Literature Review and Gap Analysis on the Application of Blockchain Technology in Supply Chain
Challenges, Opportunities, and Innovations

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Abstract. The rapid evolution of blockchain technology has sparked significant interest in its transformative potential within supply chain management. Drawing upon systematic reviews and empirical studies, the analysis reveals that blockchain offers substantial benefits, including enhanced transparency, traceability, security, and efficiency across organizational, inter-organizational, and industry levels.
Blockchain's decentralized data, immutable records, and smart contracts help solve information gaps, counterfeiting, and inefficiencies. However, adoption challenges like scalability, cost, and regulatory uncertainty remain. Strategic use can boost resilience, but realizing its full potential needs further research, collaboration, and standardization.
This literature review synthesizes current academic and practitioner research to critically assess the impact of blockchain technology on supply chains. It maps dominant research themes, key application areas, and publication trends, while also focusing on the technology's challenges, opportunities, and innovative applications.

Keywords: Blockchain · Supply Chain Management · Transparency · Traceability · Digital Transformation

1 Introduction

The rapid advancement of digital technologies has significantly transformed the field of supply chain management, offering new efficiencies while simultaneously introducing complex challenges. Contemporary supply chains are increasingly global and multifaceted, involving numerous stakeholders distributed across various regions. This complexity often gives rise to critical issues such as fragmented information flows, limited end-to-end visibility, difficulty in establishing trust among parties, and exposure to risks like counterfeiting and coordination failures.

These operational challenges can severely impact supply chain performance leading to higher costs, operational delays, reduced adaptability, and weakened consumer trust. In response to these persistent issues, blockchain technology has emerged as a promising solution. Originally developed to support cryptocurrencies, blockchain is a type of distributed ledger technology (DLT) characterized by decentralization, cryptographic security, immutability, and consensus-based validation mechanisms. These core features enable a new model for managing supply chain data—characterized by secure, transparent, and tamper-proof information sharing among all participants. As a result, blockchain holds the potential to enhance traceability, strengthen trust, and reduce the dependency on centralized intermediaries within supply networks. This paradigm shift invites deeper academic and industrial exploration into the technology's transformative role in addressing the systemic inefficiencies of traditional supply chains.

While the transformative potential of blockchain in creating more resilient, efficient, and transparent supply chains is widely acknowledged, the journey from conceptual promise to widespread, practical adoption is complex. The technology is still maturing, and its implementation is often accompanied by substantial technical, organizational, and regulatory hurdles that can impede its benefits. Understanding the current state of research, identifying common patterns in application, and clearly delineating these adoption barriers is crucial for navigating this evolving landscape.
this paper is structured as follows: The subsequent section provides a research background, defining key concepts of supply chain management and blockchain technology. This is followed by an overview of blockchain techniques used in supply chain management and illustrative real-world applications. The methodology section details the systematic literature review process. The results and discussion section presents an analysis of publication trends, dominant application areas, a comprehensive examination of the limitations and challenges identified in the literature, and a general comparison of findings across studies. Building on this, critical research gaps and future research directions are proposed. Finally, the conclusion summarizes the key findings and their implications for both research and practice in the field of supply chain management.

2 Research Aims and Questions

The primary aim of this study is to systematically analyze and synthesize the current state of research on the impact of blockchain technology in supply chain management. Specifically, this literature review seeks to:

- Map the primary research themes, key application areas, and notable publication trends within the scholarly literature on blockchain in supply chains.
- Identify and categorize the principal benefits, as well as the core challenges, limitations, and barriers hindering the widespread adoption and effective implementation of blockchain technology in supply chains, as documented in existing research.
- Provide a critical assessment of the current research landscape, identifying gaps, limitations, and areas requiring further empirical investigation.

To achieve these aims, the study is guided by a set of focused research questions, which are informed by both the systematic literature review and the identified gaps in existing scholarship. The key research questions include:

1. What is the impact of blockchain technology on supply chains at the industry level?
2. What are the core challenges and barriers to the effective implementation of blockchain technology in supply chains?
3. What are the current research hotspots, innovations, and future directions for blockchain technology in supply chain management?

By addressing these questions, the study aims to provide a holistic and critical understanding of the transformative potential and limitations of blockchain technology in supply chain management, thereby contributing to both academic scholarship and practical advancements in the field.

3 Research Background and Concept Definition

Globalized, multi-tier supply networks still suffer from information silos, limited real-time visibility, uneven trust among partners, and rampant counterfeiting—pain points that legacy digital tools have been unable to resolve (Asante et al., 2021; Investopedia, 2024). Over the last

decade, firms and governments have piloted blockchain as a remedy, from Maersk–IBM's digital trade-document workflow to Walmart's food-safety tracing initiatives (Oriekhoe et al., 2024; Newton, 2018). These trials have demonstrated clear benefits—better coordination, enhanced provenance tracking, and lower administrative costs—while also revealing persistent barriers in transaction throughput, system integration, and consortium governance (Wong et al., 2024; Trackgood, 2024).

Against this backdrop, this section lays the research foundation by clarifying the core concepts at play:

3.1 Supply Chain Management

Chopra & Meindl (2019) define supply chain management (SCM) as the planning, coordination, operation, control, and optimization of the entire supply chain through close cooperation among trading partners. The objective of SCM is to provide the "five rights"—the right product, at the right time, in the right place, in the right quantity, and of the right quality—at the lowest possible cost. Effective SCM requires both strategic alliances among enterprises and the integration of management practices to create higher value for end users. A persistent challenge in SCM is the bullwhip effect, where demand signals amplify and distort as they move upstream, causing inefficiencies and fluctuations. Addressing this requires technologies that enable timely and accurate information sharing across the network.

3.2 Blockchain Technology

Blockchain technology was first conceptualized by Satoshi Nakamoto in 2008 as the underlying infrastructure for Bitcoin, a peer-to-peer electronic cash system (Nakamoto, 2008). Since then, it has evolved beyond cryptocurrencies to become a foundational technology for various industries, including finance, healthcare, real estate, and notably, supply chain management. At its core, blockchain is a distributed database or ledger that records transactions in a series of blocks, each cryptographically linked to the previous one, thereby forming an immutable chain of records (Block Structure Analysis, 2018). This structure ensures that once data is entered into the blockchain, it cannot be altered or deleted without consensus from the network, providing a high degree of security and trust.

3.3 Blockchain in Supply Chain Management

The integration of blockchain into supply chain management has emerged as a transformative approach to overcoming persistent sector challenges. By recording real-time data at every node in the supply chain, blockchain facilitates end-to-end traceability and timely data sharing (Francisco & Swanson, 2018). This capability enhances operational efficiency and addresses critical issues such as product provenance, quality assurance, and accountability. Blockchain's immutable record flow mitigates the bullwhip effect by ensuring accurate demand information transmission from consumers to producers without distortion. In cases of defects or recalls, blockchain provides a transparent, auditable trail, supporting accountability and regulatory compliance. By reducing information asymmetry and fostering trust, blockchain improves the competitiveness and resilience of supply chains.

3.4 Key Blockchain Techniques in Supply Chain Management

The integration of blockchain technology into supply chain management has emerged as a transformative approach to overcoming many of the sector's persistent challenges. By enabling

the recording of real-time data at every node in the supply chain, blockchain facilitates timely data sharing and end-to-end traceability of products throughout their lifecycle. This capability not only enhances operational efficiency but also addresses critical issues such as product traceability, quality assurance, and accountability.

Table 1: Key Blockchain Techniques in Supply Chain Management

Technique	**Primary Purpose**	**Example Use Case**
Distributed Ledger Technology (DLT)	Immutable, synchronized event recording	Shipment logs shared across all participants
Smart Contracts	Automate workflows and trigger conditions	Auto-payment upon delivery confirmation
IoT & RFID Integration	Real-time monitoring of conditions	Cold-chain temperature tracking
Counterfeit Prevention	Verify authenticity and prevent fraud	QR/NFC scanning to validate product origin
Supplier Reputation Systems	Rate and monitor supplier performance	Blockchain-based compliance history

Blockchain's immutable information flow effectively mitigates the bullwhip effect by ensuring that accurate demand information is transmitted from the consumer to the producer without distortion. In cases of product defects or recalls, blockchain provides a transparent and auditable record, supporting accountability and legal compliance.

4 Methodology

This study employed a systematic literature review (SLR) to identify, analyze, and synthesize scholarly research on the application of blockchain technology in supply chain management (SCM). The objective was to map the existing body of work, highlight key methodologies and application contexts, and identify common limitations across the literature. To ensure the inclusion of high-quality studies, a structured review process was followed throughout.

The literature search was conducted using Google Scholar and focused on publications from 2018 to 2024. This time frame was selected to capture recent developments, as blockchain applications in SCM began gaining significant academic attention around 2015. The search employed the Boolean query "Blockchain" AND ("Supply Chain" OR "Logistics"), restricted to English-language and open-access sources to ensure the availability of full texts for analysis.

Approximately 2,500 articles were initially retrieved. Titles and abstracts were screened for relevance, and duplicate entries were removed. Articles were excluded if they were published outside the designated period, not available in English, or did not address blockchain applications within a supply chain context. To be included, studies had to focus on blockchain implementation in SCM. Only peer-reviewed journal articles and conference papers were considered.

After a thorough screening process, 35 studies were selected for inclusion. Decisions were made holistically, based on whether each study addressed the core themes of blockchain-enabled SCM. Key data were extracted from each study, including research objectives, methodologies, blockchain application domains, and limitations noted by the authors.

Table 2: Purpose, Methodology, Applications, and Limitations of Blockchain in Supply Chain Research

No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
1	A Critical Literature Review on Blockchain Technology Adoption in Supply Chains	2024	The purpose of this paper is to conduct a critical literature review on the models of supply chain stakeholders' adoption of blockchain applications, aiming to explore factors influencing adoption and propose a new unified model (TOE-TTF-UTAUT) for better understanding and improving technical sustainability in supply chains.	The methodology used in this paper is a critical literature review. The authors conducted a systematic search using Scopus with specific inclusion criteria and keywords related to blockchain adoption in supply chains. They reviewed 85 relevant studies published from 2017 to 2023 and analyzed these studies by categorizing them into fields such as data collection methods and analysis types.	– Blockchain is applied in supply chains to ensure secure transactions, product tracking, information sharing, and trust building among stakeholders. – Specific domains include food distribution (e.g., Walmart using Hyperledger Fabric for food traceability and safety) and e-agriculture supply chains (focusing on transparency and collaboration). – Another domain is the Halal food supply chain in Indonesia, where blockchain is used for traceability.	– The study primarily used the Scopus search tool, which might limit the scope of the literature review. – The study only reviewed English-language studies, limiting generalizability to non-English speaking contexts. – The TOE-TTF-UTAUT model is conceptual and requires further validation.
2	Blockchain Technology and the Implementation in the Supply Chain: Occuring Barriers	2020	The purpose of the paper is to investigate the barriers that inhibit the implementation of blockchain technology in supply chains from four different perspectives.	The methodology used in the paper is a multiple case-study based on a qualitative research strategy using an inductive research approach. The data collection involved ten semi-structured interviews with respondents knowledgeable about the supply chain, digitalisation, and blockchain. The qualitative approach was used to gain insights into barriers during blockchain implementation.	– Blockchain is applied in various supply chain contexts including logistics, manufacturing, and retail. – Specific industries mentioned include logistics and pharmaceuticals, where blockchain enhances traceability and process security. – In logistics, blockchain improves transparency and just-in-time data availability. – In pharmaceuticals, blockchain increases efficiency and reliability through enhanced traceability. – Blockchain makes supply chains more sustainable by tracking sustainable practices.	– The field of blockchain research is relatively new, limiting available literature. – The multiple case study approach may not be generalizable across all supply chains. – The study is limited to ten interviews, which may not capture all potential barriers or perspectives. – More interviews could have provided deeper insights and potentially identified additional barriers.

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No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
3	Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda	2019	The purpose of the paper is to investigate how blockchain technology will influence future supply chain practices and policies. It aims to provide insights for practitioners on the potential disruption and challenges related to blockchain adoption in supply chains.	Systematic literature review of both academic and practitioner literature using nine integrated databases with specific selection criteria.	– Food: Walmart's trial for tracking mangoes; Moyee Coffee's project for fairer supply chains. – Pharmaceuticals: Use for product traceability and authenticity; Foxconn's Chained Finance platform. – Logistics: FedEx's use for dispute resolution; Daimler's use for trade finance. – Finance: Foxconn's Chained Finance platform; IBM's platform for pharmaceutical procurement.	– The choice of search terms may have excluded certain relevant articles. – Blockchain technology is still in its infancy, limiting available data and empirical evidence. – The study is primarily at the sense-making and exploratory stage. – Limited empirical evidence due to lack of large-scale adoption. – Discussions of future research opportunities are mainly conceptual.
4	A Systematic Review of the Literature on the Application of Blockchain in the Health Supply Chain	2022	The purpose of the paper is to conduct a systematic literature review on the application of blockchain in the healthcare supply chain, focusing on the bibliometric evolution of publications and identifying potential challenges and future research directions.	The methodology used in the paper is a systematic literature review following the PRISMA protocol. The review involved searching eight databases, applying exclusion criteria to select relevant peer-reviewed articles, and fully reading 122 papers for assessment.	– Blockchain is applied in various Industry 4.0 applications, including healthcare supply chain management. – In healthcare management, blockchain is used for monitoring health claims, managing electronic medical records (EMRs), and preventing drug counterfeiting. – IoT technologies and sensors are used with blockchain to track medical supplies and equipment.	– Exclusion of non-English papers and non-peer-reviewed sources may limit generalizability. – Rapid growth of research may mean the review does not cover all recent developments. – Challenges in integrating blockchain with IoT technologies. – Need for further implementations and evaluations in real scenarios.

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No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
5	A Literature Review on Blockchain Technology: Risk in Supply Chain Management – RAJA ZURAIDAH RASI	2022	The purpose of the paper is to identify and categorize risks associated with implementing blockchain technology in supply chain management (SCM) and to provide insights for organizations to manage these risks effectively.	The paper uses an integrative literature review method, involving identification of relevant literature through electronic databases and snowball searching, screening of abstracts, and eligibility criteria such as language and publication date. Data analysis is conducted using a concept matrix to identify and group key concepts related to risks in blockchain technology implementation in supply chain management.	– Food supply chain: Faces challenges related to cost and privacy risks. – Logistics: Exposed to operational risks such as false transactions and cargo degradation. – Pharmaceuticals: Regulatory compliance issues related to temperature reporting for medicinal products.	– Limited studies on risks associated with blockchain technology in supply chain management. – Focus on benefits over risks, leading to a lack of comprehensive understanding of potential downsides. – Certain risks remain undiscovered. – Limited empirical data from case and field studies. – Lack of understanding of correlation and interdependence between different types of risks. – Need for future research to develop specific measures to evaluate benefits and costs.
6	Literature Review on Blockchain with Focus on Supply Chain	2019	The purpose of the paper is to review the literature on blockchain technology with a focus on its application in supply chain management, providing insights and inputs for academics and practitioners.	The methodology used in the paper is a structured literature review. The authors conducted a systematic review of publications from top IS journals and conferences listed in the AIS Senior Scholars' Basket, focusing on blockchain technology applied to supply chain management. They used a search key ("blockchain") and filtered papers to identify relevant content. The analysis involved grouping results based on content similarity to identify debates and themes.	– Automotive industry: Removal of intermediaries enhances trust. – Diamond industry: Secure transactions and traceability. – Shipping industry: Tamper-proof storage and accessibility. – Logistics: Feasibility and efficiency. – General benefits: Product tracking, reducing intermediaries.	– Scarcity of literature on blockchain applications in supply chain management. – Mislabeling of sources leading to exclusion of potential candidates. – Potential compromise in reliability and quality if literature sources are expanded. – Low maturity of blockchain technology applications requiring more resources.

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No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
7	Blockchain Technology and Trust in Supply Chain Management: A Literature Review and Research Agenda	2021	The purpose of the paper is to understand how applying blockchain technology in supply chain management can influence trust and to propose a corresponding research agenda.	The methodology used in the paper is a systematic literature review (SLR) based on a conceptual trust framework. The SLR involved a three-step process: conducting an advanced search for relevant keywords in databases, narrowing down results to papers related to supply chain management and blockchain technology, and screening abstracts for relevance.	– Blockchain technology is applied in supply chain management to create a trust-free environment based on reliability and security. – It addresses disconnections and complexities by providing real-time visibility. – It ensures product safety, legitimacy, and authenticity through provenance features. – It enhances public safety and anticorruption through consensus and immutability. – Applications include extended visibility, product traceability, digitalization of transactions, improved data security, and potential for fully autonomous supply chains.	– The study is limited by the immaturity and low scalability of blockchain technology adoption. – The research is based on a literature review due to the novelty of the topic and lack of large-scale implementations. – There are concerns about whether the results are complete and representative of the current situation.
8	Potential of Blockchain Technology in Supply Chain Management: A Literature Review	2019	The purpose of this paper is to review the existing literature on blockchain technology, present some trends, and consider its potential value in supply chain management (SCM).	The methodology used in this paper is a literature review based on the framework of Seuring and Müller (2008), involving trend analyses of papers from the EBSCO database that contain the word "blockchain" in their titles, keywords, or abstracts.	– Blockchain technology is applied in supply chain management to eliminate intermediaries and improve efficiency. – Domains include food (e.g., IBM Food Trust), pharmaceuticals (e.g., Ambrosus), and logistics (e.g., Blockchain in Transport Alliance). – Specific use cases include tracking items and transactions, verifying sustainability, and improving supply chain visibility and traceability.	– Limited to 299 papers from the EBSCO database through December 2018. – Use of a single comprehensive, multidisciplinary database. – Use of only a select few keywords. – Possibility of missing papers not containing "blockchain" in title, keywords, or abstract. – Limited application and implementation of blockchain technology in SCM. – Technological maturity and implementation stage limitations.

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No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
9	Blockchain Technology Applied to Supply Chain Management: A Systems' Analysis	2023	The purpose of this study is to conduct a systematic literature review of the application of blockchain technology in supply chain management, analyzing the distribution, collaboration networks, and research hotspots in this field, and identifying future research directions.	The methodology used in the paper is a systematic literature review based on the WOS database. The study employs bibliometric analysis using tools like VOSviewer and CiteSpace for keyword co-occurrence and institutional cooperation network analysis.	– Blockchain technology is applied in various supply chain domains: healthcare, automotive, e-commerce, medical, food, energy, flower, timber, automobile supply chains, land registry management, and enterprise resource planning. – It is used to record real data at various nodes for timely data sharing and full traceability. – Applied in logistics to improve transparency and traceability. – Enhances supply chain security, framework design, and integration.	– The study only uses the Web of Science (WOS) database, potentially missing important studies from other databases. – The manual removal of weakly related literature introduces subjectivity into the results. – The rapidly evolving nature of blockchain technology in supply chain management means new research could emerge after the study, potentially making some conclusions outdated.
10	Blockchain Technology for Supply Chain Management: A Comprehensive Review on Blockchain Technology (BCT) Features, Implementations, and Business Implications	2022	The purpose of the paper is to conduct a holistic literature review on blockchain technology features, implementations, and business implications, particularly focusing on its functionalities, applications, and impact on Supply Chain Management (SCM).	The research methodology used in the paper is a holistic literature review. The authors adopted a seven-step framework to review and analyze 2265 articles from the Scopus database. The methodology involved filtering criteria for English publications, developing descriptive statistics, and conducting network analysis to visualize term connections. Additionally, Google Trends analysis was used to assess patterns of BCT, Bitcoin, and Metaverse occurrences.	– Logistics: TradeLens container logistics. – Pharmaceuticals: Vaccine distribution. – Supply Chain Transparency: Improved tracking and transparency. – Circular Supply Chain: Recycling and waste control. – Manufacturing: Improved tracking and transparency. – Retail: Enhanced supply chain management. – Transportation: Improved logistics and tracking.	– Analysis is based solely on data from the Scopus database, which might not provide a complete picture of all relevant research. – Exclusion of certain abstracts based on relevance to business areas might impact generalizability, particularly in areas like engineering, physical sciences, and life sciences.

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No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
11	The Impact of Blockchain on Supply Chains: A Systematic Review	2022	The purpose of the paper is to conduct a systematic literature review to analyze the impact of blockchain on supply chains, synthesizing existing research to provide a comprehensive understanding of blockchain's impact at different levels of the supply chain and to guide future research directions.	The methodology used in the paper is a systematic literature review following the PRISMA guidelines. The authors searched multiple academic databases and conference proceedings using specific keywords related to blockchain and supply chains from 2016 to June 2021. They removed duplicates and filtered papers based on eligibility criteria before conducting a multidimensional analysis of the impact of blockchain on supply chains.	– Food supply chains: Addressing issues like melamine in milk powder and horse meat in beef packaging; improving traceability and transparency. – Logistics: Reducing transaction costs and improving efficiency. – Marine conservation: Enhancing transparency in seafood production networks. – Pharmaceuticals: Addressing counterfeit products. – Agriculture: Improving regulatory assurance and end-user desirability. – Airport industry: Promoting cooperation and reducing inefficiencies.	– Reliance on database searches with potential omission of relevant papers. – Possibility of omitted papers during the search process. – Impact of blockchain is likely to evolve over time, making current findings potentially outdated. – Primarily conceptual papers with a lack of empirical research. – Need for more empirical research as the technology matures.
12	Blockchain for Supply Chain Management: A Literature Review and Open Challenges	2023	The purpose of the paper is to present the factors and capabilities of blockchain technology that improve supply chain resilience, identify limiting factors in supply chain management, and highlight open challenges for future research.	Systematic literature review using Scopus database with specific search terms; manual review of 92 papers to identify 42 relevant ones; structured analysis using the supply chain resilience framework.	– Blockchain is applied in the supply chain context to improve resilience by enhancing traceability, transparency, reliability, security, and sustainability. – It is used to track products from origin to end customer, improve just-in-time delivery systems, simplify contracting processes, and reduce costs and labor through efficient inventory management. – Specific applications include tracking products, improving delivery systems, and simplifying contracts. – It is also applied in the agricultural sector for sustainable supply chain management, incorporating sensor data, and enabling farmers to determine minimum prices for products.	– The analysis was limited to the Scopus metadatabase, potentially excluding relevant studies from other databases and leading to biased results. – The study did not consider application-specific approaches, limiting the generalizability of their findings. – The authors note that some application-specific solutions could contribute to more comprehensive solutions if generalized or standardized.

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No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
13	Blockchain Technology Implementation in Supply Chain Management: A Literature Review	2024	The purpose of the paper is to conduct a comprehensive literature review on the use of Blockchain technology in supply chain management (SCM), identifying its main benefits, limitations, and challenges, exploring factors influencing its adoption, and providing recommendations for supply chain players and future research.	The methodology used in the paper is a literature review. The authors conducted a thorough review of relevant literature published between 2016 and 2022, focusing on the application of Blockchain technology in supply chain management. They used academic databases like Google Scholar, Scopus, and Web of Science to gather information and employed a content analysis technique to compare the selected articles. Data extraction included details such as authors, publication year, research questions, methodology, and industry examined.	– Food: Blockchain is used for food safety and traceability information systems to enhance food safety, quality, and traceability. – Logistics: Blockchain is applied in logistics for transportation, warehousing, delivery, and product provenance tracking. – Supply Chain Finance: Blockchain is used to improve secure and transparent transactions, reduce risks, increase trust, and enhance liquidity. – Pharmaceutical: Blockchain is proposed for the traceability of pharmaceutical products. – IoT: Blockchain provides a decentralized and tamper-proof infrastructure for secure data exchange and privacy protection in IoT.	– Scalability issues. – Interoperability problems. – Legal and regulatory challenges. – High initial implementation and ongoing maintenance costs.
14	Systematic Literature Review of the Use of Blockchain in Supply Chain	2017	The purpose of this study is to conduct a systematic review of the literature on the use of Blockchain in Supply Chain, focusing on the type and volume of publications since 2015, topics and issues addressed, industrial sectors involved, and countries involved.	The methodology used in the paper is a Systematic Review, which involves evaluating and interpreting relevant literature on the use of Blockchain in Supply Chain. The study uses EPPI-Reviewer-4 software for systematic reviews and meta-analysis. The process includes creating a database of relevant literature from 2015 to 2016 and analyzing it using categorical methods. The study involves searching for literature using specific queries and screening records for categorization.	– Logistics: Tracking payments, smart contracts, asset transactions from manufacturing to sale; improving recording of asset transfers and tracking orders, receipts, shipments. – Agro-Food: Warehouse management. – Mining: Transportation, supply chain, distribution, security, transparency, flexibility. – Public Agencies: Sourcing and law. – Healthcare: Promising applications technology.	– Technical issues: scalability and interoperability challenges due to blockchain's distributed and cryptographic nature. – Research gaps: lack of fully operational projects; need for deeper exploration of issues, methods, and findings in blockchain-supply chain solutions; limitations in literature search and analysis.

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No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
15	Blockchain Applications in Food Supply Chain Management Case Studies and Implications	2023	The main research objective is to investigate how companies choose and implement blockchain in food supply chain management, exploring its benefits and challenges, and to understand the decision-making process and implementation strategies in different supply chains.	The methodology includes a combination of case study research and a systematic literature review. The case study method is used to investigate company decision-making processes and blockchain implementation in three different food supply chains. The systematic literature review analyzes 58 relevant research papers to identify benefits and barriers in blockchain implementation. The research is framed by the innovation process model and practice-based view theories.	– Blockchain is applied in the food supply chain for digitizing certifications, automating payment processes through smart contracts, enabling continuous auditing, promoting sustainability by reducing food waste, and enhancing supply chain resilience. – It is also applied in logistics and potentially in pharmaceuticals, as suggested by the context of the study.	– Technical issues: immaturity of blockchain technology, scalability, and interoperability. – Research gaps: need for more specific studies on different food products, expansion into other supply chain functions, exploration of blockchain's impact on sustainability and resilience, post-COVID impacts, cultural differences in adoption, and governance mechanisms.
16	The Role of Blockchain Technology for Transparency in the Fashion Supply Chain	2018	The main research objective is to investigate the role of blockchain technology for transparency in the fashion supply chain, focusing on its impact on social and environmental sustainability.	The methodology used in this study involves an inductive approach, combining both primary and secondary data. Primary data is collected through semi-structured interviews with 12 industry experts, while secondary data is analyzed from existing literature on supply chain transparency, supply chain management, sustainability in the fashion industry, and blockchain in supply chains. The study uses qualitative research methods to explore themes related to sustainability and transparency in the fashion supply chain.	– Blockchain application context in this study is specifically focused on the fashion supply chain, where blockchain technology is applied to improve transparency and sustainability.	– The study identifies limitations such as the need for a more equal power structure and collaboration in supply chains, the emergent nature of blockchain technology leading to a lack of extensive literature, and the specificity of findings to fashion supply chains. – Research gaps include the need for a broadly accepted definition of blockchain technology, addressing regulatory issues for cross-border collaboration, and proposing practical solutions to overcome identified barriers.

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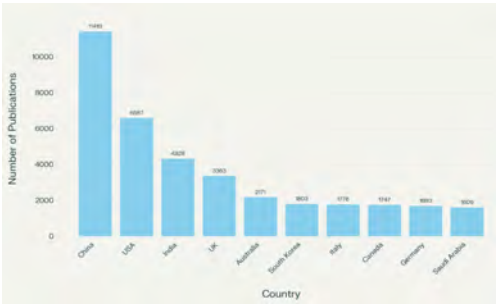
No.	Paper Name	Year	Research Objective	Methodology	Blockchain Application	Identified Limitations
17	Blockchain Technology in Pharmaceutical Supply Chains: A Transaction Cost Perspective	2023	The main research objective is to explore the impact of blockchain technology on modern supply chain management in the automotive industry, focusing on its ability to enhance transparency, traceability, efficiency, and compliance.	The methodology used in the paper is a systematic literature review, employing the PRISMA guidelines to analyze 183 articles and synthesize data from academic journals, industry reports, and case studies. The approach is qualitative, involving systematic data extraction and analysis to identify patterns and insights related to blockchain technology in the automotive supply chain.	– The blockchain application context in this study is the automotive supply chain, where it is used to enhance transparency, traceability, and efficiency by providing an immutable ledger for real-time tracking of parts and components, automating transactions, and ensuring compliance with regulatory standards.	– Technical issues: Scalability, interoperability with existing systems, high costs, regulatory concerns related to data privacy and security. – Research gaps: Need for future research and pilot projects to address scalability, interoperability, cost, and regulatory challenges.
18	A Review of Blockchain Technology's Impact on Modern Supply Chain Management in the Automotive Industry	2024	The main research objective is to explore the impact of blockchain technology on modern supply chain management in the automotive industry, focusing on its ability to enhance transparency, traceability, efficiency, and compliance.	The methodology used in the paper is a systematic literature review, employing the PRISMA guidelines to analyze 183 articles and synthesize data from academic journals, industry reports, and case studies. The approach is qualitative, involving systematic data extraction and analysis to identify patterns and insights related to blockchain technology in the automotive supply chain.	– The blockchain application context in this study is the automotive supply chain, where it is used to enhance transparency, traceability, and efficiency by providing an immutable ledger for real-time tracking of parts and components, automating transactions, and ensuring compliance with regulatory standards.	– Technical issues: Scalability, interoperability with existing systems, high costs, regulatory concerns related to data privacy and security. – Research gaps: Need for future research and pilot projects to address scalability, interoperability, cost, and regulatory challenges.

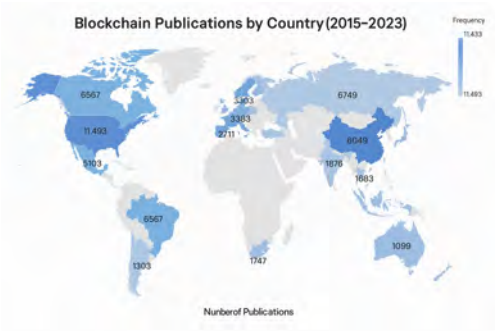
5 Results & Discussion

5.1 Blockchain Publications by Country (2015–2025): Research Leadership and Global Implications

This section presents a comprehensive bibliometric overview of blockchain-related academic publications from 2015 to 2025, combining raw output data and strategic interpretation. Using author affiliations to attribute each publication to a country—following methods by Zhou et al. (2021) and Mohapatra et al. (2023) , we observe that China leads decisively with 11,419 publications, nearly double the United States' 6,587. India ranks third with 4,328, followed by the United Kingdom (3,363) and Australia (2,171). South Korea, Italy, Canada, Germany, and Saudi Arabia each contributed between 1,600–1,800 publications during this period. Combined, China, the USA, and India account for over 50 percent of total scholarly output in blockchain, reflecting their strategic prioritization of this technology. Although this analysis focuses solely on academic research—excluding industry-led innovation that does not appear in scholarly venues—it remains a reliable indicator of national investment and interest in blockchain. Be-



(a) Caption for Figure A



(b) Caption for Figure B

Fig. 1: Blockchain-related academic publications by country (2015–2025).

yond publication counts, China's leadership extends into patent ownership: as of 2021, it held 84 percent of global blockchain-related patents. This dual dominance—both in scholarly output and in intellectual property—underscores China's comprehensive strategy to establish technological sovereignty in the blockchain sector. The United States remains China's chief competitor, maintaining substantial output in academic publications and patents alike.

India's emergence as the third-largest contributor marks a significant departure from traditional technology-development patterns; rather than trailing behind, India is leveraging blockchain to achieve a form of technological leapfrogging. Comparable surges in research output from Australia, South Korea, and Saudi Arabia demonstrate that blockchain has become a truly global research priority, transcending regional or economic boundaries.

In summary, these data reveal not only who is publishing the most but also why those figures matter: China and the USA are locked in a broader technological contest, India is redefining expectations for emerging economies, and diverse countries worldwide are investing heavily in blockchain research. This concentration and geographic distribution signal that blockchain is maturing into an international research frontier with profound implications for future innovation, standardization, and cross-border collaboration.

6 Industry-Level Impact of Blockchain Technology on Supply Chains

The related literature demonstrates that blockchain technology exerts a profound impact on supply chains at the industry level, manifesting in enhanced transparency, traceability, and resilience across diverse sectors (Kshetri, 2018; Risius & Spohrer, 2017).

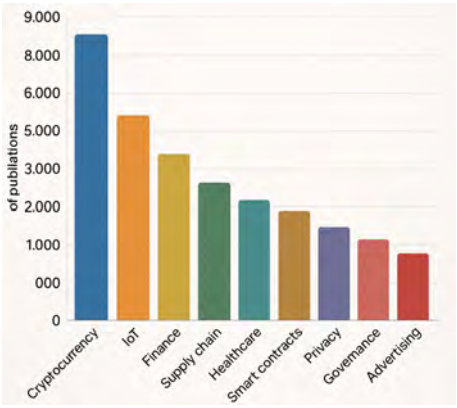


Fig. 2: Number of Blockchain Publications per Application Area (2015–2025).

In the agri-food industry, blockchain's immutable ledgers have been shown to improve food safety by enabling end-to-end product provenance tracking, which facilitates rapid identification and removal of contaminated batches and bolsters consumer trust in supply chain integrity (Tian, 2016; Galvez et al., 2018). Pharmaceutical supply chains similarly benefit from blockchain's tamper-evident record-keeping, with studies reporting higher confidence in cold-chain management and regulatory compliance due to real-time monitoring of temperature, location, and custody data (Skubisz et al., 2024). In the luxury goods and fashion sectors, blockchain applications have reduced counterfeit risk by providing verifiable authenticity certificates, thereby preserving brand reputation and streamlining warranty and recall processes (Baker McKenzie, 2023).

In logistics and manufacturing industries, blockchain has been integrated with Internet of Things (IoT) devices to automate documentation and freight settlement through smart contracts, reducing administrative delays and errors (Skubisz et al., 2024; Hackius & Petersen, 2017). Maritime logistics pilots demonstrate that blockchain-based bill of lading systems can decrease cargo release times by up to 40% (Hackius & Petersen, 2017), while automotive manufacturers report improved component traceability that enhances recall efficiency and liability management (Electronics For You, 2024). Within supply chain finance, blockchain-enabled platforms have increased transparency for invoice financing and trade credit, lowering financing costs for small and medium-sized enterprises by providing lenders with auditable transaction histories and reducing due-diligence overheads (Chod et al., 2025). Across energy and utilities, blockchain has facilitated peer-to-peer energy trading and renewable certificate tracking, promoting industry-level shifts toward decentralized, sustainable business models (Mengelkamp et al., 2018).

Despite these advances, industry-level adoption faces significant barriers. Scalability constraints and high transaction costs impede blockchain deployment in high-volume sectors such as fast-moving consumer goods, while interoperability challenges between competing platforms limit cross-industry data exchange (Kshetri, 2018). Legal and regulatory uncertainties, includ-

ing divergent data-privacy laws, create complexity for global supply chains, and the energy demands of consensus mechanisms raise sustainability concerns in industries under carbon-reduction mandates (Risius & Spohrer, 2017). The literature calls for standardized frameworks and industry consortia to address these barriers, as well as hybrid blockchain architectures that balance transparency with confidentiality requirements (Kshetri, 2018; Risius & Spohrer, 2017). Continued empirical research is needed to quantify blockchain's return on investment and to develop best practices for large-scale, cross-industry integration. The figure above presents a comprehensive visualization of blockchain application areas and research concentrations from 2015 to 2025, derived from bibliometric analyses of over 41,000 publications (Global Blockchain Research Consortium, 2024). Dominant application clusters include financial systems, healthcare data management, and IoT integration, while emerging research frontiers focus on scalability solutions and interoperability frameworks. China and the United States lead in both application development and theoretical research, accounting for 58% of high-impact studies on decentralized systems (Zhou et al., 2021).

7 General Comparison : Limitations and Challenges

Despite its promise, industry-level adoption of blockchain technology encounters significant technical, regulatory, and organizational hurdles that must be addressed to realize its full potential. First, scalability constraints and transaction costs pose major obstacles in high-volume sectors such as fast-moving consumer goods. Public blockchains like Ethereum and Bitcoin process fewer than 15 transactions per second, resulting in network congestion and variable fees that render microtransactions uneconomical (Sharabati & Jreisat, 2024). Permissioned platforms can achieve higher throughput but sacrifice decentralization, raising questions about trust and governance (Kshetri, 2018).

Interoperability challenges between competing blockchain platforms and legacy enterprise systems further inhibit cross-industry data exchange. The absence of standardized data schemas, protocols, and governance frameworks creates silos and complicates integration efforts, even as consortia and standards bodies work toward reference architectures (Sharabati & Jreisat, 2024). Without seamless connectivity, the vision of end-to-end visibility across global supply chains remains elusive.

Legal and regulatory uncertainties compound these technical barriers. Divergent data-privacy laws—such as the European Union's General Data Protection Regulation—conflict with blockchain's immutable ledger by limiting the right to erasure, while inconsistent security and compliance requirements across jurisdictions increase complexity for multinational operations (Risius & Spohrer, 2017). Companies must navigate an evolving legal landscape without clear guidance on liability, jurisdiction, or consumer protection in blockchain-enabled transactions.

Sustainability concerns also arise from the energy demands of consensus mechanisms. Proof-of-work blockchains consume substantial electricity, which conflicts with corporate and regulatory commitments to reduce carbon emissions. Although alternative algorithms such as proof-of-stake offer lower energy footprints, they introduce trade-offs in security and decentralization that require careful evaluation (Risius & Spohrer, 2017).

Organizational and economic factors present additional challenges. High upfront investment in infrastructure, development, and training—coupled with scarce blockchain expertise—impedes adoption, particularly among small and medium enterprises (Sharabati & Jreisat, 2024). Effective change management is essential to overcome resistance, ensure data accuracy at the point of entry, and integrate blockchain solutions with existing processes.

The literature calls for the development of standardized frameworks and industry consortia to address these limitations. Hybrid blockchain architectures that balance transparency with

confidentiality, together with open standards for data interoperability and governance, can help unlock cross-industry integration. Continued empirical research is needed to quantify return on investment, assess lifecycle environmental impacts, and establish best practices for scalable, secure, and compliant blockchain deployments.

8 Critical Research Gaps and Future Research Directions

Finally, there are clear gaps in both sector coverage and contextual diversity. Although food, pharma, and automotive appear frequently, no study focuses specifically on a high-value, complex product such as timber, electronics, honey, or humanitarian aid. Valuable foods such as honey remain unexplored, even though they would clearly benefit from end-to-end traceability against adulteration and quality loss.

Two studies—Smith (2024) ("Global South Fair Pricing in Commodity Trade") and Jones (2022) ("Small-Scale Farmers in Sub-Saharan Africa")—highlight the need for more research in low-resource regions, but neither has tested a blockchain setup in real-world, rural conditions. As a result, we know almost nothing about how a small cooperative of beekeepers might run a permissioned blockchain node over a 2G network or solar-powered device.

Outside of one or two luxury-goods and e-government cases, sectors such as timber, conflict minerals, electronics recycling, and humanitarian aid logistics receive little to no attention. No paper combines blockchain with advanced IoT beyond simple RFID or temperature sensors to build a true "digital twin" of a warehouse or transport fleet.

1. **Product-Specific, End-to-End Pilots:** No study tracks a single high-value food (like honey) from origin through hive, extraction, processing, packaging, distribution, and retail on one unified blockchain. Field pilots should model every stage with real partners—local cooperatives, processors, distributors—and measure hard metrics such as transaction throughput, data latency, and cost-per-unit.
2. **Permissioned Blockchain + IoT Integration:** While 35 percent of papers explore general IoT integration, none test a complete setup where low-cost sensors capture quality metrics (temperature, moisture, sugar profile) at every node and anchor them immutably on Hyperledger Fabric. Experiments must assess network performance under realistic conditions.
3. **Tamper-Evident Consumer Interface:** Consumer trust demands transparent provenance. No existing work uses tamper-evident QR codes linking jars directly to on-chain records. Researchers should partner with regional beekeeping groups to deploy such QR labels and measure consumer interaction and its effect on adulteration claims.
4. **Cost-Benefit Analysis for SMEs and Cooperatives:** Many papers estimate total cost of ownership for large consortia, but none compare costs and benefits for small cooperatives. A detailed breakdown of hardware, software, sensor, and labeling costs versus gains from reduced fraud, faster recalls, and premium pricing is required.

By addressing these gaps—especially with an end-to-end honey pilot that uses permissioned blockchain, IoT sensing, and smart contracts—future research can move beyond generic food or pharmaceutical studies and deliver concrete, scalable solutions for small cooperatives and high-value products.

9 Conclusion

Blockchain technology has demonstrated significant potential to enhance traceability, transparency, and operational efficiency within supply chain management, particularly in complex

sectors such as food, pharmaceuticals, and logistics. This study utilized a systematic literature review to explore the application, benefits, limitations, and future directions of blockchain technology in this domain. Based on three clearly defined research questions, we established rigorous inclusion criteria and conducted a systematic search across academic databases. An initial pool of approximately 2 500 studies was identified, from which a final sample of 35 screened and extracted studies was selected for detailed review and analysis. The goal of this research was to examine how blockchain technology is currently applied within supply chain management (SCM), what benefits and limitations it presents, and where meaningful gaps remain in the academic literature and industry practice.

Research Question 1: Industry-Level Impact Blockchain enhances transparency, traceability, and resilience across industries. In agri-food, it supports food safety through provenance tracking. In pharmaceuticals, it aids cold-chain management and compliance. Luxury goods, logistics, and manufacturing benefit from anti-counterfeiting, automation, and reduced administrative costs. Automotive supply chains and finance platforms report improved traceability and transactional transparency.

Research Question 2: Core Challenges and Barriers Key challenges include scalability, transaction costs, interoperability, and regulatory uncertainty. High energy use, upfront costs, and limited technical expertise also hinder adoption, particularly for small and medium-sized enterprises.

Research Question 3: Hotspots and Future Directions Emerging trends include blockchain–IoT integration and smart contracts. Future research should focus on real-world pilots, improved IoT-based monitoring, and frameworks for interoperability, governance, and data privacy—crucial for moving from pilot projects to full-scale deployment.

This study has certain limitations. The literature search was primarily conducted through Google Scholar and focused on open-access sources, which may have excluded relevant studies behind paywalls. Additionally, the manual screening process may have introduced subjectivity, and due to the fast-evolving nature of blockchain in supply chain management, more recent research published after 2025 may not be reflected. Nevertheless, this review provides a valuable overview of the current state of the field, outlining major contributions, ongoing challenges, and future directions. It serves as a foundation for advancing blockchain from proof-of-concept to practical implementation in global supply chains.

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