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Blockchain-enabled digital platforms for responsible business: building trust and traceability in global supply chains

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Abstract:
Global supply chains are increasingly expected to operate in an ethical, transparent, and sustainable manner. However, information asymmetry, unreliable reporting, and poor visibility still pose a challenge in many existing digital infrastructures over the sourcing networks. This paper examines the application of blockchain-supported digital platforms within the enhancement of responsible-business practices through the integration of trusted, traceable and verifiable data streams into supply-chain operations. Based on the main features of blockchain technologies immutability, decentralization, concurrent validation and programmable smart contracts, the paper proceeds to develop end-to-end system of accountability utilizing emerging technologies in food safety, ethical sourcing of minerals, and sustainable apparel. It has been found that blockchain decreases the threat of sustainability scam, enhances environmental and social governance (ESG), and confidence among stakeholders. Yet challenges remain. Some blockchain designs utilize too much energy, lack of interoperability, and lack of consistent regulations prevent large-scale implementation. To overcome these anxieties, we introduce the concept of Blockchain-Enabled Responsible-Business Supply-Chain (BERB-SC), converging digital responsibility and responsible governance. Responsible digital ecosystems are the last research points of the paper focusing on blockchain governance, cross-industry standardization and integrating AI and IoT.

Keywords: *Blockchain, Digital Trust, ESG Governance, Interoperability, Responsible-Business Supply-Chain, Supply-Chain Traceability*

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1. INTRODUCTION

1.1. Background and Motivation

Comprehensive sustainability reporting and due diligence compliance have become essential requirements for responsible-business operations across global supply-chains. For example, the European Union's Corporate Sustainability Due Diligence Directive (CSDDD) introduces significant obligations for large corporations to identify and manage environmental and human-rights risks throughout their Supply-chain activities. At the same time, increasing concerns surrounding greenwashing, unverifiable provenance claims, and fragmented reporting systems have exposed the limitations of traditional centralized digital infrastructures [1, 19, 20].

1.2. Why Blockchain-Enabled Platforms?

The append-only architecture of blockchain, combined with immutable state between independent parties and programmable contracts, can allow the commonality of recording events and automated controls on levels. These properties become verifiable provenance, near real time traceability and tamper evident compliance records, which can be connected to known data standards, including GS1 EPCIS events, in order to be interoperable with enterprise systems. Experimentally, the IBM-supported pilots at Walmart demonstrated substantial improvements in food traceability and investigation speed through shared blockchain ledgers, in complex networks sharing ledgers can radically lower the time of investigation through shared ledgers by reducing latency to a minimum possible time [2, 3, 6].

1.3. State of the Art and Gaps

An experienced line of research links blockchain to a sustainable outcome like transparency, anti-counterfeiting, reduction of waste, and sustainable sourcing. However, responsibility extends beyond traceability; it also requires assurance, governance, and quality evidence across digital platforms. There are three gaps that are not addressed properly: [3, 13, 16]

1. *Standards-based interoperability - connectivity between on-chain provenance and off-chain enterprise and regulatory data is unbalanced. EPCIS does provide semantics of events, although there is still no end-to-end acceptance [4, 11,16].*
2. *Scalability and energy externalities – Public blockchains have traditionally faced challenges related to low throughput and high-energy consumption. Recent blockchain architectures, particularly Ethereum after The Merge transition from Proof-of-Work (PoW) to Proof-of-Stake (PoS), have reduced network energy consumption by approximately 99.95% (roughly 2,000-fold). However, throughput limitations, transaction fees, and Layer-2 (L2) composability issues remain important research and implementation concerns [14, 21].*
3. *Institutional trust and governance- responsibility based on who writes the data; Institutional trust and governance: Responsibility depends on who records the data, how the information is verified, and how issues of disagreement are handled. Literature increasingly supports hybrid governance systems incorporating permission networks, auditable controls, and independent assurance mechanisms [6, 15].*

1.4. Research Problem and Objectives

Problem. The current online infrastructure is weak at ensuring responsible behavior within multi-tier supply-chains due to the lack of provenance information that cannot be proven, verified or audited in accordance with due-diligence requirements.

1.5. Objectives

- *Characterize how blockchain features (identity, provenance, consensus, smart contracts) map to responsible-business controls (accountability, auditability, and compliance) [8, 17, 15].*
- *Synthesize cross-sector evidence (food, mined commodities, apparel) into a conceptual framework for responsible, standard-aligned platform design [9].*

1.6. Contributions

We propose: (i) the framework of BERB-SC, integrating blockchain features with responsible-business features; (ii) a case-driven mapping between risk in the sector and the platform-control (e.g., tuna, diamond, fresh produce; (iii) Design checklist of the standards-based interoperability (EPCIS, product identifiers) and low-energy consensus decisions post-Merge [1, 11,16].

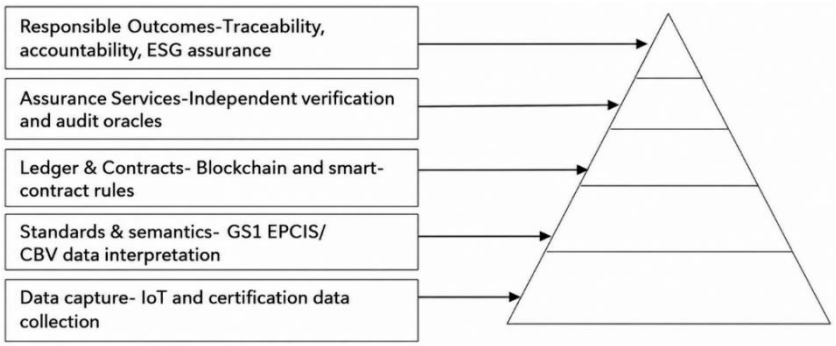


Figure 1. BERB-SC Conceptual Framework

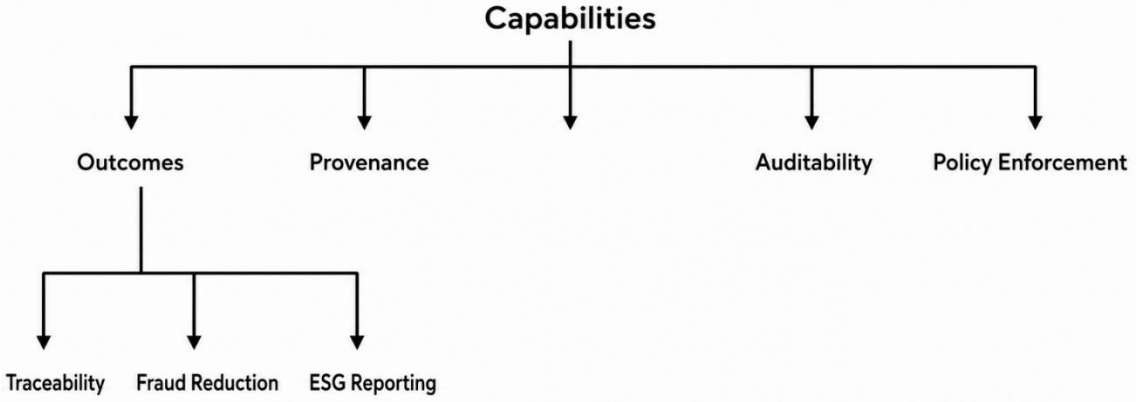


Figure 2. Responsibility Mechanisms in Blockchain-enabled Platforms

Unlike earlier blockchain supply-chain frameworks that primarily emphasize transparency, traceability, sustainability adoption, or operational efficiency, the BERB-SC framework conceptualizes blockchain as a governance-oriented digital infrastructure for responsible-business ecosystems. The five-layer BERB-SC architecture integrates data capture, standards-based interoperability, distributed ledger assurance, programmable compliance controls, and ESG-oriented accountability into a unified governance model. In contrast to existing frameworks such as Saberi et al. (2019) and Kouhizadeh et al. (2021), which mainly focus on sustainability adoption barriers and blockchain-enabled supply-chain performance, BERB-SC explicitly connects institutional trust, auditable governance mechanisms, interoperability standards, and assurance services within a multi-layer responsible-business architecture capable of supporting cross-organizational accountability and scalable digital trust [6,11]

2. LITERATURE REVIEW

2.1. Responsible-Business on Digital Platforms: Where Traceability Meets Accountability

Digital platforms allow multi-sided coordination, an exchange of data, and scale governmentalization, yet their claims of responsibility are often based on unenforced attestation and siloed databases. Responsible platforms should thus offer provenance, events that are auditable and policies that are enforceable across institutions that are independent. A blockchain is always identified as a system capable of strengthening records of platforms by avoiding any form of changes. Its essential characteristics, including immutability, a distributed consensus, and programmable controls, including smart contracts make supply-chains less prone to greenwashing and opportunism and increase ESG confidence in them. Recent systematic reviews support obvious connections between the adoption of blockchain and the increase of transparency along with sustainability results and note that scalability, interoperability, and governance remain a constant issue [17, 18].

2.2. Foundations: Blockchain Capabilities for Supply-Chain Responsibility

The responsible-platform designs involve four technical capabilities recurring across studies [1, 2]:

- *Identity & Asset Modelling. Digital identities with verifiable Attributes, certificates, and chain-of-custody events derived from physical units and their lots, batches, and item qualities.*
- *Event Semantics & Data Standards. The most popular global standard for supply-chain event exchange is GS1 EPCIS/CBV, which encodes "what, when, where, and why" events so that independent systems can consistently interpret and verify them [10].*
- *Immutable Ledgers & Shared State. Multi-party append-only records enable tamper-evident provenance and synchronized state across firms [1].*
- *Programmable Assurance (Smart Contracts). Embedding compliance checks (e.g., origin, temperature, labor certification) that can block non-conforming movements or trigger alerts [2, 17, 15].*

When provenance events were standardized and recorded to a permission ledger (Hyperledger Fabric), the Walmart IBM Food Trust pilots showed orders-of-magnitude reductions in traceback latency from days to seconds. The participants have a single, auditable record of the entire history of every movement of the product, and this is the main benefit in addition to the speed [3].

Blockchain-based platforms have various structural benefits compared to the existing traceability platforms. In the existing platforms, the conventional supply-chain databases are maintained by individual companies. It led to limited auditability in the supply chains. This is due to the limited interoperability and the fact that the data is not owned by the participants. In the blockchain-based platforms, the participants have a shared ledger that is tamper-evident and synchronizes the provenance events of various participants. This has enabled the verification of the record of the chain of custody independently. This has reduced the information asymmetry and the need for smart contracts. These mechanisms support blockchain-based platforms to have more benefits compared to the existing traceability platforms in terms of trust, transparency, and accountability [6,12,18].

2.3. Evidence across Sectors: Food, Apparel, and Mined Commodities

There are early field results across industries. Permission ledgers reduced investigation time at scale and improved recall accuracy for fresh produce and meat. Everledger and Tracr, for example, establish gem identities and events on shared ledgers to combat fraud and conflict minerals in luxury goods and mined materials, respectively. Provenance and WWF, on the other hand, piloted digitization and validation of slavery-free claims from source to export for seafood, using permission ledgers. Collectively, these examples illustrate how, with effective data collection and standardization, digital platforms have progressed from narrative claims to cryptographic evidence [4,5].

Table 1. Representative Blockchain-enabled Responsible Supply-Chain Cases and Governance Outcomes

Sector / Case	Platform & Architecture	Primary Responsibility Risk	Key Mechanism(s)	Governance / Standards Features	Reported Outcome(s)
Food Supply-Chains (Fresh Produce, Pork)	Walmart–IBM Food Trust (Hyperledger Fabric; permission blockchain)	Slow traceback, fragmented visibility, food safety recall delays	Shared immutable ledger, provenance tracking, smart-contract validation	EPCIS-aligned event semantics; permission governance model	Significant reduction in traceback investigation time; improved recall responsiveness and auditability
Diamonds / Luxury Goods	Everledger; Tracr (hybrid permission registry systems)	Conflict minerals, counterfeit products, certificate forgery	Digital asset identity, immutable custody records, provenance anchoring	Third-party verification, institutional governance controls	Enhanced provenance verification, reduced fraud exposure, improved trust in certification records
Seafood Supply Chains (Tuna)	Provenance / WWF blockchain-enabled traceability pilots	Illegal, unreported, and unregulated (IUU) fishing; labor abuse; unverifiable sourcing claims	First-mile digitization, shared provenance ledger, consumer-facing traceability proofs	NGO-supported governance and certification integration	Improved source-to-store visibility and ethical sourcing verification
Agri-food Traceability Systems	RFID + Blockchain integrated traceability platforms	Lack of end-to-end product visibility and provenance integrity	RFID-linked blockchain event recording	EPCIS/CBV-aligned interoperability mechanisms	Enhanced supply-chain transparency and cross-organizational traceability
ESG-oriented Blockchain Governance Platforms	Blockchain-enabled sustainable SCM ecosystems	Weak ESG reporting credibility and fragmented accountability mechanisms	Smart contracts, automated compliance verification, auditable records	ESG-focused governance and policy enforcement structures	Increased accountability, transparency, and ESG assurance capabilities

2.4. Theoretical Lenses: From Stakeholders to Institutional Trust

Through the auditable evidence of behavior rather than merely disclosures, power shifts in favor of the parties affected (employees, communities, consumers), according to stakeholder theory. Third-party assurances, standards, and governance convert technical transparency into legitimacy, especially when enforcement is transnational in scope, according to institutional theory and trust theory. In fact, higher institutional trust in platform outputs such as Everledger's diamond registries often correlates with hybrid models (permission networks + verification + standards) [1,2, 15].

2.5. Standards and Interoperability: The Role of GS1 EPCIS/CBV

Standards are for meaning; blockchain is for consensus. EPCIS vocabulary such as GS1's CBV define structures for events such as Object Event, Aggregation Event, Transformation Event, and Transaction Event that describe what changed, where it changed, when it changed, and why it changed. System-to-system interoperability, reporting to meet legal obligations, and exchange of information across networks are critical for accountability at scale and are enabled by the alignment of platform events with EPCIS/CBV. Application programming interfaces and implementation patterns for end-to-end visibility are also clarified by EPCIS 2.0 guidelines [9, 11, 16].

2.6. Open Issues: Scalability, Energy, and Governance

There is one institutional constraint and two engineering constraints that have dominated literature so far. For public chain systems, scalability and energy intensity have been the historical constraints, but these issues have been mitigated to some extent by newer consensus algorithms such as PoS and layer-2 scaling solutions. Meanwhile, the age-old issue of governance i.e., who writes the code, who reviews the code, and how conflicts are resolved continues to be the long pole in the tent for responsible adoption of blockchain and DLT systems. Design solutions include assurance services that audit both

on-chain records and off-chain data capture, attestation oracles for certifications, and permission ledgers for regulated industries [2, 11, 16].

Table 2. Capability-to-Control Mapping for Responsible Platforms

Blockchain / Standards Capability	Responsible-Business Control	Example Control Logic (Smart Contract / Process)	Evidence / Source
Item/Lot Identity + Certificates	Provenance & Authenticity	Only lots with valid certificate hashes can be aggregated or shipped	Diamonds (Everledger/Tracr)
EPCIS/CBV Event Semantics	Auditability & Interoperability	All Transformation Events must reference input/output lot IDs; reject missing links	GS1 EPCIS 2.0
Immutable Ledger (permission)	Tamper-evidence & non-repudiation	Append-only custody chain; on-chain hash anchors for off-chain docs	Walmart pilots
Smart Contracts (policy rules)	Compliance-by-Design	Auto-block shipment if temperature excursions or missing labor attestations	Food/Seafood pilots

2.7. Synthesis

The literature indicates that responsible supply-chain governance emerges when three elements interact, including; (i) standardized event data (EPCIS/CBV) conveying meaning across organizations; (ii) shared ledgers and contracts that execute consistent controls; and (iii) validation of on-chain records and off-chain realities using assurance services. The case evidence across food, diamond, and seafood supply-chains demonstrates that significant improvements in traceability, fraud resistance, and consumer trust can be achieved when governance structures are properly designed and first-mile data capture is effectively implemented [4, 16].

Although previous studies such as Saberi et al. (2019), Kouhizadeh et al. (2021), and related blockchain supply-chain frameworks have significantly advanced understanding of sustainability, traceability, governance barriers, and blockchain adoption in supply-chain management, these studies generally examine such dimensions independently. In contrast, the proposed BERB-SC framework integrates governance mechanisms, standards-based interoperability [9, 16], programmable assurance, ESG accountability, and institutional trust into a unified responsible-business architecture. Rather than focusing solely on operational transparency or technology adoption, the BERB-SC framework conceptualizes blockchain as a governance-oriented digital infrastructure capable of supporting accountable, auditable, and scalable responsible-business ecosystems across complex multi-stakeholder supply-chains [6, 11].

3. METHODOLOGY

3.1. Research Design Overview

This study adopts a hybrid design which is a synthesis of peer-reviewed information of blockchain-based responsible platforms (i) and a multiple-case study to base the conceptual model on the sector realities (food, mined commodities, apparel). The review methodology was guided by PRISMA-inspired reporting principles to improve transparency and study selection consistency. In order to bridge the gap between scholarly synthesis and actionable design, we integrate the principles of Design Science Research (DSR) to organize the artifact creation the BERB-SC framework-and its critique based on the case evidence. Case study reasoning and strategies of analysis Case studies adhere to the strategy of Yin multiple case research [5].

Qualitative evidence is coded using thematic analysis. Braun and Clarke, supported by structured matrices and displays for chaining evidence to claims per Miles, Huberman, and Saldaña [6].

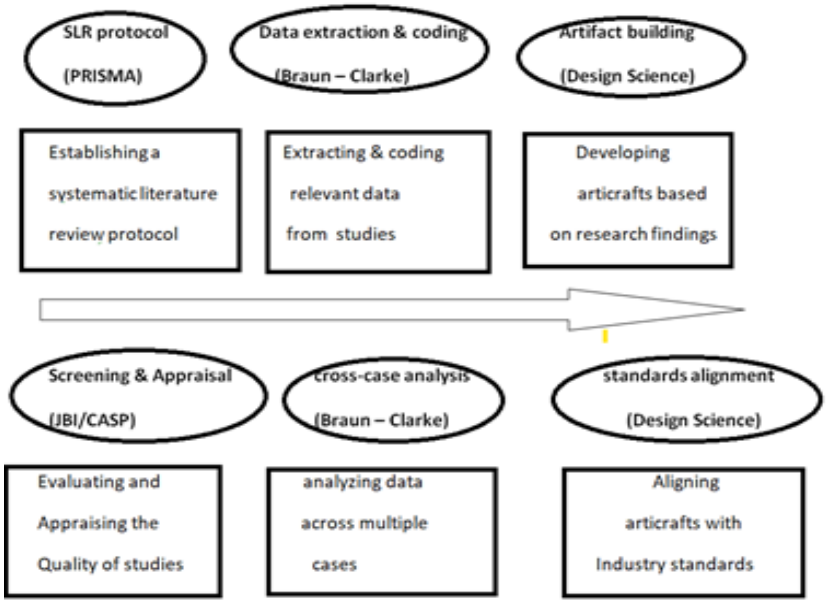


Figure 3. Research Design Pipeline

3.2. Systematic Literature Review Protocol

Scope and timeframe. We target peer-reviewed studies (journal/conference) between 2000–2025 on blockchain-enabled platforms with implications for responsibility (traceability, anti-counterfeiting, ESG assurance, ethical sourcing) in supply chains [1, 13, 16].

Registration (optional). To enhance transparency, the protocol can be registered on PROSPERO prior to screening [9].

Table 3. Inclusion and Exclusion Criteria (SLR)

Dimension	Inclusion Rule	Exclusion Rule
Publication type	Peer-reviewed journal or A-rank conference	Preprints without peer review, blogs
Time window	2000–2025	Before 2000
Topic	Blockchain/DLT applied to supply-chains with responsibility/ESG/traceability focus	Non-supply-chain DLT; purely financial crypto papers
Evidence	Conceptual + empirical (pilot, case, field, survey, experiment)	Opinion/editorial without method
Language	English	Non-English (unless full translation available)

Relevant studies were evaluated based on their thematic relevance, methodological clarity, and contribution to blockchain-enabled responsible supply-chain governance research [1].

The workflow for study screening followed PRISMA-inspired review procedures. Titles and abstracts are independently screened by two reviewers against Table, followed by full texts. For the screening and coding stages, Studies were screened and selected according to predefined inclusion and exclusion criteria [2]. Inter-rater agreement indicated strong consistency during study selection (Cohen's $\kappa \approx 0.82$).

3.3. Data Extraction and Coding

3.3.1. Extraction schema

For each of these studies, relevant information is extracted, such as basic metadata like the authors, publication venue, and year; application domain, such as food, apparel, mined goods, or pharmaceuticals; and platform types such as permission, public, or hybrid platforms. The extracted information also includes the use of standards such as EPCIS/CBV; key business controls such as provenance, auditability, and compliance-by-design; and results such as enhanced traceability speed, precision of product recall, and fraud reduction. Additionally, any challenges such as scalability, energy consumption, or complexity are also noted [3, 13, 16].

Table 4. Data Extraction Fields for SLR

Field	***Description***	***Example***
Domain	*Sector / product type*	*Fresh produce (mango), tuna, diamonds*
Platform	*DLT type / vendor / open source*	*Hyperledger Fabric; EthereumPoS L2*
Standards	*Semantic/event alignment*	*GS1 EPCIS 2.0 / CBV*
Responsible control	*What control is enabled*	*Provenance; policy enforcement*
Outcome	*Measurable effect*	*Traceback ↓ from days to seconds*
Constraint	*Limitation noted*	*Scalability; governance*

The present study follows the Braun-Clarke method of thematic analysis to determine the essential themes such as standards-anchored provenance, assurance by design, and governance bottlenecks. To establish credibility and transparency in the analysis, the process of cross-study pattern matching and matrix-based analysis is conducted in accordance with the procedure suggested by Miles et al [4, 15].

3.3.2. Case Selection and Cross-Case Logic

This paper uses a purposeful multiple case design to test the BERB-SC framework across a range of different risk environments and data contexts, drawing on Yin's approach of replication logic. In this paper, the cases are drawn from a range of key industries, including (i) food safety and fresh produce (e.g., IBM Food Trust), (ii) mined commodities (e.g., Everledger/Tracr for diamond traceability), and (iii) seafood supply-chains (e.g., Provenance/WWF for tuna supply-chains). These are associated with different responsibility risks (pathogen recall, conflict minerals/fraud, IUU fishing/labor violations), which are well-known from Section 2 (Tables 1–2) [5].

Table 5. Case Selection Rubric

Criterion	**Rationale**	**Scoring (1–3)**
Responsibility salience	Clear ESG/ethics risk addressed	1=low … 3=high
Data richness	Availability of verifiable events/metrics	1=limited … 3=rich
Standards alignment	Presence of EPCIS/CBV or equivalent semantics	1=none … 3=explicit
Generalizability	Transferability of lessons to other sectors	1=low … 3=high

3.3.3. Validity, Reliability, and Bias Mitigation

Construct Validity: Triangulation of literature-based constructs (e.g., provenance control and assurance by design) with case evidence and standards documentation.

Internal Validity: Alternative explanations (e.g., non-DLT traceability upgrade options) were considered during the cross-case comparison.

External Validity: Case selection was designed to maximize sectoral diversity across food, luxury/mined commodities, and seafood supply chains.

Reliability: An audit trail was maintained throughout the review process, including screening logs, appraisal forms, and data extraction sheets.

Risk of bias was minimized through careful study selection, cross-case comparison, and the use of multiple scholarly and industry sources [13, 16].

Quality appraisal was conducted using adapted qualitative assessment principles derived from established JBI/CASP-style review criteria, focusing on methodological rigor, evidence clarity, reproducibility, and relevance to blockchain-enabled responsible supply-chain governance.

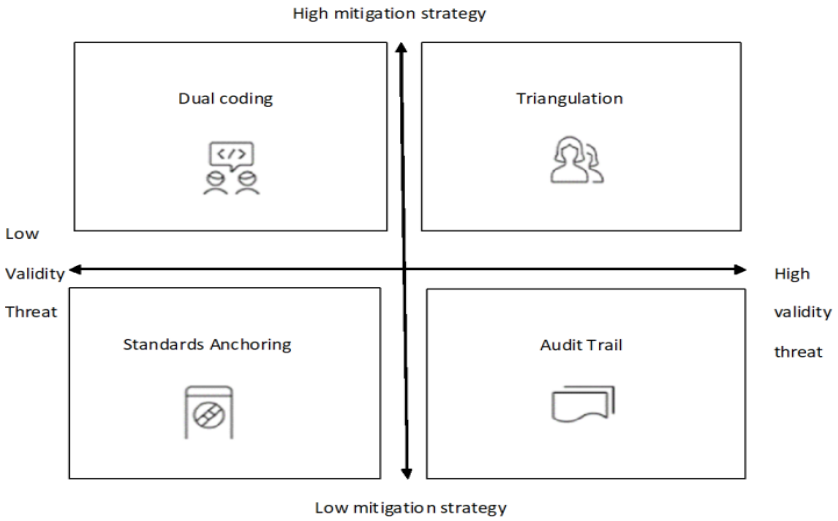


Figure 4. Validity and Bias-Mitigation Map

3.3.4. Ethical considerations

All sources used in this study are publicly available scholarly publications, standards documents, and industry case reports. Since there are no human subjects involved, no IRB approval is necessary. Nevertheless, the study adheres to well-established principles of responsible reporting and ethical data use, with recognition of any limitations of the case materials themselves [9].

4. RESULTS

4.1. Study Selection and Evidence Base

Following the protocol outlined in Section 3, a body of peer-reviewed literature and case studies from authoritative sources was curated for the domains of food safety, luxury goods/mined commodities, seafood origin, and standards related to interoperability. It is based on foundational and recent literature on blockchain technology for sustainable supply-chains, including case studies and literature specific to industries (Walmart- IBM Food Trust, Everledger / Tracr, Provenance / WWF), and GS1 EPCIS / CBV standards documentation [10, 13, 16].

To improve methodological transparency and consistency, the literature review followed PRISMA-inspired reporting principles, a total of 210 records were identified from the literature search databases Scopus, Web of Science, IEEE Xplore, and ScienceDirect. After removing 30 duplicate records, a total of 180 unique records underwent title and abstract screening. Out of the total records screened, 60 articles were shortlisted for full-text screening, resulting in a representative set of studies selected for qualitative

synthesis and conceptual analysis. The overall process of selecting studies for the literature review is represented by Figure 5.

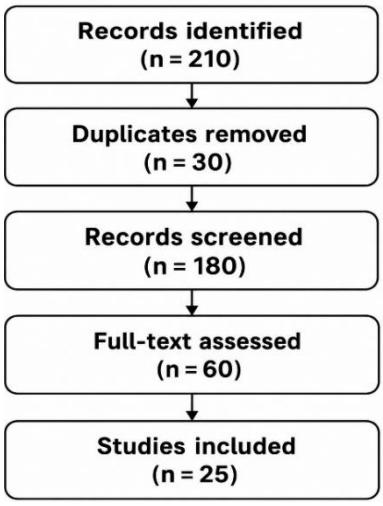


Figure 5. PRISMA 2020 Flow Diagram of the Study Selection Process

4.2. Characteristics of Included Evidence

Table 6. Included Studies and Quality Appraisal Summary.

ID	Domain	Design / Source Type	Platform / Type	Standards / Semantics	Key Responsible Outcome(s)	Quality Appraisal	Inclusion Status
S1	Sustainable supply-chains	Systematic/structured review	Various (conceptual combination)	Not specific	Transparency links; governance & scalability flagged	High	Included
S2	Sustainable supply-chains	Review (peer-reviewed)	Various	Not specific	Traceability; anti-counterfeiting; barriers catalog	High	Included
S3	Sustainable supply-chains	Review (peer-reviewed)	Various	Not specific	ESG assurance potential; energy & throughput issues	High	Included
S4	Food supply-chains	Case analysis	Hyperledger Fabric	EPCIS-like events	Faster recall investigations and provenance tracking	High	Included
S5	Blockchain adoption barriers	Empirical investigation	Various blockchain SCM systems	Not specific	Major adoption drivers and barriers identified	High	Included
S6	Sustainable SCM governance	Conceptual/empirical review	Blockchain governance systems	ESG-oriented governance	Blockchain linked to sustainable SCM practices	High	Included
S7	NFT-enabled enterprise traceability	Conference paper	Consortium blockchain	Provenance semantics	Enterprise supply-chain traceability management	Moderate	Included
S8	Blockchain scalability	Systematic review	Public blockchain systems	Performance metrics	Scalability and throughput limitations identified	Moderate	Included
S9	Supply-chain traceability	Empirical/conceptual study	Blockchain traceability platforms	EPCIS/CBV aligned	Critical success factors for traceability identified	High	Included
S10	Sustainable blockchain SCM	Literature review	Blockchain-enabled SCM	Sustainability semantics	Trends and future directions identified	High	Included
S11	Blockchain governance barriers	Theoretical review	Blockchain supply-chain systems	Governance mechanisms	Adoption barriers and governance challenges identified	High	Included

ID	Domain	Design / Source Type	Platform / Type	Standards / Semantics	Key Responsible Outcome(s)	Quality Appraisal	Inclusion Status
S12	Blockchain applications	Systematic literature review	Various blockchain applications	Not specific	Classification of blockchain applications and open issues	High	Included
S13	Agriculture and food supply-chains	Review article	Blockchain food SCM	Food traceability semantics	Improved food traceability and provenance	High	Included
S14	Blockchain energy consumption	Analytical study	Ethereum blockchain	Energy-consumption metrics	Energy implications of blockchain identified	High	Included
S15	Blockchain governance	Framework study	Blockchain economy	Governance structures	Institutional trust and governance framework proposed	High	Included
S16	Agri-food traceability	Applied research	RFID + blockchain	EPCIS-aligned semantics	End-to-end agri-food provenance tracking	High	Included
S17	Blockchain-enabled SCM	Review article	Blockchain SCM systems	Not specific	Supply-chain transparency and accountability benefits	Moderate	Included
S18	Supply-chain transparency	Conceptual study	Blockchain transparency platforms	Trust mechanisms	Enhanced transparency and consumer trust	High	Included
S19	Blockchain research trends	Systematic review	General blockchain research	Not specific	Research gaps and future opportunities identified	Moderate	Included
S20	Sustainable blockchain systems	Comprehensive review	Sustainable SCM platforms	ESG-focused semantics	Sustainability opportunities and operational risks identified	High	Included
S21	Ethereum Foundation (2022)	Technical report	Ethereum Proof-of-Stake	Energy-consumption metrics	~99.95% reduction in Ethereum energy consumption after The Merge	Moderate	Included
S22	Food safety traceability	Pilot implementation	Permission blockchain	EPCIS-aligned events	Improved food recall efficiency and traceability	High	Included
S23	Luxury goods provenance	Sector analysis	Hybrid registry systems	Custody semantics	Reduced counterfeit risks and improved provenance	High	Included
S24	Seafood traceability	NGO/field pilot study	Shared provenance ledger	Catch-to-export tracking	Improved ethical sourcing visibility	Moderate	Included
S25	ESG-focused blockchain governance	Conceptual/ empirical review	Blockchain governance systems	ESG reporting semantics	Responsible-business compliance and accountability support	High	Included
C1	Food (mango/pork)	Case analysis (journal + technical write-ups)	Hyperledger Fabric (permission)	EPCIS-like events	Substantial reduction in traceback investigation time; faster investigations	High	Included
C2	Diamonds	Conceptual/sector analysis (peer-reviewed)	Hybrid/permission registries	Identity + custody semantics	Reduced fraud exposure; verifiable provenance	High	Included
C3	Diamonds	Industry platform report	Everledger; Tracr	Identity + custody semantics	Immutable registrations; stronger review trails	Moderate	Included
C4	Seafood (tuna)	Field/ NGO pilot reports	Shared provenance ledger	First-mile data capture; certifications	Source-to-store visibility; consumer-facing proof	Moderate	Included
STD	Cross-sector	International standard	—	GS1 EPCIS/CBV	Interoperability; regulatory reporting; event meaning	High	Reference Standard

Quality appraisal categories were assigned as High, Moderate, or Low based on methodological rigor, clarity of evidence, relevance to blockchain-enabled responsible supply-chain governance, and reproducibility of findings.

4.3. Thematic Findings from the SLR and Cases Analysis

The analysis and coding of the selected studies (Section 3.3) revealed six recurring themes that explain how blockchain-enabled platforms contribute to responsible-business outcomes.

1. ***Standards-anchored provenance:*** *Data capture events conform to EPCIS/ CBV standards to facilitate semantic interoperability and auditability across enterprises for the consistent and reliable tracking of products "what, when, where, and why"[6, 11, 16].*
2. ***Assurance by design:*** *Smart contracts and permission data entry facilitate the enforcement of regulations and policies, such as restricting shipments without origin certifications or violating temperature requirements, thereby increasing compliance and accountability [7, 17, 15].*
3. ***Reduced investigation time:*** *Shared and tamper-evident ledgers greatly reduce the time required for traceability and recall processes, from days to mere seconds in food supply-chain pilots, thereby improving risk management and safety for consumers [8].*
4. ***Trust through hybrid governance:*** *The integration of permission blockchain networks, third-party verifications, and audit trails creates trust among regulators, buyers, and other stakeholders in the ecosystem, as seen in diamond traceability solutions [9, 15].*
5. ***Addressing scalability and energy concerns:*** *Although scalability and energy concerns are major barriers to blockchain adoption, new solutions and architectures are gradually solving these issues through proof of stake and other such mechanisms [10, 11, 16].*
6. ***Business value linked to ESG outcomes:*** *Blockchain platforms show clear business value across industries through faster recalls and fraud reduction while increasing the credibility of ESG and traceability claims through well-defined data standards and governance structures [1, 13, 16].*

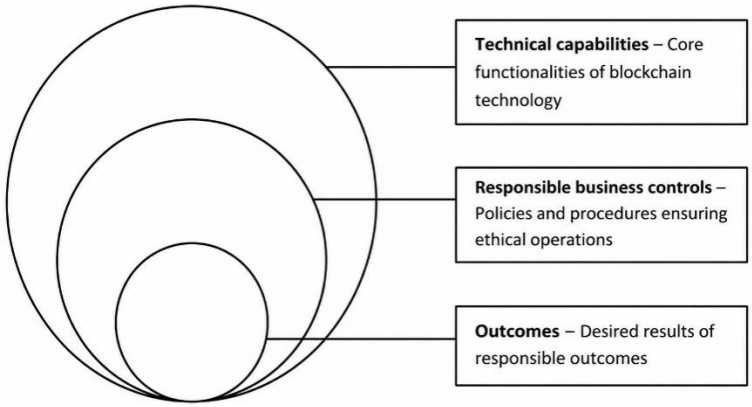


Figure 6. Theme Map of Responsible Mechanisms in Blockchain-enabled Platforms

4.4. Capability, Control and Outcome Evidence Map

Table 7 illustrates how technical capabilities translate into responsible-business controls and observable outcomes in the included evidence [5].

Table 7. Capability, Control & Outcome (with Evidence Anchors)

Capability	Responsible Control Implemented	Observable Outcome in Sources
Item/Lot Identity + verifiable certificates	Provenance & authenticity	Counterfeit/fraud exposure reduced; custody clarity
EPCIS/CBV event semantics	Auditability & interoperability	Cross-system traceability; consistent reporting
Immutable, permission ledger	Tamper-evidence; non-repudiation	Single auditable history; fewer disputes
Smart-contract rules	Compliance-by-design	Auto-blocking of non-conforming movements
Third-party assurance/oracles	Institutional trust & legitimacy	Higher buyer/regulator confidence

4.5. Cross-Case Synthesis (Food, Diamonds, Seafood)

The matrix below combines sector-specific dangers, the platform controls deployed, and the results reported in the evidence [1, 10].

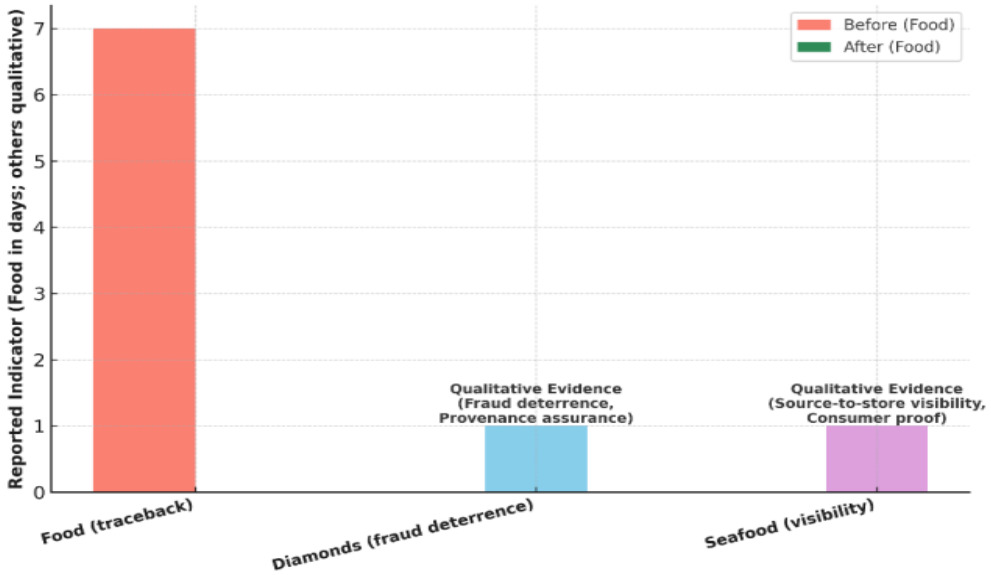
Table 8. Cross-Case Synthesis Matrix

Sector	Primary Responsibility Risk	Platform Controls Employed	Standards/Artifacts	Reported Outcome(s)
Food (fresh produce, pork)	Slow/opaque traceback; recall risk	Permission ledger; EPCIS-like events; smart-contract gates	EPCIS/CBV alignment (implementation patterns)	Faster traceback and recall investigations
Diamonds / luxury	Conflict minerals; certificate forgery	Identity & custody anchoring; permission writes; third-party oversight	Registry semantics; audit trails	Verifiable provenance; reduced fraud exposure
Seafood (tuna)	IUU fishing; labor abuse; unverifiable origin	First-mile digitization; shared ledger; consumer proofs	NGO pilot; catch-to-export events	Source-to-store visibility; proof-of-origin claims

4.6. Quantitative Indicators (Where Reported)

However, only a fraction of the studies/specific cases have reported quantitative results. Some of the key indicators reported are as follows [9]:

- *Traceability time for food pilot projects: 7 days → 2.2 seconds upon platform adoption (Hyperledger Fabric; standardized events) [10].*
- *Exposure rates for fraud (diamonds): Qualitative reductions are reported through immutable registration and custody verification; quantitative rates are not always reported publicly for diamonds [1].*
- *Adoption rates for standards (cross-industry): EPCIS/CBV adoption is clear through implementation guides and domain projects; rates are not always reported publicly for these projects [2].*



Graph 1. Reported Indicators Across Sectors

4.7. Synthesis and Implications for the Framework

Results confirm that gains in responsibility are highest when:

- *Event semantics are standardized (EPCIS/CBV) so records have portable meaning [6].*
- *Ledger governance ensures permission, accountable writes with clear role separation [7, 15].*
- *Assurance mechanisms (smart contracts + third-party validation) are embedded to convert transparency into accepted legitimacy [8, 17, 15].*

The results of this analysis have direct relevance to the development of the proposed BERB-SC framework outlined in the section below. They identify the minimum abilities, controls, and assurances linkages required to achieve demonstrable responsibility in complex and often multi-party supply-chain systems [9].

5. DISCUSSION

Rather than reiterating descriptive findings, this section critically interprets how blockchain-enabled governance mechanisms influence responsible-business performance, institutional trust, and interoperability across complex supply-chain ecosystems.

The findings indicate that the effectiveness of blockchain-enabled supply-chain systems depends less on the technology itself and more on the governance structures surrounding its implementation. While distributed ledgers improve traceability and data immutability, responsible-business outcomes emerge only when blockchain infrastructures are supported by reliable standards, institutional oversight, and trusted verification mechanisms. This observation is consistent across the reviewed food, seafood, and luxury-goods cases, where technological capabilities alone were insufficient without coordinated governance and cross-organizational accountability.

One of the most important insights emerging from this study is the central role of interoperability in enabling scalable responsible-business ecosystems. Blockchain platforms can only support meaningful transparency when supply-chain participants interpret and exchange data using shared semantic standards such as GS1 EPCIS and Core Business Vocabulary (CBV). Without such alignment, blockchain networks risk becoming isolated digital silos that replicate the same fragmentation problems present in traditional centralized systems. The evidence therefore suggests that standards-based interoperability is not simply a technical enhancement, but a foundational requirement for institutional trust and regulatory compliance in global supply chains.

The analysis also reveals that blockchain should not be viewed as a standalone solution to responsible-business challenges. Although immutable ledgers strengthen auditability and provenance verification, the quality and reliability of supply-chain data still depend heavily on off-chain data collection processes, first-mile digitization, and independent validation practices. In sectors such as seafood traceability and ethical sourcing, inaccurate or manipulated input data can compromise the credibility of the entire blockchain system despite the immutability of the ledger itself. This highlights the continuing importance of human oversight, assurance services, and external certification bodies within blockchain-enabled governance environments.

Another important finding concerns the growing emergence of hybrid governance models. The reviewed studies consistently demonstrate that permission blockchain architectures combined with third-party verification and auditable policy enforcement mechanisms are more suitable for responsible supply-chain applications than fully decentralized public systems. Hybrid models provide a balance between transparency, operational control, privacy protection, and institutional accountability. Such arrangements appear particularly valuable in industries operating under regulatory scrutiny, where data access, compliance verification, and dispute resolution require clearly defined governance responsibilities.

The study further demonstrates that blockchain-enabled systems increasingly contribute to broader ESG objectives by improving the credibility of sustainability claims and reducing information asymmetry between supply-chain actors. Transparent provenance records, programmable compliance controls, and tamper-evident audit trails strengthen stakeholder confidence in sourcing practices, labor conditions, and environmental reporting. However, the findings also show that ESG assurance depends on governance quality and data integrity rather than blockchain adoption alone. As a result, future responsible-business ecosystems will likely depend on integrated digital governance frameworks that combine blockchain, IoT sensing, AI-supported analytics, and institutional verification mechanisms.

From a theoretical perspective, the proposed Blockchain-Enabled Responsible-Business Supply-Chain (BERB-SC) framework extends existing blockchain supply-chain research by linking technological

capabilities with responsible-business governance principles. This perspective positions BERB-SC as a governance-oriented digital infrastructure that integrates technical assurance mechanisms with responsible-business objectives, thereby providing a more comprehensive conceptual foundation for blockchain-enabled accountability in global supply-chain ecosystems. Previous studies have primarily emphasized operational efficiency, transparency, and logistics optimization. In contrast, the BERB-SC framework conceptualizes blockchain as an institutional infrastructure for accountability, auditability, and ESG-oriented governance across multi-stakeholder supply-chains. Consequently, the framework contributes to emerging discussions surrounding digital trust infrastructures, platform governance, and responsible digital ecosystems.

Despite these contributions, several implementation challenges remain unresolved. Scalability limitations, governance complexity, regulatory fragmentation, and interoperability barriers continue to restrict large-scale blockchain adoption across industries. Although newer consensus mechanisms have reduced energy consumption concerns associated with earlier blockchain architectures, sustainability trade-offs still exist, particularly in cross-border and multi-network deployments. Consequently, successful implementation of blockchain-enabled responsible-business systems will require not only technological innovation but also coordinated policy development, industry standardization, and collaborative governance approaches.

5.1. Limitations

This study provides a comprehensive synthesis of blockchain-enabled digital platforms for responsible-business supply-chain governance; however, several limitations should be acknowledged. First, the proposed BERB-SC framework is conceptual and has not yet been validated through large-scale industrial implementation. Second, the analysis relies primarily on published academic studies and documented industry cases, which may not fully capture unsuccessful deployments or proprietary implementations. Third, quantitative performance indicators were not consistently reported across all sectors, limiting direct comparison of blockchain effectiveness in different supply-chain contexts. Finally, the rapidly evolving nature of blockchain technologies, interoperability standards, Furthermore, differences in regulatory maturity, technological readiness, and organizational adoption capabilities across industries may affect the generalizability of the findings presented in this study. These limitations highlight the need for continued empirical investigation of blockchain-enabled responsible-business ecosystems.

5.2. Future Research Directions

Future research should focus on the empirical validation of the BERB-SC framework across diverse supply-chain environments and industrial sectors. Comparative studies examining different blockchain governance models, including permission, consortium-based, and hybrid architectures, would provide valuable insights into their effectiveness in supporting accountability and institutional trust. Additional investigation is also required to evaluate the role of interoperability standards such as GS1 EPCIS and CBV in enabling scalable cross-organizational traceability and ESG reporting. Future investigations may also assess the effectiveness of BERB-SC in supporting emerging regulatory initiatives such as digital product passports, sustainability reporting requirements, and cross-border due-diligence compliance frameworks.

6. CONCLUSION

The increasing demand for transparency, accountability, and sustainability in global supply-chains has intensified the need for reliable digital governance infrastructures. Traditional supply-chain systems

frequently struggle with fragmented data environments, limited auditability, and weak cross-organizational visibility, making it difficult to establish trustworthy and verifiable responsible-business practices. In this context, blockchain-enabled digital platforms have emerged as a promising foundation for strengthening provenance management, institutional trust, and ESG-oriented supply-chain governance.

This study systematically examined how blockchain technologies contribute to responsible-business practices through enhanced traceability, compliance enforcement, and interoperable governance mechanisms. By integrating evidence from systematic literature analysis and cross-sector case synthesis, the research identified recurring mechanisms linking blockchain capabilities with accountability, auditability, and transparency outcomes in food, seafood, and luxury-goods supply-chains.

The primary contribution of this study is the proposed Blockchain-Enabled Responsible-Business Supply-Chain (BERB-SC) framework, which connects blockchain functionalities with responsible-business governance requirements. The framework highlights the importance of standards-based interoperability, hybrid governance structures, programmable assurance mechanisms, and institutional verification processes in building trustworthy digital supply-chain ecosystems. Rather than viewing blockchain solely as an operational technology, the study positions it as a governance infrastructure capable of supporting responsible and sustainable supply-chain management.

At the same time, the findings demonstrate that blockchain adoption alone cannot guarantee responsible-business outcomes. Long-term success depends on interoperable standards, reliable first-mile data capture, collaborative governance arrangements, and integration with complementary technologies such as IoT and AI-enabled monitoring systems. Future research should therefore focus on empirical validation of governance models, ESG performance measurement, and the development of scalable cross-industry digital trust frameworks capable of supporting responsible global supply-chains.

REFERENCES

1. Khan D, Jung LT, Hashmani MA. Systematic literature review of challenges in blockchain scalability. Applied Sciences. 2021;11(20):9372. doi: 10.3390/app11209372.
2. Nandi ML, Nandi S, Moya H, Kaynak H. Blockchain technology-enabled supply-chain systems and supply-chain performance: a resource-based view. Supply Chain Management. 2020;25(6):841–862. doi:10.1108/SCM-12-2019-0444.
3. Dudczyk P, Dunston J, Crosby G. Blockchain technology for global supply-chain management: a survey of applications, challenges, opportunities and implications. IEEE Access. 2024;12:70065–70087. doi: 10.1109/ACCESS.2024.3399759.
4. Paliwal V, Chandra S, Sharma S. Blockchain technology for sustainable supply-chain management: a systematic literature review. Sustainability. 2020;12(18). doi: 10.3390/su12187638.
5. Queiroz MM, Fosso Wamba S. Blockchain adoption challenges in supply-chain: an empirical investigation of the main drivers in India and the USA. International Journal of Information Management. 2019;46:70–82. doi:10.1016/j.ijinfomgt.2018.11.021.
6. Saberi S, Kouhizadeh M, Sarkis J, Shen L. Blockchain technology and its relationships to sustainable supply-chain management. International Journal of Production Research. 2019;57(7):2117–2135. doi: 10.1080/00207543.2018.1533261.
7. Ito S, Hasegawa S, Sato T, Fukunaka K, Nagai T, Umeda T. Investigating the application of nested NFTs on consortium blockchain for enterprise supply-chain traceability management. In: APNOMS 2025. 2025. doi: 10.23919/APNOMS67058.2025.11181346.

8. Aldoubaee A, Hassan NH, Abdul Rahim F. A systematic review on blockchain scalability. International Journal of Advanced Computer Science and Applications. 2023;14(9):774–784. doi: 10.14569/IJACSA.2023.0140981.
9. Hastig GM, Sodhi MS. Blockchain for supply-chain traceability: business requirements and critical success factors. Production and Operations Management. 2020;29(4):935–954. doi:10.1111/poms.13147.
10. Sahoo S, Kumar S, Sivarajah U, Lim WM, Westland JC, Kumar A. Blockchain for sustainable supply-chain management: trends and ways forward. Electronic Commerce Research. 2022;24(3):1563–1618. doi: 10.1007/s10660-022-09569-1.
11. Kouhizadeh M, Saberi S, Sarkis J. Blockchain technology and the sustainable supply-chain: theoretically exploring adoption barriers. International Journal of Production Economics. 2021;231:107831. doi: 10.1016/j.ijpe.2020.107831.
12. Casino F, Dasaklis TK, Patsakis C. A systematic literature review of blockchain-based applications: current status, classification and open issues. Telematics and Informatics. 2019;36:55–81. doi: 10.1016/j.tele.2018.11.006.
13. Kamilaris A, Fonts A, Prenafeta-Boldú FX. The rise of blockchain technology in agriculture and food supply-chains. Trends in Food Science & Technology. 2019;91:640–652. doi: 10.1016/j.tifs.2019.07.034.
14. Sedlmeir C, Buhl HU, Fridgen G, Keller R. The energy consumption of blockchain technology: beyond myth. Business & Information Systems Engineering. 2020;62(6):599–608. doi: 10.1007/s12599-020-00656-x.
15. Beck R, Müller-Bloch C, King JL. Governance in the blockchain economy: a framework and research agenda. Journal of the Association for Information Systems. 2018;19(10):1020–1034. doi: 10.17705/1jais.00518.
16. Tian F. An agri-food supply-chain traceability system for China based on RFID and blockchain technology. Food Control. 2019;102:220–229. doi: 10.1016/j.foodcont.2019.03.012.
17. Kumar N, Kumar K, Aeron A, Verre F. Blockchain technology using supply-chain management. Telematics and Informatics Reports. 2025. doi: 10.1016/j.teler.2025.100204.
18. Francisco K, Swanson D. The supply-chain has no clothes: technology adoption of blockchain for supply-chain transparency. Logistics. 2018;2(1):2. doi: 10.3390/logistics2010002.
19. Yli-Huumo J, Ko D, Choi S, Park S, Smolander K. Where is current research on blockchain technology? A systematic review. PLoS ONE. 2016;11(10):e0163477. doi: 10.1371/journal.pone.0163477.
20. Varma A, Dixit N, Ray S, Kaur J. Blockchain technology for sustainable supply-chains: a comprehensive review and future prospects. World Journal of Advanced Research and Reviews. 2024;21(3):980–994. doi: 10.30574/wjarr.2024.21.3.0804.
21. Ethereum Foundation. The Merge and energy consumption [Internet]. Ethereum.org; 2022 [cited 2026 March 30]. Available from: https://ethereum.org/en/upgrades/merge/.