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Establishing the Theoretical Foundations of Metaverse-Sustainable Tourism Nexus. Mapping the Research Front

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Abstract

The tourism sector is widely recognized as a pivotal catalyst for global development and economic growth. However, it faces significant challenges, which have intensified the search for alternative and more sustainable tourism models. Digital technologies have become essential tools for transformation, with the metaverse emerging as a disruptive and promising innovation strategy for the tourism industry. Thus, this study aims to provide a comprehensive review of all previous scientific literature related to the adoption of the metaverse in the context of sustainable tourism, developing a bibliometric analysis (through techniques such as co-citation analysis of references and author keyword co-occurrence) of all articles indexed in Web of Science database from January 2021 to September 2025. Specifically, the references co-citation analysis has concluded three main thematic clusters related to conceptual foundations, technological advances, and metaverse adoption possibilities, respectively. The results obtained indicate that research on the metaverse in sustainable tourism is still at an early stage of development and is primarily conceptual in nature. This study contributes to the emerging research field of metaverse and sustainable tourism by offering a comprehensive review to establish its theoretical foundations and identify opportunities for future research.

Keywords: digital technologies; Metaverse; sustainable tourism; bibliometric analysis

1. Introduction

The tourism sector has generated an estimated USD 1.6 trillion in international tourism receipts, driven by the movement of 1.4 billion tourists worldwide. The average expenditure per tourist has been approximately USD 1100 and total tourism-related exports (including passenger transport) have reached USD 1.9 trillion (UN Tourism, 2025). These figures emphasize the central role of tourism in driving economic growth and consolidating its position as a fundamental pillar of global development (Chon & Hao, 2025; Streimikiene et al., 2021). However, the rapid expansion of the tourism sector has highlighted a range of challenges, including environmental degradation, unsustainable use of resources, threats to cultural heritage, and complex impacts on local communities (Agarwal et al., 2024; Streimikiene et al., 2021). As a result, there has been a growing interest in the development

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of sustainable tourism practices aimed at balancing economic growth with environmental protection and sociocultural preservation (WTO, 2005).

Digital technologies have emerged as powerful and valuable tools to support the transition from traditional models to sustainable models in the tourism industry (Goyal, 2024; Socratous et al., 2025). Thus, technologies such as artificial intelligence (AI), virtual reality (VR), augmented reality (AR), mixed reality (XR), extended reality (MR), big data, the Internet of Things (IoT) and, more recently, the metaverse can profoundly help to reshape how tourism is experienced, managed and promoted (Buhalis et al., 2023a; Dwivedi et al., 2022; Meena et al., 2024). In fact, they can improve the efficient use of resources, reduce the ecological footprint, promote responsible consumer behaviours, and foster greater inclusivity and participation of the stakeholders (Chon & Hao, 2025; Socratous et al., 2025).

The metaverse stands out as a disruptive and transformative technology capable of redefining the tourism experience (Adnan et al., 2024; Meena et al., 2024). By creating immersive, interactive and real-time virtual environments, the metaverse can allow users to explore destinations, engage with cultural heritage, and plan their trips without physical constraints (Dwivedi et al., 2022; Kılıçarslan et al., 2025). Its integration with VR, AR, and AI technologies further increases its potential to deliver personalized, accessible and environmentally conscious experiences (Adnan et al., 2024). Nevertheless, the adoption of these advanced technologies also raises critical legal, ethical, social and environmental concerns which could have an adverse effect on tourism (Chakraborty et al., 2025; Dwivedi et al., 2022; Gössling & Mei, 2025; A. Kumar et al., 2025). Since these issues remain largely unexplored, a deeper and more comprehensive understanding is needed of how the metaverse can be effectively integrated into the tourism sector to promote sustainability and address these challenges.

This study conducts a bibliometric analysis of all articles indexed in the Web of Science database from January 2021 to September 2025, using techniques to uncover patterns and trends within the literature focused on performance analysis and scientific mapping, such as co-citation analysis of references and author keyword co-occurrence analysis. Thus, the study aims to provide a comprehensive understanding of the role of the metaverse in shaping sustainable tourism practices by systematically analyzing a broad body of literature. It also seeks to offer a theoretical foundation for future research in the study field.

This research contributes to advancing knowledge for (a) mapping the research front of the relationship between the metaverse and sustainable tourism, identifying the most relevant authors, articles and journals from January 2021 to September 2025; (b) identifying the main topics or themes underlying the metaverse research in sustainable tourism; (c) identifying future lines of research on the application of advanced technologies to sustainable tourism. Thus, this study provides valuable insights for researchers seeking to understand the current state of this emerging research field; for policymakers aiming at identifying the main aspects to consider when designing strategies that foster sustainable development within the tourism sector; and for tourism professionals seeking to understand how emerging digital technologies and, in particular metaverse, can improve destination management, business performance and competitiveness.

The rest of the paper is structured as follows: the second section describes the conceptual framework of the topic under study; the third section explains the methodology used; the fourth section outlines and discusses the main findings; and finally, the fifth section includes the main conclusions of the paper, the theoretical and practical implications and the future lines of research.

2. Literature Review

2.1. Tourism, Sustainability and Technologies

Tourism has emerged as a significant driver of global development, shaping economic growth, job opportunities and cultural interactions across different regions (Chon & Hao, 2025; Streimikiene et al., 2021). The phenomenon of tourism, which depends on a diverse range of natural, cultural, and social resources (Gil-Cordero et al., 2025), contributes to the diversification of the local economy and promotes the development of infrastructure and services to support tourism-related activities (Verma et al., 2022). However, the rapid growth of tourism also poses significant challenges, including environmental conservation, resource management, preservation of cultural identity, and relations with local communities (Agarwal et al., 2024; Streimikiene et al., 2021). The raising awareness of the negative impacts of tourism has raised concerns among policymakers, industry stakeholders, local residents and the entire society (Agarwal et al., 2024), who have increased their demands for a shift towards more sustainable tourism models (Hao et al., 2025). In this way, sustainable tourism has gained significant prominence on the international agenda as an alternative to conventional tourism models (Agarwal et al., 2024).

Sustainable tourism can be defined as a development of tourism that adequately balances environmental, economic and socio-cultural dimensions with the aim of ensuring long-term viability (WTO, 2005). Thus, sustainable tourism seeks to mitigate the adverse impacts associated with tourism by fostering practices that are environmentally responsible, economically sustainable, and socially equitable (Agarwal et al., 2024; Pan et al., 2018). In particular, the development of sustainable tourism emphasizes, among others, the creation of employment opportunities, the conservation of natural ecosystems, the mitigation of climate change, the reduction in pollution and waste, and the promotion of environmentally friendly and sustainable consumption practices (Streimikiene et al., 2021). To achieve these goals, digital transformation and the adoption of emerging technologies can play a crucial role, as they offer innovative tools and strategies to address the complex challenges faced by the tourism sector (Goyal, 2024; Socratous et al., 2025).

New technologies and digitalization in the tourism industry (ICTs, AI, immersive technologies (VR/AR/XR/MR), 3D and 360° technology, blockchain, voice assistant robotics, big data, biometrics, metaverse or IoT) allows the opening up of a range of possibilities for promoting the development of sustainable practices (Buhalis et al., 2023b). For instance, digital platforms can facilitate a more equitable distribution of economic benefits by expanding market access for local vendors and service providers. AI and big data analytics can be used to optimize the use of resources and minimize negative environmental impacts. Also, AI and digital platforms can support crisis management and risk assessment through real-time data analyses and informed decision-making processes (Chon & Hao, 2025). Metaverse, together with immersive technologies such as VR and AR, can offer innovative approaches to experiencing and preserving cultural heritage, enabling low-impact remote access to sensitive sites (Go & Kang, 2023; Socratous et al., 2025). Therefore, digital technologies emerge as a valuable asset in driving sustainability in tourism, offering tools for biodiversity and ecosystem conservation, enhancing cultural equity and human well-being, providing socio-cultural tourism benefits to all stakeholders, encouraging more responsible travel behaviours, and engaging the customers in tourism-related decision-making (Chon & Hao, 2025; Socratous et al., 2025).

2.2. Advanced Technology: Metaverse

Advanced and transformative technologies are driving significant changes in the landscape of contemporary tourism industry, enhancing traveller experience, improving operational efficiency, and supporting sustainable practices (Chon & Hao, 2025; Hao et al.,

2025). Metaverse is at the heart of this transformation enabling virtual exploration, real-time interaction and personalized services, and fundamentally redefining the ways in which tourism is experienced and delivered (Adnan et al., 2024; Meena et al., 2024). The metaverse can be defined as a three-dimensional, immersive virtual space where the digital and physical worlds converge, allowing users to interact, socialize, work and play in real time through digital avatars (Dwivedi et al., 2022; Kılıçarslan et al., 2025). Thus, metaverse allows users to connect, share, and immerse themselves using avatars in diverse activities within a shared digital space capable of overcoming time, space and physics limitations (Adnan et al., 2024).

Metaverse is characterized by several core attributes that define its functionality and user experience, namely: (1) space–time, which refers to the alignment of temporal progression with real-world time, while the spatial dimension exists in a virtual environment; (2) immersiveness, which means that users can experience a highly realistic and captivating sense of presence enabled by advanced virtual technologies; (3) real-time, which means that metaverse has high bandwidth and low latency providing an excellent real-time performance; (4) sustainability, which means that, driven by its own rules and operational rationale, the metaverse is self-sufficient and can maintain itself indefinitely; (5) interoperability, which means that metaverse is an interconnected ecosystem that enables seamless data exchange across different platforms, allowing users' digital avatars to move freely between virtual spaces; and (6) data sensitivity, which means that the metaverse may compromise personal privacy and security by collecting information and data from users through advanced technology (Buhalis et al., 2023a; Dwivedi et al., 2022).

The unique characteristics of metaverse have placed it as a disruptive technology with the potential to reshape a wide range of fields (marketing, management, strategic planning, etc.) and sectors (education, medicine, etc.) and specifically tourism (Buhalis et al., 2023a; Dwivedi et al., 2022; Meena et al., 2024). The advent of the metaverse represents a paradigm shift in the tourism sector, which challenges traditional technologies such as online booking systems, GPS, environmental management information system (EMIS), destination management system (DMS), computer simulation or mobile applications. These conventional technologies mainly support customer relations, operational processes and destination management, while also shaping information processing and adapting to the evolving demands of consumers, suppliers and virtual communities (Ali & Frew, 2013). Conversely, the metaverse enables human interaction with both digital and physical environments by creating immersive, interactive virtual spaces in real-time (Adnan et al., 2024; Meena et al., 2024). From a tourist perspective, the metaverse can play a significant role in pre-, during- and post-trip experience by offering realistic and immersive simulations using multiple technologies such as VR headsets, AI algorithms, haptic gloves, AR and XR (Buhalis et al., 2023a; Kılıçarslan et al., 2025). In the pre-trip planning phase, future travellers can virtually visit accommodations, tourist attractions and local environments, enabling them to make more informed and confident decisions (Meena et al., 2024). During the trip and on-site, the metaverse can help tourists access augmented textual and audiovisual information supported by 3D mapping, AR or MR headsets about cultural and historical aspects related to the destinations (Chen, 2025). Furthermore, driven by AR or VR, the metaverse can enable users to be active participants or virtual actors in the context of their choice; for example, in restaurants, providing extra sensory experiences (Buhalis et al., 2023a). After the trip, the metaverse can facilitate virtual social interactions by allowing travellers to share their experiences, advice and recommendations with others (Chen, 2025; Meena et al., 2024). From a business perspective, the metaverse technology can be very useful for tourism businesses because companies using AI, VR and data analytics can better understand tourists' preferences and behaviours, helping them create personalized

itineraries, activities and services (Chen, 2025). Therefore, the metaverse can serve as a bridge between the real and virtual worlds, enabling tourists to create content and shape their own virtual environments to make their tourism experiences more personalized and meaningful (Kılıçarslan et al., 2025; A. Kumar et al., 2025).

Metaverse technologies can have the potential to transform tourism into a hedonistic, emotional, and participatory experience, where users actively engage with digitally enhanced environments. This aligns with Experiential Consumption Theory (ECT) that suggests that consumers are primarily motivated by the pursuit of sensory, affective, and symbolic experiences—such as aesthetic appreciation, pleasure, fantasy, novelty, excitement, and thrill—rather than mere utility (Holbrook & Hirschman, 1982). In this sense, within the context of tourism through interactive environments and multisensory interfaces, travellers can find in the metaverse immersive and emotionally engaging encounters that stimulate the senses and generate memorable experiences. Furthermore, these new environments further enhance the experiential value by allowing tourists to 'co-create' their trips through AI technologies (avatars, virtual simulations, etc.).

The adoption of the technologies associated with the metaverse can also raise several underexplored concerns regarding legal, ethical, social and sustainability issues. From a legal perspective, challenges can include safeguarding personal and sensitive data, ensuring user privacy, or implementing effective cybersecurity measures (Asif et al., 2025; Chakraborty et al., 2025; Dwivedi et al., 2022). From an ethical perspective, challenges can involve the responsible and safe use of technologies, the equitable access for diverse populations, or the high costs associated with their implementation (Dwivedi et al., 2022; S. Kumar et al., 2024). From a social perspective, the metaverse can introduce major risks such as addiction and dependency, isolation and loneliness, mental health problems, cyberbullying, digital identity theft, or financial exploitation (Chakraborty et al., 2025; A. Kumar et al., 2025). The perspective of sustainability cannot be ignored, from which the challenges associated with the metaverse include a high level of energy consumption leading to an increase in carbon emissions and environmental impact (Gössling & Mei, 2025).

2.3. Metaverse in Sustainable Tourism

The metaverse can foster sustainable practices by creating a virtual space that integrates social, environmental, and economic interactions (Asif et al., 2025; Hao et al., 2025). From an environmental perspective, the metaverse reduces the necessity for physical travel, which contributes to reducing carbon emissions related to transportation (Adnan et al., 2024; Asif et al., 2025). To address challenges such as overtourism and overcrowding, the metaverse offers a viable alternative through virtual tourism experiences that can help reduce pressure on heavily visited and environmentally vulnerable destinations, while preserving natural and cultural resources (Adnan et al., 2024) and raising awareness and advocacy for sustainable practices (Chon & Hao, 2025; Go & Kang, 2023). From an economic perspective, the metaverse may have great potential to foster new business models and diverse revenue streams, for example, e-mobility solutions such as electric vehicles, e-bikes, and other electric transportation modes (Asif et al., 2025; Chon & Hao, 2025). From a social perspective, the metaverse can influence social structures by translating travel and tourism experiences into technological platforms, impacting on aspects such as inclusion and empowerment (Chon & Hao, 2025; Dwivedi et al., 2022). In this sense, inclusive tools, such as adapted apps and assistive devices, are facilitating universal access to travel, regardless of age, physical abilities or other challenges (Chon & Hao, 2025). Finally, the metaverse can also boost socioeconomic development in low-income communities empowering them to participate actively in tourism development by supporting local businesses, facilitating community tourism, or providing digital training (Chon & Hao, 2025). The usefulness and

relevance of the metaverse technologies, such as immersive (VR and AR) or IA tools (Adnan et al., 2024), in enhancing the development of the tourism sector throughout sustainable practices, leads to the need of analyzing their influence on immersive consumer experiences (Bretos et al., 2024; Çalışkan et al., 2025; Jiang et al., 2025a).

VR can be defined as a computer-generated visualization technology that simulates real environments and enables users to become fully immersed in a digital world (Guttentag, 2010). VR is characterized by offering users the possibility of having immersive experiences in a virtual environment through all five senses, simulating them as authentically as those of the real world (Adnan et al., 2024; Verma et al., 2022). In the context of the tourism sector, VR technology is applied in different areas such as smart cities, cultural heritage, mobile uses, tourism destination marketing, tourist behaviour, tourism planning, education, entertainment, heritage preservation, museums, or barrier-free access (Bretos et al., 2024; Jiang et al., 2025b). In turn, VR can play an important role in sustainable tourism, offering immersive experiences that reduce the need for physical travel, especially to destinations that are overcrowded or vulnerable to mass tourism. Thus, driven by VR, travellers can explore the environment, culture and history without disrupting the environment or infrastructure. Furthermore, this type of technology can be an effective tool for promoting greater awareness of the need for more respectful and responsible behaviours. In addition, VR can provide safe alternatives to activities that involve some physical risk or endanger sensitive ecosystems. Also, economically declining or less attractive destinations can enhance their heritage and culture through virtual reconstructions, thus attracting new audiences without compromising their structural and cultural integrity (Chon & Hao, 2025; Goyal, 2024).

AR can be defined as a technology that enhances the perception of the real world by overlaying digital information—videos, images, and 3D objects—on the physical environment in real time (Bec et al., 2019). Using AR, 3D virtual objects are seamlessly integrated into the physical environment creating the illusion that they coexist with elements of the real world (Bec et al., 2019; Fan et al., 2022). Thus, AR supports users in visualizing, appreciating and interacting with their surrounding environment, transforming the experience to be more interactive, immersive, and meaningful (Cranmer et al., 2023). In the tourism sector, AR technology can be used in situations related to cultural heritage, cultural tourism, travel, museums, restaurants, hotels, or marketing (Çalışkan et al., 2025). These technologies empower visitors to experience immersive 360-degree environments that go beyond the traditional boundaries of space and time, also strengthening more sustainable tourism practices. For instance, users can virtually explore distant destinations, revisit historical periods, or immerse themselves in imaginative worlds without the need for physical travel. In addition, AR opens new and valuable possibilities for individuals with mobility challenges, providing accessible and inclusive travel experiences (Goyal, 2024).

AI can be defined as a set of technologies designed to emulate human intelligence, enabling the solving of complex problems, informed decision-making, and adaptive learning (Bulchand-Gidumal et al., 2024). Further than processing information, AI can actively recognize patterns, make autonomous decisions, and adapt to new data inputs (Bulchand-Gidumal et al., 2024; Gössling & Mei, 2025). In the context of the tourism sector, AI tools can be used to improve personalisation and recommendation engines, deploy bots and conversational agents (chatbots and voice assistants), improve forecasting models, provide intelligent travel assistance, enable language translation applications and support the development of intelligent tourism destination management systems (Bulchand-Gidumal et al., 2024). In turn, AI can play a crucial role in sustainable tourism, supporting data-driven decision-making and improving the management of tourism resources. Thus, AI technologies (computer vision or predictive analytics) can help preserve heritage, monitoring the

condition of historical sites, identifying early signs of deterioration, and supporting timely restoration efforts. AI-based systems can also improve the quality of life in tourist destinations by regulating visitor flows, reducing congestion, and adapting tourism development to the needs of local communities. Moreover, AI can enable real-time environmental monitoring using sensors and satellite data to detect ecological changes and support proactive tourism management. Finally, AI can analyze reviews, social media, and surveys to assess tourist satisfaction and guide sustainable service improvements (Gössling & Mei, 2025).

The acceptance and use of the metaverse technologies largely depend on their successful implementation. Technology Acceptance Model (TAM) is the most widely used model for the acceptance and use of innovative technology by users (Davis, 1989). Thus, TAM has become a very useful tool for examining consumer attitudes towards technologies (i.e., chatbots, e-commerce platforms or online shopping tools) (Araújo & Casais, 2020; Gefen et al., 2003), contributing also to explain consumers' attitudes and behaviours (Gefen et al., 2003) and purchase intentions (Araújo & Casais, 2020).

3. Method

In this section, it is explained how the documents that constitute the research front for the application of the metaverse to sustainable tourism from 2021 to 2025 were selected. The theoretical foundations of the bibliometric techniques applied in the analysis are also explained.

3.1. Bibliometric Methods

A bibliometric analysis is a scientific method focused on the quantitative analysis of bibliographic material that enables the identification of the knowledge structure within a specific research field (Pritchard, 1969). In recent decades, bibliometric methods have gained significant relevance in scientific evaluation, contributing to the advancement of both theoretical and practical knowledge (Mukherjee et al., 2022). This approach is particularly suitable for establishing a theoretical foundation that enables the analysis of the influence of an emerging technology, such as the metaverse, in the field of sustainable tourism. Consequently, it is necessary to identify how this field of study has been configured, which conceptual approaches predominate, and what the main existing scientific contributions are (Zupic & Čater, 2015). In this context, bibliometric analysis allows for the systematic and objective analysis of existing scientific output, drawing conceptual connections through bibliometric techniques. This facilitates the identification of trends and the delimitation of the research front in emerging fields, such as the application of the metaverse to sustainable tourism (Donthu et al., 2021). Furthermore, it provides a transparent and replicable procedure for synthesizing scientific literature and building a structured foundation for subsequent theoretical development and the identification of future lines of research (Aria & Cuccurullo, 2017).

Within bibliometric analysis, two main approaches can be distinguished: performance analysis, which measures the scientific impact of authors, journals, or institutions through indicators such as the number of publications, citations, or the h-index (Hirsch, 2005); and science mapping, aimed at identifying the structure and dynamics of a field through co-citation networks, bibliographic coupling, and keyword co-occurrence (Asif et al., 2025; C. Wang et al., 2019). The co-citation technique, the most applied in scientific literature, is focused on analyzing the reference lists of documents included in the database to identify the intellectual structure of the field (Small, 1973). Bibliographic coupling, based on shared citations, occurs when two documents have at least one reference in common, allowing for the delimitation and organization of the research front (Kessler, 1963). Finally, the co-occurrence analysis of keywords analyzes the most frequently occurring keywords in

documents to detect thematic and conceptual patterns in scientific output (Callon et al., 1983). These tools enable the identification of the most relevant topics, as well as the anticipation of emerging trends and future research directions (Zupic & Čater, 2015).

First, a performance analysis was conducted to examine: (i) the research areas in WoS related to the application of the metaverse to sustainable tourism; (ii) the number of publications per years; (iii) the number of citations received per year; (iv) the most cited publications; and (v) the main metrics of the most cited journals. Second, techniques focused on scientific mapping, such as co-citation and keyword co-occurrence, were employed to map the state-of-the-art of the most recent academic contributions on the application of the metaverse to sustainable tourism. Co-citation analysis, the most widely used and validated bibliometric indicator (Boyack & Klavans, 2010; Piñeiro-Chousa et al., 2025; Romero-Castro et al., 2025; Zupic & Čater, 2015), was used to conclude the publications that are most frequently cited together, and the possibility that they address similar topics and share interests or objectives (Lievrouw, 1989; Zupic & Čater, 2015). Furthermore, co-citation analysis establishes the research foundations of a field (López-Cabarcos et al., 2020). Consequently, this technique is particularly suitable for identifying the structure of the field and delimiting the contributions that shape the state-of-the-art in emerging research areas. Author keyword co-occurrence analysis offers valuable information regarding the predominant topics that have been extensively studied in the application of the metaverse to sustainable tourism, the evolution of these keywords over time (Su & Lee, 2010; Zupic & Čater, 2015), and the trends for future research (Zhang et al., 2016). Furthermore, this analysis expresses the precise relevance of the content of each paper to the topic under study (Piñeiro-Chousa et al., 2025; Zhang et al., 2016). The choice of these techniques implies discarding others, such as bibliographic coupling, which is aimed at identifying documents that share references (Zupic & Čater, 2015) but is less suitable for mapping the state of the art in a field of study.

The software VOSviewer (van Eck & Waltman, 2010), previously applied in many recent bibliometric studies (Knani et al., 2022; Piñeiro-Chousa et al., 2025; Santos et al., 2021; Romero-Castro et al., 2025), version 1.6.20 has been used (CWTS, 2023). The different networks generated by each type of analysis can be visualized through graphs or maps formed by nodes and links, which are also grouped into non-overlapping clusters. In these visualizations, nodes correspond to elements such as documents, authors, journals, or keywords, while links indicate the co-occurrences between them. In the configuration used in VOSviewer, the size of the nodes is determined by the number of connections with other nodes. Additionally, the proximity between nodes or the thickness of the lines connecting them reflects the strength of the relationship (Waltman & van Eck, 2019). In these analyses, it is crucial to establish thresholds or the minimum number of citations/occurrences to directly control the granularity and focus of the resulting clusters (Romero-Castro et al., 2025). In this case, an iterative testing process was applied, increasing the thresholds until the total number of nodes was manageable and the clusters were sufficiently distinct for interpretation.

3.2. Dataset Configuration

Web of Science (WoS) Core Collection database was used to search for scientific research related to sustainable tourism and the metaverse. Compared to other databases, WoS is a widely used resource in bibliometric studies (Birkle et al., 2020; Khan et al., 2022; Piñeiro-Chousa et al., 2025; Zupic & Čater, 2015), due to the superior quality of its bibliometric data compared to other databases (Baghini et al., 2024). It presents a lower rate of duplicate records and a broader coverage of high-impact journals (Baghini et al., 2024). In certain areas, such as 'Social Sciences' and 'Humanities', WoS offers greater

coverage (Huang et al., 2020; Vera-Baceta et al., 2019). Furthermore, the subject classification provided by the WoS categories seems to be the most widely accepted in bibliometric studies (Pranckutė, 2021; Q. Wang & Waltman, 2016), providing a more appropriate large-scale citation analysis and more comprehensive information about the authors of indexed publications (Pranckutė, 2021).

A search was performed for publications containing the terms 'sustainable', 'sustainability', 'tourism', and 'metaverse' in the title, keywords, or abstract fields over the past five years. The Boolean operator AND was used to combine the terms. The research equation employed was ('sustainable' OR 'sustainability' OR 'sustainab*') AND 'tourim*') AND 'metavers*'. This provided a higher quality dataset with less 'noise', which is essential to accurately map the core intellectual structure, locate the main authors in the field under study, and conclude the real academic evolution of the link between sustainable tourism and the metaverse. The search was conducted in September 2025 and resulted in the initial selection of 76 publications dated between 2022 and 2025.

3.2.1. Application of Filtering Criteria

Given that the objective of the research is to map the state-of-the-art concerning the relation between the metaverse and sustainable tourism, a series of filtering criteria were applied to better outline the publications explaining this link. Regarding the timeframe, all available publications between 2021 and 2025; precisely, the absence of records in previous years highlights the emerging and recent nature of the field under study. Second, no criteria were established about the type of documents to be considered in the analysis, although most of the selected documents were articles (more than 85%), produced by 243 researchers from 160 countries and 262 organizations. Third, all WoS categories were included to avoid potential biases arising from the exclusion of relevant studies that, although they addressed the relationship between the metaverse and sustainable tourism, might not be classified within social sciences. Finally, acknowledging the significant importance of English as the language for writing, publishing and achieving broader global visibility (Duszak & Lewkowicz, 2008; López-Navarro et al., 2015; Romero-Castro et al., 2025), the results were filtered by language, resulting in a final sample of 71 articles. All metadata available in WoS for these documents was downloaded, including title, authors, institutions, countries, keywords, abstracts or references.

3.2.2. Data Cleaning

The downloaded metadata underwent a data cleaning process using text files and Microsoft Excel. Keywords were reviewed to avoid semantic duplications and merge under a single label term with equivalent meanings, ensuring their accurate representation within the dataset. Otherwise, identical concepts expressed differently could have been treated as separate entities, distorting their meaning. Furthermore, the author names were reviewed to correct potential typographical errors or inconsistencies in compound surnames, which could affect the accuracy of bibliometric analyses.

4. Results and Discussion

This section presents the main results obtained (through author and reference co-citation, as well as keyword co-occurrence) related to the relationship between the metaverse and sustainable tourism.

4.1. Performance Analysis

The main results of the bibliometric analysis related to the metaverse and sustainable tourism are presented below. Table 1 shows the top ten research areas related to the relationship between the metaverse and sustainable tourism. The research areas re-

flect a multidisciplinary approach with a notable predominance of the social sciences (50.70%), suggesting that studies on the metaverse and sustainable tourism mainly focus on social, cultural, and behavioural aspects. The field of economics and business (28.17%) highlights the interest in exploring market opportunities, business models, and management strategies. Computer science (19.72%) and other technological disciplines (18.31%) are also represented, reflecting the technical dimension inherent in the development of virtual environments. Additionally, disciplines such as environmental science and ecology, communication, and psychology offer complementary perspectives on sustainability, human–technology interaction, and user perception. As it was already mentioned, no research areas were excluded from the analysis.

Table 1. WoS research areas in sustainable tourism and the metaverse.

Wos Research Areas	Number of Records	% of 71
Social Sciences Other Topics	36	50.70%
Business Economics	20	28.17%
Computer Science	14	19.72%
Science Technology Other Topics	13	18.31%
Environmental Sciences Ecology	11	15.49%
Communication	6	8.45%
Psychology	4	5.63%
Engineering	2	2.82%
Information Science Library Science	2	2.82%
Operations Research Management Science	2	2.82%

Source: WoS Database. Recovered September 2025.

Figures 1 and 2 show the number of publications and citations per year. The first article on this topic dates from 2022, and since then, there has been a significant increase in the number of papers, with 2024 being the year with the highest number of publications at the time of the analysis. This indicates that the topic is clearly attracting the attention of researchers. Tiwari and Srivastava (2025) indicate an annual growth rate of 29.12% in their research. This trend may be attributed to multiple converging factors. On the one hand, the maturity and accessibility of immersive technologies such as AR, VR and XR have facilitated experimentation and application of the metaverse in diverse tourism contexts (Zainal Abidin et al., 2025). The post-pandemic digital transformation and the growing awareness of the need to decarbonise the tourism industry and mitigate overtourism have driven the search for innovative and sustainable solutions, emerging the metaverse as a promising tool (Correia, 2025; Go & Kang, 2023). The relevance of this research area is reinforced by its alignment with the Sustainable Development Goals (SDGs) and the interest in exploring how virtual experiences can contribute to more equitable, inclusive and responsible tourism development (Mihalic, 2025; Petrova et al., 2025). It is expected that the number of publications will continue growing in the following years. The data corresponding to 2025 were collected at the end of September 2025, which can explain the lower figures observed in Figures 1 and 2 for that year.

The citation analysis reveals similar results, showing a significant increase in the number of citations in 2023, 2024, and 2025. This upward trend is expected to continue in the coming years, given the growing interest the topic is generating within the scientific community. It is worth remembering that when using citation-based indicators, recent publications (logically) show a lower number in the early years and their subsequent trajectory can vary greatly, making it difficult to estimate their true short-term impact (Stegehuis et al., 2015).

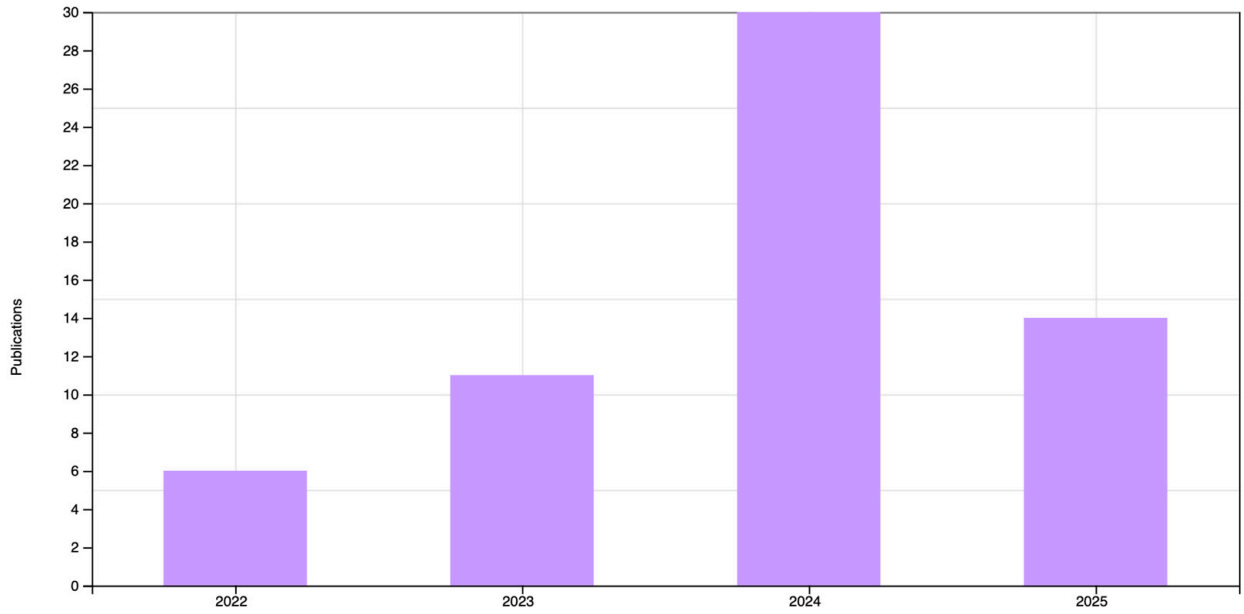

Figure 1. Number of articles published per year. Source: WoS Database. Recovered September 2025.

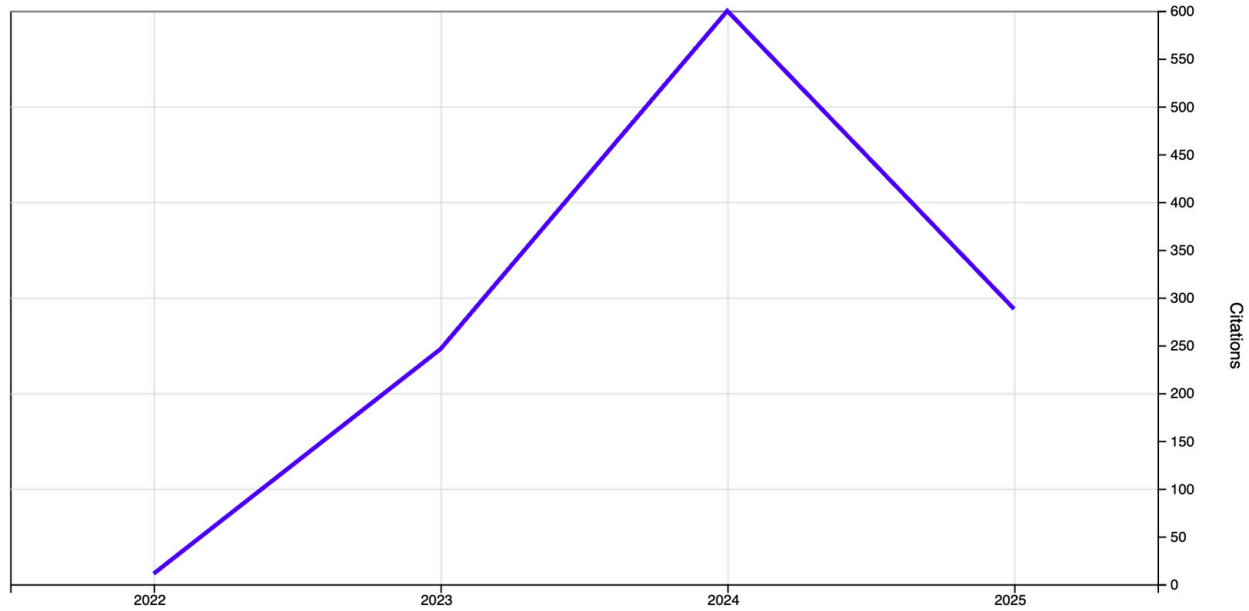

Figure 2. Number of citations per year. Source: WoS Database. Recovered September 2025.

According to the metadata provided by WoS, Table 2 presents the top ten articles based on the average number of citations per year. The most cited article is 'Metaverse marketing: How the metaverse will shape the future of consumer research and practice' by Dwivedi et al. (2023). This article examines how the increasing adoption of the metaverse will transform both marketing practices and consumer behaviour research. Through a conceptual review, the authors argue that the metaverse will enable immersive and personalized consumption experiences, leading to a redefinition of traditional communication and sales strategies. They also identify significant challenges, particularly concerning privacy, data security, and equitable access to the metaverse technologies. This article is cited more than twice as much as the following article on the list, making it one of the most influential works for understanding the relationship between the metaverse and sustainable tourism.

Table 2. Most cited papers in the metaverse and sustainable tourism.

R	Reference	AC	TC
1	Dwivedi et al. (2023)	90.5	362
2	Go and Kang (2023)	36	144
3	Buhalis et al. (2023d)	27.5	110
4	Monaco and Sacchi (2023)	22.67	68
5	Lee (2022)	13	52
6	Suanpang et al. (2022)	11	44
7	Zaman et al. (2022)	9.75	39
8	Mladenović et al. (2024)	11.67	35
9	Wong et al. (2024)	7.67	23
10	Özdemir Uçgun and Şahin (2024)	7.67	23

R: ranking according to WoS Core Collection, AC: average citations per year, TC: Web of Science Core Collection times cited count. Source: WoS Database. Recovered September 2025.

The second most cited article is 'Metaverse tourism for sustainable tourism development: Tourism Agenda 2030' by Go and Kang (2023), which focuses on defining the concept of tourism in the metaverse and examining its potential to promote the sustainable development of tourism according to the Sustainable Development Goals (SDGs). The authors conduct a theoretical review and analysis of digital trends analysis, concluding that immersive tourism experiences in virtual environments can complement or even replace physical tourism, thereby reducing pressure on natural resources and overcrowded destinations. The third most cited article, 'Smart hospitality: from smart cities and smart tourism towards agile business ecosystems in networked destinations' by Buhalis et al. (2023d), explores the role of the metaverse in transforming the tourism industry, highlighting how immersive technologies enable the creation of gamified, interactive and personalized experiences in virtual environments. The authors argue that the metaverse will not replace physical tourism but rather complement it through the co-creation of value between tourism businesses and consumers. In this way, the article proposes the metaverse as a key tool for enriching the tourism ecosystem and contributing to a more sustainable and inclusive sector activity.

The rest of the publications explore the impact of the metaverse and associated immersive technologies (mainly VR and AR) on the tourism sector. Wong et al. (2024) and Monaco and Sacchi (2023) adopt conceptual and exploratory approaches to examine how the metaverse is reshaping industry dynamics, highlighting opportunities to create innovative and sustainable tourism experiences. Özdemir Uçgun and Şahin (2024) argue that the metaverse has the potential to redefine the concept of traditional tourism, focusing on the inclusion of disadvantaged groups, the creation of new jobs, and the possibility of generating highly realistic virtual experiences. Mladenović et al. (2024) introduce the concept of 'metaWON' to analyze how immersive experiences can transform consumer recommendations. Lee (2022) demonstrates that the media richness of VR tourism content positively influences perceived usefulness, enjoyment, satisfaction and intention to visit destinations. In turn, Zaman et al. (2022) conclude that people's willingness to travel through the metaverse (for example during COVID-19) grew, especially among those with high technological capabilities and a strong fear of missing out on travel opportunities ('travel FOMO'). Finally, Suanpang et al. (2022) focus on the design of a 'smart tourism city' aimed at creating immersive tourism experiences.

The results of the analysis of the main journals publishing papers on sustainable tourism and metaverse are shown in Table 3.

Table 3. Main metrics of the journals publishing papers about the metaverse and sustainable tourism.

ISO Abbreviation	H-Index	Document	Citation
Appl. Soft Computing	208	2	12
Sustainability	207	9	223
Int. J. Contemp. Hosp.	139	6	60
Curr. Issues Tourism	123	4	37
Tourism Review	71	7	172
Journal of Metaverse	17	2	4

Source: WoS Database. Recovered September 2025.

The most productive journals in our research (those including most of the documents) are 'Sustainability', with 9 documents, which represents 13% of our database, and 223 citations. 'Tourism Review' is the second journal in our database, with 7 documents and 172 citations. The journals with the highest h-index are not always those with the highest impact; thus, 'Applied Soft Computing' is the journal with the highest h-index; however, the number of publications is 2 documents, with 12 citations.

4.2. Co-Citation Analysis of References and Authors

Table 4 shows the top ten results of the references and author co-citation analysis. The two most cited articles are 'The metaverse in the hospitality and tourism industry: An overview of current trends and future research directions' by Gursoy et al. (2022), who propose a conceptual framework for the creation of virtual experiences by introducing the concept of the metaverse into the field of tourism and hospitality; and 'Metaverse as a disruptive technology revolutionizing tourism management and marketing' by Buhalis et al. (2023a), who propose a framework that integrates technology, experience design and user engagement to enrich the tourism offer in the virtual environment through the co-creation of immersive, gamified and interactive virtual environments in the metaverse.

The third most cited article is 'Metaverse tourism for sustainable tourism development: Tourism Agenda 2030' by Go and Kang (2023). The authors define the concept of tourism in the metaverse and explore its potential to contribute to the sustainable development of the sector. The article argues that tourism products can expand available resources, generate alternative income, and align with the SDGs.

'Metaverse beyond the hype: Multidisciplinary perspective on emerging challenges, opportunities, and agenda for research, practice and policy' by Dwivedi et al. (2022) is the fourth most cited article. From a multidisciplinary approach, the article analyses the technological, ethical and social challenges of metaverse development, and proposes a research agenda aimed at understanding its economic, psychological and legal implications.

The fifth article, 'Metaverse marketing: How the metaverse will shape the future of consumer research and practice' by Dwivedi et al. (2023), analyses how the metaverse redefines marketing strategies through immersive experiences and more interactive brand–consumer relationships. From a conceptual perspective, the article proposes a strategic framework to foster consumer engagement in virtual environments, considering ethical, technological and commercial implications.

'Metaverse as a driver for customer experience and value co-creation: Implications for hospitality and tourism management and marketing' by Buhalis et al. (2023c), is the sixth most cited article. From a conceptual approach, it examines how the metaverse can facilitate the co-creation of experiences and value in the hospitality and tourism sectors, identifying opportunities and challenges related to the integration of virtual environments into management and marketing.

The article 'Mixed Reality (MR) for Generation Z in cultural heritage tourism towards metaverse' by Buhalis and Karatay (2022) occupies the seventh position. It analyses how

XR can enrich Generation Z's experiences in heritage tourism and its future integration into the metaverse. From an empirical approach, the study explores the usability of XR, users' willingness to adopt it, and its potential to transform cultural visits through immersive technology.

Table 4. Co-citation analysis of authors and references.

Authors	Citation	Link Strength	Reference	Authors	Citation	Link Strength
Buhalis, D.	73	541	The metaverse in the hospitality and tourism industry: An overview of current trends and future research directions	Gursoy et al. (2022)	26	139
Dwivedi, Y. K.	48	426	Metaverse as a disruptive technology revolutionizing tourism management and marketing	Buhalis et al. (2023a)	26	132
Gursoy, D.	34	292	Metaverse tourism for sustainable tourism development: Tourism Agenda 2030	Go and Kang (2023)	21	115
Go, H.	23	178	Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy	Dwivedi et al. (2022)	19	102
Koo, C.	14	123	Metaverse marketing: How the metaverse will shape the future of consumer research and practice	Dwivedi et al. (2023)	14	79
Hair, J.F.	13	122	Metaverse as a driver for customer experience and value co-creation: implications for hospitality and tourism management and marketing	Buhalis et al. (2023c)	13	76
Monaco, S.	12	124	Mixed Reality (MR) for Generation Z in Cultural Heritage Tourism Towards Metaverse	Buhalis and Karatay (2022)	13	71
Tiwari, S.	12	48	Metaverse tourism: conceptual framework and research propositions	Koo et al. (2023)	13	79
Ajzen, I.	11	74	Metaverse	Mystakidis (2022)	10	40
Allam, z	10	83	The Metaverse as a Virtual Form of Smart Cities: Opportunities and Challenges for Environmental, Economic, and Social Sustainability in Urban Futures	Allam et al. (2022)	9	46

Source: WoS Database. Recovered September 2025.

The eighth article is 'Metaverse tourism: Conceptual framework and research propositions' by Koo et al. (2023). They provide an initial conceptualisation of tourism in the metaverse through four key propositions that highlight its potential to generate immersive experiences, shape realistic expectations in the pre-travel stage, consider tourists' multiple identities, and promote creative economy models.

'Metaverse' by Mystakidis (2022) occupies the ninth position and offers a conceptual review of the term metaverse, addressing its definition, historical evolution, associated technologies, and its possible applications in areas such as education or tourism.

Finally, the last position is for the article 'The metaverse as a virtual form for smart cities: Opportunities and challenges for environmental, economic and social sustainability in urban futures' by Allam et al. (2022). It analyses how digital technologies (especially the metaverse) can redefine urban tourism in a post-pandemic context through an integrated vision of smart tourist cities, where virtual environments complement physical experiences fostering resilience, sustainability and inclusion. The link strength expresses the strength of the link between an element and the rest in a co-citation network, representing how many times the same authors or publications appear together in scientific publications (Waltman & van Eck, 2019). The results show that the paper with the highest link strength is by

Gursoy et al. (2022) (link strength = 139). The second position is for the paper by Buhalis et al. (2023a), which shows a better link strength (link strength = 132) than their 2023 article, ranked in sixth place (link strength = 76), and their 2022 article, ranked in seventh place (link strength = 71). The third position is for the article by Go and Kang (2023) with a link strength of 115. The fourth and fifth positions are for two articles by Dwivedi et al. (2022, 2023) with a link strength of 102 and 79 respectively. The ninth position is for the paper by Allam et al. (2022), with a link strength of 49. Finally, the last position is for the paper by Mystakidis (2022), who shows the lowest link strength (link strength = 40).

The results of the author co-citation analysis reveal the most cited authors in the research field. Six of the ten authors on the list have published at least one of the top ten publications derived from the reference co-citation analysis. The first author is Buhalis, who has published three of the ten most cited papers. In second position is Dwivedi, who has published two of the most cited papers. The third position is occupied by Gursoy, the author of the most cited paper. The fourth, fifth, and tenth positions go to Go, Koo, and Allam respectively, whose papers are among the ten most cited. Finally, Hair, Monaco, Tiwari, and Ajzen occupy the sixth, seventh, eighth, and ninth positions respectively and their papers are not included among the top ten according to the results of the co-citation analysis.

Author co-citation analysis provides a synthesis of the main authors and publications; however, it is important to consider that the database configuration itself influences the architecture of the co-citation network, which could underrepresent relevant non-indexed or low-visibility literature (Mongeon & Paul-Hus, 2016; Harzing & Alakangas, 2016; Aksnes & Sivertsen, 2019). Furthermore, the identification of the most cited authors can be affected by disambiguation errors (Kim & Owen-Smith, 2021). To minimize this bias, a data cleaning process was performed on the database. Figure 3 shows the results of the reference co-citation analysis. Each reference is identified by a label whose size reflects the frequency with which it has been cited in the database; thus, the larger the size, the greater the number of citations. The proximity between the references indicates the likelihood of co-citation, with shorter distances indicating a stronger association. The colours distinguish the different groups or clusters identified, suggesting that references within the same group tend to be cited together more frequently. The identified clusters are sensitive to methodological decisions; thus, reasonable variations in parameters can produce different structures and hierarchies (Zupic & Čater, 2015; Aria & Cuccurullo, 2017; van Eck & Waltman, 2017). Following Piñeiro-Chousa et al. (2025), the minimum cluster size was set at five authors to avoid excessive fragmentation and ensure that each cluster includes at least two different documents. Furthermore, VOSviewer establishes links between co-authors of the same publications; therefore, the identified clusters can be influenced by citation strategies, distorting the link insensitivity (Chorus, 2016; Taşkın et al., 2021; Fong et al., 2023).

Three different clusters can be identified. The red cluster includes the papers that address the metaverse from a conceptual and strategic perspective, positioning it as a transformative axis of the tourism industry as a whole. The papers included in this cluster are located at the centre of the network and are the largest in size, which means they can be considered the most relevant. The publications that belong to this cluster also have the greatest link strength and are related to other papers belonging to the other two clusters. Therefore, this cluster, which forms the foundation of the research field, can be labelled 'foundations of the metaverse in sustainable tourism'. It includes papers already mentioned: Buhalis et al. (2023c), who position the metaverse as the evolution of smart tourism, highlighting user-centric immersive experiences; Go and Kang (2023) analyze the potential to advance the tourism SDGs; Yang and Wang (2025), who propose a four-dimensional taxonomy to classify the metaverse tourism experiences and their integration

with physical reality; Gursoy et al. (2022), who present a conceptual framework focused on experience, consumer behaviour and operational strategies; and Fan et al. (2022), who introduce the concept of 'augmented experiential values' refer to the enhanced experience provided by AR and VR technologies in tourism.

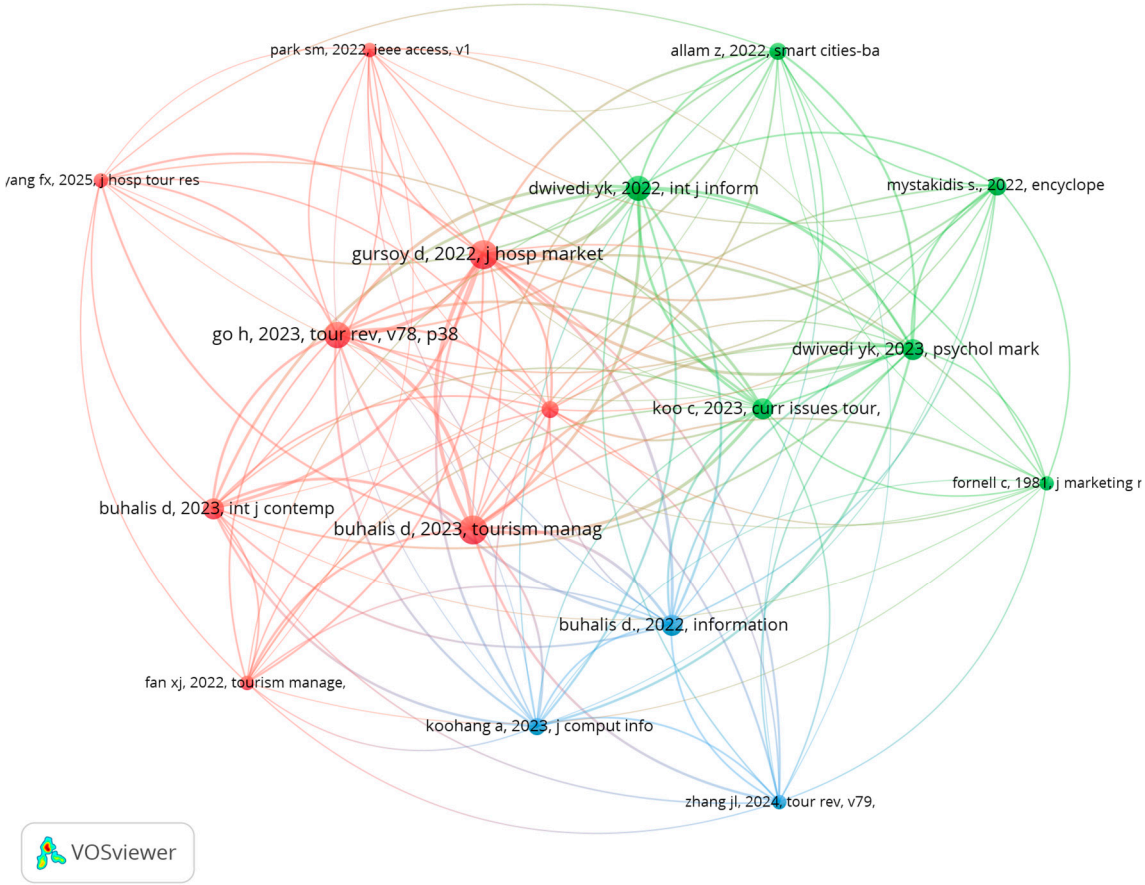

Figure 3. Co-citation analysis of references. Source: WoS Database. Recovered September 2025.

The cluster 'foundations of the metaverse in sustainable tourism' not only constitutes the base of the research field but also acts as a connector between technological infrastructure and user adoption. Developments in the literature show a conceptual evolution from 'smart tourism' to the application of the metaverse to sustainable tourism, with an emphasis on immersive and user-centred experiences (Buhalis et al., 2023c). A deeper consideration of ethical and regulatory dimensions has been incorporated, recognizing social risks and the need for ethical development and digital literacy in these new environments (Dwivedi et al., 2023). The introduction of concepts such as 'augmented experiential values' (Fan et al., 2022) and taxonomies for physical–virtual integration (Yang & Wang, 2025) demonstrates a maturation within the research field, moving from mere technological exploration towards a nuanced understanding of its implications and applications. Theoretically, this cluster contributes to sustainable tourism by positioning the metaverse as a tool for decarbonisation, the mitigation of overtourism and the push for regenerative tourism (Go & Kang, 2023; Correia, 2025). Regarding digital transformation, a qualitative leap is illustrated from Web 2.0 platforms to persistent 3D immersive environments, analyzing how tourism companies redefine their business models and interaction with consumers within these new virtual spaces.

The green cluster includes publications that address the essential aspects for understanding the metaverse, such as the necessary technological infrastructure (for example, VR and AR), the role of the platforms, and the conceptual framework of tourism in vir-

tual environments. This cluster, labelled as 'technological foundations', includes articles such as Allam et al. (2022), who explore the metaverse as a tool for sustainable tourism planning based on data and emerging technologies; Dwivedi et al. (2023) analyze the cross-cutting impact of the metaverse, highlighting social and regulatory risks; Koo et al. (2023), who introduce the four principles that structure tourism experience in the metaverse; and Mystakidis (2022), who define metaverse as an immersive environment requiring ethical development, digital literacy and participatory design. This cluster constitutes the foundation upon which strategies and experiences for the application of the metaverse to sustainable tourism are built. It delves deeper into digital transformation, specifically into hardware and software requirements and the scalability of virtual platforms. Understanding the technological foundations is essential for the development of immersive experiences and for the effective implementation of sustainable tourism solutions (Allam et al., 2022). Green cluster includes authors who analyze new forms of interaction and services within the tourism sector related to immersive and user-centred experiences (Buhalis et al., 2023a), consumer behaviour (Gursoy et al., 2022), and the potential to contribute to the SDGs (Go & Kang, 2023).

The blue cluster includes studies focused on the application of the metaverse to specific sectors and understanding the motivations for its adoption. This cluster, labelled as 'metaverse adoption', includes articles such as Buhalis and Karatay (2022), who link smart tourism through immersive experiences and advanced technologies; Dwivedi et al. (2022), who highlight the effects of the metaverse on digital marketing and brand–consumer relationships; Koohang et al. (2023), who present a multidisciplinary view of the impact of the metaverse on key sectors to identify opportunities and challenges; and Zhang et al. (2024), who analyze the factors that influence the intention to consume tourism through the metaverse among young people.

This cluster is linked to TAM since some studies explain the consumers' intention to consume tourism services through technologies related to the metaverse (such as immersive tourist experiences) (Zhang et al., 2024; Wu et al., 2024); and to ECT since the cluster also includes studies that prove that the adoption of technologies related to the metaverse in the tourism sector is not driven solely by utility criteria, but by the search for enjoyment and novelty, concluding that digital experiences can generate emotional and behavioural value comparable to or even greater than physical experiences (Wu et al., 2024).

4.3. Author Keyword Co-Occurrence

Author keyword co-occurrence analysis allows for the synthesis of thematic structure and the identification of clusters, but its interpretation is conditioned by the data that determine which keywords are represented (Harzing & Alakangas, 2016; Aksnes & Sivertsen, 2019). The research string can also affect the observed frequencies and co-occurrences of terms (Donthu et al., 2021; Gusenbauer & Haddaway, 2020). Furthermore, the results depend on the quality of the record and preprocessing (duplicates, field inconsistencies, and spelling variation), which can fragment terms and connections (Valderrama-Zurián et al., 2015; Nowakowska, 2025). To minimize these potential biases, author keywords were preprocessed in the database. The inclusion criterion for the author keyword co-occurrence analysis required at least three co-occurrences to reduce noise and focus on a solid concept. This decision was made to encompass a broader set of author keywords and thus draw more general conclusions, excluding terms used only once or twice that might introduce noise into the sample rather than contribute meaningful information.

Figure 4 shows the results of the author keyword co-occurrence analysis. It has been considered a threshold of two occurrences, which is met by a total of 16 keywords. The keywords with the highest number of occurrences are 'metaverse' (33 occurrences), 'tourism'

(10 occurrences), 'sustainability' (10 occurrences) and 'virtual reality' (9 occurrences). This corroborates the relationship between the metaverse and the different technologies involved and sustainable tourism. Other keywords such as 'virtual museum', 'extended reality', 'technology', or 'marketing' explain the connection of the metaverse with emerging technologies and their adoption.

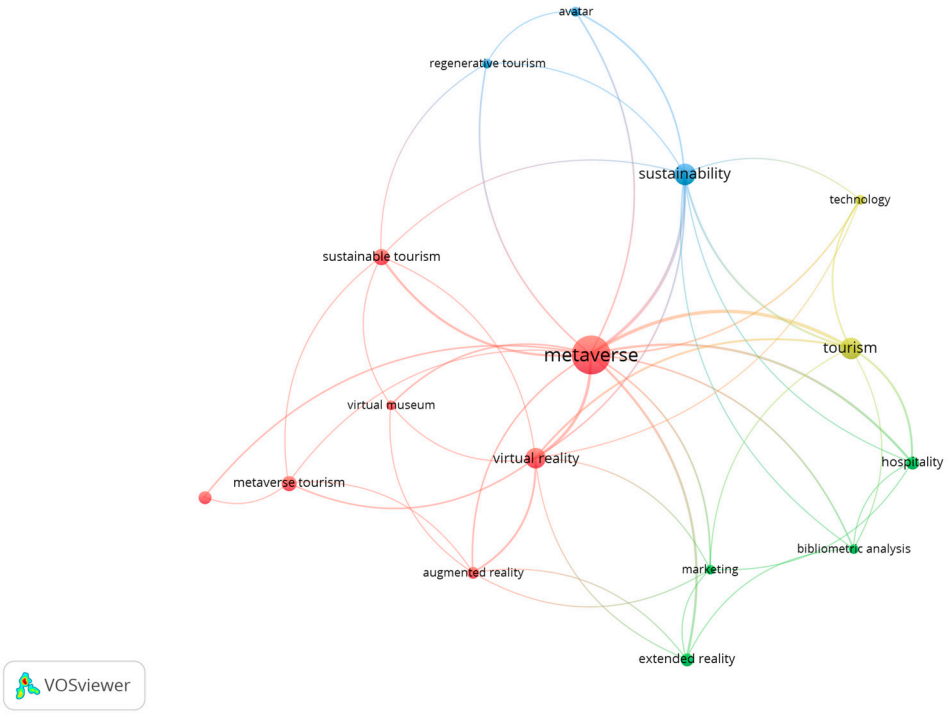

Figure 4. Author keywords co-occurrence. Source: WoS Database. Recovered September 2025.

The largest circle located at the centre of the map, 'metaverse' represents the term with the greatest presence in the literature. In addition, four different clusters can be distinguished. The red cluster, named 'tourism and metaverse', focuses on technological aspects applied to tourism in the metaverse, bringing together research on immersive environments applied to tourism, with particular attention to digital experiences, the virtual recreation of cultural spaces, and the use of emerging technologies. The green cluster, labelled as 'conceptualisation of tourism', groups studies oriented towards the application of the metaverse in tourism and hospitality management. The blue cluster, labelled 'tourism and sustainability', is linked to research that explores the potential of the metaverse to promote responsible, inclusive and regenerative tourism practices. Finally, the yellow cluster (the smaller), labelled as 'tourism and traditional technology', is focused on linking technology and tourism, including general studies on technological innovation in the tourism sector.

Figure 4 illustrates a knowledge network in which the central term 'metaverse' operates as a gravitational core that articulates the interconnection of four clusters. In this structure, the red cluster, 'tourism and metaverse', concentrates technological developments (Allam et al., 2022) and immersive experiences (Buhalis et al., 2023c; Gursoy et al., 2022). The green cluster, 'conceptualisation of tourism' is focused on reformulating and proposing hospitality management models and experience design adapted to new contexts (Mystakidis, 2022). In turn, the blue cluster, 'tourism and sustainability', introduces the strategic orientation of such applications (Dwivedi et al., 2022), emphasizing that innovation associated with the metaverse should be aligned with responsible tourism practices and sustainable value creation beyond mere technological deployment (Adnan et al., 2024).

Finally, the yellow cluster, 'tourism and traditional technology', although smaller in size, shows the evolution from traditional tourism technology approaches to new technological advances as the metaverse, enabling an understanding of the digital transformation of the tourism sector (Talawar et al., 2024).

Overall, this interconnection suggests that the application of the metaverse to sustainable tourism constitutes a multidisciplinary phenomenon across its technological, conceptual, sustainable and evolutionary dimensions. Moreover, this relationship is driven by research advances exploring how virtual environments can promote practices that not only reduce impacts but also actively contribute to the restoration and improvement of tourism destinations (Liu & Hao, 2024). For example, it is increasing research on the use of avatars as mechanisms for eco-literacy and for encouraging pro-environmental behaviours (Hui et al., 2023). Finally, the virtual recreation of cultural heritage sites is consolidating as a line of applied research, generating new visitor experiences while supporting the preservation and accessibility of resources, thus mitigating the pressures associated with mass tourism (Jiang et al., 2025a).

The results obtained from the different analyses confirm that so far there is not a consolidated theoretical basis that structurally supports scientific research on the metaverse in the field of sustainable tourism. The novelty of the topic under study and the thematic fragmentation of current studies largely explain this absence. This situation, far from being a limitation, represents a significant opportunity for the development of new lines of research that can contribute to defining conceptual frameworks, validating applied models, and delving deeper into the technological, social and sustainable implications of the metaverse applied to the tourism sector.

5. Conclusions, Implications and Research Opportunities

The metaverse can be considered a disruptive technology that has the potential to reshape tourism industry through immersive, interactive, and personalized environments. The adoption of this advanced technology can be a useful and valuable tool to develop environmental, social, and economic practices. For instance, virtual tourism experiences can help reduce physical travel, lowering transport-related emissions and alleviating pressure on fragile natural and cultural sites. At the same time, AR can improve accessibility and inclusion among people with mobility limitations or economic constraints, allowing more responsible and conscious behaviours to enjoy destinations, while creating new development opportunities for communities with limited tourism infrastructures. However, it is scarce academic research focused on the environmental, social, ethical and sustainable risks and challenges associated with adopting these technologies.

The different bibliometric techniques applied to analyze the intersection between the metaverse and sustainable tourism suggest that previous research is characterized by a strong conceptual and theoretical component, with a predominance of studies establishing analytical frameworks, reviews and proposed models, rather than robust empirical research. Furthermore, the bibliometric analysis made has identified three clearly differentiated groups that highlight the need to conduct more empirical research to consolidate the theoretical foundations and guide future studies. In this sense, from an academic perspective, one future line of research involves investigating the environmental, social and economic impact (digital sustainability) associated with the development and use of the technologies inherent to the metaverse; for example, energy consumption, carbon emissions or the life cycle of digital infrastructures. Although literature strives to highlight the potential of the metaverse to mitigate the negative effects of traditional tourism (Go & Kang, 2023; Jiang et al., 2025a), it is crucial to adopt a broader perspective that also

considers its hidden ecological, social, and economic costs, thus ensuring a more balanced and evidence-based assessment of its implications for sustainability.

For tourism professionals and managers, the findings highlight the need to incorporate immersive technologies and digital solutions into their management and promotion strategies, such as implementing virtual and hybrid experiences to reduce visitor pressure on fragile sites, enhancing accessibility for people with mobility or financial constraints, personalizing services based on tourist preferences, and adopting energy-efficient digital infrastructures to support digital sustainability. From an economic and management perspective, the study emphasizes the growing interest in new business models, value co-creation initiatives, innovative marketing strategies, and personalized experiences in the metaverse. Managers can leverage these opportunities to create competitive advantages, generate additional revenue streams and foster collaborations with local communities. For policymakers and public policy designers, the metaverse can represent an emerging tool to align tourism development with the Sustainable Development Goals (SDGs). In this regard, policies should guide the development of regulatory frameworks for responsible technological innovation, ensure equitable access, protect data privacy, prevent cultural appropriation, and address potential digital exclusion. Furthermore, policies should also promote the adoption of sustainable digital infrastructures and direct investment toward innovative, resilient and inclusive tourism solutions.

Nonetheless, it is important to understand that, while bibliometric analysis is an effective method for summarizing and synthesizing literature, it is not without limitations. The search stream used to configure the bibliographic database could be more loosely defined or be based on different search criterion terms, which might have resulted in a broader or simply different database. It is also possible that some articles have been lost with the use of a single database. New studies could use other databases such as Scopus or Google Scholar to complement the study's findings. Furthermore, the nature of bibliometric methodology itself constitutes a limitation. In particular, qualitative statements derived from bibliometrics can be quite subjective, given that bibliometric analysis is quantitative in nature (Donthu et al., 2021), and the relationship between quantitative results and qualitative interpretations is often not straightforward. In this respect, researchers should be especially cautious when making qualitative statements based on bibliometric observations and, where appropriate, supplement them with content analysis (Gaur & Kumar, 2018).

Furthermore, there is a possibility that authors may omit relevant information, such as the source of the data or metadata fields (abstracts or keywords), which can reduce the visibility and potential citation of the articles. Another limitation relates to the variability in export formats. While some platforms offer multiple formats (e.g., BibTeX, CSV, RIS, plain text), others provide only a single option. This inconsistency can complicate the integration of data from different sources and affect the structure of the available information for subsequent bibliometric analysis. The reliance on metadata is an additional limitation, as inconsistencies between databases, such as spacing, punctuation, or diacritics, can lead to errors during manual data cleaning and retrieval. In this regard, there is a structural limitation linked to the nature of metadata, since the thematic representation of the field depends heavily on keywords defined by the author and abstracts that may be incomplete, strategically selected, or may not accurately reflect the methodological or conceptual content. All of this can bias thematic maps by underrepresenting or overrepresenting topics, methods, or theoretical frameworks (Zupic & Čater, 2015). Furthermore, there is a degree of subjectivity related to decisions about the number of author keywords to include in different types of analyses (Piñeiro-Chousa et al., 2025). Moreover, indexed databases can introduce linguistic and regional biases, limit the visibility of local contributions or those published in other languages, and restrict the generalizability of observed patterns

(Mongeon & Paul-Hus, 2016). Similarly, citation-based metrics are subject to a cumulative advantage—the Matthew effect-, which tends to reinforce established authors and journals and may reflect visibility dynamics rather than theoretical contributions (Hicks et al., 2015).

Finally, despite efforts to maintain objectivity, a degree of subjectivity may persist due to the dynamic nature of databases. Thus, this study represents a snapshot in time conditioned by the moment of data collection, meaning that future updates could partially alter the composition of the corpus and some results (Mongeon & Paul-Hus, 2016).

To address some of these issues, researchers can adopt specific procedures and develop a set of best practices regarding data collection and analysis, such as manual inspection. In particular, transparency in the justification of parameters and the use of robustness checks help to strengthen the reproducibility and interpretive soundness of the findings.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial intelligence
VR	Virtual reality
AR	Augmented reality
XR	Mixed reality
MR	Extended reality
IoT	Internet of Things
WoS	Web of Science
ICT	Information and Communication Technologies
EMIS	Environmental Management Information System
DMS	Destination Management System
TAM	Technology acceptance Model
ECT	Experiential Consumption Theory

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