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Knowledge Structure of Augmented Reality for Sustainable Development in E-Commerce

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ABSTRACT

Augmented reality (AR) is increasingly examined as a digital technology for supporting sustainable development in e-commerce, yet evidence remains fragmented across consumer, informational, and operational domains. This study maps the intellectual structure, thematic evolution, and sustainability-related evidence of this research field. A science mapping review and structured content synthesis were conducted using 59 publications indexed in the Web of Science Core Collection. Performance analysis, keyword and trend-topic analysis, and bibliographic coupling were employed to examine publication patterns, conceptual development, and knowledge structures. The findings show rapid publication growth after 2023 and identify six knowledge clusters spanning digital transformation, virtual try-on and consumer adoption, phygital decision support, green consumption, product returns, and logistics and traceability. Evidence remains predominantly consumer-oriented, with 35 studies (59.3%) concentrated in consumer-related clusters, whereas only six (10.2%) directly address returns, logistics, traceability, and operational sustainability. Overall, the literature provides more consistent evidence of AR's effects on information processing and consumer decision-making than of its effects on measurable environmental outcomes. Its contribution to sustainable e-commerce therefore appears context-dependent and mediated through behavioural, informational, and operational mechanisms. Future research should prioritize observable outcomes related to product returns, waste, resource use, energy consumption, emissions, and lifecycle performance.

1. INTRODUCTION

E-commerce research has primarily examined transactional behaviours such as purchase frequency, spending levels, return rates, and customer retention [1-3]. However, with the rapid evolution of digital technologies, consumer behaviour in online environments is increasingly understood as a multidimensional process encompassing cognitive evaluations, experiential responses, and behavioural intentions [4-6]. The expansion of e-commerce has intensified environmental concerns, particularly those associated with excessive product returns, packaging waste, and resource consumption [7]. These challenges have become increasingly important within the broader sustainability transition, especially under the Sustainable Development Goals (SDGs), which emphasise responsible production and consumption. In the context of e-commerce, these sustainability concerns extend across several specific domains, including responsible consumption, product-return and waste prevention, circularity and reuse, sustainability information and transparency, traceability, and operational and resource efficiency. Selected applications may also relate to socio-cultural sustainability, although this remains a comparatively peripheral stream. Although digital commerce offers considerable opportunities to support these sustainability domains, the available evidence remains uneven across environmental, behavioural, operational, and socio-cultural outcomes [6, 8, 9].

In response to these challenges, digital commerce has evolved through successive waves of technological innovation, including big data analytics, machine learning, and AI, which have significantly enhanced firms' capabilities in prediction, personalisation, and operational efficiency [2]. However, despite these advances, such technologies primarily operate at the analytical and algorithmic level. As a result, they remain limited in addressing a fundamental constraint of e-commerce, the lack of sensory richness and product tangibility, which often leads to consumer uncertainty and suboptimal decision-making [10].

To address these limitations, immersive technologies have emerged as an important enabler of digital commerce by narrowing the gap between online and offline shopping experiences [11]. Among them, Augmented Reality (AR) enables consumers to visualise and interact with digital product representations within real-world environments, including through virtual try-on applications, thereby improving product evaluation and reducing purchase

uncertainty [10]. Beyond enhancing customer experience, recent studies suggest that AR may contribute to sustainability-related outcomes by reducing unnecessary purchases and product returns, facilitating interactive sustainability communication through eco-labels and product transparency, and supporting more responsible consumption decisions [3, 12-14].

In this study, the sustainability relevance of AR is therefore examined across responsible consumption and decision quality, return and waste prevention, circularity and reuse, sustainability communication and transparency, traceability, and operational and resource efficiency. These domains provide a more specific basis for evaluating where AR may contribute to sustainable e-commerce and where empirical evidence remains limited.

Despite the rapid growth of studies on AR, e-commerce, and sustainability, existing review studies remain fragmented. Previous reviews have examined AR and VR in retail marketing [14], immersive technologies in sustainable consumption [4], consumer-related outcomes of AR [13], sustainability marketing applications [6], and the contribution of immersive technologies to the SDGs [15]. However, none provides a comprehensive synthesis of how AR has been examined across the specific sustainability domains of responsible consumption, product returns and waste, circularity, sustainability communication, traceability, and operational sustainability within e-commerce. Consequently, current knowledge remains dispersed across consumer behaviour, digital marketing, retail technology, and sustainability research, making it difficult to determine which sustainability domains are relatively well supported, which rely mainly on consumer-level evidence, and which remain underdeveloped.

Against this background, a systematic synthesis of AR-enabled sustainability in e-commerce is both timely and necessary. Beyond consolidating existing evidence, this review develops an integrated understanding of where and through which mechanisms AR is associated with sustainability-related outcomes across consumer, circular, informational, operational, and environmental domains. Specifically, this study makes three contributions. First, it consolidates fragmented evidence on AR across the main sustainability domains identified in e-commerce, including responsible consumption, return and waste prevention, circularity and reuse, sustainability communication and transparency, and operational and traceability-related outcomes. Second, it maps the intellectual structure, thematic evolution, and emerging research frontiers of this rapidly expanding research domain. Third, it identifies the uneven distribution of evidence across these sustainability domains, distinguishing consumer-level and behavioural outcomes from more direct operational and environmental measures, and develops a future research agenda accordingly. Accordingly, this study addresses the following research questions:

RQ1: How has research on sustainability performance in e-commerce through AR evolved in terms of publication performance, influential contributors, and collaboration patterns?

RQ2: What are the major intellectual themes and knowledge structures shaping research on sustainability performance in e-commerce through AR?

RQ3: What future research directions can advance sustainability performance in e-commerce through AR?

Answering these questions provides a systematic understanding of the evolution, intellectual foundations, and future trajectory of AR-enabled sustainability research in e-commerce. The findings provide an evidence-based foundation for researchers, practitioners, and policymakers seeking to understand the role of AR in responsible consumption, return and waste prevention, circularity, sustainability communication, traceability, and operational sustainability in e-commerce.

2. MATERIALS AND METHODS

2.1 Bibliometric approach

This study adopts a bibliometric approach to examine the development of research on sustainability performance in e-commerce through AR. A bibliometric review is a quantitative method that applies statistical analysis of a large volume of bibliographic resources, such as review papers, articles, and books [16]. The study follows the PRISMA 2020 framework introduced by Page et al. [17]. The overall research design and literature screening procedure are illustrated in Figure 1.

2.2 Data collection

The dataset was retrieved from the Web of Science Core Collection (WoSCC) on 19 September 2026, using its standardized bibliographic records for scholarly publications. To ensure that the retrieved studies simultaneously addressed AR, e-commerce, and sustainability, the search was conducted in the Topic (TS) field, covering titles, abstracts, and author keywords. The following search strategy was employed:

TS = ("augmented reality" OR "AR shopping" OR "augmented reality shopping" OR "web augmented reality" OR "web-based augmented reality" OR "mobile augmented reality" OR "augmented reality retail") AND (e-commerce OR ecommerce OR "electronic commerce" OR "online shopping" OR "online retail*" OR "digital commerce" OR retail* OR shopping) AND (sustainab* OR "sustainability performance" OR "sustainable consumption" OR "responsible consumption" OR "environmentally responsible" OR "environmental sustainability" OR "circular economy" OR "waste reduction" OR "return reduction" OR "product return*" OR "carbon footprint" OR "carbon emission*" OR SDG* OR "Sustainable Development Goal*").*

The search identified 83 records. To improve the consistency and academic quality of the dataset, only journal articles and review papers published in English were retained. Other document types, including conference proceedings, book chapters, editorial materials, notes, and meeting abstracts, were excluded [18, 19]. This step reduced the dataset from 83 to 73 records.

Following the principles of bibliometric content analysis and systematic relevance assessment outlined by Klarin [20], the remaining 73 records were manually screened by three authors using predefined inclusion and exclusion criteria. Titles and abstracts were independently examined to determine whether each study substantively addressed the intersection of AR, e-commerce or retail-related contexts, and sustainability-related issues, rather than merely mentioning these concepts incidentally. Studies without a meaningful connection to the review scope were excluded. Any differences in screening judgments were discussed among the authors until consensus was reached. This process excluded 14

records, resulting in a final dataset of 59 publications used for the subsequent bibliometric and structured content analyses.

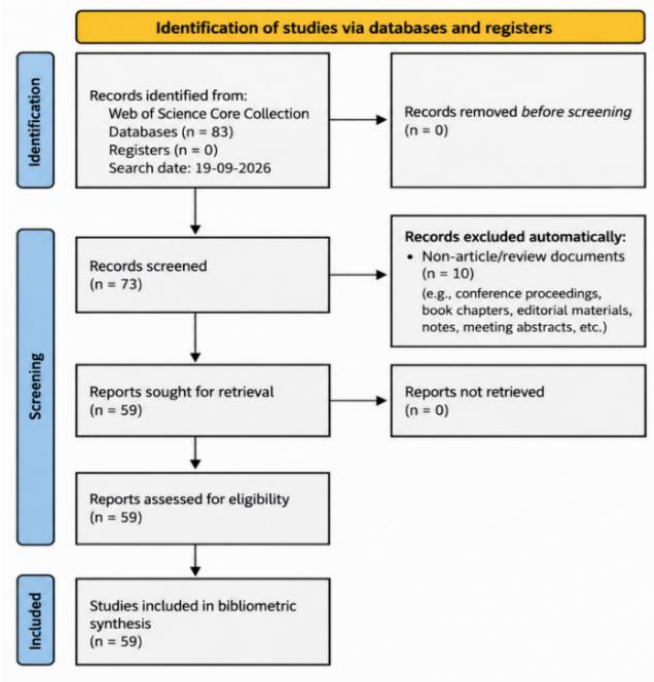


Figure 1. PRISMA 2020 flow diagram of the study

2.3 Data analysis

The analysis was conducted in three sequential stages. First, a performance analysis was conducted to describe the overall development of the field using publication trends, leading journals, country contributions, and highly cited publications. These indicators provide an overview of the productivity and scientific influence of research on sustainability performance in e-commerce through AR.

Second, Biblioshiny was used to explore the field's conceptual development [21]. Word Cloud analysis identified the most frequently occurring keywords, while Trend Topics analysis illustrated the temporal evolution of research interests and emerging themes over time.

Third, the intellectual structure of the field was examined using bibliographic coupling analysis in VOSviewer [22]. By clustering publications according to shared reference patterns, bibliographic coupling identifies closely related studies and reveals the major knowledge domains that underpin the contemporary research landscape. Compared with co-citation analysis, bibliographic coupling is better suited to emerging research fields because it captures current research fronts rather than historical intellectual foundations [23]. The combined application of performance analysis, Biblioshiny, and VOSviewer provides complementary perspectives on the productivity, conceptual evolution, and intellectual structure of the literature, ensuring a comprehensive understanding of sustainability performance in e-commerce through AR.

3. RESULTS

3.1 Performance analysis

3.1.1 Publication and citation trends

A total of 59 publications on AR and sustainable development in e-commerce were identified in the Web of Science Core Collection. As shown in Figure 2, annual publication output increased markedly over the study period, from 2 articles in 2020 to 4 in 2021, 3 in 2022, 7 in 2023, and 9 in 2024, before rising to 17 articles in both 2025 and 2026. The sharp increase after 2023 indicates growing scholarly attention to the intersection of AR, e-commerce, and sustainability, although the 2026 figure should be interpreted as representing an incomplete publication year.

Citation patterns show a different temporal distribution. Publications from 2021 received the highest total number of citations (260), followed by those published in 2022 (186) and 2023 (164). Articles published in 2025 had accumulated 133 citations, while those from 2024 received 90 citations. The lower citation count for 2026 (26 citations) is consistent with its shorter citation window. Overall, the citation profile suggests that studies published during the earlier phase of the field have had more time to accumulate scholarly influence, while the continued growth in publication output since 2023 reflects an expanding research base.

The temporal pattern also indicates a shift in the scale of research activity. Earlier studies were relatively limited in number, whereas the substantial increase in publications during 2024–2026 suggests broader engagement with AR-enabled applications in sustainable e-commerce. Rather than demonstrating a complete thematic transition by itself, the annual production trend provides evidence of the field's increasing visibility and diversification, which is examined further through the keyword, trend-topic, and cluster analyses in the following sections.

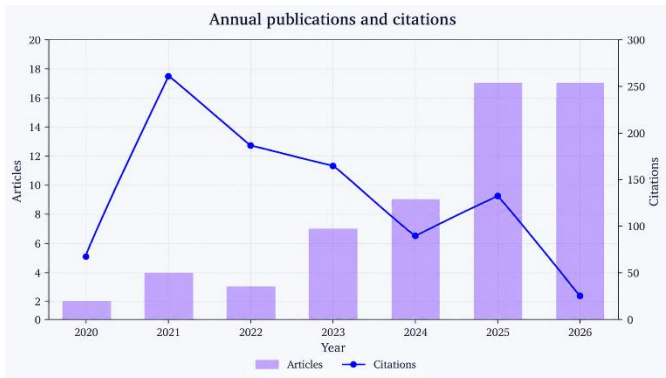


Figure 2. Publication and citation trends

3.1.2 Source contributions

As shown in Figure 3, the 59 publications were distributed across a diverse set of journals. *Sustainability* was the most productive source with 11 publications, accounting for 18.6% of the dataset. It was followed by the *Journal of Retailing and Consumer Services* with 4 publications and the *Journal of Business Research* with 3. The *International Journal of Consumer Studies*, *International Journal of Retail & Distribution Management*, and *Sustainable Futures* each contributed 2 publications, while the remaining leading sources contributed one article each.

The source distribution indicates that research on AR and sustainable e-commerce is published across sustainability, marketing, consumer behaviour, and retailing outlets rather than being concentrated within a single disciplinary domain. Although *Sustainability* remains the most prominent outlet, contributions from journals such as the *Journal of Retailing and Consumer Services* and the *Journal of Business Research*

also highlight the strong consumer- and retail-oriented character of the field. Overall, the publication pattern reflects the interdisciplinary positioning of AR research at the intersection of digital commerce, consumer behaviour, and sustainability.

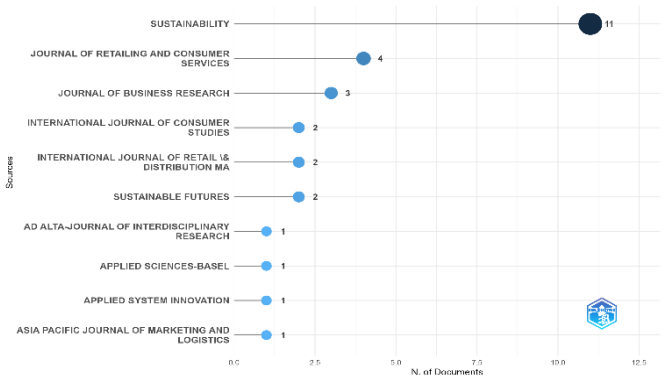


Figure 3. Top 10 relevant sources

3.1.3 Country contribution

Country-level analysis identified contributions from 27 countries, indicating a geographically diverse but uneven research landscape. As shown in Figure 4, China was the leading contributor with 14 articles (24.1%), followed by India with 6 (10.3%). Germany, Italy, Malaysia, Poland, and the United Kingdom each contributed 3 articles (5.2%), while Canada, France, and Spain each produced 2 (3.4%). The remaining countries contributed one publication each.

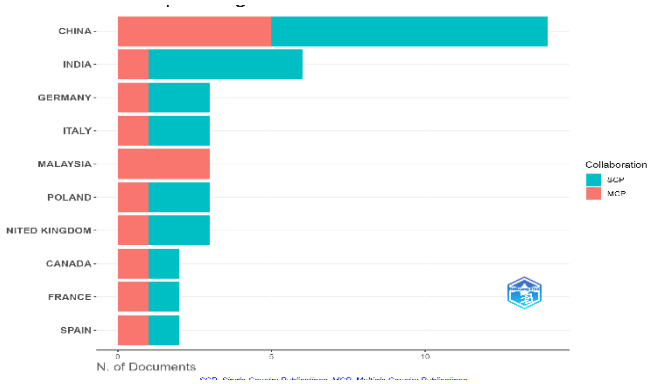


Figure 4. Country contribution and collaboration map

The single-country publications)–multi-country publications (SCP–MCP) distribution also indicates varying levels of international collaboration. China produced 9 SCP and 5 MCP, corresponding to an MCP ratio of 35.7%. Malaysia recorded three MCP publications and no SCP publications, although this pattern is based on a relatively small publication base. Germany, Italy, Poland, and the United Kingdom each reported an MCP share of 33.3%, while Canada, France, and Spain reached 50%. Overall, the results suggest that research on AR and sustainable e-commerce involves contributions from multiple national contexts, with China and India accounting for the largest shares of output and international collaboration varying considerably across countries.

3.2 Keyword dynamics

The word cloud (Figure 5) shows that AR is the most frequent keyword, appearing 32 times, followed by e-commerce (11), sustainability (10), virtual reality (6), and consumer behaviour (5). Other recurring terms include consumer and virtual try-on (4 each), as well as artificial intelligence, bibliometric, and consumer experience (3 each). This distribution confirms that AR constitutes the central technological focus of the literature, while e-commerce and sustainability represent its two main application and outcome domains. The prominence of consumer-related terms and virtual try-on further indicates that much of the research remains oriented toward consumer experience, product evaluation, and technology-enabled shopping. At the same time, the presence of artificial intelligence and related digital technologies suggests an emerging integration of AR within broader digital commerce ecosystems. Overall, the keyword structure reflects a field that connects AR primarily with e-commerce applications, consumer-oriented mechanisms, and increasingly with sustainability-related concerns.



Figure 5. Word cloud

The Trend Topics analysis (Figure 6) provides a temporal view of how the main research themes developed between 2022 and 2026. *Sustainability* (Frequency = 10) shows the earliest temporal profile, extending from 2022 (Q1) to 2025 (Q3), with a median year of 2024. *E-commerce* (9) follows a similar pattern, concentrated between 2023 and 2025, while *virtual reality* (6) is primarily associated with the 2024–2025 period. These patterns indicate that sustainability and digital-commerce contexts formed an important early foundation for research linking immersive technologies with e-commerce.

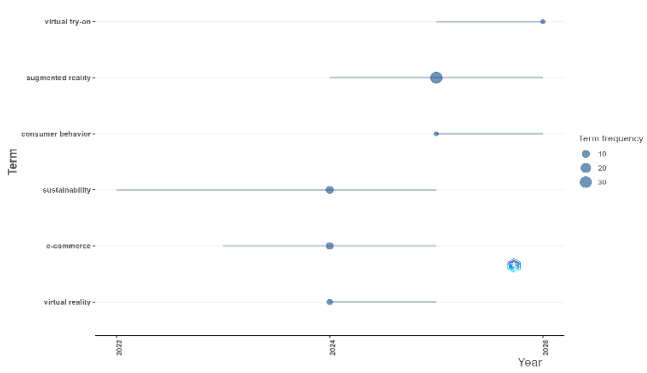


Figure 6. Trend topics

More recent topics focus on AR-enabled consumer applications. *AR*, the most frequent term (32), has a median year of 2025 and spans 2024 to 2026, indicating its sustained prominence in recent literature. *Consumer behaviour* (5) is concentrated between 2025 and 2026, while *virtual try-on* (4) has the latest temporal profile, with a median year of 2026. Overall, the temporal distribution suggests a gradual movement from broad sustainability and e-commerce themes toward more specific AR-enabled consumer applications, particularly consumer behaviour and virtual try-on. Rather than indicating a complete thematic replacement, the results suggest increasing specialization within the field as AR research becomes more closely connected with consumer

decision-making and immersive shopping applications.

3.3 Intellectual structure based on bibliographic coupling

To capture the intellectual structure of the entire research corpus, bibliographic coupling analysis was conducted with the minimum citation threshold set to zero, allowing all 59 publications to be included in the network (Figure 7) and subsequently grouped into six clusters based on their shared reference patterns.

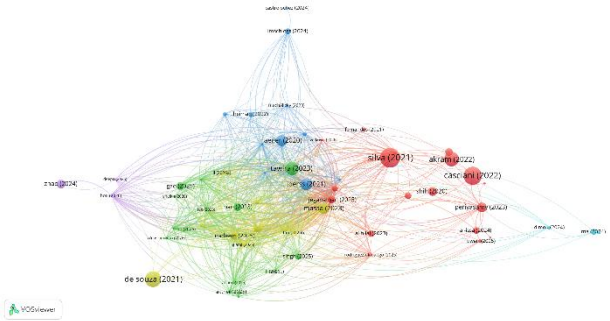


Figure 7. Bibliographic coupling network

Cluster 1. Digital transformation, digital twins, and sustainable commerce ecosystems (18 articles, 469 citations)

Cluster 1 represents the broadest technological stream, positioning *AR* within the wider *digital transformation* of commerce and value creation. Studies increasingly integrate AR with *digital twins*, *AI*, *IoT*, *blockchain*, *Industry 4.0*, and the *metaverse* to support product visualization, process digitalization, traceability, and new digital business models, particularly in fashion, retail, and manufacturing [24-27]. From a sustainability perspective, these technologies can support virtual prototyping, shorter development cycles, improved resource use, and more transparent product information. Recent applications such as *Digital Product Passports* further connect AR with product sustainability disclosure, reuse, and lifecycle information [28]. Overall, this cluster frames AR as part of a broader *sustainable digital commerce ecosystem*. However, much of the evidence remains conceptual or sector-specific, with limited direct measurement of *energy use*, *material savings*, *emissions*, and *waste reduction*.

Cluster 2. Virtual try-on, telepresence, and sustainable consumer adoption (14 articles, 122 citations)

Cluster 2 examines how *virtual try-on (VTO)* and immersive shopping technologies influence consumer decisions through *telepresence*, *trust*, *fit confidence*, *personalisation*, *perceived value*, and *immersion*. Drawing on theories such as *TAM*, *UTAUT*, *S-O-R*, and interactive-media frameworks, studies show that AR can reduce product uncertainty and improve consumers' confidence in online purchasing [29-32].

These mechanisms are relevant to sustainability because better product evaluation may reduce inappropriate purchases and *product returns*. Nevertheless, the effects are not uniformly sustainable. While some studies associate VTO with improved decision quality and return reduction, others show that immersive experiences can stimulate *purchase intention* and *impulse buying* [33]. Thus, the cluster reveals an important tension between *decision efficiency* and possible *consumption rebound effects*. More research is needed to determine whether avoided returns offset the environmental effects of increased purchasing.

Cluster 3. AR-enabled decision support and sustainable phygital retail (11 articles, 126 citations)

Cluster 3 focuses on AR and related digital technologies as tools for *decision support* in physical, digital, and *phygital retail* environments. Applications include *AR recommendation agents*, *digital signage*, *virtual dressing rooms*, *energy labels*, and platform technologies designed to improve information access, product evaluation, and responsible purchasing.

Empirical findings indicate that AR can increase consumers' attention to sustainability information and, under specific conditions, encourage the selection of more sustainable products [34]. However, stronger visual attention does not necessarily translate into sustainable purchases, as demonstrated by research comparing AR-based displays with conventional digital communication [35]. Other studies link phygital technologies with lower uncertainty, improved decision quality, and potentially fewer product returns. Overall, this cluster positions AR as a *sustainability-oriented decision-support mechanism*, although evidence based on actual environmental outcomes remains limited.

Cluster 4. AR-enabled green consumption and sustainability marketing (10 articles, 161 citations)

Cluster 4 examines how AR strengthens *sustainability marketing* and *green consumption* by making environmental information more visible, personally relevant, and emotionally engaging. Key mechanisms include *self-proximity*, *anticipated warm glow*, *anticipated pride*, *social proof*, and *social visibility*, which can influence green product choices and environmentally responsible intentions [6, 36].

The cluster also extends beyond communication to practical sustainability applications. AR combined with real-time information can support *food-waste reduction*, surplus-food purchasing, and improved resource management [37]. Overall, AR appears particularly effective in translating abstract sustainability information into engaging consumer experiences. Yet most studies continue to measure *attitudes*, *engagement*, and *purchase intention* rather than actual reductions in waste, resource consumption, or environmental impacts.

Cluster 5. Product returns, transparency, and platform coordination in sustainable e-commerce (3 articles, 28 citations)

Cluster 5 addresses *product returns* as a central sustainability challenge in e-commerce. Studies examine how AR, *information transparency*, return policies, and platform–seller coordination can improve pre-purchase information and reduce unnecessary reverse flows.

Existing evidence suggests that improved transparency can reduce information asymmetry, while AR adoption may lower returns under particular conditions involving *return costs*, technology effectiveness, and platform pricing [38, 39]. Consumer-level evidence similarly indicates that enhanced AR visualization can influence return behaviour [40]. This cluster therefore provides a direct connection between AR and *sustainable reverse logistics*. However, its small knowledge base and limited measurement of *transport emissions*, *packaging waste*, and return disposition indicate a clear need

for further empirical research.

Cluster 6. AR-enabled logistics, traceability, and operational sustainability (3 articles, 19 citations)

Cluster 6 shifts AR research from consumer-facing applications toward *logistics*, *traceability*, and *operational sustainability*. AR is combined with *spatial computing*, *digital twins*, and other digital technologies to improve information visibility, product tracking, resource management, and supply-chain transparency, particularly in food systems and distribution operations [41, 42].

Importantly, this cluster contains some of the clearest quantitative sustainability evidence. Using *Life Cycle Assessment (LCA)* and *Life Cycle Costing (LCC)*, Yan et al. [43] showed that AR implementation in an express distribution center can improve picking efficiency, reduce operating costs, and lower *Global Warming Potential*, while also revealing environmental burdens associated with AR hardware. Thus, this cluster moves from perceived sustainability benefits toward *measurable operational performance*. Nevertheless, with only three studies, broader validation across industries and supply-chain contexts remains necessary.

4. DISCUSSION

4.1 Synthesis of key findings

The structured synthesis of the 59 studies reveals a field that is gradually extending from technology adoption and immersive consumer experience toward sustainability-related applications in e-commerce. As summarized in Table 1, the six clusters differ substantially in theoretical orientation, research design, context, and sustainability outcomes. Across these differences, three broad patterns emerge: the evidence remains concentrated at the consumer level; sustainability effects are generally indirect rather than intrinsic to AR; and direct evidence on environmental and operational outcomes remains comparatively scarce.

First, the literature is strongly oriented toward consumer decision processes. Clusters 2–4, covering virtual try-on and consumer adoption, decision support and phygital retail, and green consumption and sustainability marketing, account for 35 of the 59 studies (59.3%). Across these clusters, recurring mechanisms include telepresence, immersion, trust, fit confidence, perceived value, decision comfort, self-proximity, and anticipated positive emotions. Collectively, these studies suggest that AR may improve the way consumers access, interpret, and interact with product and sustainability information. However, most reported outcomes concern adoption, intention, confidence, engagement, or product choice rather than environmental performance itself.

Second, the sustainability relevance of AR appears to operate mainly through intermediate behavioural, informational, or operational mechanisms. Virtual try-on may reduce uncertainty before purchase; sustainability-oriented AR may increase the salience of environmental information; and integration with Digital Product Passports, digital twins, or traceability systems may improve access to product and lifecycle information. These mechanisms can be relevant to return prevention, reuse, responsible consumption, and operational efficiency, but the sustainability outcome depends on whether the intermediate changes translate into observable downstream effects.

This distinction is particularly visible in Clusters 5 and 6. Together, the two clusters addressing product returns, reverse flows, traceability, logistics, and operational sustainability contain only six studies (10.2% of the corpus). Several provide evidence closer to actual behaviour or operations, but direct measurement of waste, energy consumption, transport emissions, resource use, or lifecycle impacts remains uncommon. Yan et al. [43], for example, used LCA and LCC to examine environmental and economic performance in parcel distribution, providing a relatively direct assessment compared with studies based primarily on perceptions or intentions.

Finally, the findings do not indicate that greater use of AR is necessarily associated with better sustainability outcomes. Improved product evaluation may help reduce mismatched purchases or returns, while immersive environments may also stimulate additional purchasing or impulse buying. Similarly, AR can make sustainability information more visible without necessarily changing actual product choices. Hardware, computing requirements, information credibility, and possible rebound effects further complicate the relationship.

Overall, the literature provides stronger evidence that AR can influence information processing and consumer decision-making than that it produces measurable environmental benefits. Its contribution to sustainable e-commerce therefore appears to be context-dependent and mediated by how AR is designed, what mechanism it activates, and which downstream outcome is considered.

4.2 Theoretical implications

The findings offer three related theoretical implications. First, established adoption and consumer-behaviour theories such as TAM, UTAUT/UTAUT2, S-O-R, and related frameworks remain useful for explaining consumers' responses to AR, but they capture only part of its sustainability relevance. The cross-cluster evidence suggests that these perspectives can be complemented by an affordance–mechanism–outcome logic. AR affordances such as virtual visualization, information augmentation, traceability, and spatial guidance may activate psychological, informational, or operational mechanisms that subsequently influence behavioural and sustainability-related outcomes.

Accordingly, the integrative framework developed from this review distinguishes among three analytical levels: AR affordances, intervening mechanisms, and outcomes. Psychological mechanisms include telepresence, trust, fit confidence, self-proximity, and anticipated emotions; informational mechanisms include transparency, sustainability disclosure, and decision support; and operational mechanisms include product matching, traceability, picking accuracy, and return management. This structure does not imply a single causal pathway but provides a common basis for interpreting otherwise heterogeneous findings across the six clusters.

Second, the synthesis highlights the importance of distinguishing proximal responses from downstream sustainability performance. Purchase confidence, green purchase intention, reuse intention, and favourable sustainability perceptions may precede more sustainable behaviour, but they should not be treated as equivalent to reductions in returns, waste, emissions, or resource consumption. Studies using actual shopping behaviour, platform data, return records, or lifecycle indicators therefore

address a different level of evidence from studies based primarily on perceptions and intentions.

Third, AR is more appropriately treated as a potentially sustainability-enabling capability than as an inherently sustainable technology. Its effects appear to depend on product characteristics, user responses, information quality, implementation conditions, and possible rebound or technological burdens. This perspective places boundary conditions around claims of sustainability and connects AR research more directly with consumer behaviour, circular economy, sustainable operations, and digital sustainability research.

Table 1. Integrative synthesis of theoretical, methodological, and sustainability insights across six clusters

Cluster	Theoretical Lenses / Key Mechanisms	Methods and Research Contexts	Sustainability-Related Findings
C1. Digital transformation, digital twins, and sustainable commerce ecosystems	Where explicitly reported: ELM, Expectancy Disconfirmation Theory, Rebound Theory, and ESG-oriented framing; recurring mechanisms include digital transformation, digital twins, metaverse, Digital Product Passports, and immersive interaction.	Highly heterogeneous: reviews, bibliometric studies, conceptual frameworks, quantitative consumer studies, qualitative interviews/focus groups, and technical AR applications. Main contexts include fashion, luxury retail, virtual commerce, cultural heritage, and tourism.	The literature links AR and related immersive technologies with sustainable fashion, digital product information, reuse intentions, digital transformation, and cultural preservation. DPP-related AR can improve decision comfort and reuse intentions, while heritage applications illustrate a possible contribution to cultural sustainability.
C2. Virtual try-on, telepresence, and sustainable consumer adoption	TAM, UTAUT/UTAUT2, S-O-R, Norm Activation Model, Privacy Calculus Theory, and other consumer-behaviour perspectives; telepresence, trust, fit confidence, perceived value, and immersion.	Mainly quantitative consumer studies using surveys and SEM, with some mixed-method and hybrid analytical designs. Contexts concentrate on fashion, mobile shopping, VTO, and immersive/metaverse retail.	VTO and immersive AR generally improve product evaluation, fit confidence, trust, adoption, and decision quality. Some studies explicitly associate improved product selection with fewer returns or lower return-related waste.
C3. AR-enabled decision support and sustainable phygital retail	Affordance Actualization Theory, Construal-Level Theory, and experience-oriented perspectives; information provision, decision support, and technology affordances.	Includes field experiments, longitudinal platform data, surveys/SEM, conceptual work, and studies of phygital environments. Contexts include grocery retail, e-commerce platforms, household appliances, retail services, and omnichannel/phygital consumption.	AR-based sustainability information can influence actual shopping decisions, while digital platform affordances may reduce observed product returns. Field evidence also shows that increased attention to AR does not necessarily increase sustainable-product sales.
C4. AR-enabled green consumption and sustainability marketing	Construal-Level Theory, Social Influence Theory, TAM and customer-journey perspectives; self-proximity, anticipated warm glow, social proof, and anticipated pride.	Experiments, survey studies, mixed-method scale development, case-based research, meta-analysis, systematic/bibliometric reviews. Contexts include green products, sustainable fashion, food waste, and immersive retail.	Evidence suggests that AR can make sustainability information more salient and personally relevant. Experimental studies identify warm glow and anticipated pride as mechanisms associated with green-product and sustainable-fashion responses. Digital applications are also discussed in relation to food-waste reduction and circular practices.
C5. Product returns, transparency, and platform coordination in sustainable e-commerce	Theory of Planned Behaviour, game-theoretic and supply-chain coordination perspectives; information transparency, return policies, return-cost allocation.	One cross-sectional PLS-SEM study and two analytical/game-theoretic models. Contexts focus on online product returns, marketplace platforms, and new/remanufactured-product supply chains.	The studies associate AR or greater information transparency with lower return behaviour or model conditions under which returns can be reduced. Coordination mechanisms may also improve platform/seller outcomes.
C6. AR-enabled logistics, traceability, and operational sustainability (3 articles; 19 citations)	Traceability, spatial computing, digital twins, and LCA/LCC rather than a dominant behavioural theory.	Prototype/usability evaluation, review synthesis, and LCA/LCC-based analysis. Contexts include food supply chains, food traceability, and parcel distribution.	AR and spatial-computing applications are associated with improved traceability, information visibility, resource management, and logistics performance. Emerging evidence also suggests potential environmental and economic benefits in distribution operations, although the empirical base remains limited.

4.3 Managerial implications

For e-commerce firms, the findings suggest that AR performance can be assessed beyond conventional engagement and conversion metrics. In categories with high uncertainty or return rates, firms could also monitor product-selection accuracy, return frequency, return-related costs, and customer confidence. Virtual try-on and enhanced visualization may be particularly relevant where incorrect fit or product expectations contribute to returns.

AR may also serve as an interface for sustainability and lifecycle information, provided that the information is credible and decision-relevant. Evidence concerning Digital Product Passports and AR recommendation interfaces suggests potential value in presenting information on product origin, materials, durability, repair, reuse, and other traceable attributes [28, 34]. Such information should be verifiable rather than relying primarily on immersive presentation, because greater attention to sustainability claims does not necessarily lead to more sustainable purchasing.

Operational applications warrant a similarly outcome-oriented approach. Emerging evidence from parcel distribution, food traceability, and spatial computing indicates possible applications in picking, sorting, product tracking, and information visibility [41-43]. Given the small evidence base, firms should evaluate these applications through context-specific operational and environmental indicators before drawing broader sustainability conclusions.

4.4 Future research directions

First, research should move further from proximal consumer responses toward observable downstream outcomes. Longitudinal platform data, transaction records, field experiments, return records, logistics data, and lifecycle assessment could be used to examine whether AR-assisted decisions are associated with changes in actual returns, reverse logistics activity, packaging waste, resource use, energy consumption, or emissions. Following products beyond the point of purchase would also clarify possible effects on refurbishment, resale, remanufacturing, recycling, and disposal.

Second, future studies should assess the net effects of AR rather than examining benefits and costs separately. Potential reductions in mismatched purchases, physical trials, or inefficient operations could be evaluated alongside changes in purchase frequency, computing demand, hardware requirements, and other rebound effects. Such designs would provide a more balanced assessment of when AR-related efficiency gains correspond to net sustainability improvements.

Third, greater attention is needed to information governance and technological integration. Emerging applications combining AR with Digital Product Passports, digital twins, AI, blockchain, and traceability systems raise questions regarding information quality, interoperability, privacy, claim verification, transparency, and perceived greenwashing. Research could examine which combinations of technologies and governance mechanisms improve both information usefulness and credibility.

Finally, the generalizability of current findings remains uncertain. Much of the empirical evidence is drawn from fashion, retail, and other consumer-facing contexts, whereas logistics, food supply chains, and other operational settings remain less developed. Comparative studies across product categories, industries, countries, and institutional environments could test whether identified mechanisms remain stable under different levels of return risk, perishability, material intensity, technological readiness, and regulatory pressure. Greater use of field, longitudinal, and multi-level designs could also strengthen evidence on how consumer-level AR effects connect with firm- and supply-chain-level sustainability outcomes.

5. CONCLUSION

This review shows that AR is increasingly being examined beyond its conventional role as an immersive shopping technology. Across the 59 studies, its relevance to e-commerce sustainability is concentrated in several areas: responsible consumption and decision quality, return and waste prevention, circularity and reuse, sustainability communication and transparency, traceability, and operational efficiency. A smaller stream also considers socio-cultural applications. The literature is strongest in explaining consumer-level mechanisms, including improved product evaluation, reduced uncertainty, and more informed decision-making, whereas direct assessments of returns, waste, resource use, emissions, and lifecycle impacts remain comparatively scarce. AR is therefore better understood as a context-dependent enabling capability whose contribution varies with the application, mechanism, and outcome considered.

This study has several limitations. The analysis was restricted to publications indexed in the Web of Science Core Collection, so relevant studies available only in Scopus, Dimensions, or other sources may have been omitted. Only English-language journal articles and reviews were included, excluding conference proceedings, books, non-English publications, and grey literature. Although bibliometric analysis was complemented by structured content synthesis, the review did not undertake formal quality appraisal or meta-analysis. Given the rapid development of AR and related technologies, future studies could broaden database coverage and employ longitudinal, field-based, meta-analytic, and lifecycle approaches to assess observable behavioural, operational, and environmental outcomes.

Taken together, the findings reveal uneven maturity across sustainability-related applications of AR in e-commerce. Consumer decision-making and sustainability communication are relatively well represented, whereas return reduction, circular flows, traceability, resource efficiency, and environmental performance remain less developed. This distinction provides a focused basis for future theoretical and empirical research on the conditions under which AR can contribute to more sustainable e-commerce practices.

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