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# A Bibliometric Analysis of Augmented Reality in E-Commerce Research

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## ABSTRACT

**This paper employs bibliometric analysis to systematically map the global research landscape on Augmented Reality (AR) in e-commerce from 2014 to 2024. A total of 610 publications retrieved from the Scopus database were analyzed, yielding 10,262 citations and an average annual growth rate of 24.97%. The results reveal three major clusters of countries: (i) research leaders in production and growth (India, the United States, China); (ii) nations emphasizing scientific collaboration and policy orientation (the United Kingdom, Germany, Portugal); and (iii) emerging contributors with regional and application-driven characteristics (Indonesia, Taiwan, Japan, Malaysia). Thematic evolution analysis highlights a clear transition from early-stage technological exploration (2014–2016) to theoretical consolidation and application expansion (2017–2024). From a theoretical perspective, the study enriches understanding of AR as not merely a visualization tool but a driver of affective engagement and consumer decision-making in digital environments. Practically, the findings offer managerial insights for e-commerce firms, technology developers, and policymakers in leveraging AR for immersive retailing, AI integration, and sustainable digital transformation. Overall, this analysis presents a comprehensive knowledge map that informs both academic inquiry and strategic application of AR in the evolving digital commerce landscape.**

**Keywords:** ***augmented reality, bibliometric, digital commerce. e-commerce.***

## 1. INTRODUCTION

Augmented Reality (AR) is an emerging technology in which computer-generated content enhances the real-world environment. In the marketing context, AR is described as a novel, strategic, and potentially disruptive subdomain (Rauschnabel *et al*., 2022). Over the past few years, AR marketing has gained significant momentum, enabling companies to harness its capabilities for innovative and engaging promotional strategies (Jayaswal & Parida, 2023). The global AR market is projected to reach USD 88.4 billion by 2026 (Markets & Markets, 2023). Consequently, leveraging this emerging technology is critical for both retailers and marketers. Since customer loyalty and repeat purchases are essential for retailers' long-term success, understanding how continued use and, more importantly, repeat purchase behavior can be encouraged through AR applications is vital (Nikhashemi *et al*., 2021). Given that AR apps are designed for repeated engagement, it is important to explore how this technology influences end-users across different stages of adoption.

Building on the evolution of AR in e-commerce, researchers have increasingly explored new opportunities and marketing applications of AR (Billewar *et al*., 2021; Raj *et al*., 2024). AR offers a distinctive sense of spatial presence—defined as the extent to which users perceive AR content as truly existing in their surroundings (Rauschnabel *et al*., 2022; Mirzaei *et al*., 2025). Prior empirical research has shown that using AR for online shopping enhances user engagement and enjoyment (Kowalczuk *et al*., 2020; Yang & Lin, 2024). Moreover, consumers tend to favor AR shopping experiences as this technology fundamentally transforms the way they shop (Sahli & Lichy, 2024). However, some studies have noted that certain users feel limited by the inability to physically touch products in AR environments (Gatter *et al*., 2022). Despite such constraints,

substantial evidence suggests that AR enables users to make more informed decisions while fostering more enjoyable and interactive shopping experiences (Sun *et al*., 2022).

The growth of online shopping has revolutionized the retail landscape, offering businesses unprecedented opportunities to reach global audiences. However, this shift toward digital commerce also presents challenges, particularly regarding the lack of physical interaction with products—an inherent feature of traditional stores (Zeng *et al*., 2020). This limitation may influence purchasing decisions and potentially reduce online retailers' profitability. To address these challenges, Augmented Reality (AR) has emerged as a promising solution that bridges the gap between digital and physical worlds by delivering interactive and immersive experiences. The global AR market was valued at USD 93.67 billion in 2024 and is projected to grow from USD 140.34 billion in 2025 to USD 1,716.37 billion by 2032, representing a compound annual growth rate (CAGR) of 43.0% during the forecast period. Over the past decade, brands and social media platforms have increasingly invested in AR-based marketing tools, anticipating significant expansion in this domain (Rauschnabel *et al*., 2019).

Previous research has examined AR's role in shaping consumer purchase decisions (Hilken *et al*., 2017; Kumar & Srivastava, 2022) and the influence of flow experience on AR usage (Barhorst *et al*., 2021; Lin & Huang, 2024). While some studies have focused on the effects of spatial presence (Kumar & Srivastava, 2022; Lavoye *et al*., 2023), others have emphasized the importance of media-related perceptions such as perceived usefulness and enjoyment (McLean & Wilson, 2019; Yim *et al*., 2017). Although prior research has explored various applications and effects of AR in e-commerce, the existing body of work remains fragmented and lacks a comprehensive overview of its intellectual development. Despite growing interest in AR applications, prior bibliometric studies have primarily concentrated on AR marketing in general contexts rather than its specific integration within e-commerce. For instance, Jayaswal and Parida (2023) conducted a bibliometric and thematic analysis on AR marketing, emphasizing consumer engagement and branding strategies but without focusing on online retail environments. Similarly, Rauschnabel *et al.* (2022) provided a conceptual synthesis of AR marketing but did not quantitatively map publication trends or thematic evolution in e-commerce applications. Moreover, existing bibliometric reviews in the digital commerce domain (e.g., Lim *et al*., 2024) have examined metaverse and immersive technologies broadly, lacking a focused exploration of AR's role as a distinct technological enabler. Therefore, there remains a clear gap in systematically mapping the intellectual structure, research evolution, and emerging themes of AR-driven e-commerce. Addressing this gap, the present study provides the first comprehensive bibliometric analysis that integrates both performance and science mapping perspectives to reveal the global research landscape of AR in e-commerce between 2014 and 2024. To date, no bibliometric study has systematically analyzed publication patterns, major research themes, and emerging trends in this field. Unlike prior bibliometric studies that often separated technological and consumer behavior perspectives, this study integrates three major theoretical foundations TAM, UTAUT, and Experiential Marketing. By linking bibliometric data with these theoretical frameworks, the study introduces an interdisciplinary approach that establishes a new model of e-commerce, namely "experiential digital commerce," and reveals novel insights into human behavior across different geographical contexts. This study addresses that gap by conducting an extensive bibliometric analysis to map the evolution and future trajectory of AR research in e-commerce.

This study aims to address the current gap in limited bibliometric analyses that focus specifically on Augmented Reality (AR)-driven e-commerce. In line with this objective, the research goals are systematically structured to explore publication trends, key contributors, and emerging research themes within the intersection of AR and e-commerce. The objectives of the study are outlined as follows:

- To analyze the patterns, trends, and key characteristics of publications, journals, authors, and countries that have significantly contributed to research on Augmented Reality (AR) applications in e-commerce.
- To map the intellectual structure of the field in order to identify emerging themes and research hotspots, thereby clarifying the current state and future directions of AR-enabled e-commerce.
- To identify conceptual gaps and underexplored areas in the existing literature, providing a foundation for future research and development on AR applications in e-commerce.

# 2. LITERATURE REVIEW

## *2.1 Augmented Reality*

Augmented Reality (AR) is broadly defined as a set of technologies that integrate the real world with digital objects (Barhorst *et al*., 2021; Rauschnabel *et al*., 2019). AR refers to "a technology that overlays computer-generated virtual images onto the physical real world" (Yoon & Oh, 2022), thereby merging the virtual and physical realms into a single interface (Oyman *et al*., 2022). The ability of AR to deliver specific, personalized, and contextually distinct content has drawn the attention of both consumers and marketers (Barhorst *et al*., 2021). Today, AR technologies are employed across a wide range of domains, from marketing and entertainment to tourism and education (Oyman *et al*., 2022). In particular, AR has gained notable attention in marketing as an effective tool for brand building (Gervautz & Schmalstieg, 2012). The most prominent attributes of AR include interactivity, novelty, vividness, and contextual distinctiveness (Yim *et al*., 2017). Fundamentally, AR applications can be deployed on wearable devices, smartphones, or stationary systems (Rauschnabel *et al*., 2019). Many companies are increasingly promoting mobile-based AR applications to capitalize on the continuous rise in smartphone usage among consumers (McLean & Wilson, 2019).

## *2.2 Augmented Reality in E-Commerce*

Augmented Reality (AR) is a technology that seamlessly blends the real world with virtual objects, creating interactive and immersive user experiences (Craig, 2013). This technology overlays computer-generated elements onto the physical environment, functioning as a bridge between the two realms to produce a "mixed reality

environment" (Cho & Schwarz, 2010). Within online shopping platforms, AR enables customers to visualize products with considerable accuracy by projecting them based on their physical attributes (Hanh *et al*., 2025; Ma & Choi, 2007). By superimposing virtual content onto the physical world, AR delivers engaging experiences that influence consumers' perceptions, attitudes, and behaviors (Yim *et al*., 2017). AR introduces innovative ways for consumers to interact with products in digital environments (Javornik, 2016). The integration of AR technology into retail settings has led to several notable outcomes, including higher consumer engagement, stronger brand connections, and increased purchase intentions (Prasertwit *et al*., 2024; Davis & Aslam, 2024). According to Alves & Reis (2020), AR offers significant advantages, particularly in the retail sector and in the marketing of physical goods. The primary motivation behind AR adoption lies in its ability to allow consumers to interact with a brand's products within their personal spaces, thereby fostering deeper brand associations.

In recent years, several bibliometric studies have emerged that provide valuable insights into the development of AR, AR marketing, and immersive technologies, while also revealing research gaps that the present study seeks to address. Jayaswal and Parida (2023) conducted a comprehensive bibliometric and thematic analysis of AR marketing, identifying key conceptual structures and performance indicators but focusing mainly on marketing contexts rather than e-commerce. Other bibliometric efforts have explored AR in specialized domains or through specific methodological lenses, Altinpulluk and Yildirim (2023) examined the evolution of AR research from 2012 to 2022. Although these studies provide valuable perspectives on technological and applied dimensions, they do not directly connect AR research to e-commerce outcomes. Similarly, Taşci *et al*. (2024) extended bibliometric mapping to the broader field of VR and metaverse marketing, but the scope remained too general to capture the specific dynamics of AR-enabled commerce. Earlier reviews such as Ebrahimabad *et al*. (2024) offered preliminary conceptual syntheses of AR literature but lacked systematic integration of performance metrics and thematic mapping within the retail and online shopping context.

Methodologically, Lim *et al*. (2024) emphasized the importance of combining and cleaning bibliometric data from multiple databases (e.g., Scopus and Web of Science) to enhance coverage and reduce bias, while also noting the challenges of duplication and inconsistency during data merging. Building on these insights, the present study differs in three key aspects: (1) it focuses specifically on Augmented Reality within e-commerce, rather than AR marketing in general; (2) it adopts a decade-long time frame (2014–2024) that reflects both the emergence and consolidation of AR in digital retail; and (3) it employs a single-source data strategy (Scopus) to ensure indexing consistency and comprehensive coverage of applied and technical journals, while avoiding cross-database duplication. Furthermore, the study integrates both performance analysis (productivity, citations, h-index) and science mapping (co-authorship, co-occurrence, co-citation) to provide a dual perspective—identifying influential actors and visualizing the intellectual structure of the field.

While previous bibliometric studies have contributed valuable overviews of AR and immersive technology research, they have not yet provided a dedicated, methodologically integrated mapping of AR in e-commerce. This study addresses that gap by offering a focused, decade-spanning bibliometric analysis that connects technological development, consumer experience, and business implications in the digital commerce landscape.

# 3. RESEARCH METHODOLOGY

A substantial body of scholarly literature has been devoted to bibliometric analysis, authored by numerous experts in the field. This study follows the step-by-step framework proposed by Donthu *et al*. (2021). Conducting a bibliometric analysis involves a structured process that begins with clearly defining the research objectives and scope, typically focusing on a broad and data-rich area of inquiry. Data should be extracted from reputable databases such as Scopus, Web of Science (WoS), and ABDC, ensuring thorough data cleaning and standardization. Subsequently, appropriate techniques and software tools are selected in alignment with the research objectives. These include performance analysis, which assesses productivity and impact using indicators such as publication counts, citation frequencies, and the h-index, and science mapping, which explores intellectual structures and relationships through citation analysis, co-occurrence networks, and co-authorship analysis.

## *3.1 Bibliometric Analysis*

The research objectives were examined using network analysis and descriptive techniques within the bibliometric framework. Bibliometric analysis is a structured and scientific approach used to evaluate the intellectual landscape of a particular research field by analyzing publications, citations, authors, and institutions (Hassan & Duarte, 2024). This process involves collecting data from relevant and reputable databases, performing rigorous data cleaning, and applying bibliometric techniques to assess the patterns, trends, and impact of research within the domain (Rehman *et al*., 2024; Lim *et al*., 2024). Such an approach facilitates the structured analysis of large volumes of unstructured data, offering scholars deeper insights and helping to identify knowledge gaps within a discipline. It serves as a robust and valuable method for understanding the evolution and development of scientific knowledge in a given research area.

This study utilized VOSviewer (version 1.6.20), an open-source software commonly applied in bibliometric research to visualize and interpret complex scientific networks. The software was used to illustrate relationships among authors, countries, journals, citations, and keywords. Its interactive mapping capabilities enabled the identification of research clusters and thematic linkages across the field, supporting a clearer understanding of its intellectual structure (Cobo *et al*., 2011). To complement this analysis, the Bibliometrix package together with its web-based interface Biblioshiny (RStudio version 4.2.764) was applied for advanced data processing and performance analysis. Originally developed by Aria and Cuccurullo (2017), Bibliometrix offers an integrated analytical environment that allows users to conduct in-depth bibliometric exploration

without coding. The software supports multiple techniques—such as co-word and co-citation mapping, collaboration network analysis, and flow-diagram visualization—that assist in tracing both structural patterns and thematic developments within the literature (Guleria & Kaur, 2021). The visual and statistical outputs generated through VOSviewer and Bibliometrix/Biblioshiny were carefully evaluated, with only the most relevant and interpretable results included in this study to ensure methodological transparency and analytical rigor.

### *3.2 Data Collection*

In bibliometric analysis, selecting an appropriate database is a critical step, as the comprehensiveness of the database directly influences the reliability of the analysis. Among the most recognized bibliographic databases frequently compared in academic research are Scopus and Web of Science (WoS) (Zaščirinska *et al*., 2024). In terms of data scope, this study relies solely on the Scopus database; therefore, it may not fully capture the comprehensive academic landscape of the field. Integrating additional sources such as Web of Science (WoS), IEEE Xplore, or Dimensions in future research would provide a more holistic and balanced perspective—particularly in relation to technical and industrial applications. Nevertheless, in terms of citation linkage quality and coverage consistency, Scopus remains superior to many older databases (Visser *et al*., 2021) Scopus was selected as the data source for this study due to its extensive coverage of peer-reviewed academic publications and its relative advantage in scope and inclusiveness. Scopus indexes a broader range of publications than WoS—particularly in the applied sciences—making it more comprehensive for evaluating diverse research outputs. Furthermore, Scopus-exclusive publications demonstrate stronger citation linkages (Pranckutė, 2021). In addition, most works indexed in databases such as WoS, Dimensions, and ABDC are also covered in Scopus. Integrating multiple databases can lead to several challenges, including duplication, inconsistent indexing formats, and difficulties in standardizing search strategies. Therefore, data for this study were extracted solely from Scopus to ensure maximum coverage and consistency.

Within Scopus, the following search string was used to retrieve relevant documents: TITLE-ABS-KEY ( ("Augmented Reality" OR "AR" OR "Mixed Reality") AND ("E-commerce" OR "Electronic commerce" OR "Online shopping" OR "Online retail" OR "Digital commerce" OR "M-commerce" OR "Mobile commerce" OR "Social commerce") ). This search strategy was designed to yield comprehensive and relevant results. The time frame for analysis spanned 2014–2024. The selected time frame (2014–2024) was determined based on both technological and academic milestones in the evolution of AR. The year 2014 marks the onset of significant commercial adoption and scholarly attention toward AR applications in e-commerce, coinciding with the release of early AR-enabled retail platforms and mobile-based marketing tools. The endpoint of 2024 represents the most recent complete year of data available at the time of collection, thereby capturing a full decade of technological advancement and conceptual development in this field. This ten-year span thus provides a comprehensive view of how AR research has progressed from its early experimental phase to its current integration into mainstream digital commerce.

Using these criteria, a total of 632 documents were initially retrieved. The dataset was then refined through a set of inclusion and exclusion criteria. Only English-language publications were retained due to language limitations, resulting in 624 records. The scope of the study was limited to the subject areas of Computer Science; Engineering; Business, Management and Accounting; Mathematics; Decision Sciences; Social Sciences; and Economics, Econometrics and Finance to ensure relevance to the research context. Only journal articles, conference papers, book chapters, and books were included, as these are peer-reviewed and widely accessible in major academic databases. The dataset was screened to remove duplicates, and gray literature was excluded because it is not peer-reviewed and may lack the reliability and consistency required for bibliometric analysis. After applying all inclusion and exclusion criteria, a total of 610 publications were identified as relevant to the field.

## 4. RESULT

### *4.1 Overview*

According to Table 1, during the period 2014–2024, the research domain of Augmented Reality (AR) in E-commerce has shown a remarkable upward trajectory, with a total of 610 publications distributed across 190 distinct sources, reflecting an annual growth rate of nearly 25%. Although relatively young—with an average publication age of 3.72 years—the field has already attracted considerable scholarly attention, evidenced by an average of 16.82 citations per document. The document type analysis reveals that conference papers dominate the field (278 papers, approximately 46%), followed by journal articles (184 papers, ~30%). In contrast, review papers and bibliometric studies remain scarce (11 reviews and 62 conference reviews), indicating that research on AR in E-commerce is still primarily concentrated on experimental and exploratory stages rather than systematic synthesis or theoretical consolidation. In terms of authorship and collaboration, the field demonstrates a strong interdisciplinary nature, with an average of 9.04 authors per publication. However, international collaboration remains limited at 15.08%, suggesting significant potential for expanding global research networks. From a keyword perspective, more than 3,400 author keywords and 2,500 extracted keywords highlight the thematic diversity and evolving research directions in this domain. These findings underscore not only the need for bibliometric systematization to consolidate the fragmented body of knowledge but also point to substantial research gaps that warrant further exploration to strengthen the conceptual foundations and guide future investigations in AR-driven E-commerce.

### *4.2 Publication Trends*

Figure 1 illustrates the annual publication trend related to Augmented Reality (AR) in the field of E-commerce. During the period from 2014 to 2024 (when data were collected), a total of 610 publications were recorded, with 10,262 citations, averaging 16.82 citations per paper and approximately 932.9 citations per year. These studies were

conducted by 3,154 authors and published across 190 different sources. Based on the quantitative data and visualized progression, the development of research in this domain can be divided into three main stages: the initial phase (2014–2016), the steady growth phase (2017–2020), and the expansion phase (2021–2024).

**Table 1** Descriptive Statistics

| Description | Results |
|---|---|
| Timespan | 2014:2024 |
| Sources (Journals, Books, etc) | 190 |
| Documents | 610 |
| Annual Growth Rate % | 24.97 |
| Document Average Age | 3.72 |
| Average citations per doc | 16.82 |
| Keywords Plus (ID) | 2506 |
| Author's Keywords (DE) | 3423 |
| Authors | 3154 |
| Co-Authors per Doc | 9.04 |
| International co-authorships % | 15.08 |
| article | 184 |
| book | 8 |
| book chapter | 67 |
| conference paper | 278 |
| conference review | 62 |
| review | 11 |

**Initial Phase (2014–2016)**

During this early stage, the number of studies remained modest and slightly fluctuated, ranging from 8 to 18 publications per year. In 2014, 17 papers were published, increasing slightly to 18 in 2015 but dropping to only 8 in 2016. Most research focused on online shopping value and technology adoption of AR/VR (Kang, 2014), evaluation of embedded AR-based online shopping systems (Wang *et al*., 2015), and estimating the impact of non-catastrophic weather on the retail sector (Rashid *et al*., 2015). Overall, this period was exploratory in nature, reflecting the search for suitable models to integrate emerging technologies into E-commerce. However, due to the limited number and scope of studies, academic influence remained relatively low, yet it laid the foundation for the strong development observed in later phases.

**Steady Growth Phase (2017–2020)**

The period from 2017 to 2020 marks an important turning point for research on AR/VR in E-commerce, showing a steady but notable increase. In 2017, 27 publications were recorded, with studies emphasizing the role of AR in enhancing online shopping experiences through interactivity and vividness (Yim *et al*., 2017). By 2018, the number of publications increased to 32, with research focusing on trade-offs between personal data control and AR experience quality, raising ethical and privacy concerns in digital retail environments (Poushneh, 2018). In 2019 and 2020, publications continued to grow to 39 and 56, respectively, with studies delving deeper into virtual presence, personalization, and the immersive nature of technology—factors influencing user experience and brand perception (Smink *et al*., 2020). On average, around 38 studies were published annually during this phase, demonstrating a gradual expansion of academic interest. Notably, research began to move beyond technological trials to include user interaction, privacy, and technology acceptance, laying an important groundwork for the rapid growth in subsequent years.

**Expansion Phase (2021–2024)**

This phase witnessed a significant surge both in the number and depth of publications. From 57 studies in 2021, the number almost doubled to 94 in 2022, rose to 104 in 2023, and peaked at 158 in 2024. This remarkable growth reflects the increasing academic and practical interest in AR as a core component of immersive and metaverse-driven commerce. Research during this phase expanded in both scope and depth. For instance, consumer responses to AR were comprehensively examined across cognitive, affective, and behavioral dimensions (Kowalczuk *et al*., 2020), showing that AR not only captures attention but also shapes emotions and purchase decisions. Subsequent studies demonstrated the direct impact of AR on business performance in retail environments (Tan *et al*., 2021), confirming that this technology delivers tangible economic value beyond mere experiential appeal. Further, research clarified how AR reduces cognitive dissonance and enhances purchase intention (Barta *et al*., 2022), highlighting its role in decision support and risk mitigation during online shopping. Moreover, recent works extended to the metaverse context, where immersion and multisensory experience are recognized as the foundation of next-generation E-commerce (Chen *et al*., 2023). Overall, the 2021–2024 period underscores a clear paradigm shift from traditional E-commerce to immersive and sustainable commerce models, setting the stage for the convergence of AR and the metaverse in the coming years.

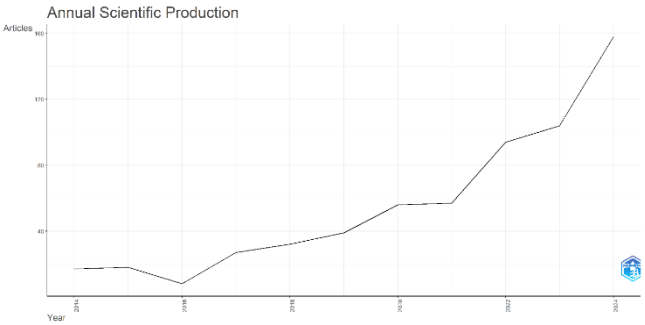


**Figure 1.** The distribution of studies over the years.

## *4.3 Most Cited Publications*

Table 2 and Figure 2 present the ten most influential publications on Augmented Reality (AR) in e-commerce, reflecting strong development in both theoretical and empirical foundations. Leading the field is the work of Yim *et al*. (2017) with 769 citations, considered a milestone for clarifying the roles of interactivity and vividness in online shopping experiences. By demonstrating that AR can enhance immersion, create novelty, and significantly influence purchase intentions and customer satisfaction, this study not only provides a solid theoretical framework but also serves as a key reference for subsequent research on customer experience and consumer behavior in technology-based e-commerce environments.

Following this, Rese *et al*. (2016), with 347 citations, approached the topic from the perspective of the Technology Acceptance Model (TAM), analyzing factors that drive or

hinder AR adoption. The highlight of this study lies in its comparison between marker-based and markerless AR, revealing that convenience and scan functionality play crucial roles in shaping attitudes and usage intentions. This work not only adds empirical evidence to TAM in the context of emerging technologies but also lays the groundwork for future studies on UX (user experience) and UI (user interface) design in AR-based e-commerce applications.

Pantano *et al*. (2017), with 313 citations, expanded the research scope to explore online shopping behavior among young consumers across two different countries, offering a cross-national comparative perspective. The results indicate that AR can reduce uncertainty in decision-making and enhance consumption experiences, affirming its universal applicability in supporting consumer behavior across diverse contexts. This study is particularly significant as it emphasizes AR's role in addressing one of the major limitations of traditional e-commerce: the uncertainty that arises when customers cannot physically experience a product.

In addition, several other works have made important contributions to deepening the field. Steinhoff *et al*. (2018, 278 citations) approached AR from a relationship marketing perspective, analyzing how AR and mobile commerce strengthen the relationship between brands and customers, showing that technology affects not only individual experiences but also customer relationship management (CRM). Shen *et al*. (2021, 270 citations) offered a novel viewpoint by systematizing the relationship between AR, the metaverse, and consumer behavior, thereby extending e-commerce into immersive virtual spaces. This study is particularly relevant as e-commerce transitions from traditional 2D environments toward multidimensional metaverse ecosystems, where AR acts as a bridge.

From a deeper empirical standpoint, Kowalczuk *et al*. (2020, 256 citations) analyzed consumers' cognitive, affective, and behavioral responses, providing clear evidence that AR not only influences rational evaluations but also stimulates emotions and strengthens brand attachment. Smink *et al*. (2020, 218 citations) further clarified factors affecting brand experience—such as presence, personalization, and intrusiveness—emphasizing the importance of balancing immersive experiences with user comfort. From another perspective, Poushneh (2018, 218 citations) directly addressed privacy and ethics, highlighting the trade-off between personal data control and AR quality. This is a vital contribution as it raises ethical concerns at a time when most studies were still focused mainly on AR's benefits.

Hilken *et al*. (2018, 214 citations) expanded the discussion to omnichannel contexts, demonstrating that AR can serve as a bridge between online and offline experiences, creating a seamless and holistic customer journey. Meanwhile, Tan *et al*. (2021, 212 citations) provided direct empirical evidence of AR's impact on retail sales, confirming that AR is not only an experiential tool but also a genuine driver of business performance.

Overall, these ten highly cited studies have collectively established the academic foundation for AR research in e-commerce. While Yim *et al*. (2017) and Rese *et al*. (2016) laid the theoretical and adoption groundwork, Pantano *et al*. (2017), Kowalczuk *et al*. (2020), and Smink *et al*. (2020) delved deeper into consumer experience and emotional response. In contrast, Steinhoff *et al*. (2018), Hilken *et al*. (2018), and Tan *et al*. (2021) clarified customer relationship and business value aspects. Meanwhile, Shen *et al*. (2021) and Poushneh (2018) expanded the research frontier to the metaverse and ethical considerations. This diversity of perspectives demonstrates that AR has the potential to comprehensively reshape the online shopping experience and open new directions for modern e-commerce, including immersive commerce, omnichannel commerce, and sustainable commerce in the digital era.

**Table 2** Most cited publications (as of December 2024).

| Document | Title | Keywords | Total Citations |
|---|---|---|---|
| Yim *et al*. (2017) | Is Augmented Reality Technology an Effective Tool for E-commerce? An Interactivity and Vividness Perspective | Augmented reality; Interactivity; Vividness; Immersion; Novelty; Previous media experience | 769 |
| Rese *et al*. (2016) | How augmented reality apps are accepted by consumers: A comparative analysis using scales and opinions | Augmented Reality (ar); E-commerce; Marker-based; Markerless; Scan Function; Technology Acceptance Model (tam); Virtual Mirror; Electronic Commerce; Mirrors; Mobile Devices; Comparative Analysis; Interactive Technology; Marker-based; Markerless; Measurement Points; Modified Technologies; Technology Acceptance Model; Virtual Mirror; Augmented Reality; Comparative Study; Electronic Commerce; Perception | 347 |
| Pantano *et al*. (2017) | Enhancing the online decision-making process by using augmented reality: A two country comparison of youth markets | Aesthetic Quality; Augmented Reality; Consumer Behaviour; Decision-making; E-tailing; Interactivity; Technology Acceptance Model (tam); Consumption Behavior; Decision Making; Esthetics; Internet; Marketing; Modeling; Retailing; Young Population | 313 |
| Steinhoff *et al*. (2018) | Online relationship marketing | E-commerce; Mobile Shopping; Online Relationships; Online Retailing; Online Shopping; Relationship Marketing; Relationship Selling; Social Media; Virtual Assistants | 278 |
| Shen *et al*. (2021) | How to Promote User Purchase in Metaverse? A Systematic | virtual commerce; consumer behavior; application design; immersive technology; metaverse | 270 |

| Document | Title | Keywords | Total Citations |
|---|---|---|---|
| | Literature Review on Consumer Behavior Research and Virtual Commerce Application Design | | |
| Kowalczuk *et al*. (2020) | Cognitive, affective, and behavioral consumer responses to augmented reality in e-commerce: A comparative study | Ar Marketing; Augmented Reality; Consumer Response System; E-commerce; Perceived Reality Congruence; Product Presentations | 256 |
| Smink *et al*. (2020) | Shopping in augmented reality: The effects of spatial presence, personalization and intrusiveness on app and brand responses | Augmented reality; Branded apps; Presence; Personalization; Intrusiveness; Online shopping | 218 |
| Poushneh (2018) | Augmented reality in retail: A trade-off between user's control of access to personal information and augmentation quality | Augmented reality; Augmentation quality; User's control of access to personal information; User satisfaction | 218 |
| Hilken *et al*. (2018) | Making omnichannel an augmented reality: the current and future state of the art | E-commerce, Customer experience, Technology in retailing, Digitalisations | 214 |
| Tan *et al*. (2021) | Augmented Reality in Retail and Its Impact on Sales | Augmented Reality, online retail, mobile app, virtual product experience, product uncertainty | 212 |

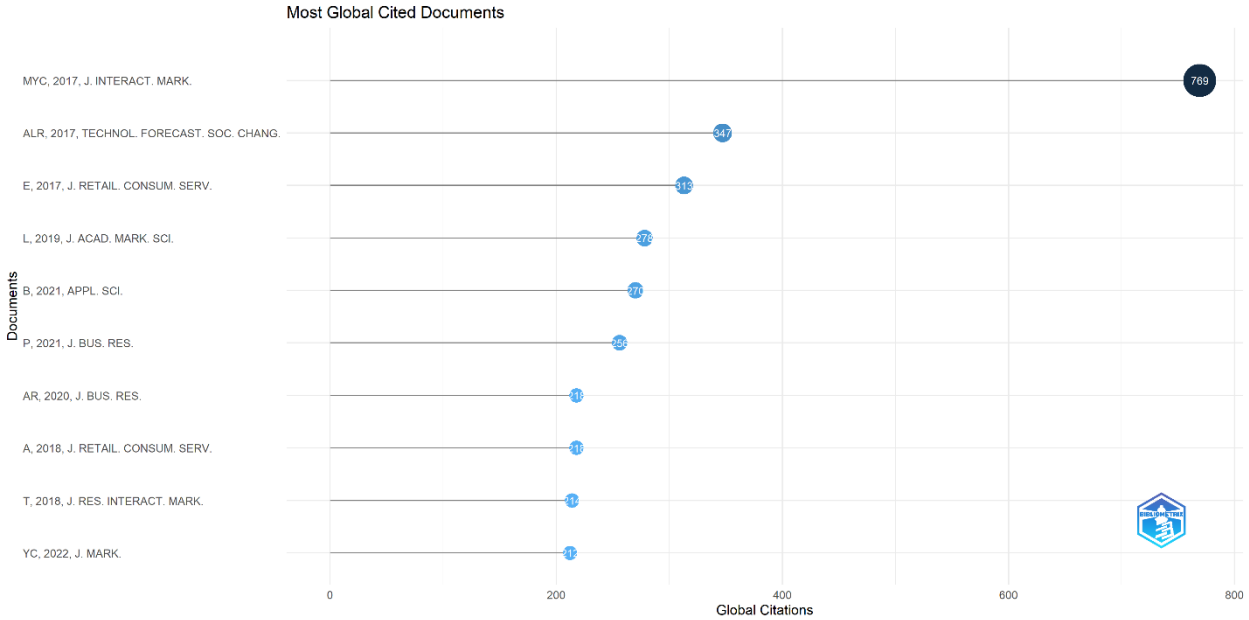


**Figure 2** Most globally cited publications

## *4.4 Countries with the Highest Number of Publications*

From Table 3, it can be seen that the top ten countries account for 408 publications, representing approximately 66.9% of all research documents on AR in e-commerce from 2014 to 2024, reflecting a notable academic concentration. Among them, India leads with 128 publications (20.98%), significantly surpassing the United States (58; 9.51%) and China (55; 9.02%). India's dominance is evident not only in publication volume but also in its high level of international collaboration, as shown by the dense connection lines on the collaboration map (Figure 3). This suggests a central role in knowledge dissemination, driven by the participation of young researchers and extensive international academic networks. Although the United States has fewer publications, it maintains a transcontinental bridging position through strong collaborations with both Europe and Asia, thereby contributing to the diffusion of methodologies and the enhancement of academic influence. In contrast, China ranks third in output but shows limited international cooperation: most of its publications are domestically focused, reflecting strong national research investment yet lacking a corresponding level of global diffusion.

India's dominance reflects its national strategy to promote digital transformation through initiatives such as Digital India and Make in India, which strongly encourage research on applying AR and AI technologies in e-commerce. In addition, the presence of major technical institutes, a young workforce, and low technology development costs have enabled India to achieve a high volume of publications and establish a vibrant academic network. In contrast, the United States, though producing fewer publications, maintains leadership in academic depth

and global influence thanks to its ability to integrate AR with advanced fields such as Artificial Intelligence (AI), Big Data, and marketing analytics a trend driven by technology giants like Meta, Google, and Amazon. This pattern suggests that U.S. research tends to emphasize theoretical development, consumer behavior analysis, and digital marketing strategies, rather than focusing solely on technical experimentation. China ranks third, supported by strong investment in digital technology and e-commerce infrastructure (notably AR projects by Alibaba and JD.com). However, Chinese studies often lack international collaboration, mainly serving domestic industrial policy goals, reflecting a pragmatic and application-oriented approach rather than one centered on global knowledge sharing.

**Table 3** Countries with the highest number of publications

| Country | N | N (%) |
|---|---|---|
| India | 128 | 20.98 |
| United States | 58 | 9.51 |
| China | 55 | 9.02 |
| United Kingdom | 35 | 5.74 |
| Germany | 27 | 4.43 |
| Indonesia | 27 | 4.43 |
| Taiwan | 22 | 3.61 |
| Japan | 20 | 3.28 |
| Malaysia | 19 | 3.11 |
| Portugal | 17 | 2.79 |

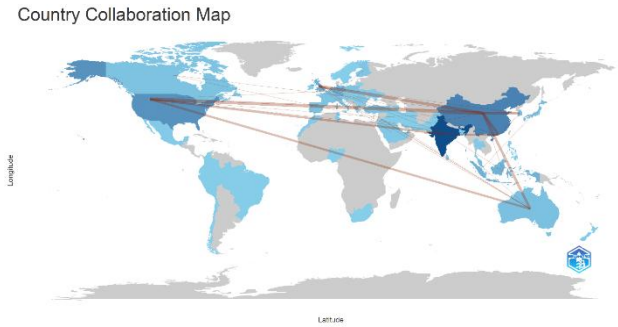


**Figure 3.** Collab world map.

According to Figure 4, European countries such as the United Kingdom (35; 5.74%), Germany (27; 4.43%), and Portugal (17; 2.79%)—although having a more modest number of publications—stand out for their strong academic cohesion and interdisciplinary research orientation. Supported by European Union research programs such as Horizon Europe, these countries emphasize international collaboration and play a pivotal role in developing theoretical frameworks, policy standards, and ethical guidelines for AR technology in digital commerce, rather than focusing solely on technological advancement. This demonstrates Europe's contribution to shaping the conceptual and normative foundations of AR in the digital economy. In the Asian region, aside from India and China, several other countries also demonstrate a notable presence. Indonesia (27; 4.43%) reflects the rise of a growing digital economy, with research emphasizing practical and application-oriented approaches, particularly in retail, tourism, and education. Taiwan (22; 3.61%) and Japan (20; 3.28%) focus more on technical research and experimental applications of AR in education and retail, while Malaysia (19; 3.11%) contributes contextually relevant studies that enrich the understanding of AR in the Southeast Asian context. These differences collectively reflect variations in the maturity of digital economies, innovation capacities, and technological transformation capabilities across countries.

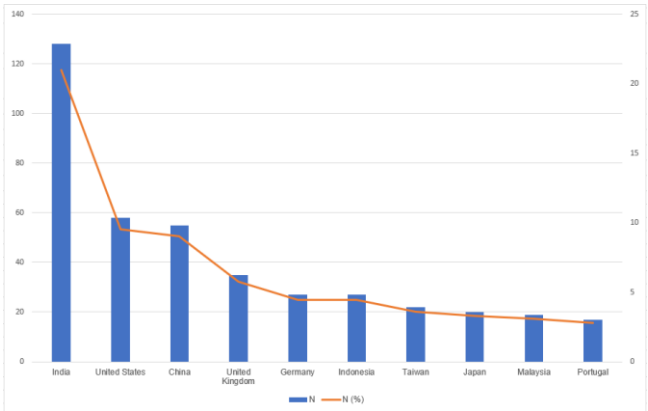


**Figure 4.** Top 10 Most Productive Countries in AR and E-Commerce Research (2014–2024)

Overall, three main clusters of countries can be identified: (i) the leading group in terms of output and growth rate (India, the United States, China); (ii) the group emphasizing scientific collaboration and policy orientation (the United Kingdom, Germany, Portugal); and (iii) the emerging group characterized by regional specificity and application-oriented focus (Indonesia, Taiwan, Japan, Malaysia). This stratification reflects the diversity of the global research ecosystem, where each country contributes not only through publication volume but also by demonstrating distinctive features in technological capability, international collaboration, and application orientation—together forming a comprehensive picture of the development of AR in e-commerce.

## *4.5 Most Frequently Used Keywords*

A total of 3,423 keywords were identified in the dataset. Figures 5 and 6 illustrate the 15 most frequently occurring keywords in studies on augmented reality (AR) technology within the field of e-commerce, extracted from the Scopus database. The total occurrences of these top 15 keywords reached 1,418, accounting for 41.4% of all keywords in the dataset, clearly reflecting the concentration of research on technology-oriented and consumer behavior themes in the digital context.

The most frequent keyword was "augmented reality," appearing 371 times (26.2% of the top 15 total occurrences). In the treemap visualization, this keyword occupies the largest area, underscoring its central position in the research domain. This indicates that scholarly works primarily focus on the application of AR technology to enhance shopping experiences and consumer behavior in e-commerce. The second most common group of terms includes variations of the concept of e-commerce ("electronic commerce," "e-commerce," and "e-commerces"), with a combined 391 occurrences (27.6% of the top 15), highlighting the dominance of e-commerce as the main research context. Following these are keywords associated with market behavior and applied dimensions such as "sales" (106 occurrences, 7.5%), "online shopping" (93 occurrences, 6.6%), and "virtual reality" (105 occurrences, 7.4%). These

terms reflect researchers' strong interest in sales effectiveness, online shopping experience, and consumer interaction with virtual technologies.

Keywords around "augmented reality," "e-commerce," and "online shopping" highlights how the field remains technology- and application-centric. This dominance signals that researchers are primarily exploring how AR is implemented in e-commerce contexts, rather than why or with what long-term effects it transforms consumer behavior.

Other moderately frequent keywords capture emerging research trends: "augmented reality technology" (36 occurrences), "mobile commerce" (36), and "user experience" (34), which emphasize the technical foundation, mobile-based applications, and user experience optimization. Similarly, "consumer behavior" (32), "virtual try-on" (32), and "customer experience" (31) point to growing attention to consumer decision-making and product trial experiences enabled by AR/VR—core to modern e-commerce practices. "Human–computer interaction" (31) and "mixed reality" (31) represent an interdisciplinary direction bridging computer science, psychology, and marketing, focusing on human–machine interaction and the emerging field of MR (mixed reality).

Overall, the visualized results from Figures 5 and 6 reveal three overarching themes technology, commerce, and consumer behavior mirroring the global country clusters identified earlier:

(1) **Core Technologies** – including augmented reality, virtual reality, mixed reality, and human–computer interaction;

(2) **Commercial Platforms** – encompassing electronic commerce, e-commerce, mobile commerce, and online shopping;

(3) **Consumer Experience and Behavior** – covering user experience, customer experience, consumer behavior, sales, and virtual try-on.

These findings indicate that current research mainly centers on the application of AR/VR to enhance consumer experience and shopping behavior in e-commerce, while expanding toward multi-platform virtual interaction models (mobile and mixed reality). This represents a promising interdisciplinary trajectory that integrates technology, consumer behavior, and business strategy in the digital era.

Figure 7 illustrates the keyword co-occurrence network in the dataset on augmented reality (AR) research within e-commerce. The network reveals the intellectual structure of the field, consisting of several tightly connected clusters of keywords. Among them, the two central nodes — augmented reality and electronic commerce — have the largest sizes, highlighting their pivotal roles in shaping the domain's knowledge structure. Nodes such as machine learning, 3D modelling, and mobile commerce function as bridging nodes, linking the clusters of technical topics with those focused on consumer behavior and marketing. The high density of connections surrounding the two central hubs (AR–e-commerce) indicates a strong degree of knowledge integration, reflecting the inherently interdisciplinary nature of this research area. The colored clusters on the map represent distinct research directions: the orange cluster corresponds to technical themes (AR–ML–3D modelling); the purple cluster focuses on customer experience and behavioral studies; the blue cluster reflects research on mobile commerce and social commerce; the green cluster centers on technology acceptance; and the red cluster represents emerging topics related to consumer behavior and retailing. Overall, the network structure not only demonstrates the thematic diversity within AR research in e-commerce but also highlights the potential connections between technological development and business applications, suggesting an increasingly integrated interdisciplinary research landscape.

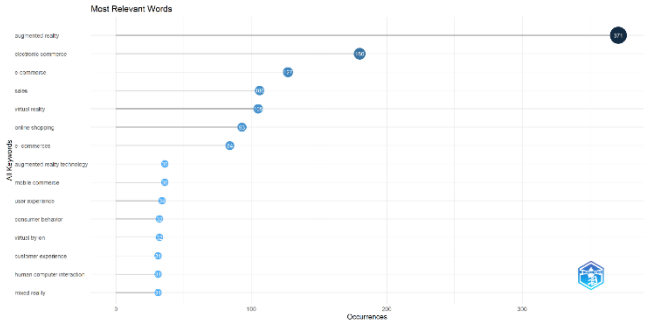


**Figure 5.** Most relevant words.


**Figure 6.** Treemap of the Top 15 most frequently occurring keywords.

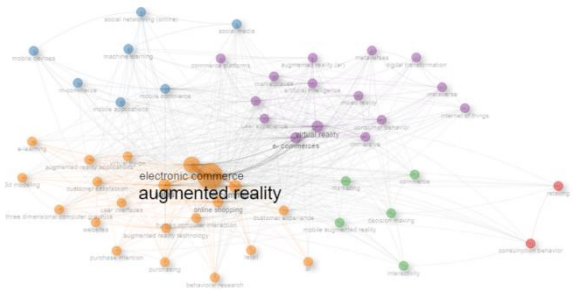


**Figure 7.** Co-occurrence network

The keyword co-occurrence analysis in Figure 8 is used to construct a thematic map, where clusters of keywords are arranged along two main dimensions: Centrality – indicating the degree of connection and importance of each theme in relation to others, and Density – representing the internal development level of each cluster. Following the classification strategy of Cobo *et al.* (2010), the themes are divided into four main categories:

(1) **Motor Themes** – well-developed and highly influential themes that drive the field;

(2) **Niche Themes** – specialized themes with strong internal development but limited connections to other areas;

(3) **Basic Themes** – foundational themes with broad influence but relatively low internal development;

(4) **Emerging/Declining Themes** – newly emerging or declining topics characterized by low centrality and density.

This classification helps clarify the position, development level, and research trends of each thematic cluster within the overall field.

**Motor Themes:** This cluster includes keywords such as *3D modeling*, *computer vision*, *machine learning*, *real-time*, and *smartphones*. It represents the technical core of the field, focusing on algorithm development and real-time AR visualization applications. Although these studies are primarily technical and simulation-oriented, they often lack empirical validation regarding how technological performance affects user experience and behavior.

**Basic Themes:** This group encompasses *augmented reality, virtual try-on, human–computer interaction (HCI), e-commerce, customer experience, marketing, mobile commerce, mobile applications, and social networking.* These constitute the foundational areas of the field, reflecting its most prevalent research directions. Studies in this cluster typically measure consumer perception and behavior when interacting with AR, mainly adopting frameworks such as TAM and UTAUT. However, these studies remain limited in multidimensional scope, especially concerning mediators (e.g., *trust*, *emotional engagement*) and moderators (e.g., *product type*, *cultural background*).

**Emerging Themes:** This cluster comprises *consumer behavior*, *retailing*, and *consumption behavior*. It represents a growing area focusing on consumer interaction and AR applications in retail. Early findings suggest that AR can reduce return rates and enhance customer satisfaction, but most of these studies remain exploratory and would benefit from expansion into field-based research.

**Niche Themes:** Keywords such as *perceived usefulness*, *intention to use*, *technology acceptance*, and *bibliometric analysis* appear in this group. Despite their high internal density, these themes have relatively low centrality, representing specialized topics focusing on technology acceptance models and perception measurement. While theoretically significant, future research in this cluster should aim to standardize measurement scales to facilitate cross-contextual comparison and meta-analytic synthesis.

The distribution of color clusters in Figures 8 indicates that AR research in e-commerce is shifting from a technical foundation toward behavioral and marketing-oriented applications. The orange and purple clusters occupy central positions, reflecting their stable development and dominant role in the knowledge network. Meanwhile, the blue and red clusters signal new directions—integrating AR into mobile, social, and retail contexts. This transition opens up opportunities for interdisciplinary research linking technology, user experience, consumer behavior, and marketing management.

Potential research directions include:

(1) integrating technical performance assessment with real behavioral data to determine AR's actual business impact;

(2) conducting longitudinal studies to measure the long-term effects of AR experiences on customer loyalty;

(3) cross-platform and cross-cultural comparisons to identify moderating factors in technology adoption;

(4) expanding research into sustainability and ethical aspects, such as privacy, facial data, and AR's environmental impact.

Overall, the structure of the thematic clusters indicates that the field is entering a convergence phase between technology and consumer behavior, offering substantial potential for future multi-method and interdisciplinary research.

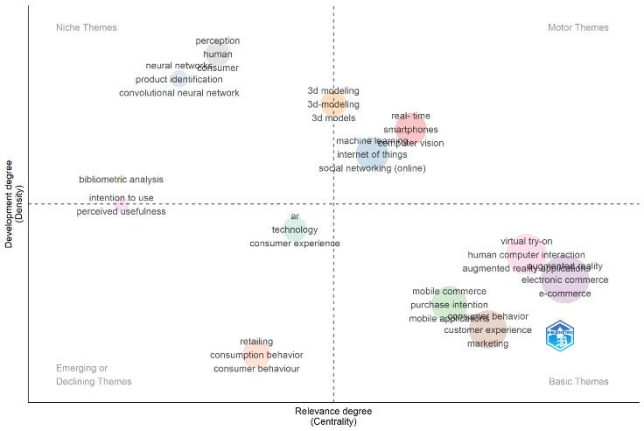


**Figure 8.** Thematic map.

In summary, global patterns of country and topic clusters suggest that AR research in e-commerce is entering a phase of convergence – integrating technological innovation with consumer behavior and experience – thus offering significant potential for future multi-method and interdisciplinary exploration.

## *4.6 Author Productivity and Collaboration Analysis*

The bibliometric analysis of publication productivity, academic impact, and co-authorship structure provides a comprehensive overview of the intellectual landscape in the field of Augmented Reality (AR) research within e-commerce. By combining data on publication counts, academic impact indicators (such as the h-index), and co-authorship networks, this section not only identifies the most prolific contributors but also highlights those with the strongest academic influence, as well as the degree of interconnectedness within the international research community during the 2014–2024 period.

The results from the Most Relevant Authors chart reveal a clear concentration of academic productivity in this field. A small group of prominent scholars including Alves, Carlos; Masuko, Soh; Ohta, Masaya; Sadalgi, Shrenik; Tan, Nicole; and Tanaka, Jiro have published between four and five papers, standing out from other authors. This phenomenon reflects a common pattern in the early developmental stage of an emerging research domain, where knowledge production and dissemination are primarily driven and sustained by a core group of authors.

In addition to the number of publications, the h-index serves as a crucial indicator reflecting the quality and academic impact of research contributions. The results from

the *Authors' Local Impact by H-index* chart show that Flotyński, Jakub, and Tanaka, Jiro have the highest h-index values (h = 4), followed by Masuko, Soh; Ohta, Masaya; Sadalgi, Shrenik; and Tan, Nicole, each with an h-index of 3.

This analysis highlights the distinction between productivity and academic influence. Some authors demonstrate high publication output but receive relatively few citations, while others, despite having fewer publications, achieve higher citation rates due to their foundational theoretical or methodological contributions. Authors with high h-index values often represent the "knowledge core" individuals who shape theoretical frameworks and pave the way for future research directions. Therefore, assessing academic performance should be based on a combination of indicators (such as publication count, average citations, and h-index) to comprehensively reflect both the quantitative and qualitative dimensions of scholarly achievement.

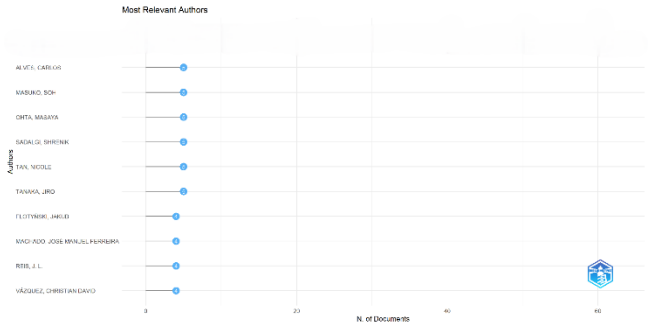


**Figure 9.** Most Relevant Authors

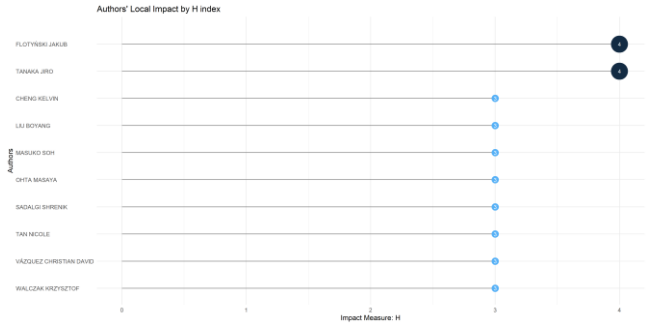


**Figure 10.** Authors' Local Impact by H index

When combining the two indicators (number of publications and h-index), three representative groups of scholars can be identified. The first group is characterized as "high productivity – moderate impact," consisting of authors who have published many papers but achieved a moderate level of citation influence. The second group, "moderate productivity – high impact," includes standout scholars such as Flotyński, Jakub and Tanaka, Jiro, who, despite having fewer publications, have made significant contributions to the academic community. Finally, the third group consists of "emerging scholars" with relatively low productivity and impact, representing the next generation gradually entering the field. This three-tiered structure reflects the natural evolution of an academic discipline: the pioneering group establishes the theoretical foundations; the development group expands practical applications; and the succeeding group consolidates and validates existing models. Strengthening collaboration among these groups would enhance the sustainability and comprehensiveness of the knowledge network.

The co-authorship map figure 11 reveals three major collaboration clusters, illustrating a clear division in both geographical and thematic dimensions. Cluster 1 (red – Europe), led by Werth, Dirk; Do, Minh Dung; and Krick, Mathias, focuses on studies related to digital transformation, logistics, and the application of augmented reality (AR) in supply chain management. Cluster 2 (blue – international) is centered around Jain, Shubham, who acts as a "knowledge bridge" between European and Asian research groups, reflecting cross-border academic interaction and exchange. Meanwhile, Cluster 3 (green – Asia), including Roy, Nihar Ranjan; Mishra, Siddharth; and Awasthi, Anubhav, concentrates on consumer behavior, online shopping experiences, and digital marketing. The dense intra-cluster connections indicate strong regional collaboration, whereas the limited inter-cluster links highlight uneven levels of international cooperation. Nonetheless, the presence of bridging authors such as Jain, Shubham suggests that a trend toward expanding global collaboration is gradually emerging, fostering knowledge integration and the standardization of international research methodologies.

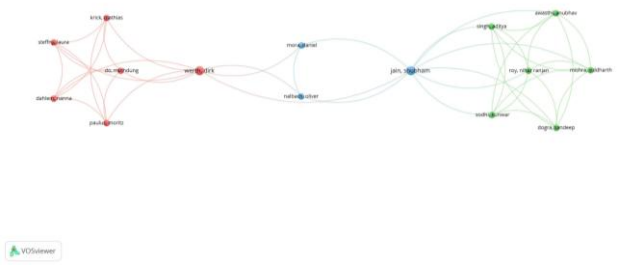


**Figure 11.** Co-Authorship

Overall, the analysis of academic productivity and collaboration networks indicates that the field of AR in e-commerce is entering a stage of maturity, characterized by the emergence of international scholar clusters, highly influential core authors, and a converging trend between technology, consumer behavior, and user experience. The combination of quantitative indicators (such as h-index and citation counts) with co-authorship network mapping not only illustrates the developmental trajectory of the field but also provides a solid empirical foundation for future research and managerial directions.

# 5. DISCUSSION

## *5.1 Discuss the Research Results*

This bibliometric analysis provides an integrated overview of the research development, intellectual structure, and thematic orientation of Augmented Reality (AR) in e-commerce between 2014 and 2024. The results reveal that AR has evolved from an emerging technological tool into a transformative mechanism reshaping digital commerce, consumer experience, and marketing strategies. The average annual growth rate of nearly 25% reflects the increasing academic interest driven by technological advances and the growing demand for interactive and immersive online shopping experiences.

The evolution of AR research in e-commerce can be divided into three main phases. The initial exploratory phase (2014–2016) focused on technological feasibility and concept validation, during which AR was primarily viewed as a novelty enhancing the online shopping experience (Kang, 2014; Wang *et al*., 2015) to enhance usefulness and ease of use, which are also the core assumptions of the Technology Acceptance Model (TAM). The theoretical consolidation phase (2017–2020) marked a significant turning point, foundational frameworks interactivity, vividness, the flow experience has been incorporated into the extended TAM framework, clarifying that users' adoption of AR is driven not only by functional needs but also by emotional value (Rese *et al*., 2016; Yim *et al*., 2017). The growing integration of interactivity and vividness into these models reflects an expanded understanding of perceived enjoyment and flow experience as key mediators linking technology performance with behavioral intention. The expansion and diversification phase (2021–2024) saw an explosion of publications, shifting attention to consumer psychology, immersive experiences, and integration with the metaverse (Shen *et al*., 2021; Chen *et al*., 2023). This transition from technological validation to experiential and behavioral exploration signifies the field's maturity and alignment with the broader global digital transformation trend. These findings also extend the implications of the Unified Theory of Acceptance and Use of Technology (UTAUT). In the early stages, performance expectancy and effort expectancy were the key drivers shaping users' intention to adopt AR. However, in the current context, social influence and facilitating conditions—such as the widespread availability of mobile devices and the reliability of AR platforms—have become increasingly decisive. Studies from Asian countries such as India and China further reveal that technological infrastructure and digital readiness play a fundamental role in determining both the adoption and continued use of AR technologies.

From a geographical perspective, India leads in publication volume (20.98%), reflecting a strong digital economy and practical focus on AR applications. The United States and China follow but with distinct profiles: the U.S. emphasizes theoretical depth and methodological rigor, while China's research remains largely domestic, showing limited international collaboration. European countries such as the U.K., Germany, and Portugal present a more balanced approach, combining technology, marketing, and policy insights. This distribution highlights a regional research gap—Asia tends toward applied and design-oriented research, while Western countries focus on theoretical development and managerial strategy. This parallel structure creates a global knowledge cycle, in which the Western context consolidates theoretical foundations, while the Eastern context drives diffusion and empirical validation.

Analysis of the most-cited publications underscores the multidimensional nature of AR in e-commerce. Foundational studies such as (Yim *et al*., 2017) and (Rese *et al*., 2016) established the impact of interactivity and perceived usefulness on AR adoption, while subsequent works like (Kowalczuk *et al*., 2020) and (Smink *et al*., 2020) explored emotional and behavioral responses. Meanwhile, (Steinhoff *et al*., 2018) and (Hilken *et al*., 2018) extended AR research to relationship marketing and omnichannel integration, demonstrating that AR creates seamless experiences bridging digital and physical realms. At the same time, scholars' attention has increasingly shifted toward the experiential value of AR. Rather than being viewed solely as a technological tool, AR is now recognized as a medium that stimulates sensory and emotional engagement, allowing consumers to "experience before purchase" within virtual environments. By enabling users to try on or visualize products in their own surroundings, AR not only reduces perceived purchase risk but also fosters a deeper emotional connection between consumers and brands. Collectively, these studies confirm that AR is no longer merely a technology—it has become a central element in brand–consumer interaction and digital retail transformation.

The keyword co-occurrence network reveals three prominent thematic clusters reflecting the field's holistic development. The first cluster—Technological Development and System Design—focuses on core concepts such as AR, VR, MR, computer vision, and machine learning, forming the technical foundation of the field. Scholars in this cluster aim to optimize algorithms, interfaces, and system performance to enhance AR applicability in digital contexts. The second cluster—E-commerce Platforms and Retail Applications—includes keywords like e-commerce, mobile commerce, and online shopping, highlighting AR's deep integration into digital business platforms to facilitate consumer interaction and decision-making. The third cluster—Consumer Experience and Behavior—brings together terms such as customer experience, consumer behavior, sales, and virtual try-on, reflecting a clear shift from technology-centric to user-centered approaches. Together, these clusters illustrate how AR research has evolved from technical exploration toward a richer understanding of emotional, behavioral, and experiential value in modern e-commerce. The studies by Kowalczuk *et al*. (2020) and Smink *et al*. (2020) demonstrate that AR simultaneously activates three layers of experience—sensory (sense), affective (feel), and behavioral (act)—enabling customers to interact directly with both the product and the brand. At the psychological level, this aligns with the concept of User Experience (UX) expansion, in which purchasing behavior is driven not only by rational evaluation but also by emotional attachment and experiential engagement.

The thematic evolution analysis further identifies four major theme groups that define the maturity and knowledge structure of AR research in e-commerce.

**Motor Themes** include *3D modeling*, *computer vision*, and *machine learning*—the technological engines driving real-time visualization, customization, and personalization.

**Basic Themes** encompass *e-commerce*, *human–computer interaction*, *mobile commerce*, and *marketing*, representing the theoretical and applied backbone of the field.

**Emerging Themes**, such as *consumer behavior* and *retailing*, indicate a growing research focus on psychological and behavioral aspects, showing increasing concern for **user experience** in AR environments.

**Niche Themes**, including *perceived usefulness*, *technology acceptance*, and *bibliometric analysis*, reflect specialized yet valuable research streams that deepen theoretical understanding.

The balance among these groups suggests that AR research in e-commerce is transitioning from fragmented subfields to an integrated knowledge system. However, key challenges remain: most studies are still confined to laboratory settings, with limited real-world application, longitudinal analysis, or cross-cultural comparison. While many studies address emotional engagement and immersion, few connect these factors to measurable business outcomes such as conversion rate, loyalty, or brand equity.

Another underexplored dimension is ethics and sustainability in AR applications. Although Poushneh (2018) discussed privacy and data control, broader issues—such as digital addiction, energy consumption, and data ethics—remain insufficiently examined. Integrating sustainability and digital responsibility frameworks into AR research would align the field more closely with the United Nations Sustainable Development Goals (SDGs).

In conclusion, bibliometric evidence shows that AR in e-commerce has evolved into a complex, multidisciplinary domain linking technology, marketing, and consumer psychology. The field is moving toward an ecosystem-based approach to digital consumption, where AR serves as both an immersive experience tool and a strategic lever for business innovation. To fully harness AR's potential, future research should develop integrated models connecting technical performance, user experience, and organizational strategy, while fostering global collaboration and promoting ethical digital transformation.

## *5.2 Theoretical Implications*

From a theoretical perspective, this study provides the first comprehensive overview of the evolution of academic knowledge related to Augmented Reality (AR) in e-commerce. The findings clarify the intellectual progression from the technological experimentation stage (2014–2016) to the model consolidation and application expansion stage (2017–2024). Quantitative analysis highlights the foundational role of Yim *et al*. (2017) and Rese *et al*. (2016), who employed theoretical frameworks such as the Technology Acceptance Model (TAM), UTAUT and Experiential Marketing interactivity, and vividness to explain AR adoption behavior. More recent studies (e.g., Hilken *et al*., 2018; Kowalczuk *et al*., 2020) have extended this perspective toward emotional experience, consumer behavior, and human–computer interaction, contributing to the formation of an interdisciplinary knowledge framework that integrates marketing, technology, and consumer psychology. This integration allows AR to be redefined not merely as a technology to be accepted, but as a mechanism for experiential value creation.These insights enrich the theoretical foundation by demonstrating that AR is not merely a visualization technology, but also a stimulus for emotional engagement, perceived value formation, and purchase intention in digital environments. Furthermore, the study strengthens the theoretical link between AR and technology acceptance models, while extending consumer behavior theories to contexts of high-interactivity e-commerce. Building on this theoretical progression, the study proposes an extended framework for understanding AR in e-commerce, reflecting the convergence of technology – user experience – business – policy dimensions. The framework can be summarized through four major theoretical extensions. First, it extends TAM and UTAUT toward a holistic experiential model, suggesting that AR adoption is driven not only by cognitive factors such as perceived usefulness and ease of use, but also by emotional variables (e.g., *presence, enjoyment*), risk perception (*privacy concern*), and personalization, which act as mediating mechanisms leading to consumer behavior. Second, the framework emphasizes the integration of technological, behavioral, and business perspectives. Technological advancements such as AI-based computer vision, 3D modelling, and latency optimization serve as inputs that activate psychological mechanisms like *presence*, *trust*, and *perceived usefulness*, ultimately generating measurable business outcomes including conversion rate, return rate, and customer lifetime value (LTV). This connection highlights how technical and psychological elements jointly influence commercial performance in AR-enabled environments. Third, the framework introduces moderating factors that shape the strength and direction of AR's effects. Cultural context, product type, technological infrastructure, and user characteristics (such as age and digital literacy) can alter how AR experiences translate into behavioral and business outcomes. These moderators suggest that AR's impact is highly contextual, requiring tailored strategies for different markets, demographics, and product categories. Fourth, the study incorporates temporal dynamics, acknowledging that the effectiveness of AR is not static but evolves over time. Early exposure to AR may generate novelty-driven engagement, while prolonged use can lead to habituation, sustained loyalty, or even disengagement. This temporal dimension calls for a shift from cross-sectional to longitudinal research designs to better capture evolving consumer reactions and long-term behavioral changes. Based on these theoretical insights, a comprehensive conceptual model is proposed to represent the theoretical evolution and mechanisms of AR in e-commerce. The model includes five key components: *(A) Enablers / Drivers*, *(B) Mediators / Psychological Mechanisms*, *(C) Outcomes*, *(D) Moderators*, and *(E) Temporal Dynamics*. Enablers encompass technological, design, and organizational factors that create the foundation for AR adoption. Mediators capture the psychological and experiential processes linking technology to outcomes. Outcomes include consumer behavior, business performance, and brand-level effects. Moderators account for contextual and user-based variability, while temporal dynamics explain how AR's influence changes over time. In summary, this extended theoretical framework and conceptual model demonstrate that AR in e-commerce has entered a new phase of theoretical convergence, where technology, behavior, and business outcomes are deeply intertwined. Together, they shape an augmented consumer experience — a central paradigm for future AR research in the era of immersive and interactive digital commerce.

## *5.3 Practical Implications*

From a practical perspective, the findings offer several important managerial implications for e-commerce firms, technology developers, and policy makers. For e-commerce businesses, AR opens new opportunities to redefine the shopping experience by combining emotional engagement with visual product demonstration. Companies can adopt AR try-on, visual preview, or AR-based store navigation applications to enhance consumer trust, reduce product

return rates, and increase conversion rates. Moreover, integrating AR into interactive marketing strategies enables brands to create stronger emotional connections with customers compared to traditional advertising. This model demonstrates, for the first time, that the geographical distribution of academic publications can reflect distinct theoretical orientations: European research clusters tend to emphasize theoretical development and consumer behavior, whereas Asian studies focus more on technological applications and practical innovation

In addition to making scholarly contributions, the study offers practical managerial recommendations that assist e-commerce businesses in making the most of AR technology. In particular, four areas of strategic action are suggested:

(1) AR-based Personalization: E-commerce firms should leverage dynamic personalization capabilities by combining behavioral data and consumer preferences. Integrating AR with AI recommender systems allows products to be displayed according to the user's size, style, or specific needs. Moreover, the implementation of smart AR try-on features enables users to visualize products in their real environment while receiving automatic suggestions for alternative or complementary items.

(2) Ethical and Transparent AR Design: As consumers become increasingly concerned about privacy, companies should design ethical-by-design AR interfaces that prioritize transparency and user control. Provide clear notifications when visual or facial data are collected, and allow users to customize the level of data sharing in compliance with regulations such as GDPR or Vietnam's Personal Data Protection Decree.

(3) Sustainability-focused AR Design: AR can serve as a tool to promote green consumption and reduce environmental impact.Companies should Develop AR simulations for eco-friendly products, helping consumers visualize their positive environmental effects; utilize AR to replace physical displays or in-person trials, reducing material waste and costs; and employ AR experiences to educate consumers about product lifecycles and recycling practices.

(4) Holistic AR Performance Metrics

Instead of evaluating AR solely through technical indicators, firms should adopt holistic performance measurement that captures emotional, behavioral, and strategic impacts. Develop integrated KPIs encompassing emotional engagement, AR interaction time, AR content sharing rate, and customer loyalty index; employ real-time dashboards to monitor feedback and optimize AR campaigns dynamically.

For technology developers, the study highlights a growing trend of integrating AR with Industry 4.0 technologies such as Artificial Intelligence (AI), Big Data, and the Internet of Things (IoT). The combination of AR and AI not only enhances personalization capabilities but also optimizes e-commerce operations, including demand forecasting, product simulation, and virtual customer support. Technology providers should focus on developing flexible AR platforms that ensure cross-system compatibility and deliver seamless multi-channel user experiences. For policy makers, the study recommends establishing regulatory frameworks that foster innovation in AR, particularly concerning data security, user privacy, and standardization of AR content in advertising. Additionally, governments should encourage investment in R&D related to computer vision and machine learning technologies, thereby facilitating the development of a sustainable AR-driven e-commerce ecosystem aligned with national digital transformation goals.

## *5.4 Limitations and Future Research*

Although this study provides several valuable insights, it is not without limitations, which in turn open promising avenues for future research. First, regarding data scope, the study relies solely on the Scopus database; therefore, it may not fully capture the comprehensive academic landscape of the field. Integrating additional sources such as Web of Science (WoS), IEEE Xplore, or Dimensions in future studies would provide a more holistic and balanced perspective—particularly in technical and industrial application contexts. Second, concerning methodological approach, bibliometric analysis is primarily quantitative, and thus may not fully reflect the conceptual depth of the research content. Future studies could combine qualitative methods, such as content analysis or expert interviews, to validate and further elaborate the thematic clusters identified in this work. Third, this study lacks empirical evidence to test the actual effects of AR on purchase behavior, brand trust, or business performance. Future research should therefore adopt experimental designs or apply structural equation modeling (SEM or PLS-SEM) to verify and quantify the relationships among key variables. Finally, the study has not yet explored in depth the issues of sustainability and digital ethics, where topics such as digital fatigue, privacy risk, and green AR commerce remain underrepresented. These areas represent promising directions for future inquiry, contributing to the responsible and sustainable evolution of AR technology in modern e-commerce. To systematize these directions, the study proposes a Future Research Framework in figure 9 with eight key orientations for the next phase of AR in e-commerce research: (1) AI–AR integration to optimize interactivity and personalization; (2) Personalization and transparency, combining AI with explainability (Explainable AI) while ensuring privacy protection; (3) Ethical design and data security, moving toward a model of "responsible AR"; (4) Cultural and contextual differences, examining moderating factors influencing AR adoption across countries and consumer groups; (5) Business effectiveness, assessing AR's impact on revenue, return rates, and brand value through empirical data; (6) Longitudinal and practical research, tracking the long-term effects of AR on brand loyalty and user experience; (7) Measurement standardization, developing unified evaluation criteria for AR experiences in e-commerce; and (8) Policy and sustainability, focusing on data governance, environmental impact, and legal frameworks supporting green technological innovation.

Overall, this study clarifies the developmental trajectory of AR in e-commerce, tracing its transformation from a supportive technology to a strategic business tool. The findings not only expand academic understanding but also offer practical guidance for businesses, policymakers, and scholars to design effective AR strategies aligned with the

broader trends of digital transformation and experience-driven consumption in the new era.

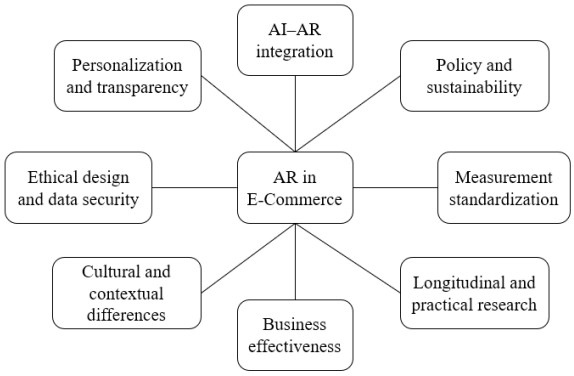


**Figure 9.** Future research framework.

# 6. CONCLUSION

This study employs bibliometric analysis to systematically organize and comprehensively evaluate the body of scientific literature on Augmented Reality (AR) technology in the field of e-commerce. The dataset comprises 610 publications from the period 2014–2024, extracted from the Scopus database, with a total of 10,262 citations and an average annual growth rate of 24.97%. These findings indicate that AR is emerging as one of the core technologies driving digital transformation strategies in e-commerce. The bibliometric analysis provides significant theoretical and practical contributions, helping to shape future research directions and guide the application of AR in the digital economy era.

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# CONFLICT OF INTEREST

The authors affirm that this research was conducted independently, with no commercial or financial connections that might be viewed as potential conflicts of interest.

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