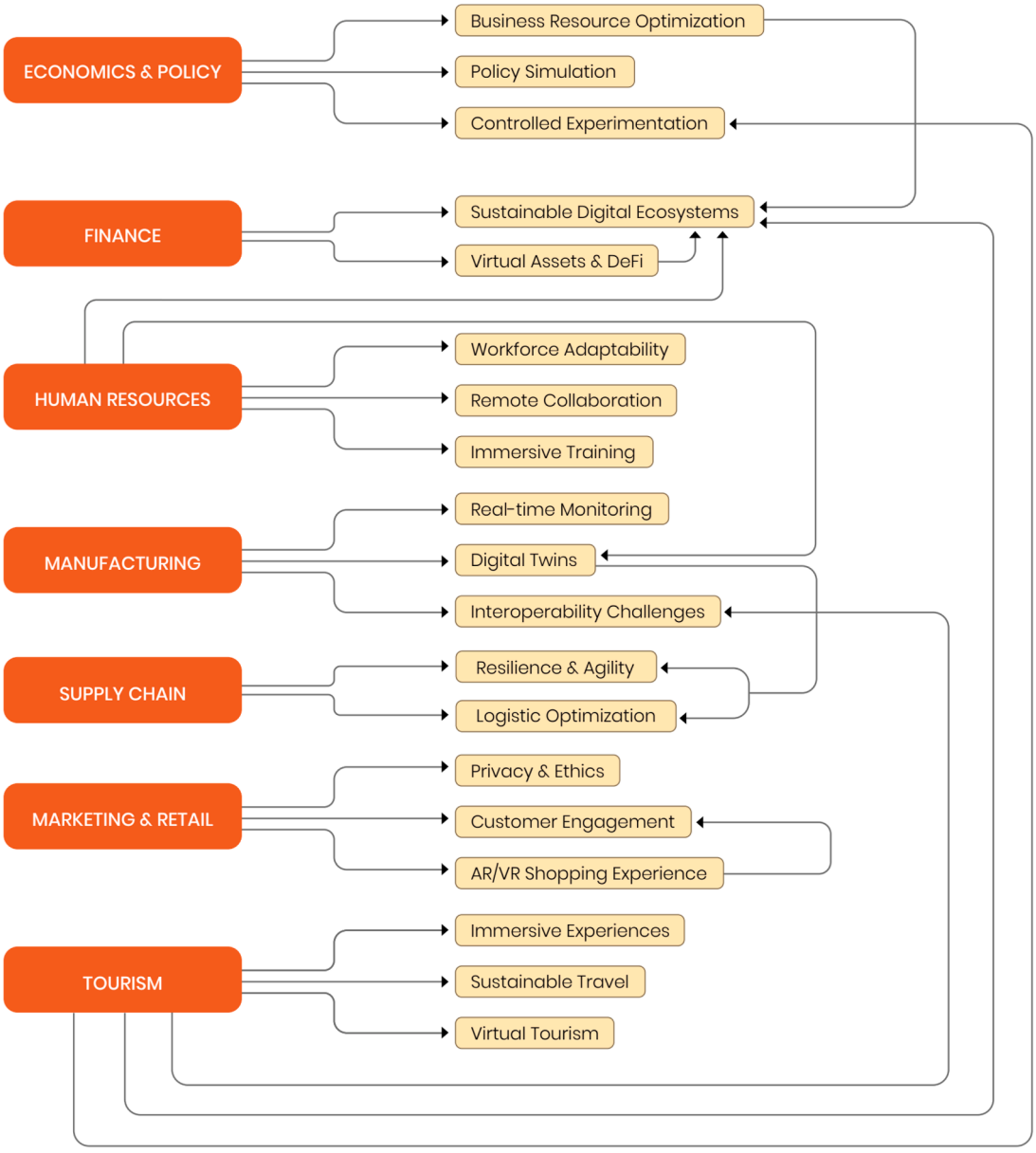

Fig. 3. Metaverse technologies in business management.

policymakers and researchers to explore economic models, consumer behaviors, and environmental policies in ways that were previously infeasible or unethical (Raman et al., 2024b). However, the scalability of these simulations to real-world policymaking remains limited, as digital representations of economic behavior often fail to account for unpredictable externalities such as socio-political factors and evolving market conditions. Moreover, the practical application of these simulations in finance demands robust mechanisms to mitigate risks associated with decentralized finance (DeFi), including volatility, security vulnerabilities, and fragmented regulatory oversight. Furthermore, while these insights benefit Finance through Virtual Assets & DeFi integration, ensuring regulatory compliance in decentralized finance remains an unresolved challenge. Additionally, policy-driven insights extend to Supply Chain Management, improving resilience and logistics optimization (Queiroz et al., 2023), but the effectiveness of these insights is contingent on data availability and the integration of real-time economic variables. A critical issue also arises in translating virtual supply-chain simulations to tangible logistics operations, where unforeseen disruptions and infrastructural limitations frequently hinder full implementation.

Finance Sector: Redefining Digital Transactions & Economic Ecosystems. The Finance sector is at the forefront of metaverse-enabled economic transformations, particularly through Virtual Assets & Decentralized Finance (DeFi), which challenge traditional banking models (Aysan et al., 2024; Belk et al., 2022). However, the practical adoption of these innovations is constrained by security risks, regulatory uncertainties, and market volatility (Mahdikhani & Meena, 2024). While DeFi systems provide new diversification opportunities, they also introduce risks related to fraud, hacking, and liquidity fluctuations, which require ongoing policy adjustments and institutional oversight. For instance, cross-border regulatory fragmentation significantly complicates the implementation and standardization of DeFi solutions, hindering their widespread acceptance by mainstream financial institutions. Furthermore, although Digital Twins and Real-Time Monitoring, originally developed for Manufacturing and Supply Chain Management, are being adopted in Finance for fraud detection and market simulations (Dutta & Singh, 2024), their effectiveness depends on the availability of high-quality financial data and cross-border

interoperability in digital finance networks. The complexity and sensitivity of financial data further exacerbate practical challenges, demanding robust cybersecurity frameworks and harmonized global standards.

Human Resource Management: Workforce Adaptability, Digital Twins & Sustainability. The Human Resources sector is leveraging immersive training, remote collaboration, and workforce adaptability solutions powered by VR and AI to enhance skill-building and employee engagement (Akdere et al., 2022; Saeed et al., 2024). However, the practical implementation of VR-driven HR strategies faces barriers such as cost, accessibility, and employee resistance. While immersive training enhances workforce capabilities, it requires significant infrastructure investment and ongoing adaptation of training content. Moreover, empirical evidence on the long-term effectiveness of VR training relative to traditional methods remains limited, raising questions about sustained employee performance improvements. Furthermore, the reliance on Digital Twins for workplace simulations introduces concerns related to employee data privacy and performance monitoring ethics. Additionally, while remote collaboration tools contribute to Sustainable Digital Ecosystems (Thite, 2022), their effectiveness in hybrid or fully remote workplaces remains contingent on workforce adaptability and digital literacy gaps across industries. Addressing these digital literacy disparities and ethical considerations around surveillance technologies is crucial for ensuring equitable adoption and acceptance among diverse employee groups.

RQ2: In what ways do virtual reality, augmented reality, and digital twins enhance operational efficiency, optimize supply chain management, and transform marketing practices within business ecosystems?

Manufacturing Sector: Digital Twins & Real-Time Monitoring for Efficiency. The Manufacturing sector, a key pillar of Industry 4.0, benefits significantly from Digital Twins, Real-Time Monitoring, and Adaptive Production Systems, which enhance production efficiency (Dolgui & Ivanov, 2023; Min et al., 2019). However, the integration of digital twins into legacy manufacturing systems presents challenges, including high initial costs, interoperability issues, and resistance from traditional industry stakeholders. For instance, legacy equipment and fragmented IT systems within manufacturing plants often limit seamless data integration, thereby reducing the effectiveness of digital twin implementations. While these technologies optimize logistics and supply chain operations, their practical scalability is dependent on standardized protocols for data sharing and machine interconnectivity (Queiroz et al., 2023). Furthermore, while Digital Twins aid financial risk modeling in Finance, their adoption in small and medium enterprises (SMEs) remains limited due to financial constraints and the technical expertise required for deployment. Overcoming these barriers requires targeted investments, supportive industry policies, and comprehensive training programs to facilitate broader adoption among SMEs and enhance industry-wide productivity.

RQ3: How do metaverse-enabled interactions, immersive retail experiences, and virtual tourism applications redefine customer engagement and the user experience in business contexts

Supply Chain Management: Logistics Optimization & Resilience. The Supply Chain Management sector is undergoing rapid transformation through Digital Twins, Logistics Optimization, and Interoperability Challenges, ensuring real-time data-driven supply chain resilience (Queiroz et al., 2023). However, despite their advantages, the practical application of digital twins in global supply chains is constrained by fragmented data ecosystems and inconsistencies in IoT implementation. For instance, variances in international data standards and regulatory compliance significantly impede effective cross-border collaboration and seamless data sharing. Additionally, while real-time monitoring improves decision-making under uncertainty, many organizations lack the infrastructure to fully leverage predictive analytics (Dolgui & Ivanov, 2023). The integration of AI-driven forecasting and blockchain for traceability is promising but faces adoption hurdles due to cybersecurity concerns and integration costs. Overcoming these obstacles requires substantial investment in secure digital infrastructures and standardized protocols to enhance trust and operational interoperability across supply chain networks.

Marketing & Retail: AR/VR for Consumer Engagement & Privacy Challenges. The Marketing & Retail sector leverages AR/VR shopping experiences, customer engagement tools, and privacy & ethics solutions to redefine consumer interactions. However, while AR/VR Shopping enhances consumer engagement, its adoption is limited by the costs of VR hardware, digital divide issues, and consumer reluctance toward immersive shopping environments (Barrera & Shah, 2023; Dang Quan et al., 2024). For instance, persistent technological discomfort among certain consumer demographics reduces the practical scalability of AR/VR experiences in mainstream retail, necessitating strategies for consumer education and accessible interfaces. Moreover, privacy concerns surrounding AR/VR-driven consumer data collection highlight the regulatory need for stricter data protection policies (Mahajan et al., 2023). Additionally, while Virtual Assets & DeFi facilitate digital retail transactions, their integration into mainstream e-commerce remains dependent on financial regulations and consumer trust in blockchain-based transactions. Addressing these trust issues requires proactive transparency measures, clear consumer communication, and robust cybersecurity frameworks to promote widespread acceptance.

Tourism: Virtual & Sustainable Travel Experiences. The Tourism sector benefits from Virtual Tourism, Sustainable Travel, and Immersive Experiences, which reduce environmental impact while enhancing accessibility (Gursoy et al., 2022; Tussyadiah et al., 2018). However, the widespread adoption of virtual tourism remains uncertain, as tourists may view VR travel as a supplement rather than a replacement for physical experiences. For instance, while virtual experiences offer solutions to overtourism and environmental degradation, consumer demand often prioritizes physical authenticity, potentially limiting broader industry acceptance. Furthermore, while AR/VR-driven customer engagement enhances tourism branding, many tourism operators lack the financial resources to develop high-quality immersive experiences. Additionally, Privacy & Ethics concerns that emerge in Retail extend into Tourism, as virtual experiences require robust consumer data protection policies. While sustainable digital ecosystems support environmentally conscious tourism, consumer perceptions of authenticity and engagement with digital tourism remain variable. Addressing these challenges requires strategic alignment between virtual offerings and tourists' evolving preferences, alongside policy support for smaller tourism operators to enable equitable adoption.

While metaverse technologies present transformative potential across industries, their real-world applicability is subject to sector-specific constraints. Regulatory uncertainty in Finance, infrastructure barriers in Supply Chain Management, technological limitations in HR, and privacy concerns in Retail and Tourism present challenges that must be addressed before large-scale adoption is feasible. The successful implementation of metaverse-driven innovations will require industry-specific adaptations, investment in digital infrastructure, and regulatory frameworks that ensure security, fairness, and inclusivity across business ecosystems. While shifting the paradigm of management from current practices to what could be done in a metaverse environment, businesses need to consider an equilibrium between innovating and ethics as well as business processes. This new means of managing (Dwivedi et al., 2022; Mahajan et al., 2023) provides the opportunity for sustainable and high-efficiency human-centric management where every effort can contribute to improving overall performance.

The reviewed literature offers insights into metaverse technologies across economic policy, finance, workforce development, supply chain management, and consumer engagement. However, certain limitations and biases should be acknowledged when interpreting these findings.

First, disciplinary biases are evident, as many studies originate from specific fields such as economics, finance, or marketing, leading to a concentration of perspectives that may overlook interdisciplinary insights. For example, while economic studies focus on virtual

experiments for policy analysis (de Solla & Martin, 2009; Innocenti, 2017), they may not sufficiently account for technological feasibility or ethical considerations in metaverse-based decision-making. Similarly, studies in financial risk management primarily analyze cryptocurrency and DeFi applications (Vidal-Tomás, 2022; Qiao et al., 2023; Li et al., 2023), potentially underrepresenting traditional banking sector implications and regulatory challenges beyond blockchain-driven financial models.

Second, methodological constraints exist in how metaverse technologies are studied. Many VR-based economic experiments and digital twin applications rely on controlled environments, which may not fully replicate real-world complexities or long-term behavioral adaptations (Olschewski et al., 2012). This limitation suggests that while these studies provide valuable preliminary insights, their applicability to large-scale policymaking or industry-wide adoption requires further empirical validation. Additionally, financial risk studies rely on historical asset performance and time-frequency analysis (Qiao et al., 2023), which may not account for future technological shifts or regulatory interventions that could reshape the metaverse's economic landscape.

Third, technological bias and accessibility issues shape how metaverse adoption is examined. The literature predominantly reflects findings from studies conducted in high-income countries and technologically advanced industries, with limited coverage of metaverse applications in developing economies or resource-constrained sectors. This geographic bias affects the generalizability of findings, particularly for workforce development and consumer engagement themes, where differences in digital literacy, infrastructure, and affordability may significantly influence adoption patterns (Malik et al., 2022; Schmid Mast et al., 2018; Thite, 2022).

Lastly, publication bias should be considered, as the reviewed literature primarily consists of peer-reviewed journal articles, which may favor positive findings and well-established technologies while underreporting failed implementations or challenges in metaverse adoption (Dwivedi et al., 2022). The evolving nature of metaverse technologies also means that some studies may quickly become outdated, requiring continuous updates to capture emerging trends and shifting business models (Grewal et al., 2017; Rauschnabel et al., 2019).

Acknowledging these biases and limitations highlights areas for future research, such as interdisciplinary approaches, longitudinal studies, and broader geographic representation, to develop a more comprehensive understanding of metaverse-driven transformations across industries.

5.1. *Implications for theory*

The integration of metaverse technologies such as digital twins, VR, AR, and mixed reality across sectors presents rich avenues for theoretical advancement, challenging and extending established concepts in management, marketing, supply chains, tourism, and human resources. In the context of digital twins and supply chain resilience, existing theories of supply chain risk management and resilience, such as the resource-based view (RBV), can be expanded to incorporate the dynamic feedback loops enabled by digital twins. Traditional models often view resources as static; however, digital twins enable real-time simulation and data-driven adaptation, calling for a redefinition of resources to include live digital models that contribute to resilience (Dolgui & Ivanov, 2023). This enhancement also supports contingency theories, as digital twins enable organizations to respond proactively to varied disruption scenarios, validating contingency principles within complex, data-rich environments (Queiroz et al., 2023; Mahdikhani & Meena, 2024).

Our findings advance existing theories by introducing insights into how metaverse technologies such as digital twins, VR, AR, and mixed reality reshape traditional assumptions and expand theoretical boundaries across various domains, including supply chain resilience, consumer behavior, tourism authenticity, and organizational learning. Our findings contribute to theoretical advancements within these fields as follows:

1. **Supply chain resilience and the resource-based view (RBV):** Our findings on digital twins in supply chain management enhance the RBV by reconceptualizing resources as dynamic, live data assets that continuously inform and adapt to real-time conditions (Huang et al., 2023; Barney, 2001). The traditional RBV focuses on the strategic value of static resources (Barney, 2001), but digital twins introduce living resources that continuously update and simulate scenarios, allowing firms to adapt instantly to supply chain disruptions. This dynamic view supports a more resilient, adaptable interpretation of RBV (Huang et al., 2023), where resources are not only possessed but also continuously engaged to create competitive advantage in complex, volatile markets.
2. **Consumer experience and technology acceptance models:** Our findings on VR and AR applications in marketing and customer engagement extend models such as the Technology Acceptance Model (TAM) (Davis, 2024) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) by showing that immersive experiences add emotional engagement as a key factor in technology adoption (Phang & Kong, 2024; Cummings et al., 2023). While the TAM traditionally focuses on perceived usefulness and ease of use, our findings reveal that in immersive environments, perceived presence and enjoyment can be as critical as utility. This finding indicates that emotional and sensory engagement should be integrated as key constructs within acceptance models when metaverse technologies are evaluated, especially in customer-facing sectors such as retail and tourism (Phang & Kong, 2024; Cummings et al., 2023).
3. **Experiential consumption and brand attachment:** Our exploration of AR's role in fostering brand attachment introduces a new dimension to experiential consumption and brand loyalty theories. Immersive AR experiences allow consumers to build emotional connections with brands through direct, vivid interactions that make the brand feel more tangible and personal (Sun et al., 2023; Cobb & Bowers, 1999). By enhancing sensory and emotional engagement, AR creates deeper brand attachments, advancing relationship marketing theories by positioning immersion and interactivity as new drivers of loyalty and repeat behavior (Cummings et al., 2023).
4. **Authenticity in tourism and service management:** Our findings on virtual tourism demonstrate that VR can alter traditional concepts of authenticity, particularly within heritage and eco-sensitive tourism (John & Supramaniam, 2024). Theories of authenticity in tourism, which often emphasize the tangible, physical experience, are expanded as VR presents a digital form of staged authenticity that resonates with tourists' emotional and cognitive expectations without requiring physical presence (Rickly & Canavan, 2024). This virtual authenticity encourages tourism theory to include virtual experiences as legitimate channels for connection and value creation, particularly for destinations where physical visitation may not be sustainable or possible (Yersüren & Özel, 2024; Sun et al., 2023).
5. **Organizational learning and situated cognition:** In the context of VR and AR in training and workforce development, our findings enrich experiential learning theories by demonstrating that immersive simulations facilitate deeper skill retention and engagement (Cobb & Bowers, 1999). Traditionally, situated cognition theory posits that learning is most effective when it occurs within the environment where the knowledge will be applied. VR's ability to create high-fidelity simulations allows learners to practice tasks as if in the real world, advancing situated cognition theory by highlighting VR's unique ability to provide experiential learning even in remote or virtual environments (Makransky & Petersen, 2021).
6. **Value cocreation and service ecosystems in tourism and hospitality:** Our findings show that metaverse technologies in tourism and hospitality promote new dimensions of value cocreation, where consumers engage actively with service providers in a virtual space.

Traditional theories of value cocreation and service ecosystems can be extended to include digital interactions that complement physical experiences (John & Supramaniam, 2024). For example, VR tours before an actual visit can enhance a tourist's connection to a destination, creating a more meaningful experience and cocreating value that begins before the physical trip (Rickly & Canavan, 2024).

In manufacturing and operations, the use of digital twins to model complex processes raises theoretical questions about system dynamics and cyber-physical integration. Cyber-physical system (CPS) theories can be expanded to consider the dynamic and predictive capabilities provided by digital twins, which enable real-time adaptation in response to changing production variables (Guo & Mantravadi, 2024). Digital twins also contribute to just-in-time (JIT) and lean production theories by offering continuous insights that enable waste reduction, predictive maintenance, and real-time adjustments. This continuous feedback loop challenges static operational models and supports the development of more dynamic theories of production and operational efficiency (Dolgui & Ivanov, 2023).

In summary, our findings advance these theories by providing empirical insights into how metaverse technologies reshape foundational constructs such as resource dynamism, consumer engagement, authenticity, experiential learning, and value cocreation. By integrating digital, immersive experiences into theoretical frameworks, we provide a modernized lens through which future researchers and practitioners can explore the growing impact of the metaverse on business practices and consumer behavior. These contributions underscore the need for theories to evolve alongside digital advancements, fostering a deeper understanding of how metaverse technologies transform both strategic operations and consumer relationships across industries (Yersüren & Özel, 2024; Dolgui & Ivanov, 2023).

5.2. Implications for policy

Metaverse technologies, including digital twins, VR, AR, and mixed reality, are rapidly transforming various sectors, such as the supply chain, manufacturing, retail, tourism, and marketing, creating both opportunities and regulatory needs. As businesses increasingly adopt these technologies, policymakers must consider the implications of data privacy, interoperability, and digital infrastructure. Digital twins, for instance, offer valuable insights for supply chain resilience, allowing companies to model real-time conditions and respond to disruptions more effectively. However, the widespread adoption of these systems requires regulatory frameworks that promote data standardization and ensure cross-platform interoperability to facilitate global supply chains. In manufacturing, the use of digital twins and IoT-powered analytics for monitoring and optimizing production could be supported by government incentives or subsidies for companies that implement energy-efficient practices, aiding both resilience and sustainability objectives. Therefore, to maximize the benefits of metaverse technologies in sectors such as tourism and retail, policies should encourage best practices around data privacy and secure customer interactions, which are central to customer trust and industry compliance.

For consumer-facing applications in sectors such as retail, tourism, and marketing, AR and VR technologies require policies focused on transparency, accessibility, and equitable access. As AR and VR enable highly personalized customer experiences, policy frameworks should emphasize clear disclosures around data collection and usage, especially as personal data and behavioral analytics become integral to tailoring these experiences. In tourism, VR applications that replicate historical or endangered sites present a unique policy opportunity to support cultural preservation through virtual experiences while managing environmental impact. Policymakers can support the expansion of VR tourism while encouraging tourism boards and businesses to use these tools in ways that promote sustainability. Finally, metaverse technologies in education, healthcare, and other service sectors should be made accessible across socioeconomic groups, calling for policies that encourage affordable access and digital literacy programs to bridge potential gaps. By addressing these aspects, policymakers can foster a digital landscape that promotes both innovation and ethical, sustainable growth across diverse industries.

5.3. Implications for practice

For practitioners across industries, the integration of metaverse technologies such as digital twins, VR, AR, and mixed reality presents actionable opportunities to enhance operational efficiency, customer experience, and sustainability. In supply chain management, practitioners should leverage digital twins to monitor, predict, and respond to disruptions in real time. For example, a logistics company could use digital twins to simulate various transportation routes and identify potential bottlenecks, enabling proactive adjustments that optimize delivery times and reduce fuel consumption. By continuously updating models with real-time data, supply chain teams can maintain an agile, resilient operation, which is especially critical during global disruptions. Manufacturing practitioners can similarly employ digital twins for predictive maintenance and quality control, reducing downtime and waste. For example, a factory could use IoT sensors and digital twins to monitor machinery performance, scheduling repairs only when needed to avoid unnecessary interventions and extend equipment life.

In customer-facing sectors such as retail, tourism, and marketing, metaverse technologies such as AR and VR can transform the consumer journey, offering innovative ways to interact with products and services. Retailers, for example, can use AR apps that allow customers to visualize furniture or decor in their own homes before purchasing, which enhances buyer confidence and reduces return rates. Similarly, marketing professionals can apply VR to create immersive brand experiences, such as a virtual tour of a destination for potential travelers, fostering emotional connections and increasing conversion rates. To optimize AR and VR experiences, practitioners should invest in content that not only captures but also respects user privacy; gathering data on user preferences should be transparently and securely managed to build trust. In tourism, VR tours of historical or eco-sensitive sites offer an alternative to physical visits, reducing foot traffic and promoting sustainable travel practices. By creating rich, interactive virtual experiences, tour operators can attract a global audience while protecting physical sites, catering to the growing market of eco-conscious travelers.

Finally, for sectors such as education, healthcare, and professional training, VR and AR can provide interactive, accessible learning environments. Practitioners in these areas should consider integrating VR simulations to offer hands-on training for complex tasks, for example, surgical training in healthcare or machinery operation in technical fields—allowing students and professionals to practice without real-world risk. Educators can create digital classrooms using VR, reaching students regardless of their location and making advanced education more inclusive. Practitioners across industries should also invest in digital literacy and accessibility initiatives, ensuring that metaverse technologies are user friendly and accessible to individuals of varying technological proficiencies. By incorporating these actionable practices, practitioners can harness the full potential of metaverse technologies to drive meaningful, customer-centric, and efficient advancements in their industries.

6. Conceptual framework, research propositions, and future research

6.1. Conceptual framework

Based on our findings and discussion, Fig. 4 illustrates our proposed conceptual framework; it depicts how metaverse technologies influence business management by delineating four components: antecedents, mediators, moderators, and consequences.

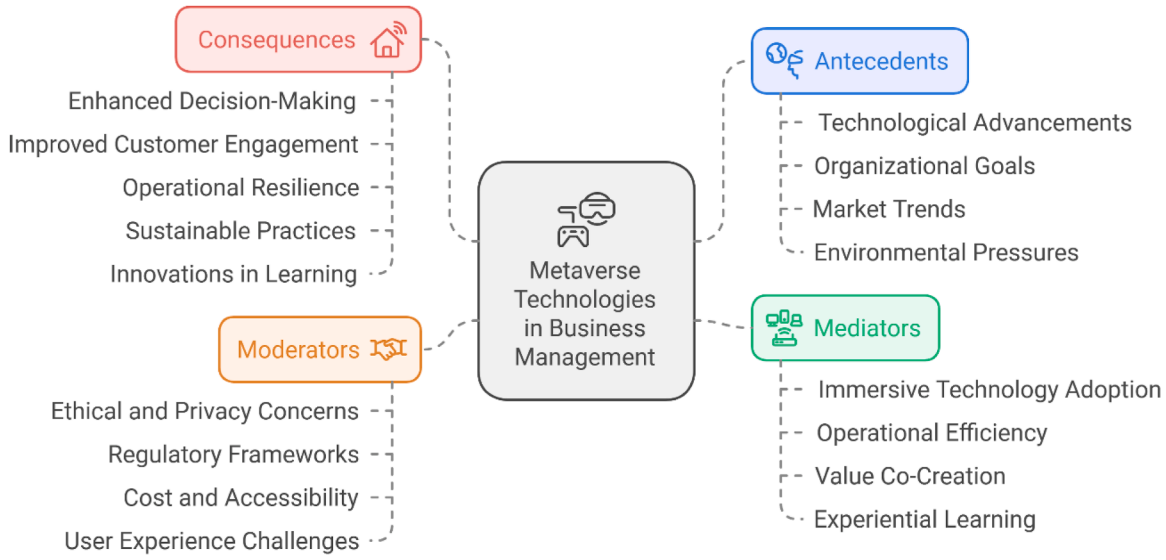

Fig. 4. Conceptual framework for metaverse technologies in business management.

The antecedents determine the future factors that favor the application of metaverse technologies in business management. This embraces developments in the domain of technology, particularly AR, VR, blockchain, and AI, which would act as the metaverse supportive infrastructure or backbone, enabling the metaverse to flourish and assisting in its market proliferation (Mahdikhani & Meena, 2024; Dwivedi et al., 2023). Immersive ecosystems improve organizational decisions, triggering more efficient behaviors, which can be considered essential transformational factors for innovation and the fulfillment of strategic alignment (Queiroz et al., 2023). In addition to addressing specific use cases, metaverse initiatives are aligned with high-level strategic objectives focused on improving customer engagement (or more general process improvement goals) (Mahajan et al., 2023).

Another critical component of the technology adoption framework, market trends', can be driven by evolving consumer expectations and the growing need for brands to provide personalized and interactive experiences through metaverse tools to maintain brand loyalty and market position (Barrera & Shah, 2023; Lim et al., 2024). Finally, environmental drivers such as the need to comply with rules, social licenses to operate, or sustainability requirements compel organizations to embrace metaverse architectures to market (i) the governance of ethical practices and (ii) the most effective use of assets (circular economic system) (Aysan et al., 2024).

On the other hand, the mediators are the mechanisms through which metaverse technologies affect business results. These tools not only can be easily integrated into a business process but also provide an immense boost to the level of engagement by turning a service into a product, given the rise of metaverse technologies such as AR and VR. VR-based environments (Saeed et al., 2024; Mahajan et al., 2023) enable high-fidelity simulations in immersive training scenarios, enhancing skill development and operational capabilities.

The metaverse excels in helping businesses achieve operational efficiency -another important mediator- by improving workflow and resource utilization. For instance, digital twins enable real-time monitoring and prediction to support decision-making and optimize productivity (Dolgui & Ivanov, 2023; Queiroz et al., 2023).

The emergence of value cocreation as an outcome is materialized through collaborative and interactive virtual environments. This approach encourages stakeholders to experience a brand and its services in an immersive way, leading to loyalty and satisfaction (Barrera & Shah, 2023; John & Supramaniam, 2024). Finally, experiential learning mirrors a game-changing moderator, wherein the VR-driven learning milieu mimics structures in the real finite world, effectively allowing employees, as well as customers, to transfer theoretical learning to practical applications. Such innovations lead to improvements in the retention and agility of knowledge, resulting in the preparedness of organizations for the future (Akdere et al., 2022; Saeed et al., 2024).

Moderators are the contextual factors that affect the strength or direction of the relationship between metaverse technologies and impacts. Issues of ethics and privacy (e.g., data security, virtual asset governance, and user consent) greatly influence public perceptions toward the metaverse and impede acceptance in organizations (Dwivedi et al., 2022; Mahajan et al., 2023). Similarly, regulatory frameworks set the legal boundaries of metaverse technology deployment while ensuring compliance and risk aversion, particularly within decentralized finance and virtual asset management (Aysan et al., 2024; Vidal-Tomás, 2023). Cost and accessibility are also extremely important determinants, as the economic viability and availability of resources affect the scalable prospects of metaverse tools, especially for SMEs (Mahdikhani & Meena, 2024; Queiroz et al., 2023). Moreover, UX-related challenges such as interface usability, technology adoption barriers, and adaptiveness to diverse user needs hinder the findings of the effectiveness and widespread use of metaverse platforms (Steffen et al., 2019; Suh et al., 2011).

Consequences describe what each of the metaverse technologies can do when enacted in business management, which shows the business change in all aspects. The system provides benefits, including better decision-making backed up by data-driven and immersive analyses such as examples of digital twins and VR, where monitoring is carried out in an analog and prediction can be performed in real time (Dolgui & Ivanov, 2023; Mahajan et al., 2023). Using these tools provides organizations with actionable insights that can enhance planning and operations.

Interactive, personalized virtual experiences lead to improved customer interaction and cultivate brand attachment while fostering consumer satisfaction. With respect to immersive environments, technological implementations in the form of AR & VR applications can help businesses devise engaging platforms aligned with changing customer preferences and thus reinforce loyalty (Barrera & Shah, 2023; Lim et al., 2024). Operational resilience is another top outcome driven by the adaptive and real-time capabilities of metaverse technologies. Such innovations facilitate proactive risk management and enable agile responses to disruptions, thereby increasing supply chain robustness (Queiroz et al., 2023).

In addition, virtual replacements for resource-hungry processes, such as digital twins in manufacturing and VR in tourism, open rooms for sustainable applications compatible with circular economy principles and lead to a lower environmental footprint (Aysan, 2024; Gursoy,

2022). Finally, next-generation learning has revolutionized workforce development: VR, AR, and immersive environments can reduce the distance between theory and the office. These tools assist the workforce in developing skills more quickly and retaining competencies faster, allowing them to pivot as the business landscape shifts (Akdere et al., 2022; Saeed et al., 2024).

Therefore, the proposed framework provides a structured understanding of the drivers, pathways, contextual influences, and impacts of metaverse technologies in the context of business management.

6.2. Research propositions

The metaverse is redefining business management by integrating immersive technologies across various domains. These technologies, including VR, AR, and digital twins, offer innovative tools for decision-making, engagement, and operational efficiency while presenting unique challenges such as privacy concerns, cost barriers, and skill requirements. Below, research propositions for each domain are presented, combining insights to provide practical and actionable directions.

The metaverse's ability to create immersive and realistic environments offers significant advancements in economic research and policy analysis, enabling ethical and innovative experimentation. However, addressing barriers such as cost and accessibility is crucial for maximizing its potential.

***P1**: The metaverse enhances empirical research and policy analysis through immersive experimentation, but its adoption requires overcoming challenges related to cost, simulator sickness, and accessibility.*

Virtual assets and decentralized finance (DeFi) within the metaverse challenge traditional financial systems by introducing unique risk profiles and transaction dynamics. Their integration necessitates updated regulatory frameworks and innovative portfolio strategies for sustainable economic models.

***P2**: The integration of virtual assets and DeFi in the metaverse requires adaptive regulatory frameworks and diversified financial strategies to manage risks and enable sustainable economic systems.*

Metaverse technologies such as VR and AR transform HR practices by enabling personalized employee development and performance evaluations. However, effective implementation should balance the benefits of these technologies with challenges such as technostress and employee well-being.

***P3**: Metaverse technologies in HR practices enhance training and adaptability but require proactive strategies to address technostress and ensure employee well-being.*

Digital twin and VR technologies drive adaptive and efficient manufacturing processes, enabling lifecycle management and sustainable practices. However, successful adoption depends on addressing integration barriers such as cost and interoperability through cross-sector collaboration.

***P4**: Digital twins and VR technologies in Industry 4.0 enhance adaptive manufacturing and sustainability but require collaboration and standardization to address cost and integration challenges.*

AR and VR redefine marketing strategies by enabling interactive, personalized consumer experiences that foster engagement and influence purchasing decisions. To maximize their impact, marketers should address privacy concerns and ethical considerations associated with immersive platforms.

***P5**: AR and VR transform marketing by enabling interactive consumer experiences, but their effective use requires addressing privacy and ethical challenges.*

AR enhances retail experiences by bridging digital and physical engagement and improving customer decision-making and satisfaction. However, retailers must balance practical and emotional benefits while addressing technological and privacy concerns for effective implementation.

***P6**: AR enhances retail engagement and satisfaction but requires balancing functional and emotional benefits while addressing privacy and technological challenges.*

Digital twins optimize supply chain management by enabling real-time monitoring, fault detection, and predictive analytics. Overcoming barriers such as integration costs and interoperability is essential for achieving resilience and efficiency.

***P7**: Digital twins enhance supply chain resilience and adaptability, but their success depends on addressing high implementation costs and interoperability challenges.*

VR and AR in tourism provide sustainable and accessible alternatives to physical travel, fostering consumer engagement and reducing environmental impact. Effective implementation requires attention to usability, authenticity, and standardization.

***P8**: VR and AR in tourism enhance sustainability and engagement but require high-quality design and standardized approaches for effective integration.*

6.3. Future research directions

Building on the findings and research propositions, several promising directions for future research have emerged (Fig. 5). These directions aim to address gaps and opportunities identified in the integration of metaverse technologies across various domains of business management, offering a roadmap for advancing both theory and practice.

Exploring the ethical dimensions of immersive business technologies: The metaverse poses serious ethical implications — from privacy to psychology to data ownership. Future research may explore paradigms to address these issues, aimed at better understanding the potential of immersive technologies in a way that is responsible for businesses. An important gap lies in understanding regulatory frameworks across jurisdictions, where comparative studies could explore how different countries approach data governance and ethical compliance in metaverse ecosystems. Research could explore the interaction between personalization and privacy concerns, especially in sectors such as marketing, retailing, and tourism, where consumer data forms the basis of providing captivating experiences (Dwivedi et al., 2022; Mahajan et al., 2023). Longitudinal studies concerning the psychological effects on employees and customers from thorough metaverse usage could offer relevant insights for policymakers and business managers (Akdere et al., 2022; Saeed et al., 2024). Additionally, empirical research on digital identity formation and its psychological implications in virtual business environments could provide a deeper understanding of user behavior and ethical considerations. Such queries are critical outcomes of the ethical and sustainable adoption of immersive technologies across industries.

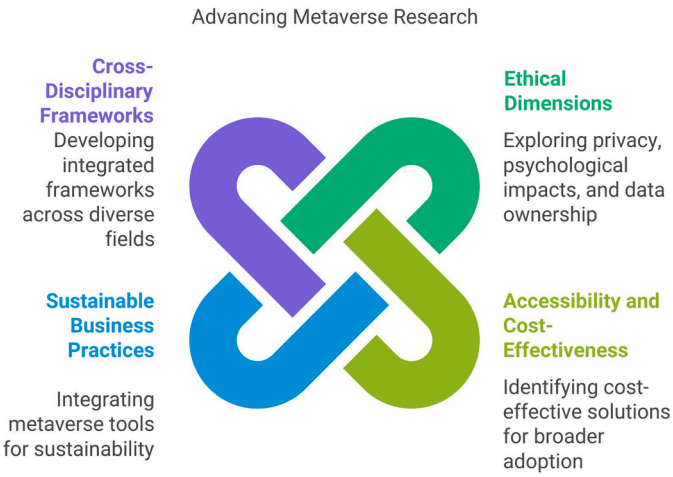

Fig. 5. Advancing metaverse research.

Enhancing accessibility and cost-effectiveness for broader adoption: The expense of metaverse technologies, including virtual reality and digital twins, restrains most firms from harnessing opportunities, with larger enterprises being able to capitalize on this technology. This requires research aimed at finding cost-effective solutions and scalable models to deploy these technologies (Dolgui & Ivanov, 2023; Mahdikhani & Meena, 2024). Future studies could explore the potential of AI-driven automation in reducing the cost of metaverse deployment, making these technologies more accessible for small and medium enterprises (SMEs). It is necessary to investigate open-source platform approaches, collaborative frameworks, and modular systems designed to lower economic and technical barriers. Case studies detailing successful low-cost implementations, particularly those utilizing open-source VR tools, may offer practical guidance for resource-constrained organizations (Queiroz et al., 2023). Furthermore, interdisciplinary research examining how blockchain-enabled smart contracts can facilitate cost-effective metaverse transactions and virtual asset management may provide innovative financial solutions. Such efforts are crucial for democratizing metaverse adoption and enabling inclusive innovation.

Integrating metaverse technologies into sustainable business practices: The metaverse offers a plethora of opportunities for augmenting sustainability, ranging from virtual tourism to lifecycle management in manufacturing, but more insight is required on how it can facilitate sustainable business models. Future research can study the role of immersive technologies in facilitating circular economy practices, optimizing resources, and lowering carbon footprint (Raman et al., 2024b; Dutta & Singh, 2024). Digital twins can be used for optimizing resource use in the manufacturing industry, leading to reduced waste and energy consumption (Dolgui & Ivanov, 2023). Further research could assess the life cycle assessment (LCA) of metaverse applications to quantify their environmental impact and identify opportunities for greener virtual environments. The utilization of specific sustainability metrics can also benefit businesses looking to align with environmental and social goals by linking metaverse applications to actionable insights (Mahajan et al., 2023). Additionally, research on how decentralized autonomous organizations (DAOs) in the metaverse can enhance sustainability governance could offer innovative strategies for businesses seeking more transparent and accountable ESG practices.

Development of cross-disciplinary theoretical frameworks for the metaverse: The metaverse covers a variety of domains, including technology, psychology, economics, and management; however, the theoretical foundation remains scarce. Further studies need to develop integrated frameworks that combine insights from diverse disciplines to steer how metaverse technologies may be used. For instance, applying behavioral economics theories to study consumer decision-making in virtual retail environments can bridge knowledge gaps in metaverse-based consumer engagement. For example, integrating user experience theories with organizational behavior might assist companies in creating metaverse settings that are attractive and operationally viable (Dwivedi et al., 2023; Roh et al., 2024). Similarly, research examining the interaction between economic and financial theories and immersive environments could shed light on regulatory and strategic approaches to virtual asset management (Aysan et al., 2024; Belk et al., 2022). Future research may also explore cognitive load theories to optimize information presentation in virtual workspaces, ensuring productivity and well-being in metaverse-based professional settings.

These future research directions emphasize the importance of bridging theoretical gaps, addressing practical challenges, and leveraging the metaverse's potential to create innovative, ethical, and sustainable business practices. A structured approach to these research gaps can be summarized in Table 12, which categorizes key future research directions across ethical, technological, economic, and sustainability dimensions. For example, frameworks addressing ethical concerns such as privacy and data security can draw from existing studies on immersive technology adoption and its societal impact (Dwivedi et al., 2022; Mahajan et al., 2023). Practical challenges, such as high implementation costs and accessibility barriers, can be addressed through scalable solutions highlighted in research on cost-effective metaverse deployments (Dolgui & Ivanov, 2023; Queiroz et al., 2023). Furthermore, studies linking immersive technologies to circular economy practices and sustainability goals provide a robust foundation for businesses aiming to align with environmental imperatives (Mahdikhani & Meena, 2024). By advancing these areas, researchers can contribute to a more comprehensive understanding of how metaverse technologies reshape the landscape of business management, fostering innovation while ensuring ethical and sustainable progress (Dutta & Singh, 2024; Roh et al., 2024).

Table 12
Summary of Future research directions in the metaverse.

Research area	Key questions	Suggested approaches
Ethical Dimensions	How do different jurisdictions regulate metaverse ethics and data privacy?	Comparative regulatory studies, empirical research on digital identity
Accessibility & Cost	How can AI-driven automation and blockchain reduce metaverse deployment costs?	Case studies, cost-effectiveness analyses
Sustainability	What are the environmental impacts of metaverse technologies?	Life Cycle Assessments, DAO-led ESG governance models
Cross-Disciplinary Theories	How do behavioral economics and cognitive load theories apply to metaverse adoption?	Theoretical framework development, interdisciplinary integration

7. Conclusions

The metaverse represents a significant transformation in business operations, integrating advanced technologies such as VR, AR, digital twins, and decentralized finance to bridge the physical and digital worlds. This study systematically reviewed the applicability of metaverse technologies across multiple industries, including marketing, supply chain management, human resource development, tourism, and finance, highlighting both their potential benefits and inherent challenges. While these technologies introduce new efficiencies, immersive experiences, and data-driven decision-making, their adoption remains uneven across industries due to sector-specific limitations, regulatory uncertainties, and technological barriers.

Despite the transformative potential, several practical challenges limit large-scale implementation. High costs of adoption, interoperability concerns, cybersecurity risks, and ethical considerations surrounding data privacy and inclusion continue to hinder widespread adoption. Additionally, the fragmented regulatory landscape for virtual assets and DeFi poses risks to financial stability, while VR-based workforce development raises concerns about technostress, accessibility, and digital literacy gaps. Moreover, disparities in infrastructure and metaverse readiness across regions and industries exacerbate implementation difficulties, making scalability and standardization critical areas for future development. The environmental impact of metaverse technologies remains an ongoing concern. While digital twins and virtual simulations offer sustainability benefits by reducing material waste and optimizing supply chains, the energy-intensive nature of blockchain and data-heavy immersive environments may offset these gains. Future research should explore ways to improve the environmental footprint of metaverse applications, balancing economic opportunities with sustainability goals.

Addressing these technological, ethical, and economic contradictions requires collaboration between policymakers, industry practitioners, and researchers to establish scalable, cost-effective solutions and ethical standards. More theoretical and cross-disciplinary approaches are needed to distinguish between technological adoption barriers and broader ethical and environmental concerns, ensuring that metaverse-driven innovation aligns with responsible business practices.

Ultimately, businesses that strategically and ethically integrate metaverse technologies will be best positioned to capitalize on new opportunities for growth, resilience, and sustainability in an increasingly digital economy. However, critical evaluation of sector-specific adoption challenges is necessary to ensure that metaverse applications do not simply replicate existing business inefficiencies but genuinely contribute to long-term digital transformation.

CRediT authorship contribution statement

Raghu Raman: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Santanu Mandal:** Writing – review & editing, Writing – original draft. **Angappa Gunasekaran:** Writing – review & editing, Writing – original draft. **Thanos Papadopoulos:** Writing – review & editing, Writing – original draft. **Prema Nedungadi:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding information

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

The data are available upon reasonable request from the corresponding author.

References

Ajao, E. (2022). Deloitte launches new metaverse services and studio. Available online at: https://www.techtarget.com/searchenterpriseai/news/252511950/Deloitte-launches-new-metaverse-services-and-studio.

Akdere, M., Jiang, Y., & Lobo, F. D. (2022). Evaluation and assessment of virtual reality-based simulated training: Exploring the human–technology frontier. *European Journal of Training and Development, 46*(5/6), 434–449.

Aysan, A. F., Gozgor, G., & Nanaeva, Z. (2024). Technological perspectives of Metaverse for financial service providers. *Technological Forecasting and Social Change, 202*, Article 123323.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99–120.

Barney, J. B. (2001). Resource-based theories of competitive advantage: A ten-year retrospective on the resource-based view. *Journal of Management, 27*(6), 643–650.

Barrera, K. G., & Shah, D. (2023). Marketing in the metaverse: Conceptual understanding, framework, and research agenda. *Journal of Business Research, 155*, Article 113420.

Belk, R., Humayun, M., & Brouard, M. (2022). Money, possessions, and ownership in the metaverse: NFTs, cryptocurrencies, Web3 and Wild Markets. *Journal of Business Research, 153*, 198–205.

Cobb, P., & Bowers, J. (1999). Cognitive and situated learning perspectives in theory and practice. *Educational Researcher, 28*(2), 4–15.

Cummings, J. J., Cahill, T. J., Wertz, E., & Zhong, Q. (2023). Psychological predictors of consumer-level virtual reality technology adoption and usage. *Virtual Reality, 27*(2), 1357–1379.

Dacko, S. G. (2017). Enabling smart retail settings via mobile augmented reality shopping apps. *Technological Forecasting and Social Change, 124*, 243–256.

Dang Quan, T., Wei-Han Tan, G., Aw, E. C. X., Cham, T. H., Basu, S., & Ooi, K. B. (2024). Can you resist the virtual temptations? Unveiling impulsive buying in metaverse retail. *Asia Pacific Journal of Marketing and Logistics*.

Davis, F. D., Granić, A., & Marangunić, N. (2024). *The technology acceptance model: 30 years of TAM*. Springer International Publishing AG.

Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2019). BERT: Pretraining of deep bidirectional transformers for language understanding. In *, 1. NAACL HLT 2019 - 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies - Proceedings of the Conference* (pp. 4171–4186).

Dincelli, E., & Yayla, A. (2022). Immersive virtual reality in the age of the Metaverse: A hybrid-narrative review based on the technology affordance perspective. *The Journal of Strategic Information Systems, 31*(2), Article 101717.

Ding, K., Chan, F. T., Zhang, X., Zhou, G., & Zhang, F. (2019). Defining a digital twin-based cyber-physical production system for autonomous manufacturing in smart shop floors. *International Journal of Production Research, 57*(20), 6315–6334.

Dolgui, A., & Ivanov, D. (2023). Metaverse supply chain and operations management. *International Journal of Production Research, 61*(23), 8179–8191.

Donthu, N., Kumar, S., & Pattnaik, D. (2020). Forty-five years of Journal of Business Research: A bibliometric analysis. *Journal of Business Research, 109*, 1–14.

Douglas, T., Capra, L., & Musolesi, M. (2024). A computational linguistic approach to study border theory at scale. *Proceedings of the ACM on Human-Computer Interaction, 8*(CSCW1), 1–23.

Dutta, A., & Singh, S. (2024). Metaverse metamorphosis: Fintech's evolution catalyzing new era of consumer behavior. *Journal of Consumer Behavior*.

Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., … Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management, 66*, Article 102542.

Dwivedi, Y. K., Hughes, L., Wang, Y., Alalwan, A. A., Ahn, S. J., Balakrishnan, J., & Wirtz, J. (2023). Metaverse marketing: How the metaverse will shape the future of consumer research and practice. *Psychology & Marketing, 40*(4), 750–776.

Dwivedi, Y. K., Ismagilova, E., Hughes, D. L., Carlson, J., Filieri, R., Jacobson, J., & Wang, Y. (2021). Setting the future of digital and social media marketing research: Perspectives and research propositions. *International Journal of Information Management, 59*, Article 102168.

Flavián, C., Ibáñez-Sánchez, S., & Orús, C. (2019). The impact of virtual, augmented and mixed reality technologies on the customer experience. *Journal of Business Research, 100*, 547–560.

Gao, H., Chong, A. Y. L., & Bao, H. (2024). Metaverse: Literature review, synthesis and future research agenda. *Journal of Computer Information Systems, 64*(4), 533–553.

Grootendorst M. (2022) BERTopic: Neural topic modeling with a class-based TFIDF procedure. http://arxiv.org/abs/2203.05794.

Guo, D., & Mantravadi, S. (2024). The role of digital twins in lean supply chain management: Review and research directions. *International Journal of Production Research*, 1–22.

Gursoy, D., Malodia, S., & Dhir, A. (2022). The metaverse in the hospitality and tourism industry: An overview of current trends and future research directions. *Journal of Hospitality Marketing & Management, 31*(5), 527–534.

Guttentag, D. A. (2010). Virtual reality: Applications and implications for tourism. *Tourism Management, 31*(5), 637–651.

Hou, H., Lai, J. H., Wu, H., & Wang, T. (2024). Digital twin application in heritage facilities management: Systematic literature review and future development directions. *Engineering, Construction and Architectural Management, 31*(8), 3193–3221.

Huang, T. L., & Chung, H. F. (2024). Impact of delightful somatosensory augmented reality experience on online consumer stickiness intention. *Journal of Research in Interactive Marketing, 18*(1), 6–30.

Innocenti, A. (2017). Virtual reality experiments in economics. *Journal of Behavioral and Experimental Economics, 69*, 71–77.

John, S. P., & Supramaniam, S. (2024). Value cocreation research in tourism and hospitality management: A systematic literature review. *Journal of Hospitality and Tourism Management, 58*, 96–114.

Kerin, M., & Pham, D. T. (2019). A review of emerging industry 4.0 technologies in remanufacturing. *Journal of Cleaner Production, 237*, Article 117805.

Khodeir, N., & Elghannam, F. (2024). Efficient topic identification for urgent MOOC Forum posts using BERTopic and traditional topic modeling techniques. *Education and Information Technologies*, 1–27.

Kim, K., Kogler, D. F., & Maliphol, S. (2024). Identifying interdisciplinary emergence in the science of science: Combination of network analysis and BERTopic. *Humanities & Social Sciences Communications, 11*(1), 1–15.

Kim, M. J., Lee, C. K., & Jung, T. (2020). Exploring consumer behavior in virtual reality tourism using an extended stimulus–organism–response model. *Journal of Travel Research, 59*(1), 69–89.

Krishnan, A. (2024). Top metaverse investors and how to start investing. Available online at: https://www.techtarget.com/searchcio/tip/Top-metaverse-investors-and-how-to-start-investing.

Kumar, A., Shankar, A., Behl, A., & Wamba, S. F. (2025). Do you believe in the metaverse NFTs? Understanding the value proposition of NFTs in the metaverse. *Technological Forecasting and Social Change, 210*, Article 123880.

Li, Y., Lucey, B., & Urquhart, A. (2023). Can altcoins act as hedges or safe-havens for Bitcoin? *Finance Research Letters, 52*, Article 103360.

Lim, D. H., Lee, J. Y., & Park, S. (2024). The metaverse in the workplace: Possibilities and implications for human resource development. *Human Resource Development Review, 23*(2), 164–198.

Mahajan, R., Lim, W. M., Sareen, M., Kumar, S., & Panwar, R. (2023). Stakeholder theory. *Journal of Business Research,, 166*, Article 114104.

Mahdikhani, M., & Meena, P. (2024). Metaverse applications and supply chain innovation: Insights from text mining. *Journal of Innovation & Knowledge, 9*(4), Article 100591.

Makransky, G., & Petersen, G. B. (2021). The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. *Educational Psychology Review, 33*(3), 937–958.

Mancuso, I., Petruzzelli, A. M., & Panniello, U. (2023a). Digital business model innovation in metaverse: How to approach virtual economy opportunities. *Information Processing & Management, 60*(5), Article 103457.

Mancuso, I., Petruzzelli, A. M., Panniello, U., & Nespoli, C. (2023b). A microfoundation perspective on business model innovation: The cases of roblox and meta in metaverse. *IEEE Transactions on Engineering Management*.
Mancuso, I., Petruzzelli, A. M., Urbinati, A., & Matzler, K. (2024). Leadership in the metaverse: Building and integrating digital capabilities. *Business Horizons*.
Min, Q., Lu, Y., Liu, Z., Su, C., & Wang, B. (2019). Machine learning based digital twin framework for production optimization in petrochemical industry. *International Journal of Information Management, 49*, 502–519.
Nedungadi, P., Surendran, S., Tang, K. Y., & Raman, R. (2024). Big data and AI algorithms for sustainable development goals: A topic modeling analysis. *IEEE Access*.
Oh, Y. K., Yi, J., & Kim, J. (2023). What enhances or worsens the user-generated metaverse experience? An application of BERTopic to Roblox user eWOM. *Internet Research*.
Olschewski, R., Bebi, P., Teich, M., Hayek, U. W., & Grêt-Regamey, A. (2012). Avalanche protection by forests—A choice experiment in the Swiss Alps. *Forest policy and Economics, 17*, 19–24.
Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ (Clinical Research Ed.)*, 372.
Phang, I. G., & Kong, Y. Z. (2024). Exploring the influence of technical and sensory factors on Malaysians' intention to adopt virtual tours in heritage travel. *Journal of Hospitality and Tourism Insights, 7*(3), 1313–1329.
Qiao, X., Zhu, H., Tang, Y., & Peng, C. (2023). Time-frequency extreme risk spillover network of cryptocurrency coins, DeFi tokens and NFTs. *Finance Research Letters, 51*, Article 103489.
Queiroz, M. M., Wamba, S. F., Pereira, S. C. F., & Jabbour, C. J. C. (2023). The metaverse as a breakthrough for operations and supply chain management: Implications and call for action. *International Journal of Operations & Production Management, 43*(10), 1539–1553.
Raman, R., Hughes, L., Mandal, S., Das, P., & Nedungadi, P. (2024b). *Mapping metaverse research to the sustainable development goal of good health and well-being*. IEEE Access.
Raman, R., Pattnaik, D., Lathabai, H. H., Kumar, C., Govindan, K., & Nedungadi, P. (2024a). Green and sustainable AI research: An integrated thematic and topic modeling analysis. *Journal of Big Data, 11*(1), 55.
Rauschnabel, P. A., Felix, R., & Hinsch, C. (2019). Augmented reality marketing: How mobile AR-apps can improve brands through inspiration. *Journal of Retailing and Consumer Services, 49*, 43–53.
Ribeiro, A., Vieira, V., Alves, L., & Maciel, C. (2024). Vishnu: An approach to support the personalization of self-expressive avatars using context-awareness. *International Journal of Human-Computer Studies, 185*, Article 103243.
Rickly, J., & Canavan, B. (2024). The emergence of authenticity: Phases of tourist experience. *Annals of Tourism Research, 109*, Article 103844.
Rodič, B. (2017). Industry 4.0 and the new simulation modeling paradigm. *Organizacija, 50*(3), 193–207.
Roh, T., Xiao, S., & Park, B. I. (2024). What makes metaverse users immersed in the flow state in an emerging market? An application of affordance theory and ISSM. *Journal of Retailing and Consumer Services, 81*, Article 104012.
Saeed, A., Ali, A., & Ashfaq, S. (2024). Employees' training experience in a metaverse environment? Feedback analysis using structural topic modeling. *Technological Forecasting and Social Change, 208*, Article 123636.
Schmid Mast, M., Kleinlogel, E. P., Tur, B., & Bachmann, M. (2018). The future of interpersonal skills development: Immersive virtual reality training with virtual humans. *Human Resource Development Quarterly, 29*(2), 125–141.
Steffen, J. H., Gaskin, J. E., Meservy, T. O., Jenkins, J. L., & Wolman, I. (2019). Framework of affordances for virtual reality and augmented reality. *Journal of Management Information Systems, 36*(3), 683–729.
Suh, K. S., Kim, H., & Suh, E. K. (2011). What if your avatar looks like you? Dual-congruity perspectives for avatar use. *MIs Quarterly*, 711–729.
Sun, C., Ye, C., Li, C., & Liu, Y. (2023). Virtual ideality vs. virtual authenticity: Exploring the role of social signals in interactive marketing. *Journal of Research in Interactive Marketing*. ahead-of-print.
Thite, M. (2022). Digital human resource development: Where are we? Where should we go and how do we go there? *Human Resource Development International, 25*(1), 87–103.
Tussyadiah, I. P., Wang, D., Jung, T. H., & Tom Dieck, M. C. (2018). Virtual reality, presence, and attitude change: Empirical evidence from tourism. *Tourism management, 66*, 140–154.
Vaid, S., Puntoni, S., & Khodr, A. (2023). Artificial intelligence and empirical consumer research: A topic modeling analysis. *Journal of Business Research, 166*, Article 114110.
Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425–478.
Venugopal, M., Madhavan, V., Prasad, R., & Raman, R. (2024). Transformative AI in human resource management: Enhancing workforce planning with topic modeling. *Cogent Business & Management,, 11*(1), Article 2432550.
Vidal-Tomás, D. (2022). The new crypto niche: NFTs, play-to-earn, and metaverse tokens. *Finance Research Letters, 47*, Article 102742.
Vidal-Tomás, D. (2023). The illusion of the metaverse and meta-economy. *International Review of Financial Analysis, 86*, Article 102560.
Wang, Z., Chen, J., Chen, J., & Chen, H. (2023). Identifying interdisciplinary topics and their evolution based on BERTopic. *Scientometrics*, Article 0123456789.
Wang, J., Ye, L., Gao, R. X., Li, C., & Zhang, L. (2019). Digital Twin for rotating machinery fault diagnosis in smart manufacturing. *International Journal of Production Research, 57*(12), 3920–3934.
Wang, Y., Zhu, M., Chen, X., Liu, R., Ge, J., Song, Y., & Yu, G. (2024). The application of metaverse in healthcare. *Frontiers in Public Health, 12*, Article 1420367.
Weking, J., Desouza, K. C., Fielt, E., & Kowalkiewicz, M. (2023). Metaverse-enabled entrepreneurship. *Journal of Business Venturing Insights, 19*, Article e00375.
Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal, 5*(2), 171–180. F.
Yersüren, S., & Özel, Ç. H. (2024). The effect of virtual reality experience quality on destination visit intention and virtual reality travel intention. *Journal of Hospitality and Tourism Technology, 15*(1), 70–103.
Yi, J., Oh, Y. K., & Kim, J. M. (2025). Unveiling the drivers of satisfaction in mobile trading: Contextual mining of retail investor experience through BERTopic and generative AI. *Journal of Retailing and Consumer Services, 82*, Article 104066.
Yim, M. Y. C., Chu, S. C., & Sauer, P. L. (2017). Is augmented reality technology an effective tool for e-commerce? An interactivity and vividness perspective. *Journal of Interactive Marketing, 39*(1), 89–103.
Zarantonello, L., & Schmitt, B. H. (2023). Experiential AR/VR: A consumer and service framework and research agenda. *Journal of Service Management, 34*(1), 34–55.
Zawadzki, P., & Żywicki, K. (2016). Smart product design and production control for effective mass customization in the industry 4.0 concept. *Management and Production Engineering Review*.