

## A Bibliometric Systematic Review of Blockchain Integration in E-commerce with Emphasis on Data Privacy and Supply Chain Transparency

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### Abstract

Driven by digital transformation and evolving consumer behavior, the e-commerce industry continues to grow rapidly across global markets. Blockchain, as an emerging technology, offers transformative potential for e-commerce operations due to its transparency, security, decentralization, and traceability features. These attributes enable improvements in areas such as data privacy, supply chain traceability, fraud prevention, and operational efficiency. However, the adoption and integration of blockchain in e-commerce remain in a nascent stage, with significant technological and regulatory hurdles yet to be overcome. This paper conducts a systematic review of blockchain applications in e-commerce with emphasis on data privacy and supply chain transparency by utilizing bibliometric techniques. All relevant publications indexed in the Scopus database were examined to extract and analyze keywords and themes. Additionally, VOSviewer software was employed to visualize co-authorship, keyword co-occurrence, and thematic clusters. Findings reveal that blockchain contributes to various domains within e-commerce, including data security, supply chain transparency, sector-specific applications, and integration with emerging technologies such as AI and IoT. Key drivers for blockchain adoption include improved traceability, automation, and fraud prevention, while barriers such as scalability, regulatory uncertainty, and high implementation costs continue to hinder widespread integration. The study offers valuable implications for both academic researchers and industry practitioners seeking to adopt blockchain for enhancing e-commerce performance.

**Keywords:** blockchain; e-commerce; privacy; supply chain; transparency

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## 1. Introduction

In recent years, the rapid advancement of digital technologies has significantly transformed the landscape of global commerce (Capocasale et al., 2025). Among these innovations, blockchain technology has emerged as a powerful tool with the potential to reshape various industries, including e-commerce. As e-commerce platforms continue to expand across borders, they face growing challenges related to data privacy, security, and supply chain transparency (Jaison & Janaki, 2024). Blockchain, with its decentralized, immutable, and transparent characteristics, offers promising solutions to these concerns (Agarwal et al., 2024). Despite its potential, however, the integration of blockchain technology into e-commerce—particularly in the domains of data privacy and supply chain management—remains an underexplored area in academic research. E-commerce involves the digital exchange of goods and services and relies heavily on the secure and efficient handling of information (Shukla et al., 2024). With increasing consumer concerns about data breaches, fraud, and unauthorized access to personal information, data privacy has become a critical issue in the digital marketplace (Mohit et al., 2024). Traditional systems often fall short in ensuring data integrity and user control. Blockchain technology, through its cryptographic and decentralized features, provides a framework that can enhance data privacy by enabling users to manage and share data securely without reliance on centralized

intermediaries (Budler et al., 2024). These features position blockchain as a potentially transformative force in addressing privacy concerns within the e-commerce ecosystem.

Another pressing challenge in e-commerce is achieving transparency in the supply chain. Consumers and businesses alike demand greater visibility into the origin, handling, and movement of products (Wong et al., 2024; Kang et al., 2024). Conventional supply chain systems often suffer from fragmentation, delays, and a lack of real-time information, which can lead to inefficiencies and mistrust. Blockchain enables real-time, tamper-proof tracking of goods across the supply chain, enhancing traceability, accountability, and trust among stakeholders (Duong et al., 2024). Smart contracts further facilitate automated, transparent transactions based on predefined conditions, reducing reliance on third parties and minimizing disputes.

While the theoretical and practical benefits of blockchain are widely acknowledged, a consolidated body of knowledge specifically focused on its implementation in e-commerce—particularly regarding data privacy and supply chain transparency—is still developing. Existing studies are often fragmented, with varying scopes, contexts, and methodologies. Some focus on the technical aspects of blockchain architecture, while others explore its potential applications across industries without delving into the unique requirements of e-commerce. Furthermore, limited attention has been given to cross-border e-commerce, which presents additional complexities related to regulatory differences, international standards, and logistical challenges. These gaps underscore the need for a comprehensive review that synthesizes current research and provides a clearer picture of blockchain's role in e-commerce supply chains.

This study aims to systematically review the existing literature on the integration of blockchain technology within e-commerce, with a specific focus on data privacy and supply chain transparency. Despite the growing interest in blockchain, current research remains limited regarding its application in managing e-commerce supply chains, particularly in cross-border contexts. By analyzing relevant scholarly works, this review seeks to consolidate the state-of-the-art knowledge and identify key trends, gaps, and future research directions in blockchain-enabled e-commerce supply chain management. The study seeks to answer key questions: How is blockchain being applied to enhance data privacy in e-commerce? What are the prevailing models and frameworks for using blockchain in transparent supply chain management? What are the key technological, organizational, and regulatory barriers influencing the adoption of blockchain in e-commerce, and how do these challenges shape future research directions? What are the emerging research directions and practical implications of these developments?

Ultimately, this review contributes to both academic scholarship and practical decision-making by highlighting the current state of research, identifying persistent challenges, and suggesting avenues for future investigation. As blockchain technology continues to mature, understanding its evolving role in e-commerce is essential for researchers, policymakers, and practitioners seeking to design secure, efficient, and transparent digital commerce environments. The findings of this review aim to provide a foundation for advancing blockchain applications that not only meet current demands but also anticipate the future needs of a rapidly transforming global marketplace.

## **2. Techniques of Blockchain**

### **2.1. Distributed Ledger Technology (DLT)**

Distributed Ledger Technology (DLT) refers to a decentralized database architecture that records transactions across multiple computers, ensuring data is shared, synchronized, and immutable (Farahani et al., 2021). In contrast to traditional centralized databases managed by a single authority, DLT distributes the control and validation processes across a network of nodes. Each participant in the network holds a copy of the ledger, which updates automatically when new transactions occur. This mechanism enhances transparency, traceability, and trust among stakeholders. In the context of e-commerce, DLT ensures that all transactional records are permanently logged and cannot be tampered with, which is critical for establishing consumer trust and verifying transaction authenticity (Li & Kassem, 2021). Furthermore, in supply chain management, DLT facilitates end-to-end visibility of goods movement, inventory tracking, and supplier accountability. The

origin and movement of a product, such as pharmaceuticals or luxury goods, can be tracked on a DLT system to prevent counterfeiting and ensure quality control. Additionally, DLT is essential in cross-border e-commerce scenarios, where multiple parties across jurisdictions interact. It eliminates the need for intermediaries, reduces transaction costs, and accelerates processing times (Antal et al., 2021). Blockchain, a popular implementation of DLT, uses cryptographic techniques and consensus algorithms to secure data and validate transactions without centralized control. Despite its benefits, DLT faces challenges including scalability limitations, energy consumption, and interoperability with legacy systems. Moreover, regulatory uncertainties and data privacy laws (such as GDPR) may impact DLT deployment in different regions (Zhou et al., 2022). Nevertheless, ongoing research and technological advancements aim to address these limitations and further unlock the potential of DLT in transforming e-commerce ecosystems. As such, understanding DLT's fundamental role is crucial to grasping how blockchain can enhance data integrity and transparency in the digital commerce landscape.

## 2.2. Smart Contracts

Smart contracts are self-executing digital agreements encoded on a blockchain that automatically carry out predefined actions once specific conditions are met (Taherdoost, 2023). These contracts eliminate the need for intermediaries, significantly reducing transaction costs and enhancing operational efficiency. Introduced with the Ethereum blockchain, smart contracts operate using a "code is law" principle, meaning the contractual terms are written in computer code rather than traditional legal language. In e-commerce, smart contracts facilitate secure and automated transactions between buyers and sellers (Hewa et al., 2021). A smart contract can automatically release payment to a seller once the buyer confirms receipt of goods (Khan et al., 2021). This minimizes the risk of fraud and disputes while improving customer satisfaction. Similarly, in supply chain operations, smart contracts can streamline processes such as order fulfillment, inventory management, and delivery verification by automating workflows and ensuring compliance with agreed terms. Another advantage is that smart contracts operate on a trustless system (Balcerzak et al., 2022). Parties do not need to trust each other but rather trust the code, which executes impartially based on input data. This is particularly beneficial in cross-border transactions where legal frameworks may vary and traditional enforcement mechanisms are limited or costly. Despite their promise, smart contracts face several technical and legal challenges (Lin et al., 2022). Bugs in code can lead to unintended consequences, as demonstrated by high-profile failures like the DAO hack. Additionally, legal enforceability remains a grey area, particularly in jurisdictions that do not recognize code-based agreements. Integrating smart contracts with existing enterprise systems and ensuring data accuracy from external sources (via oracles) are also ongoing concerns. Nevertheless, as e-commerce platforms increasingly adopt blockchain, smart contracts are poised to become foundational elements in automating trust, ensuring transparency, and enhancing the overall efficiency of digital transactions and supply chain networks.

## 2.3. Consensus Mechanisms

Consensus mechanisms are protocols used in blockchain networks to achieve agreement among distributed nodes about the validity of transactions. These mechanisms ensure data integrity and prevent fraud, even when participants do not trust one another (Lashkari & Musilek, 2021). They are foundational to maintaining the decentralized nature of blockchain by replacing central authorities with algorithmic verification processes. One of the earliest and most well-known consensus mechanisms is Proof of Work (PoW), where participants (miners) solve complex mathematical puzzles to validate transactions and add new blocks to the chain (Zhou et al., 2023). While secure, PoW is energy-intensive and has scalability limitations. In contrast, Proof of Stake (PoS) selects validators based on the number of tokens they hold and are willing to "stake" as collateral, making it more energy-efficient. In e-commerce, consensus mechanisms guarantee the authenticity and finality of transactions. Once a transaction is confirmed through consensus, it becomes immutable, reducing the risk of fraud and double-spending (Xie et al., 2023). This is particularly important in online commerce, where trust and transparency are critical for building consumer confidence. In supply chain contexts, consensus mechanisms help verify the accuracy of product movement records, supplier updates, and inventory statuses. By reaching consensus across all stakeholders, discrepancies are minimized, and the reliability of supply chain data is enhanced (Yadav et al., 2023). Advanced consensus protocols like Practical Byzantine Fault Tolerance

(PBFT) and Delegated Proof of Stake (DPoS) are also being explored for supply chain applications due to their speed and lower energy demands. However, choosing an appropriate consensus mechanism depends on the specific use case, desired performance metrics, and security requirements. Trade-offs between decentralization, scalability, and security must be carefully evaluated. As blockchain technology evolves, hybrid and customized consensus protocols are emerging to better meet the diverse needs of e-commerce and supply chain ecosystems.

#### 2.4. Cryptographic Hashing

Cryptographic hashing is a fundamental technique in blockchain technology used to ensure data integrity and security (Rahardja et al., 2021). A hash function transforms input data into a fixed-length alphanumeric string (called a hash or digest), which uniquely represents the original data. Even a slight change in the input produces a drastically different hash, making it extremely difficult to reverse-engineer the original data or manipulate records undetected. In a blockchain, each block contains a hash of the previous block, linking them together to form a chain (Velmurugadass et al., 2021). This structure ensures that tampering with one block would require recalculating the hashes of all subsequent blocks, which is computationally infeasible in a decentralized network. As a result, cryptographic hashing provides tamper-evident logs of all transactions. In e-commerce, hashing secures customer data, transaction records, and payment information. Hashed passwords prevent exposure of sensitive login credentials (Ali et al., 2023). In supply chain management, hashes can be used to create digital fingerprints of shipment data, certificates, and product information, ensuring authenticity and enabling rapid verification. Additionally, hashing supports data verification without revealing the original content (Kuznetsov et al., 2021). This is particularly valuable in privacy-sensitive applications such as health data sharing, digital identity verification, and compliance auditing. Combined with Merkle trees, a data structure that efficiently summarizes large datasets using hashes, blockchain can verify massive volumes of e-commerce or supply chain transactions with minimal computational effort. Despite its advantages, cryptographic hashing must be used correctly to avoid vulnerabilities. Choosing a secure hash function (e.g., SHA-256 or SHA-3) and managing keys properly are critical. Overall, cryptographic hashing remains a pillar of blockchain security, supporting trustworthy and verifiable digital ecosystems.

#### 2.5. Privacy-Preserving Techniques

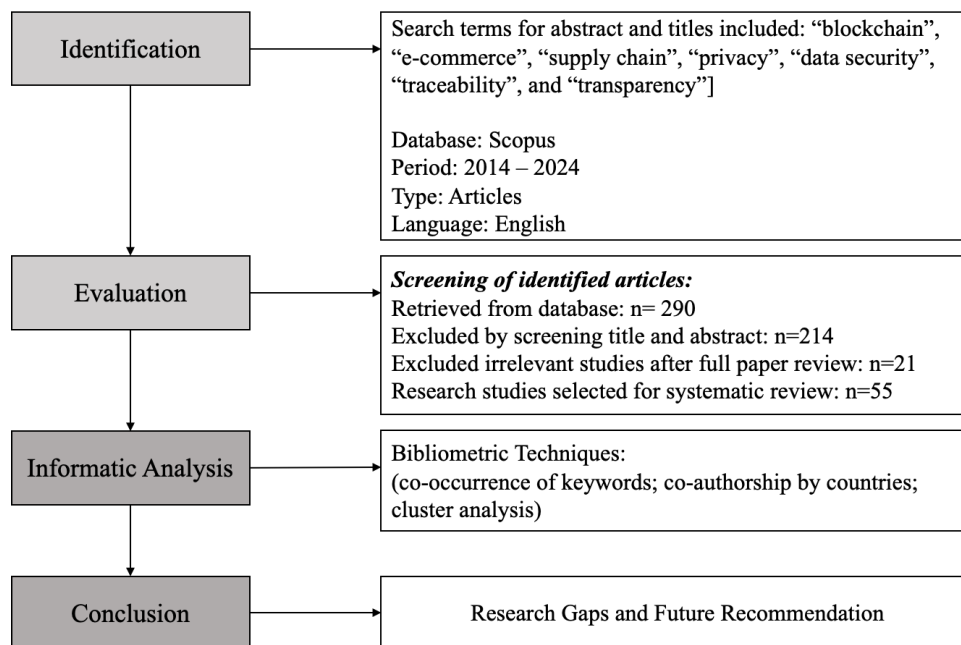
Privacy-preserving techniques are essential for protecting sensitive data in blockchain applications, especially in e-commerce and supply chain domains where customer information, transaction records, and proprietary business data must be secured (Gami et al., 2023). Unlike public blockchains where data is visible to all participants, privacy-preserving methods enable selective disclosure and confidentiality while retaining the transparency and auditability of blockchain (Kumar et al., 2021). One key technique is Zero-Knowledge Proofs (ZKPs), which allow a party to prove the validity of a statement without revealing the underlying data. In e-commerce, ZKPs can verify customer eligibility or transaction authenticity without disclosing personal information. Differential Privacy, another method, introduces statistical noise into datasets to protect individual identities while enabling aggregate analysis. Decentralized identity (DID) solutions use blockchain to give users control over their personal data. Instead of relying on centralized identity providers, individuals store encrypted credentials in a blockchain wallet and share only the necessary information with e-commerce platforms. This enhances user privacy and reduces the risk of identity theft or data breaches. For supply chain transparency, privacy-preserving techniques balance traceability with confidentiality (Valadares et al., 2023). Businesses may need to verify product origins without exposing competitive information such as supplier identities or pricing. Techniques like confidential transactions and homomorphic encryption allow data computations without revealing the raw data, supporting privacy in collaborative environments. However, integrating privacy-preserving techniques with blockchain poses technical and legal challenges. They often increase computational complexity and may affect system scalability. Additionally, compliance with data protection regulations like GDPR requires careful design to ensure that immutable blockchain records do not violate the right to erasure (Sameera et al., 2024). Despite these challenges, privacy-preserving innovations are critical to expanding blockchain's adoption in sensitive areas of digital commerce and supply chain logistics. They enable trust and compliance without compromising data confidentiality.

### 3. Methodology

This study employed a systematic literature review (SLR) approach to consolidate existing scholarly work on the integration of blockchain technology in e-commerce, with a particular focus on data privacy and supply chain transparency. The systematic review method was chosen due to its structured and replicable nature, enabling the researcher to comprehensively identify, analyze, and synthesize relevant academic literature. The Scopus database was selected as the primary source of data because of its extensive coverage of peer-reviewed journals in the fields of computer science, business, management, and information systems. Scopus also offers advanced search functionalities and robust filtering options, which made it an ideal platform for locating high-quality and thematically aligned studies.

#### 3.1. Quality Assurance and Review Validity

To enhance the reliability and validity of the review process, the PRISMA guidelines were followed throughout (Figure 1). This included maintaining transparency in article selection, employing reproducible search logic, and clearly reporting the exclusion rationale (Sarkis-Onofre et al., 2021). Each stage of the review was cross-checked to ensure consistency and minimize bias. By relying on Scopus as a single, high-quality source and by focusing on articles that directly engage with blockchain's application in e-commerce systems—especially in relation to data protection and supply chain operations—the study ensures the credibility of its synthesized findings. The resulting body of literature serves as a reliable foundation for identifying trends, research gaps, and directions for future inquiry in this evolving interdisciplinary field.



**Figure 1.** PRISMA Flowchart.

#### 3.2. Search Terms and Inclusion Criteria

The search strategy involved the use of carefully designed Boolean queries combining keywords related to blockchain and its role in e-commerce systems. Key terms included: “blockchain”, “e-commerce”, “supply chain”, “privacy”, “data security”, “traceability”, and “transparency”, among others. These terms were selected based on their frequent appearance in foundational and emerging research within the domain. The Boolean logic used in the query ensured the capture of articles that intersect multiple concepts central to the review (Ashkenasy & Ghadiri, 2004). Filters were applied to include only peer-reviewed journal articles published between 2014 and 2024. Furthermore, only articles written in English, categorized under the subject areas of computer science and business, and labeled as “final” publication stage were included. This ensured both the relevance and academic rigor of the selected studies.

### 3.3. Screening and Selection Process

The initial search retrieved a total of 290 articles from the Scopus database. A two-phase screening process was then applied to refine the selection. In the first phase, duplicate entries were removed and abstracts were reviewed to assess thematic alignment with blockchain integration in e-commerce, particularly concerning privacy and supply chain transparency. In the second phase, full-text readings were conducted to ensure that each selected study made a significant conceptual or empirical contribution to the themes under investigation. Articles were excluded if they focused solely on technical aspects of blockchain without connecting to e-commerce applications or failed to address the core issues of privacy and traceability. In total, 55 articles were ultimately selected for inclusion in this study.

### 3.4. Bibliometric Analysis

Bibliometric analysis is a widely accepted quantitative method that utilizes statistical tools to investigate the structure, development, and trends within a particular field of research. It emphasizes external features of academic publications—such as keywords, citations, and authorship patterns—to provide a structural overview of knowledge production and intellectual connectivity (Donthu et al., 2021; Akram et al., 2023). In the context of this study, bibliometric analysis was employed to examine the academic landscape surrounding blockchain integration in e-commerce, with a particular focus on data privacy and supply chain transparency.

The bibliometric data were extracted from the Scopus database, which is recognized for its extensive and multidisciplinary coverage of peer-reviewed literature. To conduct the bibliometric analysis and create visual maps of the research domain, VOSviewer software was used. Developed by the Centre for Science and Technology Studies at Leiden University, VOSviewer is a specialized tool that allows the construction of bibliometric networks and the visualization of relationships between various research entities, such as keywords, authors, and institutions (Akram & Nasar, 2023). The software transforms similarity matrices into two-dimensional spatial maps, enabling researchers to identify key themes, collaboration patterns, and emerging clusters in the literature (Arruda et al., 2022). This visualization supports a comprehensive understanding of how blockchain is being explored in e-commerce, especially concerning issues of privacy and supply chain traceability.

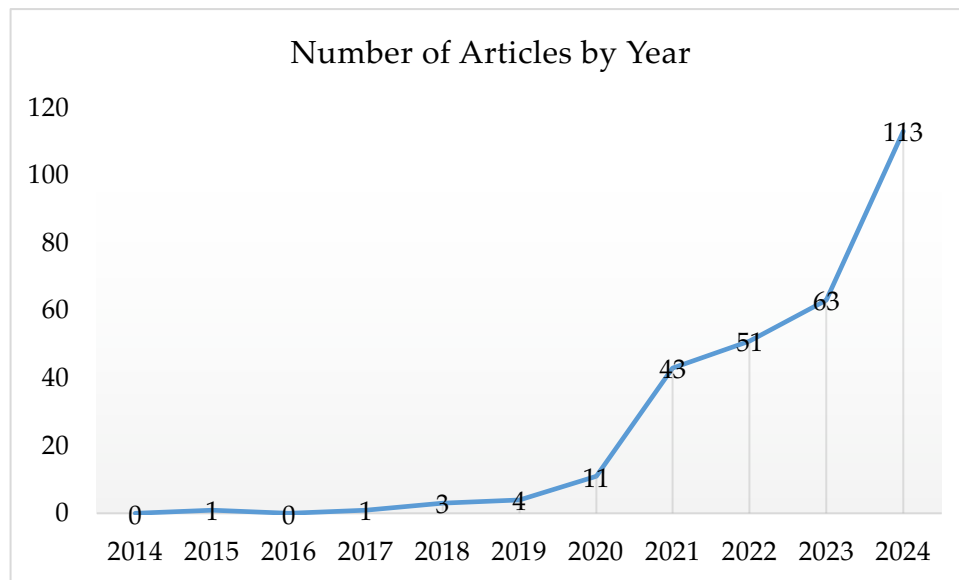
A central component of the bibliometric analysis involved co-word analysis. This technique focuses on the frequency and co-occurrence of keywords within the selected literature to identify conceptual linkages and thematic structures. Co-word analysis helps uncover how different topics are interrelated and which terms appear most frequently together, offering insights into the core research areas and their evolution over time. By analyzing these patterns, the study identified major thematic concentrations, including blockchain applications in decentralized identity, compliance with data protection regulations, and the use of distributed ledger technology in real-time supply chain monitoring. The co-word mapping conducted through VOSviewer provided a visual representation of these relationships, contributing to the identification of dominant topics and gaps in the existing body of research.

### 3.5. Data Extraction and Thematic Categorization

Following the screening, eligible articles were subjected to a rigorous data extraction process. A structured coding sheet was developed to capture relevant bibliographic and thematic information from each study. This included the publication year, research objectives, methodological approach, application area, geographic focus, and key findings. The collected data were then subjected to thematic analysis to identify major areas of research concentration. The thematic synthesis allowed the organization of the literature into eight overarching domains: blockchain fundamentals in e-commerce, data privacy and security, supply chain transparency and traceability, integration with emerging technologies, sector-specific applications, trust and adoption behavior, sustainability in supply chains, and identified challenges with future research directions.

#### 4. Results

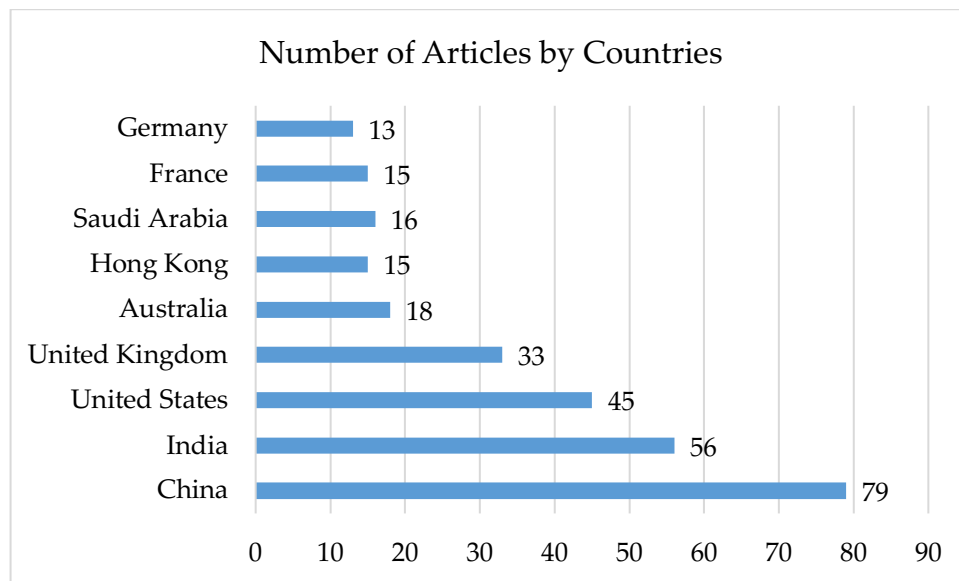
The initial data search retrieved in the Figure 2 reveals a clear and accelerating growth in scholarly interest concerning blockchain integration in e-commerce, particularly with a focus on data privacy and supply chain transparency. From 2014 to 2016, there was almost no published research on the topic, with only one article appearing in 2015. This reflects the nascent stage of blockchain technology and its limited recognition within the e-commerce and academic communities during that period. Beginning in 2017, there was a modest uptick, with one publication, followed by gradual increases in 2018 (3 articles) and 2019 (4 articles). This growth indicates a rising awareness and curiosity among researchers about the potential applications of blockchain in business and supply chain contexts. The year 2020 marked a noticeable shift, with the number of publications jumping to 11, likely driven by the global disruptions caused by the COVID-19 pandemic, which exposed the vulnerabilities in supply chains and emphasized the need for secure, transparent systems. The years 2021 and 2022 witnessed significant surges in research output, with 43 and 51 articles respectively. This sharp rise suggests that blockchain was transitioning from a theoretical concept to a viable solution for real-world challenges in e-commerce, particularly as digital transformation accelerated worldwide. The momentum continued in 2023, reaching 63 articles, and peaked dramatically in 2024 with 113 publications. This latest spike indicates that blockchain has become a mainstream research focus, drawing attention from scholars across disciplines such as information systems, business, logistics, and law.



**Figure 2.** Articles published by year.

The initial data search retrieved in Figure 3 reveals the geographical distribution of scholarly contributions to the study of blockchain integration in e-commerce, with a particular emphasis on data privacy and supply chain transparency. China leads the way with 79 publications, reflecting its strong commitment to advancing digital technologies, especially in areas like logistics, manufacturing, and e-commerce. This dominance is consistent with China's national strategy to become a global leader in blockchain and related technologies. India follows closely with 56 articles, showcasing its rapidly growing research community and interest in leveraging blockchain for improving digital commerce and addressing challenges related to data security and transparency. The significant contribution from India also highlights the country's strategic emphasis on digital innovation and fintech applications. The United States ranks third with 45 publications, indicating its sustained interest in blockchain's transformative potential. While the U.S. has traditionally led technological innovation, the slightly lower count compared to China and India may reflect a more cautious regulatory environment or diversified research interests across broader domains. The United Kingdom, with 33 articles, and Australia, with 18, represent active contributors from the Western academic sphere. Their research likely focuses on governance, legal implications, and enterprise applications of blockchain in supply chain systems. Notably, the inclusion of Hong Kong (15 articles) and Saudi Arabia (16 articles) signals increasing engagement from regions investing heavily in smart infrastructure and digital transformation, especially within trade and logistics sectors. France and Germany, each contributing 15 and 13 articles respectively, demonstrate the

European Union's continued interest in blockchain's role in secure data practices and its alignment with privacy regulations such as GDPR.



**Figure 3.** Articles published by countries.

Table 1 showcasing the top 10 journals by number of articles published on blockchain integration in e-commerce highlights the interdisciplinary nature of this research domain as per initial data search. IEEE Access leads with 17 articles, indicating the journal's openness to cutting-edge, technology-focused research and its appeal to scholars working on applied aspects of blockchain technology, including its deployment in e-commerce platforms and supply chains. Computers and Industrial Engineering follows with 10 articles, reflecting the strong alignment between blockchain technology and industrial operations, especially in optimizing supply chain systems. The inclusion of IEEE Transactions on Engineering Management (9 articles) suggests a growing scholarly interest in exploring blockchain from a strategic and managerial standpoint, emphasizing its role in innovation management and operational efficiency within e-commerce settings. The International Journal of Information Management, with 6 publications, further underscores the importance of information governance, data security, and digital infrastructure in blockchain-related studies. This journal often features research that connects technological advancement with organizational processes, making it a suitable outlet for examining privacy and data handling in blockchain-based e-commerce. Journals such as Blockchain: Research and Applications, Business Strategy and the Environment, and Electronics (Switzerland), each with 5 articles, suggest that blockchain research spans specialized domains — from purely technical perspectives to its environmental and strategic implications. The presence of Cluster Computing (4 articles) also indicates that computational efficiency and network-based systems are essential areas of study, especially when analyzing decentralized ledgers and smart contracts. Lastly, Benchmarking and Electronic Commerce Research and Applications, each publishing 3 articles, highlight the evaluative and practical focus of blockchain in real-world e-commerce applications. These journals emphasize performance metrics, system comparisons, and customer-facing innovations, reinforcing the applied nature of research in this field.

**Table 1.** Top 10 journals with the number of articles published.

| Journals                                        | Articles |
|-------------------------------------------------|----------|
| IEEE Access                                     | 17       |
| Computers and Industrial Engineering            | 10       |
| IEEE Transactions on Engineering Management     | 9        |
| International Journal of Information Management | 6        |
| Blockchain: Research and Applications           | 5        |
| Business Strategy and the Environment           | 5        |
| Electronics (Switzerland)                       | 5        |
| Cluster Computing                               | 4        |
| Benchmarking                                    | 3        |
| Electronic Commerce Research and Applications   | 3        |

The analysis of the top 10 most cited articles in the domain of blockchain applications in supply chain and e-commerce reflects the scholarly community's focus on foundational, comprehensive, and empirically-driven research in Table 2. The most cited article by Dutta et al. (2020), published in *Transportation Research Part E*, has received 1,069 citations, indicating its critical contribution in outlining applications, challenges, and future research directions of blockchain in supply chain operations. This paper serves as a cornerstone in the field, offering both theoretical grounding and practical insights. The second most cited work by Kouhizadeh et al. (2021), with 888 citations, explores barriers to blockchain adoption in sustainable supply chains. Its high citation count reflects the growing interest in sustainability and the need for theoretical exploration of implementation challenges. Similarly, the paper by Queiroz and Wamba (2019), with 790 citations, empirically investigates adoption drivers in India and the USA, providing valuable cross-country insights that appeal to both academia and industry. Wong et al. (2020) appears twice in the top 10, with studies focused on Malaysian SMEs and adoption determinants, cited 561 and 313 times, respectively. This emphasizes the significance of regional and organizational contexts in understanding blockchain integration. The work by Bai and Sarkis (2020), with 493 citations, introduces a technology appraisal model for evaluating blockchain in terms of sustainability and transparency, showcasing a strategic and evaluative approach. The inclusion of Berdik et al. (2021), who conducted a survey on blockchain's role in information systems and security (466 citations), highlights the relevance of data protection and management in current discussions. Other significant contributions include Frizzo-Barker et al. (2020) with a systematic review on blockchain as a disruptive business technology, and Lim et al. (2021), who analyzed thematic and methodological trends. Liu and Li (2020) round off the list with a specific focus on cross-border e-commerce supply chains, reinforcing blockchain's importance in global logistics. Collectively, these articles underscore the field's evolving priorities around adoption, sustainability, transparency, and security.

**Table 2.** Top 10 most cited articles.

| Sources                      | Title                                                                                                                                        | Journals                                                            | Citations by Scopus |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------|
| (Dutta et al., 2020)         | Blockchain technology in supply chain operations: Applications, challenges and research opportunities                                        | Transportation Research Part E: Logistics and Transportation Review | 1069                |
| (Kouhizadeh et al., 2021)    | Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers                                            | International Journal of Production Economics                       | 888                 |
| (Queiroz & Wamba, 2019)      | Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA                          | International Journal of Information Management                     | 790                 |
| (Wong et al., 2020)          | Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs                   | International Journal of Information Management                     | 561                 |
| (Bai & Sarkis, 2020)         | A supply chain transparency and sustainability technology appraisal model for blockchain technology                                          | International Journal of Production Research                        | 493                 |
| (Berdik et al., 2021)        | A Survey on Blockchain for Information Systems Management and Security                                                                       | Information Processing and Management                               | 466                 |
| (Frizzo-Barker et al., 2020) | Blockchain as a disruptive technology for business: A systematic review                                                                      | International Journal of Information Management                     | 424                 |
| (Wong et al., 2020)          | Unearthing the determinants of Blockchain adoption in supply chain management                                                                | International Journal of Production Research                        | 313                 |
| (Lim et al., 2021)           | A literature review of blockchain technology applications in supply chains: A comprehensive analysis of themes, methodologies and industries | Computers and Industrial Engineering                                | 303                 |
| (Liu & Li, 2020)             | A blockchain-based framework of cross-border e-commerce supply chain                                                                         | International Journal of Information Management                     | 290                 |

The analysis of keyword occurrences using VOSviewer software provides valuable insights into the central themes and conceptual structure of the literature on blockchain in e-commerce and supply chain contexts in Table 3. The keyword "Blockchain" appeared most frequently with 128 occurrences and the highest total link strength of 603, signifying its dominant role and strong association with other research terms. Interestingly, a variation in spelling, "Block-chain," also emerged with 109 occurrences and a total link strength of 538, indicating that both forms are commonly used interchangeably in the literature, albeit they refer to the same concept. The keywords "Supply chain" (44 occurrences) and "Supply chain management" (46 occurrences) reflect the substantial attention given to blockchain applications in logistics and operational processes. Their

significant total link strengths of 238 and 186, respectively, further demonstrate strong connections to other thematic areas within the research field. "Distributed ledger" and "Smart contract" also feature prominently, highlighting the technical backbone of blockchain and its use in automating and verifying transactions. Keywords like "Data privacy" (17), "Privacy" (18), and "Security" (14) reveal a critical concern among researchers about the protection of information and secure transactions in blockchain-enabled systems. Similarly, "Transparency" (13) and "Decentralized" (16) underline two of the most touted benefits of blockchain technology. Other notable terms include "Internet of things" (18), suggesting its intersection with blockchain for real-time data sharing in supply chains, and "Sales" (20), which points toward the technology's potential to enhance commercial activities. The keyword co-occurrence analysis indicates a strong focus on blockchain's technical mechanisms, security and privacy implications, and its integration within supply chain and e-commerce operations.

**Table 3.** Occurrences of keywords by VOSviewer.

| No | Keywords                | Number of Occurrences | Total Link Strength |
|----|-------------------------|-----------------------|---------------------|
| 1  | Blockchain              | 128                   | 603                 |
| 2  | Block-chain             | 109                   | 538                 |
| 3  | Supply chain            | 44                    | 238                 |
| 4  | Supply chain management | 46                    | 186                 |
| 5  | Distributed ledger      | 21                    | 125                 |
| 6  | Smart contract          | 19                    | 115                 |
| 7  | Blockchain technology   | 19                    | 112                 |
| 8  | Data privacy            | 17                    | 107                 |
| 9  | Sales                   | 20                    | 98                  |
| 10 | Information management  | 17                    | 96                  |
| 11 | Privacy                 | 18                    | 96                  |
| 12 | Internet of things      | 18                    | 93                  |
| 13 | Security                | 14                    | 87                  |
| 14 | Transparency            | 13                    | 87                  |
| 15 | Decentralized           | 16                    | 85                  |

Based on the keywords gathered by the authors, a co-word analysis diagram was generated (see Figure 4). Co-word analysis, as a method of content analysis, effectively illustrates the frequency with which keywords appear together and helps uncover the underlying network of relationships within the dataset. Hence, five cluster appeared in the co-word analysis.

Cluster 1: "Blockchain Security and Privacy Infrastructure", this cluster emphasizes the technical and security foundations of blockchain technology. Keywords such as access control, cryptography, cybersecurity, data privacy, decentralized, and distributed ledger indicate that research in this cluster is primarily concerned with protecting data and ensuring secure transactions in digital environments. The inclusion of privacy-preserving technologies, smart contract, and internet of things suggests a focus on developing systems that balance automation and data protection. This cluster also highlights blockchain's role in securing ecommerce and digital storage systems, making it a central theme in infrastructure design.

Cluster 2: "Technology Adoption and Market Dynamics", this cluster represents the economic, managerial, and adoption-related aspects of blockchain in digital commerce. Keywords like commerce, costs, competition, sales, supply chain management, and marketing reflect business-related concerns, while technology acceptance model and technology adoption point to theoretical approaches used to examine how blockchain is embraced in organizational settings. Terms such as digital technologies, internet, and game theory indicate a cross-disciplinary perspective, with machine learning appearing again to show integration with predictive and analytical tools. This cluster reflects a strong intersection between technological innovation and market performance.

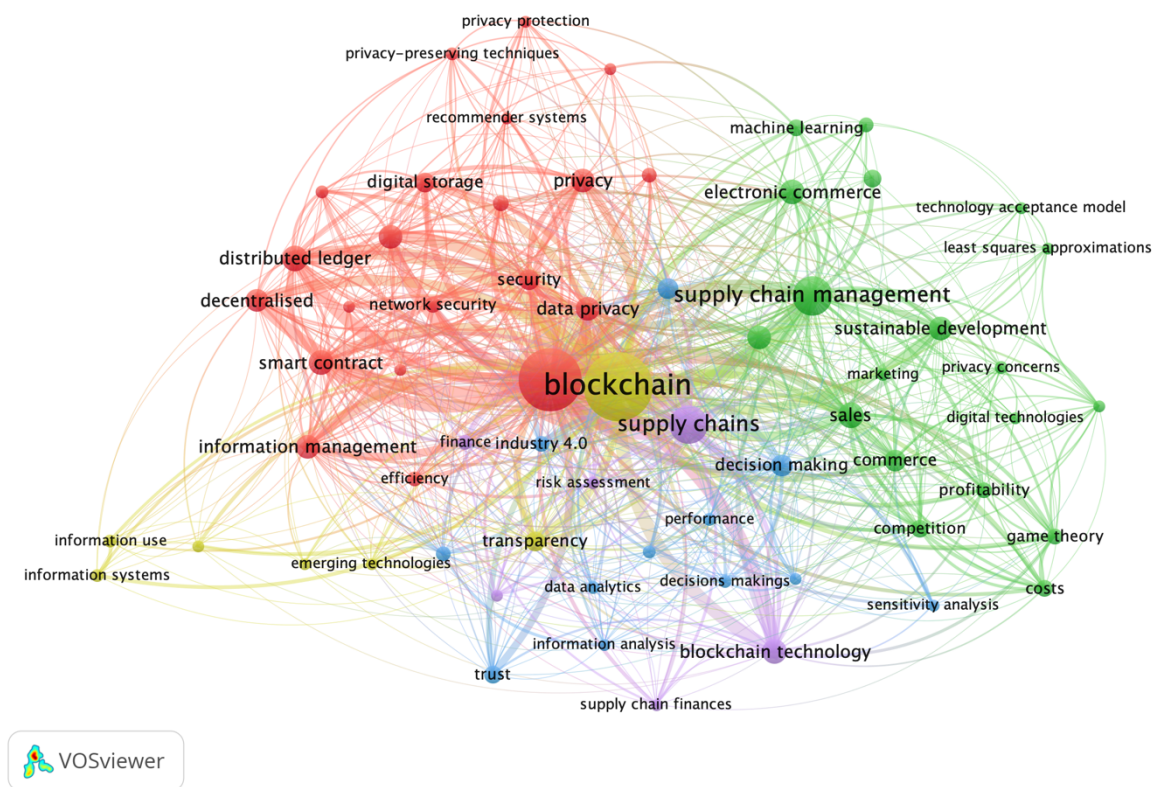
Cluster 3: "Decision Analytics and Intelligent Systems", this cluster centers on the application of analytics and artificial intelligence in decision-making processes. Keywords like artificial intelligence, behavioral research, decision theory, and sensitivity analysis indicate a focus on how intelligent technologies support business performance and strategic decisions. The presence of trust and performance suggests that researchers are also exploring how these technologies influence human factors and organizational outcomes. This cluster typically

involves frameworks from industry 4.0, integrating digital transformation with enhanced data-driven decision-making.

Cluster 4: "Transparency and System Innovation", this smaller but significant cluster highlights conceptual research on decentralization, emerging technologies, and transparency—key features of blockchain systems. The inclusion of information systems and information use suggests a systemic view of blockchain's impact on organizational and societal transparency. This cluster may reflect theoretical discourse and qualitative studies that evaluate how blockchain transforms information governance, emphasizing secure and open data environments.

Cluster 5: "Blockchain in Financial and Risk Management", this cluster narrows down to blockchain's role in financial transactions and supply chain finance. Keywords such as finance, risk assessment, risk management, and supply chain finances indicate that this group of studies concentrates on how blockchain enhances financial transparency, traceability, and risk mitigation in supply chain operations. This cluster bridges blockchain technology with economic modeling and practical applications in managing uncertainty and operational risks.

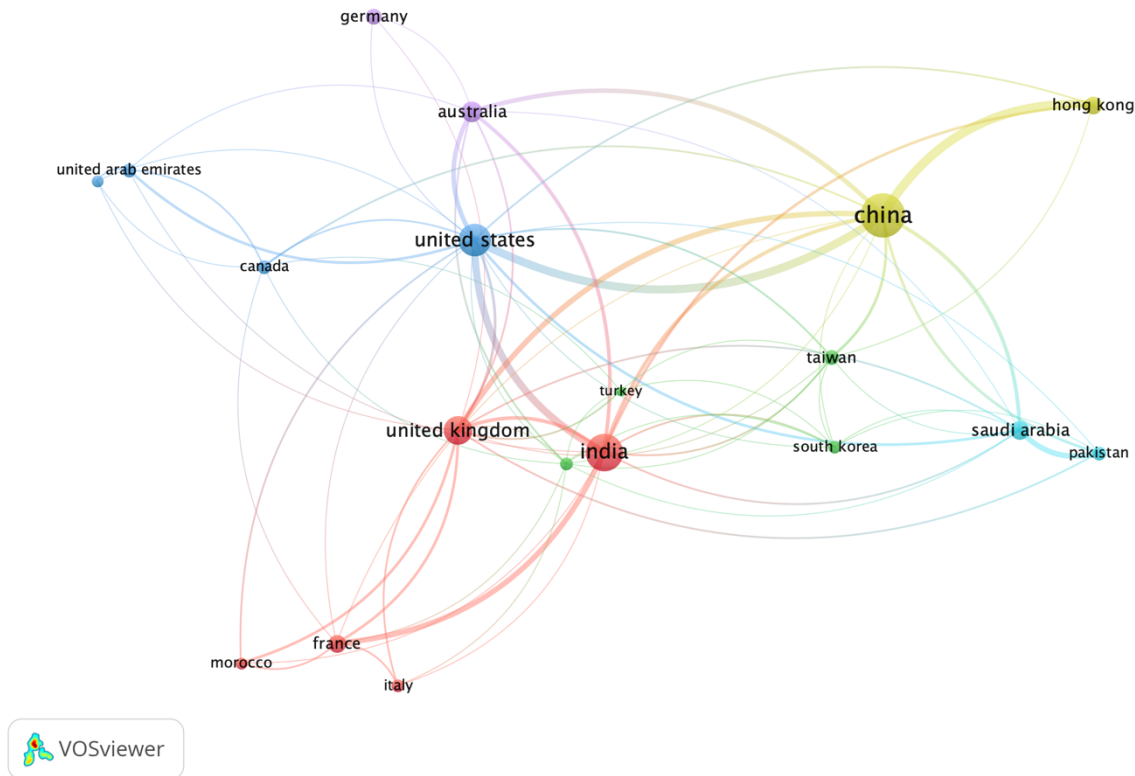
Each cluster highlights a distinct research trajectory—ranging from secure infrastructure and privacy (Cluster 1), adoption behavior and economic models (Cluster 2), intelligent decision systems (Cluster 3), conceptual transparency and innovation (Cluster 4), to finance and risk in supply chains (Cluster 5). Together, these clusters provide a comprehensive thematic map of current blockchain research in commerce and supply chain domains.



**Figure 4.** Co-occurrence of keywords.

Figure 5, which presents the co-authorship by countries, illustrates the extent and nature of international collaboration in the research domain related to blockchain applications in e-commerce and supply chain management. The visualization highlights how frequently researchers from different countries have co-authored publications, indicating patterns of global scholarly cooperation. It is evident that countries such as China, the United States, and India have prominent positions within the network, reflecting their high levels of research output and frequent collaboration with other nations. The strength of the links between countries

suggests close partnerships—for instance, China and the United States demonstrate strong co-authorship ties, indicating frequent joint publications and active knowledge exchange. Additionally, the network reveals clusters of countries that tend to collaborate more closely with each other, possibly due to regional proximity, shared research interests, or institutional partnerships. Countries from Europe, such as the United Kingdom, Germany, and France, also appear well-integrated into the network, showing their contributions to the global research dialogue.



**Figure 5.** Co-authorship by countries.

## 5. Thematic Analysis

### 5.1. Blockchain Fundamentals in E-Commerce

The foundational understanding of blockchain in e-commerce begins with its core architectures and enabling technologies such as Distributed Ledger Technology (DLT), smart contracts, and consensus algorithms. These elements ensure secure, transparent, and decentralized transaction records, eliminating the need for intermediaries (Liao, 2024). Compared to traditional systems, blockchain provides enhanced traceability, automation, reduced costs, and improved fraud prevention (Arora et al., 2020). Traditional centralized databases are prone to manipulation, outages, and single points of failure, while blockchain offers immutable and real-time data integrity. However, the adoption of blockchain is influenced by a combination of drivers and barriers. Drivers include enhanced operational efficiency, auditability, and customer trust (Taherdoost & Madanchian, 2023). On the other hand, challenges such as high initial implementation costs, scalability issues, regulatory uncertainties, and integration complexity hinder widespread adoption. Organizations must evaluate cost-benefit dynamics and invest in technical upskilling to fully capitalize on blockchain's potential (ZhuanSun et al., 2021). Additionally, regulatory alignment and the development of industry-wide standards are vital for the technology's maturation. Understanding the fundamentals of blockchain is essential for any e-commerce business aiming to modernize operations and stay competitive in the digital economy (Hongmei, 2021). As blockchain continues to evolve, a firm grasp of its architecture, advantages, and limitations will enable strategic decisions that leverage this transformative technology.

## 5.2. Data Privacy and Security in Blockchain-Enabled E-Commerce

Data privacy and security represent pivotal concerns in blockchain-enabled e-commerce. Despite blockchain's reputation for high security, protecting sensitive consumer and transactional data within decentralized systems remains complex (Shaikh & Iliev, 2018). Innovative privacy-preserving techniques such as Zero-Knowledge Proofs and Differential Privacy allow data verification without exposing personal information. These technologies strike a balance between transparency and confidentiality, which is crucial for customer trust. Decentralized identity management frameworks give users more control over their personal data and reduce reliance on vulnerable centralized databases, mitigating the risk of data breaches (Jiang et al., 2019). However, the immutable nature of blockchain presents a compliance challenge with data protection laws such as the General Data Protection Regulation (GDPR), particularly in enforcing the right to be forgotten. Public blockchains may conflict with GDPR requirements, while private blockchains offer more flexibility but often at the cost of decentralization. Navigating these legal and technical hurdles requires careful design of blockchain applications to ensure lawful processing of data (Gao, 2019). E-commerce platforms must also stay informed about evolving regulatory landscapes and adopt hybrid architectures where necessary. Ensuring robust privacy and security mechanisms not only safeguards businesses from legal repercussions but also enhances consumer confidence, which is integral to the growth and adoption of blockchain solutions in e-commerce ecosystems.

## 5.3. Supply Chain Transparency and Traceability

Blockchain technology has emerged as a transformative solution in supply chain management, particularly in enhancing transparency and traceability. The decentralized and immutable nature of blockchain enables the creation of a shared ledger accessible to all stakeholders, which ensures real-time visibility of goods throughout the supply chain (Sunny et al., 2020). Provenance tracking, a key use case, has been successfully implemented in sectors like food, pharmaceuticals, and luxury goods to authenticate origin and verify ethical sourcing. This helps mitigate risks such as counterfeiting and quality breaches (Francisco & Swanson, 2018). Moreover, blockchain supports fraud prevention through its tamper-resistant records, which are vital for regulatory compliance and brand trust. In the context of cross-border supply chains, blockchain facilitates interoperability and standardized processes, ensuring seamless data exchange among disparate systems and jurisdictions (Centobelli et al., 2022). However, achieving full traceability requires collaboration among supply chain partners and adherence to technical standards. Blockchain-based supply chain systems not only foster accountability and consumer trust but also optimize logistics, reduce waste, and enhance responsiveness to market changes. Despite these benefits, issues such as integration with legacy systems and initial implementation costs remain challenges. Nevertheless, blockchain continues to redefine transparency and traceability across complex global supply networks.

## 5.4. Integration with Emerging Technologies

The integration of blockchain with emerging technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and smart contracts is revolutionizing digital commerce and supply chain management (Iyer, 2022). AI enhances blockchain functionality by enabling predictive analytics, fraud detection, and intelligent automation of decisions based on real-time data stored securely on blockchain networks (Nguyen et al., 2020). This combination leads to more accurate forecasting and risk management. IoT devices, when connected to blockchain, allow for real-time monitoring and data verification of assets in transit, enhancing traceability and reducing human error. For instance, sensors embedded in logistics can automatically record temperature or location and store it immutably on the blockchain, ensuring product quality and compliance. Smart contracts serve as automated protocols that execute predefined actions when conditions are met, streamlining operations like payment processing or inventory management. These integrations result in enhanced operational efficiency, cost savings, and trust among ecosystem participants. However, seamless integration requires robust IT infrastructure, data interoperability standards, and security mechanisms to protect against system vulnerabilities (Akoka & Comyn-Wattiau, 2017). As businesses strive for digital transformation, the synergistic use of blockchain and other advanced technologies offers significant potential to enhance

transparency, agility, and sustainability in various industries, setting new standards for automated and data-driven commerce.

### 5.5. Sector-Specific Applications

Blockchain's adaptability has led to its application across various sectors, delivering tailored solutions to industry-specific challenges. In healthcare, blockchain ensures secure data sharing among hospitals, patients, and insurers while maintaining data integrity and privacy (Attaran, 2022). Drug traceability systems built on blockchain can verify authenticity, combat counterfeit medicines, and comply with stringent regulations. In agriculture, blockchain enables farm-to-table transparency by recording every stage of food production and distribution, fostering consumer trust and supporting fair trade practices (Xiong et al., 2020). This is particularly useful for organic or sustainably sourced products. The financial sector benefits significantly through applications such as blockchain-based payment systems, smart contracts in trade finance, and real-time settlement of cross-border transactions (Mishra & Kaushik, 2023). These applications reduce operational costs, improve transaction speed, and enhance transparency. Additionally, blockchain can improve loan issuance and credit history verification through immutable records. Each of these sector-specific applications addresses unique pain points, from traceability and fraud prevention to transaction efficiency and regulatory compliance. While the potential is vast, successful implementation often hinges on overcoming technical challenges, ensuring legal clarity, and aligning stakeholder incentives. Still, blockchain's versatility positions it as a foundational technology for future advancements across diverse economic sectors.

### 5.6. Trust, Behavioral Adoption, and User Perspectives

Trust plays a central role in the adoption of blockchain technology, especially in e-commerce and supply chain contexts where multiple stakeholders interact (Shin & Bianco, 2020). Consumers' willingness to engage with blockchain-based platforms is closely tied to their perceptions of security, transparency, and control over personal data. Behavioral adoption models suggest that perceived usefulness, ease of use, and social influence significantly affect user acceptance of blockchain (Norbu et al., 2024). From an organizational perspective, factors such as technological readiness, leadership support, and employee competence determine the pace and scale of adoption. CEOs and decision-makers often assess blockchain implementation in terms of strategic alignment, cost-benefit analysis, and long-term value creation. Cultural contexts also influence adoption patterns, with certain regions exhibiting higher trust in decentralized systems than others. Furthermore, regulatory environments can either encourage innovation or inhibit experimentation, depending on their clarity and flexibility (Shin, 2019). Understanding user behavior—both at the individual and organizational levels—is essential for designing blockchain systems that meet expectations and foster widespread engagement. Education, user-centric design, and transparent communication about the benefits and limitations of blockchain are crucial to building the trust necessary for successful adoption.

### 5.7. Sustainability and Circular Economy

Blockchain technology contributes significantly to sustainability goals by enabling transparent and traceable supply chains, crucial for environmental accountability (Upadhyay et al., 2021). In green supply chains, blockchain tracks emissions, energy usage, and resource inputs, helping organizations monitor and reduce their carbon footprint. By storing immutable records of sustainable practices, blockchain aids in verifying compliance with environmental regulations and sustainability standards. In the circular economy, blockchain supports waste management and recycling traceability by recording material lifecycles and promoting responsible consumption (Chaudhari et al., 2022). Blockchain can authenticate the reuse or recycling of products, preventing waste and encouraging circular flows of materials. Moreover, it facilitates the resale or leasing of goods with a verifiable usage history, supporting new business models. Environmental, Social, and Governance (ESG) reporting benefits from blockchain's transparent recordkeeping, allowing firms to publish verifiable data on their social and environmental impact. This transparency enhances corporate credibility and helps attract sustainability-conscious investors and consumers (Basile et al., 2023). However, blockchain's energy consumption—especially in proof-of-work systems—poses environmental concerns, prompting the shift to energy-efficient consensus mechanisms like proof-of-stake. As blockchain evolves, its integration into

sustainability strategies can offer innovative ways to build environmentally responsible, circular, and socially accountable economies.

## 5.8. Challenges and Future Research Directions

Despite its promise, blockchain faces several challenges that require attention in future research. Scalability remains a major concern, especially as transaction volumes increase in commercial applications. Many current blockchain networks struggle with throughput and latency issues, which can hinder real-time operations. Energy efficiency is another critical challenge, particularly in consensus mechanisms like proof-of-work, which consume substantial resources. This calls for the development and adoption of greener technologies like proof-of-stake or hybrid consensus models. Governance in decentralized systems is complex, raising questions about accountability, dispute resolution, and protocol updates. Without clear governance frameworks, blockchain networks may become fragmented or prone to manipulation. Furthermore, blockchain's interdisciplinary nature necessitates collaboration among computer scientists, economists, legal experts, and business professionals to address multifaceted challenges. Legal ambiguities regarding data ownership, smart contract enforceability, and jurisdiction further complicate adoption. Ethical concerns about surveillance and data permanence also demand scrutiny. Future research should explore cross-border regulatory harmonization, user-centric design, and integration with legacy systems. There is also a need for empirical studies that evaluate real-world performance, costs, and socio-economic impacts of blockchain projects. Addressing these gaps will be essential for realizing blockchain's full potential as a transformative and sustainable digital infrastructure.

## 6. Implications to Theory and Practice

### 6.1. Theoretical Implications

The findings and thematic analysis of blockchain applications in e-commerce contribute to existing theoretical frameworks in information systems, digital trust, and innovation diffusion. By exploring blockchain's role in enhancing transparency, decentralization, and data integrity, the study extends trust-based models and provides empirical grounding to the Technology-Organization-Environment (TOE) framework. Additionally, the integration of privacy-preserving mechanisms such as Zero-Knowledge Proofs within decentralized platforms enriches theories on data protection and digital identity. The study also advances understanding in institutional theory by highlighting how regulatory compliance shapes technological design and adoption. Moreover, the exploration of behavioral adoption models in blockchain contexts supports the refinement of the Unified Theory of Acceptance and Use of Technology (UTAUT), incorporating factors like transparency, control, and perceived security. Overall, the theoretical implications lie in bridging blockchain's technical attributes with socio-organizational behaviors, offering a multi-disciplinary contribution to both technology and management literature.

### 6.2. Practical Implications

For practitioners, the insights offer actionable strategies for blockchain implementation in e-commerce. Businesses can leverage blockchain to improve operational efficiency, product traceability, and consumer trust by integrating smart contracts and decentralized ledgers into supply chain and transactional systems. Privacy-preserving tools and decentralized identity frameworks provide practical pathways to enhance data security while complying with data protection regulations like GDPR. Firms are encouraged to adopt hybrid blockchain architectures for flexibility and legal alignment. From a strategic perspective, managers should evaluate blockchain readiness in terms of cost, scalability, and employee capability, investing in training and pilot projects to mitigate risk. Policymakers can also use these insights to design adaptive regulations that promote innovation without compromising user rights. Ultimately, the study informs the development of blockchain solutions that are not only technically robust but also aligned with business goals, regulatory standards, and consumer expectations.

## 7. Conclusion

The systematic review underscores the transformative potential of blockchain technology in e-commerce, particularly through its foundational capabilities in decentralization, data integrity, and security. The study revealed how blockchain not only redefines traditional transaction systems but also addresses pressing concerns related to transparency, privacy, and trust. As blockchain continues to evolve, its integration with emerging technologies such as Artificial Intelligence and the Internet of Things promises to automate and optimize various operations, from supply chain management to secure data sharing. Moreover, sector-specific applications highlight the technology's versatility and its ability to drive innovation across finance, healthcare, and agriculture. However, widespread adoption remains challenged by regulatory, technical, and organizational barriers that must be carefully navigated. Addressing issues of compliance, scalability, and interoperability will be key to unlocking blockchain's full potential. Ultimately, a collaborative approach involving businesses, regulators, and technology developers is essential to create sustainable, secure, and efficient blockchain ecosystems. This research provides both theoretical insights and practical frameworks to guide future development and adoption of blockchain in the e-commerce domain.

## 8. Research Limitations and Future Research Directions

This study provides a thematic exploration of blockchain applications in e-commerce, but several limitations must be acknowledged. First, the analysis primarily relies on existing literature and secondary data, which may not fully capture recent developments in this rapidly evolving field. Moreover, thematic categorizations may be influenced by subjective interpretations, limiting the generalizability of the findings. The study also focuses more on technological and managerial perspectives, while overlooking deeper legal, ethical, and cultural dimensions across diverse geographical contexts. Additionally, empirical validation through case studies, interviews, or surveys was beyond the scope of this research, which constrains the ability to confirm practical effectiveness or user experience outcomes.

Future research should aim to bridge these gaps through interdisciplinary and empirical investigations. Comparative studies across regions could highlight how cultural, regulatory, and infrastructural differences impact blockchain adoption in e-commerce. Furthermore, real-time longitudinal studies may uncover how blockchain integration evolves over time within organizations. Research exploring the intersection of blockchain with ethics, sustainability, and human behavior would also enrich the discourse. Finally, the development of scalable, energy-efficient, and regulation-compliant blockchain models remains a critical avenue for future exploration. These directions can support more inclusive, secure, and sustainable implementation of blockchain in global e-commerce ecosystems.

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