CHAPTER 17

Blockchain for Sustainable Supply Chains: Driving Transparency, Trust, and Eco-Innovation in Industry 5.0

*Aastha Nitin Pawar**

ABSTRACT

Sustainability has become a strategic priority for organizations worldwide, yet traditional supply chains continue to face challenges such as lack of transparency, fraud, inefficiency, and environmental harm. Emerging technologies offer promising solutions, and among them, blockchain has gained global attention as a driver of sustainable innovation. This paper explores the role of blockchain in building transparent, resilient, and eco-friendly supply chains. Through a review of existing literature and analysis of real-world case studies such as Walmart and IBM Food Trust, the paper highlights how blockchain can enable end-to-end traceability, reduce carbon footprint, and ensure ethical sourcing of materials. Furthermore, the study evaluates the integration of blockchain with Industry 5.0 technologies such as IoT and AI to create intelligent and sustainable ecosystems. The findings suggest that blockchain not only enhances operational efficiency but also contributes to the United Nations' Sustainable Development Goals (SDGs), particularly responsible consumption and climate action. The paper concludes with recommendations for businesses and policymakers to adopt blockchain-based sustainable supply chain models, while outlining future research directions in scalability, energy efficiency, and regulatory frameworks.

Keywords: Blockchain; Sustainable supply chains; Sustainable Development Goals (SDGs); Industry 5.0.

1.0 Introduction

The way businesses operate today is very different from a few decades ago. In an interconnected and highly competitive world, organisations are not judged only by their efficiency or profitability. They are also measured by their social conscience, environmental responsibility, and ability to act transparently. Climate change, resource depletion, and unethical labour practices have placed global supply chains under intense scrutiny. Traditional supply chains, designed with cost efficiency as their primary goal, are now under fire for their lack of visibility and accountability.

**Student, Department of BCA, Dr. Moonje Institute of Management and Computer Studies (DMIMCS), Nashik, Maharashtra, India (E-mail: aasthanpawar2006@gmail.com)*

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Products cross borders, pass through multiple intermediaries, and often reach the consumer with little or no information about their origin or the conditions under which they were produced. This lack of visibility creates fertile ground for problems: counterfeiting, fraud, worker exploitation, and environmental violations.

Sustainability has therefore moved from being a "nice-to-have" to a core requirement in both research and practice. Sustainable Supply Chain Management (SSCM) calls for businesses to create value not just for shareholders but also for society and the environment. Yet, achieving this balance is complex. It requires tools that can bridge gaps of trust, improve transparency, and support eco-friendly innovation.

One such tool is blockchain technology. Initially known as the backbone of Bitcoin, blockchain has grown far beyond cryptocurrencies. At its core, it is a secure, decentralised ledger that records transactions in a way that cannot be tampered with. Every participant has access to the same verified data, eliminating manipulation and building trust.

Real-world examples already show its impact. Walmart, in partnership with IBM, reduced the time needed to trace contaminated food from a week to just over two seconds. Maersk, the global shipping leader, has used blockchain to cut paperwork and inefficiencies in logistics through its TradeLens platform. These are not futuristic experiments—they are practical applications reshaping industries today.

The conversation becomes even more compelling when we place blockchain within the vision of Industry 5.0. Unlike Industry 4.0, which focused on automation and efficiency, Industry 5.0 emphasises human-centric innovation, resilience, and sustainability. It seeks a world where technology and human creativity collaborate to solve pressing global challenges. Blockchain, combined with artificial intelligence (AI) and the Internet of Things (IoT), can provide exactly this foundation. In addition, blockchain directly supports the United Nations' Sustainable Development Goals (SDGs)—from ensuring responsible consumption (SDG 12) and fighting climate change (SDG 13) to promoting decent work (SDG 8). But blockchain is not a magic wand. Issues such as scalability, energy consumption, integration costs, and unclear regulations continue to pose obstacles. This study therefore sets out to explore blockchain's potential critically—its promises, its pitfalls, and its path forward.

The objectives are:

- To understand the limitations of traditional supply chains.
- To examine how blockchain enhances transparency and trust.
- To learn from real-world case studies.
- To explore blockchain's integration with Industry 5.0 technologies.
- To recommend practical ways for businesses and policymakers to adopt blockchain sustainably.

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2.0 Review of Literature

2.1 Sustainable supply chains

Over the last two decades, sustainability in supply chains has gained momentum. The concept rests on the triple bottom line—economic performance, environmental stewardship, and social equity (Seuring & Müller, 2008). Research shows that companies embedding sustainability into strategy are not only better at risk management but also at innovation (Carter & Rogers, 2008). Yet challenges remain. Visibility across multi-tier suppliers is weak. Traditional audits are costly and prone to manipulation. As a result, companies may unknowingly be complicit in child labour, deforestation, or unsafe working conditions.

2.2 Barriers in traditional supply chains

- Lack of Transparency – Complex networks make it nearly impossible to trace origins.
- Inefficient Information Flow – Data silos reduce speed and trust.
- Environmental Damage – High emissions and waste are hard to track.
- Ethical Issues – Forced labour and poor working conditions remain hidden.
- Counterfeiting – Pharmaceuticals, food, and luxury goods are especially vulnerable.

2.3 Blockchain's relevance

Blockchain offers unique advantages:

- Transparency – Shared ledgers cut through information asymmetry.
- Traceability – Immutable tracking of products from source to shelf.
- Security – Cryptography prevents unauthorised tampering.
- Smart Contracts – Automated enforcement of ethical and environmental standards.

2.4 Blockchain for sustainability

Case studies back this up. Walmart improved food safety, De Beers used blockchain to eliminate conflict diamonds, and Provenance verified sustainable fishing practices. Each example highlights blockchain's ability to provide trust and accountability where traditional methods fail.

2.5 Industry 5.0 integration

Industry 5.0 focuses on resilience and human-centric production. Here, blockchain works in tandem with IoT (capturing real-time data such as carbon emissions) and AI (optimising processes). For instance, in textiles, IoT sensors measure water usage, AI suggests efficiencies, and blockchain verifies and records sustainability metrics.

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2.6 Research gaps

Despite progress, gaps include limited large-scale adoption, energy-hungry blockchain models, regulatory ambiguity, integration costs, and a shortage of empirical, long-term impact studies.

3.0 Relevance of the Study

- The significance of this study lies in its attempt to address one of the most pressing global challenges—building supply chains that are not only efficient but also ethical, transparent, and environmentally responsible. Traditional supply chain models often struggle with opacity, inefficiencies, and unethical practices, which directly affect trust, consumer safety, and sustainability. By exploring blockchain's role in overcoming these gaps, the study provides meaningful insights for both academia and industry.
- In the current era of Industry 5.0, where the focus is shifting towards human-centric innovation and sustainable growth, blockchain emerges as a key enabler of resilience and eco-innovation. The findings are relevant for businesses seeking to align with the United Nations' Sustainable Development Goals (SDGs), particularly those relating to responsible consumption, climate action, and decent work.
- Moreover, this research contributes to the ongoing debate on how emerging technologies can be leveraged to create intelligent, transparent, and green ecosystems. It highlights practical applications, showcases industry case studies, and identifies barriers that need to be addressed for large-scale adoption. For policymakers, it offers direction on developing supportive frameworks and standards, while for businesses, it emphasizes how blockchain can become a strategic tool to gain competitive advantage through sustainability.
- Ultimately, the study is relevant not just from a technological perspective, but also from economic, environmental, and social standpoints, making it a timely contribution to both research and practice.

4.0 Objectives of the Study

- To identify the limitations and challenges of traditional supply chain systems.
- To examine how blockchain technology can improve transparency, trust, and accountability.
- To analyze real-world case studies that highlight blockchain's role in sustainable supply chains.
- To explore the integration of blockchain with Industry 5.0 technologies such as AI and IoT.

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- To recommend strategies for businesses and policymakers to adopt blockchain-enabled sustainable models effectively.

5.0 Research Methodology

This study adopts a qualitative, exploratory design using secondary data and case analysis.

- Literature Review – covering SSCM, blockchain in supply chains, and Industry 5.0.
- Case Studies – Walmart–IBM, Maersk–TradeLens, De Beers–Tracr, Provenance, and Everledger.
- Comparative Analysis – to identify patterns across industries.

The analytical framework focuses on four dimensions: transparency, trust, eco-innovation, and Industry 5.0 integration. Limitations include dependence on secondary sources, reliance on pilot projects rather than large-scale data, and the absence of universal sustainability metrics.

6.0 Results

6.1 Transparency

- Walmart–IBM Food Trust: traced mangoes in seconds instead of days, reducing food waste and enhancing safety.
- Maersk–TradeLens: streamlined logistics by digitising shipping records, cutting errors, delays, and emissions.

6.2 Trust

- De Beers' Tracr: eliminated conflict diamonds by assigning digital identities to each stone.
- Everledger: secured authenticity of diamonds, art, and wine, preventing fraud.

6.3 Eco-innovation

- Provenance: verified sustainable tuna fishing.
- Plastic Bank: turned plastic waste into a tradable digital asset, promoting recycling and reducing pollution.

6.4 Industry 5.0 integration

- Smart Agriculture: IoT soil and water data recorded on blockchain, AI optimised farming decisions.
- Logistics: AI predicted routes, blockchain verified carbon compliance.

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6.5 Cross-case findings

Blockchain consistently improves visibility, trust, sustainability reporting, and innovation.

6.6 Challenges

Scalability, high energy use (proof-of-work), unclear regulations, and integration costs remain pressing hurdles.

7.0 Key Findings

- Transparency: Walmart-IBM Food Trust reduced food traceability from days to seconds.
- Efficiency: Maersk's TradeLens digitized shipping records, cutting errors and emissions.
- Ethical sourcing: De Beers' Tracr ensured conflict-free diamond supply.
- Eco-Innovation: Provenance verified sustainable fishing; Plastic Bank converted plastic waste into tradable assets.
- Industry 5.0 Integration: IoT and AI enhanced agriculture and logistics, while blockchain verified data accuracy.

8.0 Implications of the Study

The findings confirm that blockchain can transform supply chain management by:

- Enhancing transparency and reducing fraud.
- Supporting eco-innovation and waste reduction.
- Contributing to SDGs such as responsible consumption and climate action.
- Building consumer trust through verified product origins.

However, challenges such as scalability, high energy consumption, adoption costs for SMEs, and regulatory ambiguity remain. Policymakers should create supportive frameworks and incentives to drive wider adoption.

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