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Blockchain for Sustainable Supply Chains: Triple Perspective Analysis

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Abstract

The emphasis has changed from financial to socio-environmental aspects in light of growing environmental concerns. The development of blockchain has transformational potential for ethical supply chains. This study examines how blockchain fits into these chains while evaluating issues of governance, social justice, and environmental protection. The research, which examined 100 publications, adheres to the triple bottom line of sustainability. There are difficulties with blockchain adoption across industries. The results demonstrate how blockchain may alter supply chains for greater sustainability via resource efficiency, accountability, smart contracts, trust-building, fraud reduction, and social effect. Managers and practitioners may learn from this research's insights about the acceptance of blockchain technology and its successful use for sustainable supply chains.

Keywords: Sustainable supply chain; Smart contracts; Trust-building; Fraud reduction; Transformative change

Introduction

Supply chain professionals formerly focused primarily on financial benefit. However, due to The focus has switched from economic to sustainability in society and the environment due to the high rate of environmental degradation. Corporations are being forced to reorganize their internal as well as external supply chain systems to respond to environmental worries and social demands due to pressure from stakeholders including government organizations, regulating bodies, and consumers. Every step of the process incorporates various green efforts, such as sustainable supply chains and practices are a significant topic of research. Recycling, reuse, and circular supply chains are additional sustainability principles [1]. To guarantee society's wellbeing, numerous firms use green and sustainable techniques to cut down on waste, reduce emissions, and maximize energy use. There are numerous novel technologies that give businesses a competitive edge. Rapid technological advancement influences firms' capacity to maintain their social and environmental systems. The sustainability is significantly impacted by blockchain (distributed ledger), one of the most recently established technologies [2-4]. A distributed accounting system called blockchain is used to manage the expanding data through automatic transaction execution. High uniformity, information dependability, traceability, and safety are a few of its key traits.

Because it is an open, safe platform that will improve the tracking and identification process, blockchain is thought to be a technology that will change the supply chain. Blockchain technology has several advantages for the food supply chain, including cost reductions, fraud prevention, quality maintenance, and anti-counterfeiting [5]. A thorough value chain must have effective traceability since one company's lack of accountability will have an impact on the whole distribution chain. People's trust, risk management techniques, legal requirements,

platform design, and data validity are further driving forces for blockchain adoption. Economic activity based on goods will change to an "information-based economy" thanks to blockchain [6].

Numerous studies with a variety of titles have been published around supply chain blockchain technology. These researchers' major goal was to examine how the implementation of blockchain technology affected the supply chain's overall efficiency. [7] Investigated the potential of blockchain and concluded that it could enhance traceability and transparency. After reviewing the implications of block chain technology in the agro-based supply chain concluded that blockchain is indeed a step in the direction of openness in the food chain. Reviewed the various aspects of blockchain technology and suggested a framework for its integration into food traceability. Outlined the major obstacles to blockchain deployment and offered in-depth knowledge on how blockchain is used in the biopharmaceutical cold chain[8]. The use of a descriptive approach was to examine various themes and adoption strategies for the blockchain. Used the visual mapping of bibliographic data to carry out a review on the blockchain. The primary focus of research is the transparency of items using cutting-edge contemporary technologies talked about the strategies used by several industries, including public services, e-commerce, and agriculture, to achieve a competitive edge through the efficient use of blockchain[9]. The literature on information and communication technology in agriculture was studied According to blockchain can be used to enhance all sustainability indices.

The past study only addresses the economic effects of blockchain on the supply chain. Additionally, the bulk of literature evaluations on blockchain focus on the cold supply chain and the food and agricultural supply chain as application domains, where the transformative potential of blockchain is examined via a variety of qualities including transparency, openness, and cybersecurity[10]. In the prior literature, issues with adoption and financial impediments to blockchain deployment have been extensively covered.

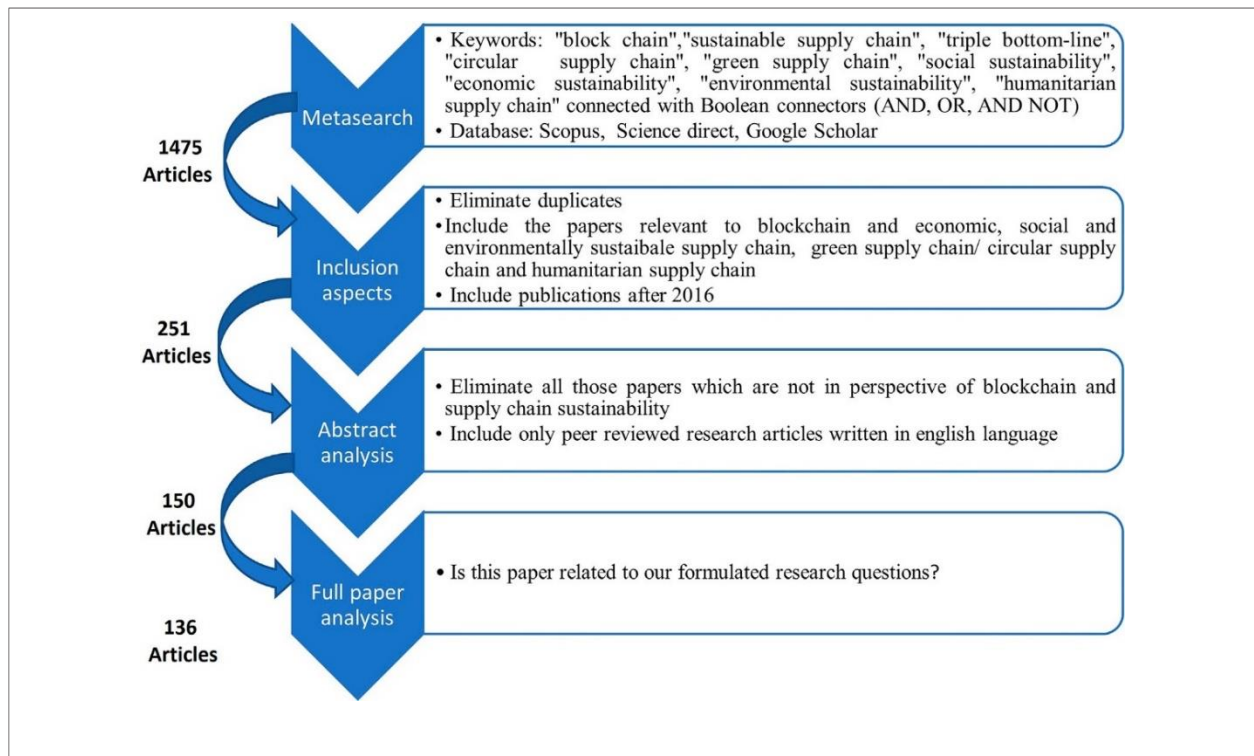


Figure 1: Framework for Conducting the Review.

Since the Supply chain for humanitarian purposes has received much of the study attention, more research is needed to determine how digitalizing supply chains affects risk management and sustainability, especially during disasters. These information gaps are addressed by this work.

The primary goal of this study is to gather publications on blockchain technology from respectable journals and analyze their applicability to creating sustainable supply chains. The articles have been grouped according to their contributions to social, environmental, and economic sustainability standards. The study includes a range of theoretical frameworks, case studies from the actual world, and theoretical views on sustainability. The subject of social sustainability has been expanded to include content on global supply chains and welfare initiatives.

This research is very important because it gives academics a way to assess the social and environmental effects of blockchain technology. It also sheds light on how blockchain technology may be employed in establishing a supply chain that is ecologically conscious.

Literature Review

The main distinction between a systematic literature review and a traditional A systematic examination is a review of the literature has strictly outlined questions, a thorough relevant research, its main objective, carefully assessed, and summarized findings is to transparently summaries the best research that is currently available on a relevant topic. A methodical literature review can be used to analyses research in any discipline and to appraise it SLR, or methodical literature review, was used for this study.

Research questions

The phase of planning is when research questions are created. The inquiries ought to be explicit and straightforward. The following are the research questions for this study:

1. What recent research has been done on how blockchain technology and sustainable supply chains interact?
2. From an economic, social, and ecological standpoint, What deficiencies exist and potential research directions in enhancing the overall integrity of the distribution chain utilizing blockchain?

Based on study questions, search terms were created to look up literature about blockchain and the supply chain's sustainability. The terms "logistics," or "supply chain," and "social sustainability," "environmental sustainability," or "green supply chain," "economic sustainability," and "circular supply chain" or "humanitarian supply chain" were used to gather these articles. The Scopus database and Scopus-indexed journals were used for data collection. The search was coupled with other forums like ScienceDirect and Google Scholar. The publications from 2018 until 2023 were chosen as the development of the digital currency blockchain is still in its early stages. Screening: To ensure that the research was objective, criteria for inclusion and exclusion were applied [11]. Included publications must be related to the use of blockchain in green procurement, the circular supply chain, or the implications of blockchain on social sustainability because the goal of this research was to learn more about blockchain and supply chain sustainability [12]. Additionally, selection criteria included articles on financial stability through traceability, openness, and visibility. Peer-reviewed journal publications and a select few conference papers that are pertinent to the earlier posed questions have been included. In a Criteria for exclusion this study focused mostly on blockchain and lowest-floor sustainability throughout the supply chain. The items that don't fit this description were taken off the list.

Exploring the Convergence of Blockchain and Sustainable Supply Chain Management

Businesses may reduce their carbon emissions thanks to blockchain, which helps the environment stay sustainable. It creates an image-based system that incentivizes participants to create a long-term remedy for emissions since everyone engaged is fully conscious of the financial rewards associated with maintaining a good reputation. The adoption of blockchain technology can help find all counterfeit items. Product tracking may reduce rework, which will reduce resource usage and greenhouse gas emissions. Customers that value the environment will opt to purchase goods created using environmentally friendly manufacturing techniques One strategy to encourage environmental sustainability is to impose a carbon fee[12, 13]. Customers will prefer

items with lesser pricing as products' scopes expand and their carbon footprints rise. Blockchain may help reduce carbon emissions when goods are delivered to their ultimate customers. The latest version is SCEnAT incorporates the Internet of Things (IoT), blockchain, and artificial intelligence. This tool presents a framework for assessing the carbon emissions of all elements engaged in supply chains [14]. IBM is developing blockchain-based green assets that will let businesses monitor, measure, and reduce their carbon footprints. The primary outline for this study is presented in "Figure 2." Consensus amongst partners, immutability, cyber security, intelligent contracts, and distributed networks of data on a distributed ledger are some of the characteristics of blockchain. This remarkable information exchange technology will elevate the ability to track, reveal, establish confidence, and adaptability of supply chains. Through meticulous tracking and controlling carbon emissions, it becomes possible to amplify sustainability reporting [15]. Likewise, smart contracts can facilitate the implementation and periodic evaluation of carbon taxation policies. When products are traceable and the supply chain exhibits responsiveness, businesses can earn greater customer trust. In addition to helping companies' supply chain members become more socially responsible, all of these qualities of blockchain will indeed be essential for monitoring and supervising the complete process of the supply chain system. There are a total of three categories for the papers in this research piece.

1. Articles discussing how blockchain's traceability, openness, accountability, and visibility might promote economic sustainability.
2. Included are articles covering model evolution, theoretical foundations, case analyses, adoption challenges, emission reduction, supply chain sustainability, and closed-loop. Additionally, other articles go through the difficulties of incorporating blockchain into supply chains, its implications for society, and its importance for supply networks that support humanitarian causes.

Enhancing Economic Sustainability

The supply chain is changing as a result of digitalization; in particular, the food supply chain and customer preferences are shifting toward more environmentally and socially responsible goods. As a result, safety, sustainability, and traceability have emerged as the main problems[16]. The main industry 4.0 tool is thought to be blockchain technology, which is viewed as a disruptive and inventive technology. Traceability is one of the many characteristics of blockchain.

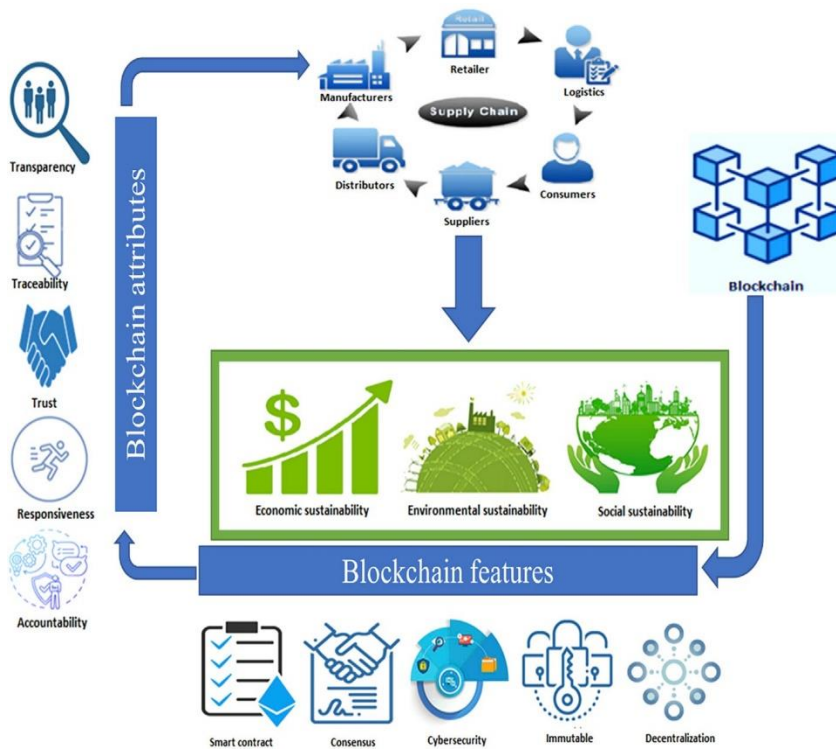


Figure 2:A conceptual framework for supply chain transformation using blockchain to achieve triple bottom line.

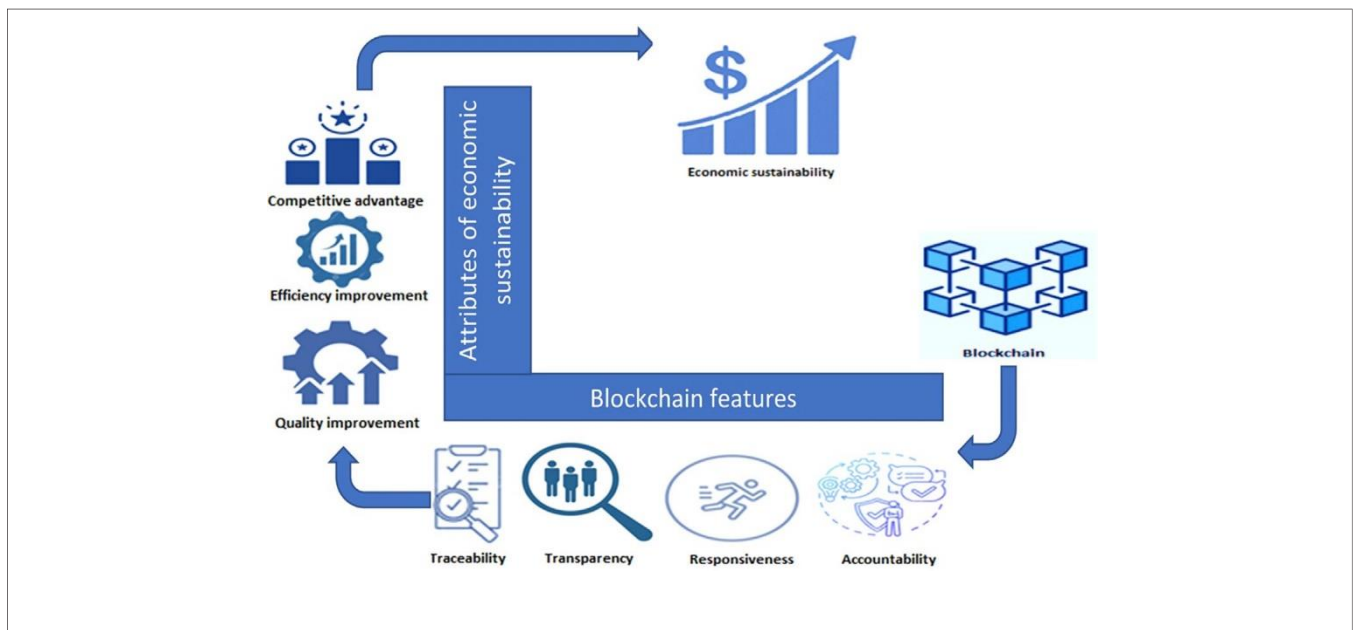


Figure 3:conceptual framework for the blockchain-enabled supply chain's economic viability.

Decentralization, immutability, privacy, and a consensus method. Agility, resilience, reactivity, and sustainability are the results of the blockchain. Figure 3 depicts the conceptual framework for the supply chain's

economic sustainability using blockchain. As was covered in earlier parts, the major characteristics of blockchain are its accountability, effective traceability, transparency, and responsive supply chain. These characteristics will be included in supply chain operations, which will raise the quality of goods or services. Additionally, it will increase process effectiveness, giving it a competitive edge.

Blockchain-Based Distribution Network Model in Agriculture, Food, and Health Care, Financial Sustainable Framework

Blockchain is a great system for exchanging information. its uses in the food, agriculture, and medical fields

Table 1:Development of models and frameworks for blockchain-based supply chains and economic sustainability in various industries.

Sr	Author	Objective	Solution Approach	Area of application	Limitation and future research direction
1.	Sahebi et al. (2022)	The authors discovered blockchain accelerators throughout the supply of renewable energy chain.	Fuzzy interpretive structural modeling	Energy sector	In the future, case study validation should be performed.
2.	Francisco and Swanson, (2018)	A framework was created using the unified theory of technology adoption and use.	Conceptual framework	Technology sector	The influence of organizational culture and society acceptability on blockchain adoption should be investigated.
3.	Longo et al. (2019)	The authors created a software bridge between blockchain and business information systems.	Developed software connector	Technology sector	To investigate the benefits of blockchain, a detailed investigation is necessary.
4.	Fan et al. (2020)	Customers' understanding of traceability concerns is critical to the successful adoption of blockchain.	Operation research Technologysector		A suggested model must be empirically validated.
5.	Bai and Sarkis, (2020)	This article discuss blockchain metrics in terms of sustainability.	Hybrid group decision, integrated hesitant fuzzy set	Technology sector	It is a conceptual model, and it lacks the real-world practical application.
6.	Yadav and Singh, (2020b)	The primary goal of this paper is to demonstrate why blockchain is more sustainable.	Quantitative research methodology	Technology sector	The findings of this article cannot be generalized due to the limited number of respondents.
7.	Helo & Shamsuzzoha, (2020)	This article discusses the creation of a gateway system with effective trace and trading.	Cloud-based portal	Technology sector	The integration of blockchain into ERP and transportation control process should be practically validated.
8.	Budak and Çoban, (2021)	The goal of this essay is to assess the consequences of innovation in the supply chain.	Cognitive maps method	Technology sector	Future study should concentrate on the use of cognitive maps in diverse industrial settings.
9.	Erol et al. (2022)	The authors have prioritized the most important vital functions of a durable supply chain.	Fuzzy SWARA	Technology sector	The research used a small number of criteria and specialists.
10.	Figorilli et al. (2018)	This study focuses on the design of architecture for such wood supply chain.	Conceptual architecture	Wood supply chain	Empirical validation of this conceptual framework is required.
11.	Shudih Ernest Chang et al. (2019)	The authors have proposed a framework of blockchain using smart contracts.	Conceptual framework	Supply chain re-engineering	The provided framework should be used in other sectors in the future study.
12.	Yousefi and Mohamadpour Tosarkani, (2022)		The research focuses on the relationship between blockchain and supply chain sustainability via smart contracts, traceability, and transparency.		

To reduce the loss of perishable food items and temperature-controlled pharmaceutical products, perishable foods, vaccinations, and cold supply chains need this revolutionary technology. The researchers have created many frameworks and models from the standpoint of supply chain transparency, accountability, traceability, and visibility utilizing blockchain [17, 18].

In "Table 1," a variety of frameworks and models connected to blockchain technology and supply chain economic sustainability are listed. The following are the primary characteristics of these models:

- Even though some of the articles are relevant to the pharmaceutical and healthcare industries, the bulk of the developed models and suggested frameworks are geared toward the food and agricultural industries.
- The development of frameworks and models based on smart contracts as well as traceability solutions is the focus because contracts can aid in the growth and improvement of relationships throughout the supply chain network. It enhances data sharing between all parties and is a constant work in progress.
- Some articles are focused on conceptual research, and many ways to solving problems are utilized, such as machine learning, Python programming, the "SWARA" method, serialization, mathematical modelling, and prototype development.

Other approaches include Ethereum and Hyperledger Fabric. Food production has been a significant issue for a long time. The market demands cannot be addressed by the outdated methods of agri-food logistics and transportation. The radio frequency identification-based traceability system for the agri-food value chain should be created with food safety in mind. From this vantage point, Becht's is offered a framework that unifies all the data about containerized food onto a single, secure platform for information sharing known as the blockchain. Conducted three stages of research[19]. They developed a model for the assessment of blockchain maturity for the agriculture industry after first using the SWARA approach to rank several blockchain-related variables. They used a questionnaire to assess their model in the third phase. According to their research, smart contracts and transaction records are more significant in every aspect of the supply chain.

The following are some key points:

- Specific articles discuss software development, technological implementation, or various aspects of blockchain. These fall under the technology industry category.
- Postal services, the supply chain for wood, the energy industry, urban logistics, and the defense sector are some further application areas.
- Numerous the articles are conceptual; other methods of problem-solving include fuzzy intellectual mapping, automated neural networks, hierarchical deterministic wallets, stored in the cloud portals, graph-based methods, the creation of a blockchain-based logistics surveillance system (BLMS), fuzzy MICMAC, fuzzy analytical network procedures, quantitative analysis, and functioning research techniques.

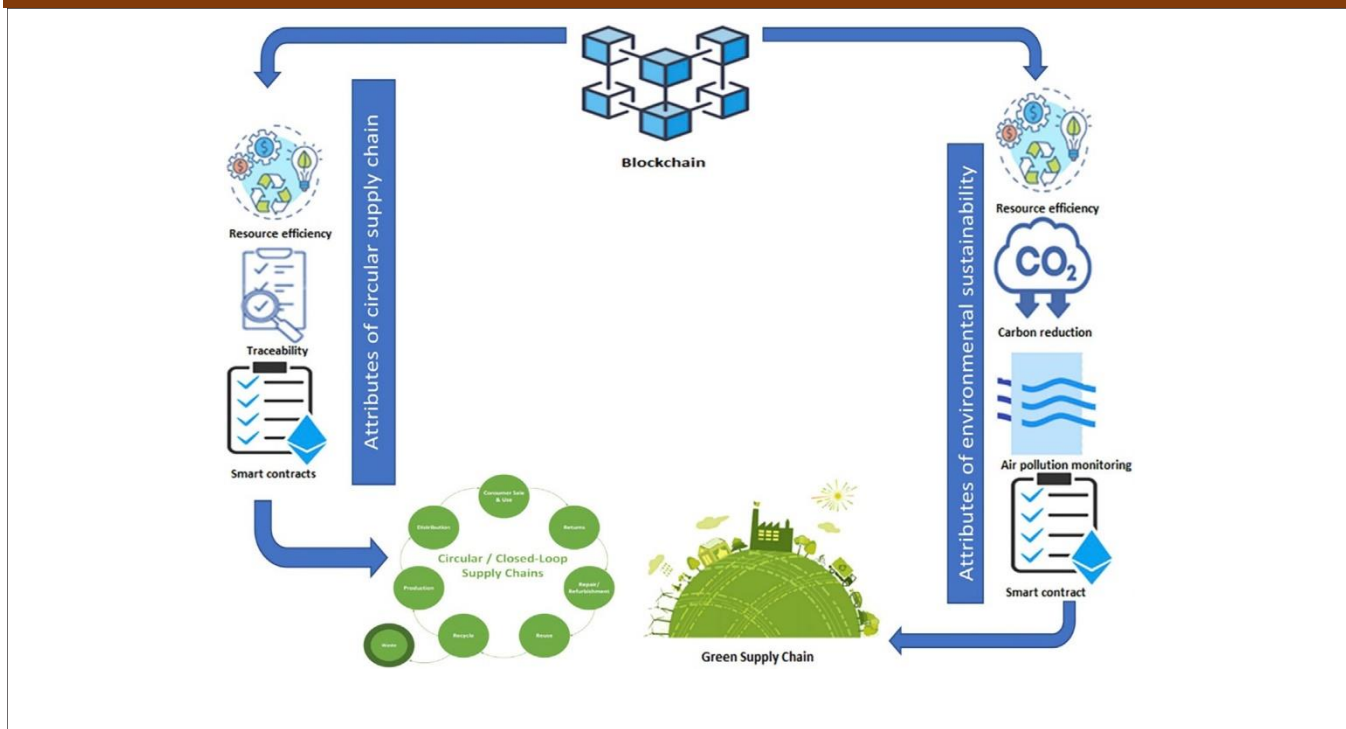


Figure 4: shows the main ideas behind making the supply chain greener or more circular.

Blockchain-based circular/green supply chain management

The main goal for businesses is to improve technical expertise without compromising the triple bottom line. These elements are taken into consideration when resources and information go from the supplier to the final consumer in a sustainable supply chain. Many nations are using blockchain to effectively manage carbon emissions. Figure 4 depicts the conceptual framework for a blockchain-based circular or green supply chain. The two ideas this model addresses are creating circular and green supply chains utilizing blockchain technology.

Modeling, Architecture, and Framework for Green and circular supply chains based on blockchain.

Blockchain technology ensures transparency and the defense of human rights, blockchain-related academic research for an ecologically friendly supply chain is advancing swiftly, even though it is still in its early phases. These frameworks emphasize concepts like green supply chains, circular supply chains, and techniques for lowering greenhouse gas emissions through reuse, automated agreements, and repurposing. Emerging technologies like blockchain and the physical internet (PI) hold the promise of enhancing sustainability by reshaping entire supply chain structures.

For example, one study employed the Bayesian formula to construct a model that forms the foundation for their outlined green supply chain framework. Their approach was evaluated using simulations in Python 3.5. Another model was developed to optimize operational costs and carbon emissions.

The circular supply chain concept represents a shift towards reuse and sustainability, departing from traditional disposal methods. A research endeavor delved into designing such a circular supply chain system. Additionally, addressing sustainability challenges, a unique blockchain-based model for an agricultural supply chain was introduced. This model harnessed smart contract-driven multi-agent systems, offering the significant advantage of comprehensive supply chain traceability through blockchain technology[20].

Exploring Case Studies and Theoretical Advancements of Blockchain in Sustainable and Circular Supply Chains

To lessen the negative impacts on society and the environment across their supply chain, organizations utilize sustainable practices. All organizations now have the possibility to rethink their supply networks thanks to the rise of sustainability. The pursuit of sustainability goals related to traceability, security, environmental preservation, and ethical concerns may be considerably enhanced by using the synergy of big data, blockchain, and artificial intelligence. The following characteristics capture the salient features of these case studies.

These case studies are applicable to a wide range of fields, including the marine industry, solid waste management, packaging waste management, agriculture, forestry, fisheries, and even one article that places the COVID-19 epidemic in historical perspective.

These research projects are largely focused on the circular supply chain concept, creative methods for turning waste into energy, addressing packaging waste issues, and integrating blockchain with Internet of Things (IoT) technologies. They are primarily grounded in conceptual models that are supported by case studies.

The emerging idea of a "circular economy," which promotes the reuse of things beyond their original function, has gained a lot of support. Mastos developed a waste-to-energy model within this framework and tested it using three industrial paradigm scenarios involving the supply chain's use of wood waste.

Although the circular economy concept is gaining popularity, little is known about how it may really be implemented, especially in underdeveloped countries. It was suggested to use blockchain technology in a circular supply chain to promote social and environmental sustainability.

Concerns about social issues and the environment are receiving more attention in the modern setting. The core characteristics of blockchain technology have been examined in this context, including decentralized databases, encrypted transactions, open information sharing, and smart contracts. Understanding blockchain applications was suggested as a viable solution to the rapid environmental deterioration caused by the marine sector.

The Green/Circular Supply Chain's Blockchain: 6 Key Success Factors, Barriers, and Challenges

The most important success element is customers' knowledge of blockchain technology. If manufacturing becomes green, consumers who care about the environment will want to purchase the products. This section examines the obstacles to the adoption of blockchain for circular or green supply chains and covers the essential components for success. One of these publications examined the drawbacks of implementing blockchain technology by using qualitative as well as quantitative methods of research.

In the second study within the manufacturing sector, the decision-making trial and assessment laboratory (DEMATEL) technique was employed to examine critical success factors. Despite the valuable insights offered by articles addressing case studies and theoretical advancements within the context of a blockchain-driven circular or green supply chain, several limitations are apparent. A common constraint among these studies is their cross-sectional nature, preventing a comprehensive evaluation of blockchain's impact across diverse economic domains. A longitudinal approach is necessary to thoroughly understand the enduring implications of this emerging technology. Furthermore, the majority of research has been confined to specific industries within distinct geographical locales. The geographical, cultural, legal, and demographic aspects of the study context can potentially influence the findings and conclusions drawn from these investigations. It's evident that a predominant portion of the research has taken a qualitative route, often relying on structured or semi-structured interviews. Incorporating more quantitative methodologies is essential to yield measurable outcomes and provide a deeper understanding of the consequences associated with various attributes.

Implications for practical

This comprehensive exploration of recent advancements the point between blockchain and supply chain operations holds significant value for managers, academics, practitioners, and policymakers across the industry spectrum. Blockchain's transformative potential extends to various sectors, including finance, healthcare, retail,

agriculture, and logistics. The core themes of this study encompass the creation of diverse models, theoretical frameworks, and case instances illustrating blockchain's application. This research is of paramount importance as it consolidates the latest developments in blockchain technology and their profound implications for enhancing supply chain sustainability across multiple domains, including agri-food, pharmaceuticals, manufacturing, automotive, aviation, and a multitude of local and global enterprises. The article evaluates a spectrum of blockchain attributes, including supply chain resilience, worker well-being, animal welfare, and food safety. It also underscores the societal advantages of blockchain, spanning social welfare enhancements, reliable collaboration, food safety assurance, and logistical support for humanitarian endeavors [21]. Businesses stand to leverage blockchain to foster societal dynamism and reinforce their eco-conscious operations. Furthermore, blockchain's potential in fostering a green supply chain is noteworthy, offering efficient tracking capabilities and ensuring compliance with environmental regulations throughout the supply chain continuum. By facilitating streamlined tracking, blockchain contributes to reduced resource consumption and minimized energy wastage. The incorporation of smart contracts aids in curtailing transaction costs and elevates the accuracy, speed, and efficiency of the supply chain. This technology can significantly contribute to effective natural resource management and the utilization of sustainable energy sources.

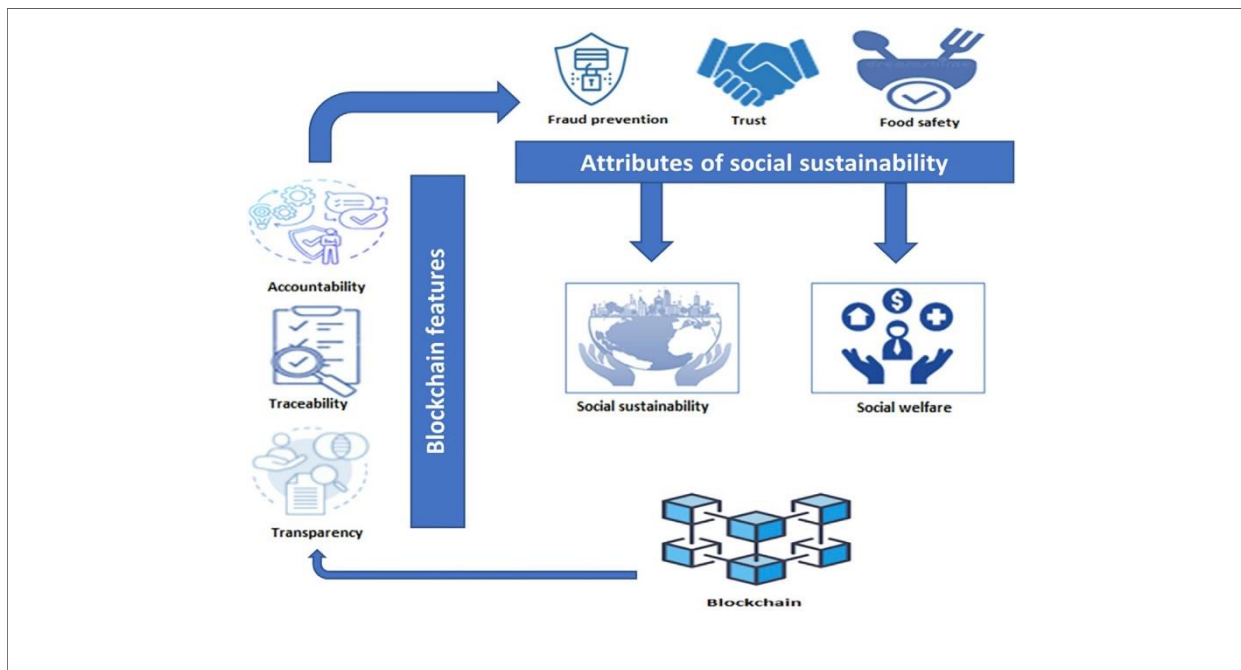


Figure 5: Conceptual model for supply chain transformation to achieve social sustainability via blockchain.

Conclusion

The supply chain has been impacted by the big data and blockchain eras, which have the power to completely transform the network. Three categories were used to group the research. For the first category, the relationship between blockchain technology and the economy was examined using pertinent literary works. Assessing blockchain properties including immutability, traceability, accountability, visibility, decentralization, and cybersecurity was required for this. By reading relevant literature, the second category evaluated how blockchain fits into circular and environmentally friendly supply chains. The third category in-depth assessed how blockchain's social consequences via food safety, fraud prevention, and trust-building as well as its advantages in humanitarian supply chains. Only a few of the numerous positive features of blockchain include its robustness, connectivity, ability to avoid fraud, promotion of social welfare, and reduction of supply chain risk. Although the present study targets the sustainability's three bottom-line considerations, it also includes a list of articles pertinent to the humanitarian supply chain, so its scope is very wide. Other supply chain

characteristics, such as resilience, responsiveness, and robustness, were not included by the study since it was primarily conducted from a sustainability perspective. For the article selection, only journals with a Scopus index were employed, leaving out other essential data sources like book chapters. The crucial question is still open: Is blockchain really a game-changing technological advancement for social innovation or is it just a technological advancement with marginal strategic value for long-term supply chain sustainability. Blockchain may supply traceable, legal, and dependable flow of information contracts by using smart contracts. Blockchain technology is now used in several countries across numerous sectors. Leading nations for blockchain adoption and implementation include developed nations like the United States and Japan. Africa and Asia are home to several of the first countries to use blockchain technology. In underdeveloped countries, the adoption of blockchain and environmentally friendly supply chains and procurement techniques is still in its infancy. To put these concepts into effect, regulatory authorities at the governmental level must be formed. If blockchain technology is successfully used in poor countries with focused changes, the supply chain will perform better in terms of complying to social and environmental standards and become more economically robust. Future research should use blockchain together with big data, life cycle evaluation methods, the IoT and RFID. From the perspective of developmental research, this is. Future research should include the blockchain's governance structure, smart contract viability, and constraints on the handling of information. The adoption of blockchain may be impacted by non-technological variables including business policy, culture, and societal acceptability, among other questions that still need to be solved. The COVID-19 accident has taught us to control risk and increase resilience. It is important to research how blockchain will affect operating costs, risks, and uncertainties. Future studies should look at the role that politics has had in the adoption of blockchain technology. As a result, this article will provide academics and researchers the chance to fully comprehend the three essential elements of the blockchain-based supply chain.

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