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Muhammad Shujaat Mubarik
Muhammad Shahbaz *Editors*

Blockchain Driven Supply Chain Management

A Multi-dimensional Perspective

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Management for Professionals

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ISSN 2192-8096 ISSN 2192-810X (electronic)
Management for Professionals
ISBN 978-981-99-0698-7 ISBN 978-981-99-0699-4 (eBook)
https://doi.org/10.1007/978-981-99-0699-4

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

*To Hadi, Hashim, and Emaan, my ultimate source of inspiration and love (*Muhammad Shujaat Mubarik*)*

*To my mother, father, and my teacher Professor Sabihuddin Butt (*Muhammad Shahbaz*)*

Preface

Long before the COVID-19 pandemic, incidents like the e-coli breakout, the horse meat scandal, and the Rana plaza disasters raised questions about supply chain traceability, sustainability, visibility, and resilience worldwide. The COVID-led supply chain disruptions proved that those concerns were right and essential to address. We could see that during COVID-19, most firms struggled hard to keep the chains afloat. Interestingly, in the early phase of the pandemic, several companies, especially those with first- and second-tier suppliers outside China, did not devote any importance to those disruptions. The overarching argument of such firms was that the pandemic would not affect them as their immediate suppliers or even the second-tier suppliers were not from China. However, during July-August 2020, almost every firm was fighting with the pandemic-led disruptions, and those who did not warrant any importance in the early days were in hot water. The response of such firms was highly unorganized, disconcerted, and devoid of any strategic depth.

Once the impacts of COVID started abating, practitioners, managers, policy matters, and firms across the globe began exploring what went wrong in dealing with the COVID and what could have been capitalized on to develop a more resilient, prepared, and responsive supply chain. The issues of trust, traceability, visibility, and integration of the supply chain also came under the limelight. During such debates, discussions, and scholarly work, blockchain, which was already catching momentum before the COVID-19 era, went under the spotlight. Many firms started considering blockchain-driven supply chain management as a strategic tool to recover from supply chain disruptions and improve the visibility, traceability, and trust in the supply chain. Both practitioners and researchers started arguing that blockchain technology, with its unique capabilities, has the potential to mitigate supply chain inefficiencies by increasing visibility, traceability, compliance, and verification to manage better and control the supply chain network. This is why a great deal of literature, consulting reports, and policy work could be seen during 2021 and 2022, focusing on the capitalization of blockchain as end-to-end supply chain technology.

This book advances the work on blockchain-driven supply chain management by providing its multidimensional perspective. The book explores the applicability and impacts of blockchain on various performance parameters, including sustainable performance. We are confident that the book will help readers from multiple fields understand the multi-pronged role of blockchain technology in businesses.

At the end, we must thank all of our contributing authors and anonymous reviewers for contributing to this book.

Karachi, Pakistan Muhammad Shujaat Mubarik
Beijing, China Muhammad Shahbaz

Acknowledgment

We sincerely acknowledge the support of Institute of Business Management (IoBM), Karachi for supporting us to undertake the challenging task of editing this book. Likewise, our sincere acknowledgment to Higher Education Commission (HEC), Pakistan for supporting us under NRPU-20-11226.

Introduction

This book takes a diverse perspective on the blockchain-driven supply chain and attempts to delineate its various facets. The book primarily focuses on 12 significant aspects of blockchain-driven supply chain. Chapter 1 of the book focuses on explaining as to what is the architecture of the blockchain and blockchain-driven supply chain. The chapter briefly describes the blockchain and focuses on using Blockchain Technology in Smart Contracts and Supply Chains. We all know that the functioning of a supply chain builds on three essential flows: materials, information, and finances. Keeping in view these three flows, the first chapter explains the artefact of Blockchain-Enabled Smart Contracts. The chapter can help businesses understand how blockchain can improve contractual processes and make procurement and payments a swift transaction. Chapter 2 focuses on understanding the relevance of the antecedents of supply chain collaboration in the era of BCT and highlights the opportunities and challenges for BCT implementation in SC networks. It reviews some of the critical antecedents of SCC considering the BCT implementation and explains how SC partners may leverage these technologies to enhance the network's collaborative advantage. It contributes to the domain of SCC by extending the perception of underlying constructs of SCC when viewed in conjunction with the BCSCM and motivating the researchers to reconsider the idea of SCC to benefit the SC partners in the network.

Chapter 3 builds on the argument that scholastic literature is ambiguous on the impacts of BCT on SC resilience directly and through other essential strategies like SC mapping. The chapter explores blockchain-driven supply chain's influence on supply chain resilience. It operationalizes supply chain resilience as the constituent of 3Rs (Readiness, Response, and Recovery) and suggests a framework linking blockchain-driven supply chain with these three cords of supply chain resilience. The chapter can help understand the innate complexities associated with BCSCM and SC resilience. Another facet of resilience has been explained in the later part of the book in Chap. 14, with a special focus on the role of a firm's intellectual capital in capitalizing BCSCM for Supply Chain Resilience. This chapter can help reader understand the role of the human in the supply chain.

One of the long-standing issues firms are dealing with is inventory visibility and management. Despite significant development in supply chain management technologies, many aspects of inventory management are yet to be resolved. In this regard, Chap. 4 of this book explains the instrumentality of blockchain technology in managing the supply chain. A brief discussion on the role of blockchain in inventory management has been given in the chapter, followed by recent developments in the field.

Adopting blockchain in supply chain management is a challenging task that greatly depends upon the employees in the organization. To make the employees ready to accept the change, leaders have to adopt transformational leadership. Using leadership, organizations can provide the vision to employees to pursue the adoption of blockchain technology. Additionally, through leadership, organizations can address individual roadblocks hampering the adoption of blockchain. Chapters 5 and 6 have been allocated to explore the role of leadership in blockchain adoption. Chapter 5 deals with the transformational leadership-blockchain adoption paradox and explain what could be the most viable leadership style for blockchain adoption. Whereas Chap. 6 reviews the extant literature on the linkages among leadership, blockchain, and supply chain management. This chapter explains how businesses may successfully introduce and integrate blockchain technology into the management of their supply networks through the role of leadership. As mentioned earlier, traceability has been a core issue supply chains are dealing with. Be it the horse-meat scandal or the COVID-led disruptions, the visibility has always been an issue if the supply chain managers. In this regard, Chap. 7 undertakes a thorough discussion on supply chain traceability with a special focus on the food sector and highlights some of the loopholes in existing technologies, which can be overcome by BCT. The chapter can be a wonderful read for those interested in the application of blockchain for SC traceability.

Firms heavily rely on their supply chains for innovation especially open innovation. Chapters 8 and 9 of the book have been dedicated to explaining the diverse role of BCSCM in open innovation. The former (Chap. 8) offers a Supply Chain Open Innovation Networks (SCOINET) framework backed by blockchain. SCOINET can help guide policymakers to develop open innovation networks for the supply chain and other functions. The later (Chap. 9) explores the linkage of BCSCM with the open innovation.

Despite an increasing focus on supply chain resilience, sustainability has not lost its importance. We can see increasing pressure on firms from outside and inside sources to have more responsible and sustainable supply chains. Keeping in view the significance of the topic, three interrelated chapters (Chaps. 10–12) explore the various role of BCSCM in sustainability. Chapter 10 of the book examines the role that a blockchain-driven supply chain can play in improving firm sustainability. The conclusive argument of the chapter is that blockchain can be instrumental in making a firm more sustainable. Chapter 11 focuses on the Role of Blockchain Technology Adoption between Sustainability-Related Supply Chain Risks and Triple Bottom Line Performance. Whereas Chap. 12 proposes a framework illustrating the role of Intellectual Capital in Implementing Blockchain Technology-driven Sustainable Supply Chain.

Chapter 13 has been dedicated to explaining blockchain technologies' position and role in Industry 4.0. It provides an overview of Industry 4.0 and related technologies. The chapter also highlights obstacles that may give rise to future areas of study in B.Sc. and I4.0. Last two chapters of the book take a diverse approach. Chapter 15 critically reviews the marketing, supply chain management, and blockchain literature and explains the benefit from a blockchain-driven supply chain. The chapter also discusses the application of blockchain technology in marketing and the way it could disrupt the marketing mix and processes. This chapter could be useful in understating the role of a blockchain-driven supply chain in forecasting customer demands, enhancing the traceability and transparency of transactions, improving customer trust, and reduce transaction risks. The last chapter takes a macro approach and explains the linkage of Blockchain-Based Digital Economy and Industry 4.0.

Before concluding, it is important to highlight the two aspects of the blockchain-driven supply chain that must be explored. First is Interoperability across BCSC networks, which refers to the ability to trade, review, and access data across many blockchain networks without the involvement of a mediator. Secondly, the challenges, the grey or dark side of the blockchain, from the perspective of capitalizing on the true strength of the technology.

Contents

About the Authors

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Abbreviations

BCSCM	Blockchain-driven supply chain management
BT	Blockchain Technologies
HC	Human Capital
I4.0	Industry 4.0
IC	Intellectual Capital
P2P	Peer to peer
RC	Relational Capital
SC	Structural Capital
SC	Supply Chain
SCI	Supply Chain Integration
SCM	Supply Chain Management
SCOINET	Supply chain open innovation networks
SCR	Supply Chain Resilience
SCV	Supply Chain Visibility

Blockchain-Enabled Smart Contract Architecture in Supply Chain Design

Muhammad Azmat and Evanthia Thanou

1 Introduction

Supply Chains (SCs) are complex networks of multiple actors involved in delivering the right products/services to the customer. Modern SCs, however, primarily rely on the forward and reverse flow of information among all nodes in the network to realise the overreaching objectives (Xue et al., 2020). Therefore, in recent years, digital technologies and trends such as Internet 4.0, the Internet of things, Big Data Analytics and Smart Automation have profoundly been used to minimise the disruption in the flow of information between different nodes within a supply chain network.

Besides, due to globalisation and internationalisation, SCs today are dispersed and geographically very extended. Therefore, using traditional methods such as Enterprise Resource Planning (ERP) systems, which have several limitations, creates unwanted difficulties in mapping the SCs, their players and activities. Additionally, issues like inefficient transactions and suppliers' performance, frauds and fake deals, cultural barriers and language differences, international regulations and legislative constraints, and lack of trust and commitment of some suppliers call for additional information visibility, transparency, and verifiability. This will help better manage and control the supply chain network, remove all potential business risks and mitigate the inefficient transactions characterising the SC linkages (Giovanni, 2020; Azmat et al., 2022). Companies and their SCs require a better understanding of emerging digital trends to counter issues within their extended supply chains (Mubarik et al., 2020; Ali et al., 2021; Qader et al., 2022).

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_1

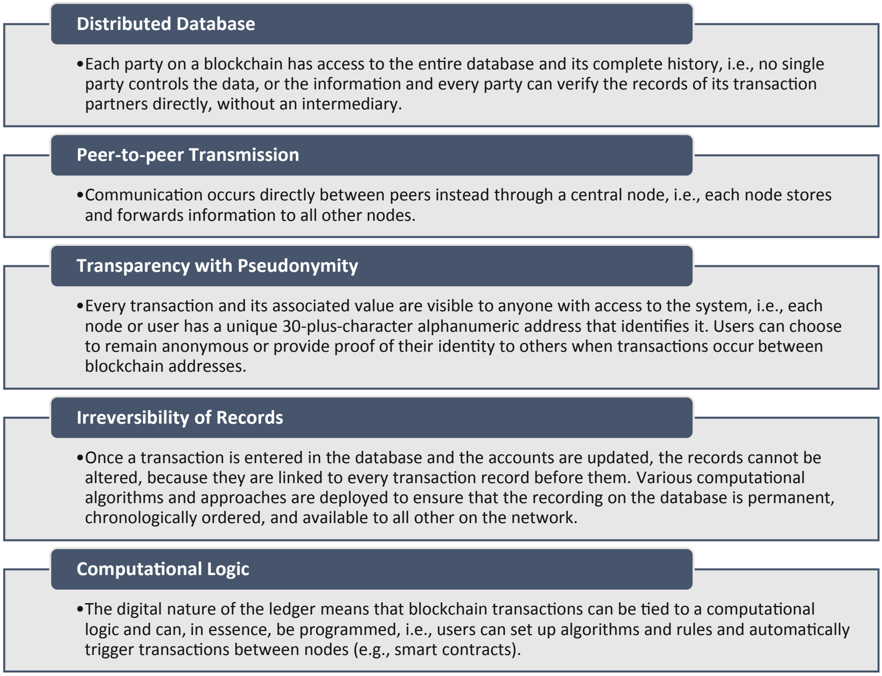

Fig. 1 Blockchain principles (adapted from Dobrovnik et al., 2018)

One such emerging technology that can effectively enable all these digital trends in supply chain management is Blockchain Technology (BCT). According to Xue et al. (2020), "Blockchain technology is a decentralised, shared ledger that combines data blocks in chronological order into specific data structures and uses cryptography to ensure it cannot be tampered with and cannot be faked. Moreover, Dobrovnik et al. (2018) suggest that blockchain consists of a set of digital applications enabling firms and SCs to track, trace, and verify how goods transit and move along the supply from the manufacturers to retailers through distribution centres and logistics facilities, thus eliminating the need for third-party intermediaries to verify or transfer ownership. However, to better understand the functioning of the Blockchain and how it can help overcome the friction in logistics and enhance efficiency in supply chain processes, we need to understand the underlying principles of the BCT (Fig. 1).

Advancements in computer technology and shared computing system design paved the path for a decentralised management model that can resolve the rebuttal between resource sharing and decentralised value creation in SCs (Xue et al., 2020). Blockchain is a distributed system that allows all supply chain members to be updated, integrated, and involved in any transaction resulting in settling transactions securely and verifiably within seconds as the ledger is replicated in several identical databases (Giovanni, 2020; Dobrovnik et al., 2018).

Hence, theoretically, it is established that BCT has the potential to transform businesses and their SCs. The same phenomenon of BCT can be carried down to Smart Contracts. The term smart contract is defined as *"a set of promises, specified in digital form, including protocols within which the parties perform on these promises"* (Wang et al., 2019, p.2266). Thus, these contracts are self-regulated, auto enforced and self-executed and are based on the programs which trigger the terms and conditions of a separate agreement or contract using pre-defined codes and computational infrastructure (Hewa et al., 2021).

2 Blockchain Technology in Smart Contract and Supply Chains

The term "Smart Contract" was first introduced in the late twentieth century by Szabo, a computer scientist and one of the early cryptographers. He explained the smart contract using a basic example involving a coin and a vending machine. According to Szabo, *vending machines take in coins and, via a simple mechanism (e.g., finite automata), dispense change and products according to the displayed price*. However, in the twenty-first century, smart contract application goes beyond vending machines; simply embedding digital signatures in processes could lead to all sorts of smart contracts in the SCs (Wang et al., 2019).

Additionally, Wang et al. (2019) suggest that in general terms, *smart contracts can be defined as the computer protocols that digitally facilitate, verify, and enforce the contracts made between two or more parties on Blockchain*. According to Guo et al. (2021), Smart contracts are also referred to as electronic contracts or e-contracts. They define an e-contract as "a computer interpretable technical specification, illustrated as a group of obligation definition that is fulfilled among involved parties, refused or waived when a future event occurs". Compared with traditional paper-based contracts, e-contracts are economical, fast, safe and readily available. The BCT is one enabler for smart contracts in modern-day SCs. According to Hewa et al. (2021), BCT allows decentralised, distributed, and immutable ledger formation that entails a cryptographically linked chain of record collection. The records are collected in blocks, and an individual record is referred to as a transaction. The ledger is not centralised; therefore, it is shared, monitored, and verified by all contributing actors in the blockchain network. These transactions add to the ledger upon verification and agreement process between the parties on board in the Blockchain. The essential features associated with Blockchain are *decentralisation, immutability, and cryptographic link (*Fig. 2*).*

In addition, the general public often interchangeably uses the word cryptocurrencies, such as Bitcoin with Blockchain. Literature suggests that Bitcoin is widely recognised as the first BCT-based cryptocurrency that supports basic smart contracts because its transactions validate only if specific terms and conditions are satisfied digitally. It enables peer-to-peer financial transactions without the intervention of trusted third parties such as local or international banks. The system operates without a third party, and the transactions committed to the network are verified by

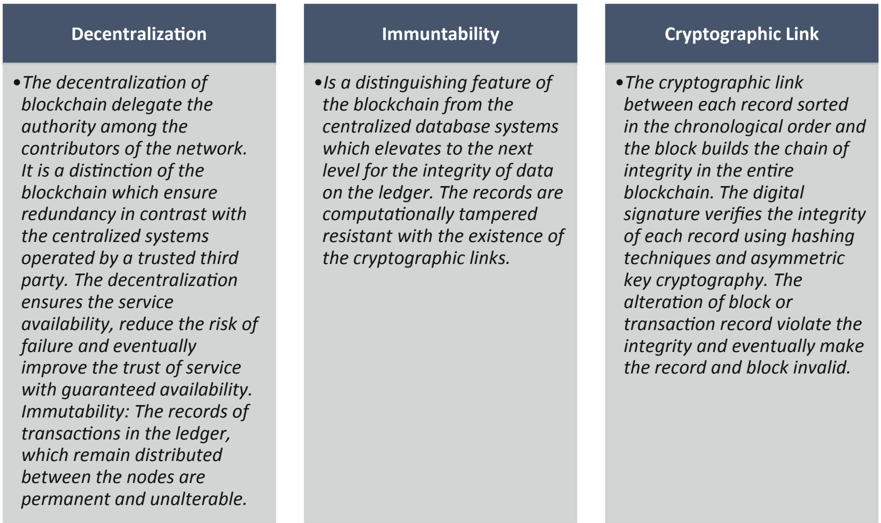

Fig. 2 Features of Block Chain technology (Adapted from Hewa et al., 2021)

dedicated nodes called miners using cryptographic techniques (Wang et al., 2019). Despite being the first generation of digital currencies, Bitcoin lacks support for creating a complex distributed application. However, the second generation of BCT gave birth to Ethereum (the second most recognised currency among cryptocurrencies). Unlike Bitcoin, it allows the building of complex distributed applications beyond cryptocurrencies (Alharby & Van Moorsel, 2017). Thus, the second-generation BCT-based virtual and digital currencies secured with digital signatures (Cryptocurrencies) enable a tamper-proof smart contract. On the other hand, Blockchain is about creating value by enabling firms and individuals to exchange assets of any kind without relying on a third party to manage the transactions using cryptocurrencies (Giovanni, 2020).

In order to understand the extent of BCT, a handful of researchers have explored its applications in different sectors. Xue et al. (2020) reported some applications of BCT in the pharmaceutical and agriculture sector. For instance, a supply chain model based on BCT creates transparent drug transaction data to mitigate challenges like fragmentation, poor traceability, and lack of real-time information. At the same time, Ozdemir et al. (2020) presented a collection of applications in the travel and tourism industry. For instance, they reported that BCT-enabled travel and tourism might allow *new forms of evaluations and review technologies that will lead to trustworthy rating systems. Furthermore, the widespread adoption of cryptocurrencies will lead to new types of customer-to-customer markets. Therefore, BCT will lead to increased disintermediation in the tourism industry.* Gunasekara et al. *(*2021*) also examine the use of BCT in the facility management procurement process. They argue that BCT has the potential to revolutionise the procurement process completely. It can act as a digital consensus mechanism that enables smart*

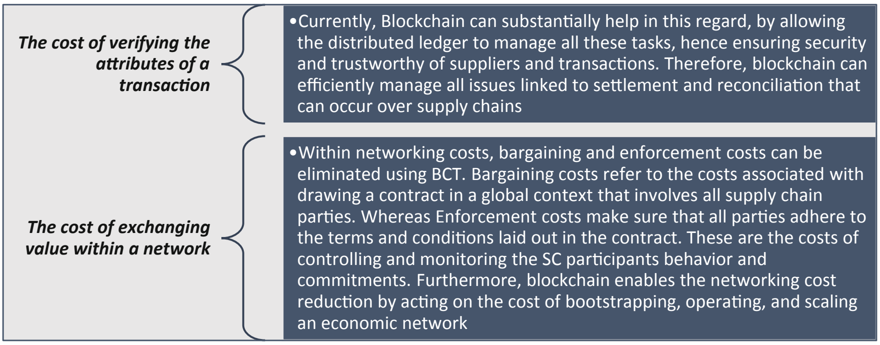

Fig. 3 BCT enabled smart contracts contribution to Supply Chain Management (adapted from Giovanni, 2019, 2020)

contracts, which act as automated contracts for the future of procurement, realising 'Procurement 4.0'.

Currently, there is an upsurge in understanding the potential applications of smart contracts in different sectors. For instance, smart contract applications are being tested in the Internet of things enabled smart properties for renting, selling or sharing anything without a trusted third party, blockchain-based smart contracts in the music industry, and eliminating a trusted third party within the e-commerce supply chains using smart contracts to enable trade between untrusted parties over the Internet (Alharby & Van Moorsel, 2017). However, it is vital to underpin the question of why in the first place, one should consider BCT-enabled smart contracts or how the SCs and the firms could benefit from them. According to Giovanni (2019, 2020), BCT is a *complementary innovation* since it supports existing innovations to reach goals never achieved. However, BCT can effectively boost the value created in SCs, where transactions occur globally. There is uncertainty on some operational features (e.g., delivery, last mile management, bullwhip effect), and traditional vendor rating procedures can be ineffective in finding trusty parties. There are at least two cost-saving fronts where BCT-enabled smart contracts can contribute significantly (Fig. 3):

3 Blockchain-Enabled Smart Contracts in Supply Chain Design

Fundamentally the functioning of a supply chain builds on three essential flows: materials, information and finances. When designing a supply chain, the goal is to structure the three flows to meet customer needs while generating supply chain profits effectively. According to the literature (Fine, 1998; Nepal et al., 2012), the primary supply chain design considerations involved in this process concern the make-or-buy decisions (e.g., whether to outsource or perform a supply chain function in-house, location and capacities of production and warehousing), the sourcing decisions (e.g., supplier selection) and the contracting decisions (e.g., supplier relationships). These are also complemented by decisions related to risk pooling, service levels, deliveries, inventory and information systems.

Structuring the three fundamental flows has become very challenging as today's supply chain designs are complex, geographically very extended and dispersed, interconnected and sophisticated. In addition to the intricate supply chain designs, the so many and diverse disruptions (e.g., pandemic-, climate-related disruptions) all over the world, the inefficient suppliers' performance, the lack of trust and commitment, the lack of capabilities to monitor events and metadata associated with a product (traceability) and the lack of compliance and flexibility are some of the critical supply chain pain points (Deloitte, 2017). In particular, the invisibility of supply networks and the difficulty in producing supply chain maps beyond the tier-1 suppliers have made critical information inaccessible, which in turn has led to slow responses to the unprecedented supply chain disruptions as well as led to barriers to implementing sustainable practices (Khan et al., 2022; Kusi-Sarpong et al., 2022).

Blockchain technology, with its unique capabilities, has the potential to remediate such supply chain inefficiencies by increasing visibility, traceability, compliance and verification to better manage and control the supply chain network and impacting supply chain design decisions at the same time (e.g., Cole et al., 2019; Giovanni, 2020; van Engelenburg et al., 2018; Li & Song, 2021). For example, traditionally, companies work hard on developing various strategies to closely collaborate with and monitor their suppliers' performance, build relationships and trust, and manually draft the terms of their agreement. Nevertheless, smart contracts, being self-enforcing and self-executing, autonomously and automatically actuate the terms and conditions of a particular agreement and contract (Hewa et al., 2021). Therefore, that directly impacts how companies design their supply chains and can radically change how companies make contractual decisions (e.g., supplier relationships, trust). For example, transparency, trust and immutability are ensured with the use of blockchain technology. As a result, companies may need to shift their focus from gaining visibility to working towards data security.

In particular, Blockchain-enabled smart contracts are argued to cause significant disruption to some complex system designs in the agreements and contractual processes, as well as unwind disputes and exposures in a trusted way (PwC, 2020). Moreover, as Blockchain has its evidential audit trail embedded at its core, it eliminates any blind spots, improves the financial flows within and across borders, saves time and lower transactional costs (Alharby & Van Moorsel, 2017; Chang et al., 2019). Compared to traditional ERP systems, smart contracts enabled by blockchain technology extend the automation, execution and enforcement of terms of agreements to the network level, providing increased visibility and automation across the supply chain (Cole et al., 2019), giving confidence to the parties involved and building solid foundations for the development of trust.

Nevertheless, the adoption of Blockchain-enabled smart contracts strengthens supply chains and makes them more vulnerable because of the high exposure and reliance on technology and automated systems. Moreover, as several works have highlighted (e.g., Chang et al., 2019; Alharby & Van Moorsel, 2017), smart contracts are no panacea for all supply chains, and several challenges exist that limit their widespread adoption (e.g., legal and privacy issues, lack of standards and protocols, codifying issues and even performance issues). The literature has also identified several security issues which Alharby and Van Moorsel, (2017) collated, namely transaction-ordering dependency (when two dependent transactions that refer to the same contract go to the same block), timestamp dependency (when a block timestamp is used to trigger and execute transactions), mishandled exception (linked to codifying problems), criminal activities, re-entrancy vulnerability and untrustworthy data feeds (when information from outside the blockchain is required and captured without any guarantees). Table 1 below presents a SWOT analysis of the adoption of Blockchain-enabled smart contracts and summarises the internal and external factors involved.

4 Mapping of the Smart Contractual Processes Architecture

Currently, a typical supply chain uses traditional ERP systems and other online platforms to manage the flow of materials, information and money. These software solutions integrate transactions-oriented data and business processes throughout the inter-organisational supply chain using internet interfaces to link data internally and with customers and suppliers. Even though these information system solutions offer significant benefits to organisations (e.g., decision support, planning and control), they are subject to problems and risks such as data accuracy, security issues, high transaction fees and other risks related to business transactions. However, on the journey to digital transformation, BCT provides the opportunity to map and track upstream, midstream, and downstream supply chains (Khan et al., 2022). In that way, BCT offers the potential for complete visibility and transparency of all the supply chain members and allows the interaction of untrusted parties to interact with each other in a distributed manner and without the need for a trusted third party (e.g., a bank). Table 2 below summarises the key differences between a traditional and a blockchain-enabled supply chain regarding data sharing and transparency, data integrity and immutability, data security and trust and data verification.

Figure 4 illustrates a simplified contractual process architecture in a traditional and blockchain-enabled smart contract supply chain. In the traditional supply chain, a linear process occurs with limited (usually dyadic) interactions among supply chain actors, consequently reducing transparency and supply chain efficiency. In this traditional design, the coordination of information (e.g., sharing, tracing) is also a big challenge, and data exchange via self-owned databases results in high costs, time investment as well as risks related to their accuracy (Chang et al., 2019; Li & Song, 2021). Contracts between the supply chain parties are manually and centrally managed based on the data and information available to the parties involved in the contract. Overall, in the traditional supply chain, there is a heavy reliance on manual operations to achieve information sharing among supply chain participants (Mubarik & Naghavi, 2020; Chang et al., 2019). On the other hand, the Blockchain-enabled smart contract supply chain presents a more innovative process design, a

Table 1 SWOT analysis of the adoption of Blockchain-enabled smart contracts (Compiled from multiples sources: Giovanni, 2020; van Engelenburg et al., 2018; Gatteschi et al., 2018; Alharby & Van Moorsel, 2017; Chang et al., 2019; Cole et al., 2019; Hewa et al., 2021; Kusi-Sarpong et al., 2022; Khan et al., 2022)

	Positive	Negative
Internal	**Strengths** • Transparency and traceability: All parties in a network can have access to data under certain conditions. • Reliability: Once data is stored, it becomes hard to modify or erase, making it a trusted way to exchange data and information. • Privacy: The parties sharing information can be limited and controlled in a private blockchain. • Accessibility: Real-time and quick access to data. • Ease: Smart contracts allow fast workflows in real time. • Automation: Allow automated facilitation, execution, and enforcement of terms of the agreement. • Process simplification: Re-engineering, low transactional costs. • Risk: Reduces checks and human error.	**Weaknesses** • Security issues: The transparency offered makes it more difficult to protect sensitive data. • The conflict between data accessibility and data protection. • High investment requirements: Cost and time can be significant to create and implement a blockchain-enabled smart contract application. • Codifying issues: Such as the inability to modify or terminate smart contracts. • Absence of regulations, legislation, and global standards. • Smart contracts neglect social contexts, e.g., related to sustainable supply chain management.
External	**Opportunities** • BCT can facilitate supply chain mapping, improve supply chain sustainability and influence sustainable production by identifying waste in the processes and reducing costs. • With increased transparency, the parties in a network can use the data to improve their planning and bullwhip effect. • BCT can help to overcome information asymmetry in the supply chain. • Smart contracts can build a strong foundation for developing trust and confidence between the various parties in the network as everyone follows the rules.	**Threats** • The transparency offered can negatively impact negotiation strategies. • The transparency offered can harm companies' competitive advantage and position. • Scalability: Low adoption means a need for more data and information. • Companies might still consider the manual drafting of contracts more beneficial.

decentralised network design, with the shared ledger at its core to synchronise the tracking and sharing of information (Treiblmaier, 2018). The self-enforcing and self-executing smart contracts also save much time in the process and are based on trusted data.

Wang et al. (2019) presented a comprehensive research framework which captures major architectural characteristics of Blockchain-enabled smart contracts

Table 2 Traditional versus Blockchain-enabled supply chain (Compiled from multiples sources: van Engelenburg et al., 2018; Gatteschi et al., 2018)

Comparative item	Traditional supply chain	Blockchain-enabled supply chain
Data sharing and transparency	• Lack of/limited data sharing among partners	• All parties can have access to data under the conditions
Data integrity and immutability	• No tamper-proof, data can more easily change	• Tamper proof, data cannot be modified or erased
Data security and trust	• Centralised protection without using an authentication protocol	• Decentralised protection, with the use of an authentication protocol
Data verification	• Not achieved	• Achieved

and organises them into six layers (Fig. 5). The first layer concerns all the infrastructure needed to support smart contract applications. It includes the trusted development environments (e.g., programming languages, clients), the trusted execution environments (e.g., consensus algorithm), and the trusted data feeds (e.g., Oracles). All these infrastructure attributes and combinations are critical choices as these will impact the smart contracts' design pattern, efficiency and security. The second layer is about the contract data and includes all the rules, terms and criteria involved in the design, development and deployment of smart contracts. At this layer, the contract terms are translated into codes using software engineering technology, which is when interaction criteria are set. The third layer is the operations layer which includes all the operations from negotiation to self-destruction to ensure the efficiency of functions, verification and security. The fourth layer includes various intelligent algorithms (perception, reasoning, learning, decision-making and socialising), which, combined with artificial intelligence technology, aim at taking into consideration social factors (e.g., learning) neglected until today. The fifth layer includes various high-level manifestation forms of smart contracts encapsulating the complexity and advancing the multiagent systems. These forms are expected to play a disruptive role and improve the traditional management systems in businesses. Finally, the sixth and last layer is about all the applications that support the manifestation layer, such as the energy and finance factors. However, as Wang et al. (2019) also highlighted, this framework represents an ideal situation which dictates the way for autonomous and intelligent future smart contracts.

5 Concluding Remarks

The advent of a new technology paradigm in the twenty-first century allows us to look at existing traditional problems differently. The latest technological advancements in the IT sector allow reimagining how we perceive specific supply chain business processes and redesigning them with new thinking philosophies. This chapter demonstrates plenty of use case scenarios, advantages, procedures, and applications of blockchain technology in the smart contractual architecture in supply

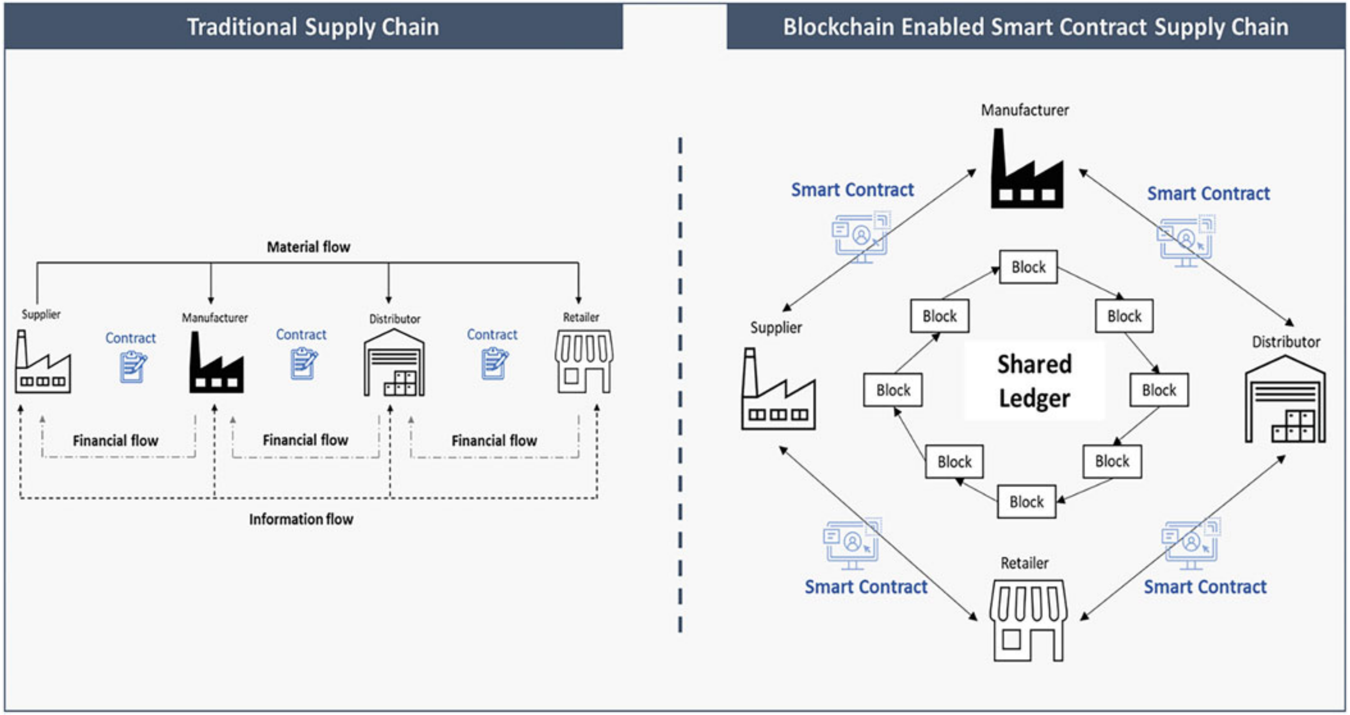

Fig. 4 Contractual process architecture in a traditional (left) and a Blockchain-enabled smart contract (right) supply chain (Author's version adapted from Chang et al., 2019)

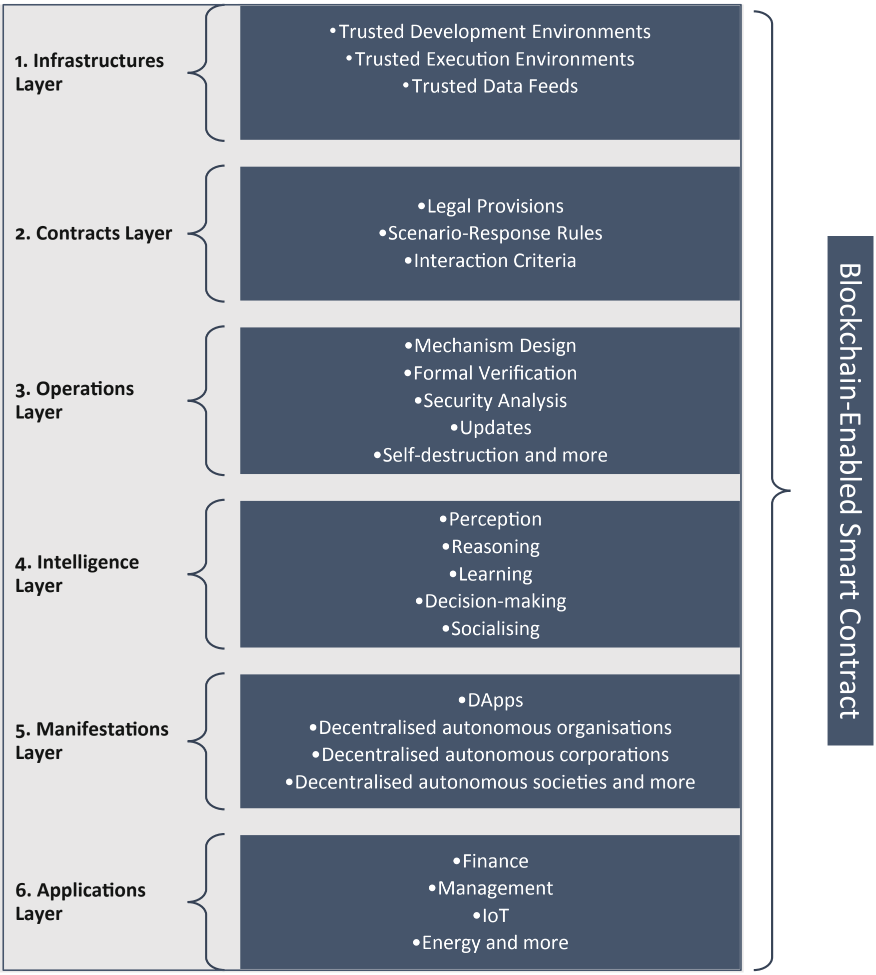

Fig. 5 Six-layer architecture of a Blockchain-enabled smart contract (Adapted from Wang et al., 2019)

chain design. SCs can effectively, efficiently, and securely circumvent the issues by implementing a blockchain application and the incubation of smart contracts is one such application in the procurement process. However, as with all digital transformations, SCs seeking to implement blockchains face high adoption and deployment costs. These costs are split into fixed (for instance, IT expert recruiting, hardware etc.) and variable costs (for example, time and energy consumed when running complex blockchain networks). Therefore, firms and SCs need to analyse the negative implications of traditional online platforms and blockchain-enabled solutions. Despite the high price a firm might need to pay initially, advanced innovative digital solutions are expected to be much cheaper in the long run.

As businesses start to realise that it is critical to gain a clear and deep understanding of how this disruptive technology can impact their business models internally as well as impact their supply chain designs. This way, they can leverage blockchain-enabled smart contracts' benefits (such as transparency and reliability). This chapter combines findings from the current literature and consulting firms and demonstrates how BCT, with its unique capabilities, can change the way companies make contractual decisions and root out current supply chain inefficiencies. A SWOT analysis was therefore presented, which also highlights the fundamental conflict between data accessibility and data protection that is magnified when using BCT. Finally, this chapter presents a mapping of the traditional and the blockchain-enabled smart contract supply chain and highlights their critical architectural differences. Given that this chapter focuses on a novel and disruptive technology whose success lies on high adoption levels (otherwise, there will be a lack of data and information), incremental research and close collaboration between academics and practitioners are needed to unlock its full potential.

6 Implications and Future Research Directions

The interest in BCT has existed for many years now, and it has seen exponential growth in the last 5 years, also followed by the massive public interest in Bitcoin. Nevertheless, the full range of potential blockchain-based applications, such as smart contracts, still needs to be determined. BCT is an under-explored area with vast potential to create business value and revolutionise supply chain management. Given that, this book chapter bears significant implications for researchers and managers alike as it can be used as a starting point or a learning resource to offer a complete standing of BCT in contractual processes. It includes the definition and clarification of terms, a description of main characteristics and processes, and mapping and comparing the architecture of contractual processes between traditional and blockchain-enabled supply chains. In addition, combining and discussing the role of blockchain-enabled smart contracts in supply chain designs opens the floor for more research and questions on how the fundamental supply chain flows (i.e., materials, information, financial) will be disrupted, how it will impact the design of complex systems and what the implications will be. As big companies and consultancies are at the forefront of this innovation, some interesting research directions could also include the potential of small and medium enterprises to support this innovation and examine its impact.

Despite the enormous investments by the industry in blockchain-enabled applications and smart contracts, in particular, its adoption is still in the infancy stage. More rigorous academic research is needed to study the various applications and the different implementations of blockchain to deploy and run smart contracts (e.g., Ethereum, Eris), as well as to investigate the potential and capabilities needed to upscale BCT in practice. Like several other researchers, the authors of this study understand that more systematic research is needed to significantly escalate the BCT's development process. There is ample room for further progress in determining the optimum framework, technologies and tools that could unlock the full potential of blockchain-based smart contracts.

7 Limitations

The study mainly relies on pre-published data from academic sources. Therefore, this study only provides basic research ideas or food for thought for academics to examine the BCT applications on the operational level and sets the direction for small and large companies to explore the potential of Blockchain-Enabled Smart Contracts in different settings. Furthermore, as the topic is still exploratory, most of the research is qualitative. Therefore, exploring and supporting suggested applications with reliable empirical analysis is pressing.

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Supply Chain Collaboration in the Era of Blockchain Technologies

Prashant Tuli

1 Introduction

Traditional antecedents of supply chain collaboration (SCC) e.g., joint dependence, proximity, trust and inter organizational systems (IOS) are vital in enabling the collaboration between the SC partners and generating the collaborative advantage. Blockchain technologies are being discussed for their potential positive impact on the supply chain management, and how they can benefit the partners in a SC network.

While there is a lot of attention on how BCT with their key characteristics of transparency, immutability and consensus can promote the collaboration between the SC partners; there is no specific discussion on how each of the antecedents of the collaboration process impacts or gets impacted by the BCT. It indicates a gap in the deeper understanding of the process of collaboration enabled by BCT. Therefore, it is required to understand the interplay of the key characteristics of BCT and the antecedents of the process of collaboration in the SC networks. It may enable the managers to better understand the context and action plan for a better implementation of BCT in the SC networks, while keeping in mind the key success factors or challenges posed by collaboration under implementation of blockchain technologies.

This chapter intends to re-examine the structure and manner of collaboration in the era of the Blockchain technologies; and understand how these technologies may be leveraged better in achieving a greater collaborative advantage. This is done by drawing on a framework of SCC in the automotive industry (Tuli, 2018), that lists the key antecedents of SCC. The chapter examines these antecedents to understand their interplay with the key characteristics of BCT and explores the opportunities and

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_2

limitations of leveraging the BCT in the process of collaboration The key objectives of the chapter are as given below:

1. Review the extant literature on the potential impacts of BC on the SCC
2. Examine the interplay of BCT and the key antecedents of SCC
3. Propose the way forward for future research in this area

The chapter primarily analyses the evolution in the structure of supply chain collaboration enabled by block chain technologies. It makes an intellectual enquiry into the current understanding of SCC as a process and its possible evolution in the era of the blockchain supply chain management (BCSCM). It contributes to the domain of SCC by extending the perception of underlying constructs of SCC when viewed in conjunction with the BCSCM and motivating the researchers to reconsider the idea of SCC with a view to benefit the SC partners in the network.

The subsequent sections will discuss the interplay of the antecedent with the key BCT characteristics; and how SCC, as a practice, may get impacted in the BCT era. The chapter also highlights the implications for the managers working in the area of SCC and concludes with the potential of further research in this area.

2 Background

Supply chain collaboration (SCC) has been defined in various ways. Some researchers have cited collaboration as generation of mutual benefits through sharing of rewards and risks enabled by information exchange as the foundation of the process (Mentzer et al., 2001; Simatupang & Sridharan, 2002; Barratt & Oliveira, 2001;). Others have defined it as a means to appropriate mutual benefits between two or more autonomous partners (Cao & Zhang, 2010) and differentiated it from cooperation, coordination or integration. While cooperation relates to a motivation to operate together, coordination involves synergy of action to pre-empt opportunistic behaviour (Snyder & Shen, 2019); integration generally refers to a governance mechanism involving contractual means and some form of central control by one of the partners (Flynn et al., 2010). However, collaboration, additionally, involves governance through relational means (Nyaga et al., 2010) with intent of creating advantage for all partners. Partners may collaborate to create mutual benefits (relational rents) or collaborative advantage, instead of individual rents or competitive advantage (Lavie, 2006; Wagner et al., 2010); and increase the overall profits as a group, in comparison to sum of individual profits without collaboration (Cao & Zhang, 2011). This is one of the most noticeable traits of SCC that needs to be considered while examining the impact of BCT on the collaborative actions of the SC partners.

While SCC remains one of the most discussed topics and has been viewed as a key lever of effective supply chain management in today's global supply chains; firms seek high levels of collaboration to leverage the knowledge and resources of their exchange partners (Barratt, 2004; Horvath, 2001; Cao & Zhang, 2011).

However, researchers also opine that collaboration as a management strategy doesn't have a good track record (Sabath & Fontanella, 2002) and actual potential of collaboration has not yet been realized fully (Barratt, 2003; Crum & Palmatier, 2004). There are only a handful of successful cases of supply chain collaboration. Mainstream implementation has not yet been so successful with only a few collaborative relationships capitalizing the potential of supply chain collaboration while others have not been able to meet the partners' expectations. There has been a lot of research on collaboration, focusing on collaborative practices that the SC partners may undertake, their antecedents and outcomes. This is probably because the process of collaboration, in addition to its enablers like information exchange or joint working groups, is also driven by the factors like trust, commitment etc. and the success of collaborative efforts is determined by a combination of many factors which may differ across the regions, cultures or the industry.

Technology-facilitated collaboration has been improving the operations and collaboration; however, it renders the supply chains more vulnerable to an array of IT-specific threats (Baker et al., 2007). Blockchain (BC) technology has been hailed as an important enabler of enhancing the supply chain performance (Cole et al., 2019) due to its attributes of immutability, decentralisation, and security etc. It can help by streamlining information exchange, resource optimisation, and enabling superior decision making among the SC partners. BC promises capabilities in SC by facilitating auditability, accountability, and transparency thereby improving the trust in SC relationships. (Rejeb et al., 2021). It also promises to strengthen collaboration and to overcome vulnerabilities in the conventional technologies for information exchange and other activities undertaken in a collaborative SC network.

However, as highlighted earlier, the implementation of BCT in the collaborative networks may not be easy to understand as it is faced with the factors that are process and system related and can probably be understood and remedied by the technological prowess that the BCT promise. However, it is equally important to consider factors that are relationship based e.g., trust and collaborative culture etc., that present a challenge to the successful implementation of the BCT.

The next sections comprise the extant literature that relates BCT to the supply chain processes and performance, and the research gaps that emerge from the current studies.

3 BCT in SCM: Literature Review

The contemporary literature on BCT application to supply chain has focused on various perspectives of SCM (Korpela et al., 2017; Kim & Laskowski, 2018) including the security of transactions, transactional trust, and privacy threats etc. (Dai & Vasarhelyi, 2017; Hong et al., 2014). Though the existing processes provide the governance mechanisms and tools for monitoring including the transaction verification etc. (Bergen et al., 1992); however, the modern SC processes are network intensive and have evolved over a period to overtake the existing processes for managing the SC related issues and risks. BC technologies have various characteristics that may help in overcoming such limitations e.g., smart contracts, transparency, and traceability among peers (Xia & Yongjun, 2017; Kamble et al., 2019). Therefore, BC has potential to provide solutions for assuring the veracity of digital SC transactions (Schmidt & Wagner, 2019) and promoting the collaborative business processes. Numerous latest studies l recently published (e.g., Azmat et al., 2022; Ali et al., 2021; Qader et al., 2022; Kusi-Sarpong et al., 2022; Piprani et al., 2022; Mubarik et al., 2022; Khan et al., 2022a, c; Khan et al., 2022b).

Researchers have explored how blockchain technologies might affect SC performance objectives like cost, quality, and flexibility etc. (Kshetri, 2018). It has been opined that the relation between blockchains and increased transparency and accountability is likely to be strong (Hald & Kinra, 2019; Mubarik et al., 2022) and BCT might present a potent solution in the form of newer business models to assure digital veracity (Schmidt & Wagner, 2019). Blockchain has also been positioned as a digital innovation, and an emergent enabling technology (Ali et al., 2021; Buer et al., 2019) that provides unique features such as immutability, automaticity etc. possibly resulting in unparalleled reliability, transparency, and efficiency in the supply chain (Treiblmaier, 2018). Introduction of BCT into the SCM, coupled with redesigned information exchange architecture, can change the hierarchical relationship within SC partners while regarding customers as the centre of the system and effectively reducing the bullwhip effect. BCT enables SCM has also been viewed to have a significant direct impact on the sustainable production of the firm (Kusi-Sarpong et al., 2022) and research findings have suggested adoption of BCT as a broad-based strategy to attain multi-tier goals, for example, supply chain mapping, sustainability, and integration. It has been opined that the notion of the sustainable SC can be significantly enhanced by mapping the different parts of the supply chains and that mapping can further improve supply chain sustainability (Mahmood & Mubarik, 2020; Mubarik et al., 2021; Khan et al., 2022a, b, c).

The best-case implementations of BCT in the SCC support and enhance supply chain capabilities, and leverage supply chain skills and intelligence. Consequently, SC partners may be perceived as sources of skills and intelligence that need to be supported for maximising the performance of the entire chain. BCT is said to move organisational processes in the closely coupled directions, where they will work to enhance the performance of each of the SC partners (Hald & Kinra, 2019; Mubarik & Naghavi, 2020).

4 What Is Lacking?

Previous research has indicated the possibilities of designing collaborative business processes based on BCT. Researchers have engaged in simulation models and surveys to opine that BC technologies may be effective in overcoming collaboration and trust issues in SCs resulting in reducing the information asymmetries between SC partners (Longo et al., 2019; Fosso Wamba & Guthrie, 2020).

However, firms generally interact based on shared mutual interests (Kumar & Banerjee, 2012); and are likely to face agency problems implying threats regarding opportunism in business relationships (Bosse & Phillips, 2016). The tendency to protect confidential information in SC partners is a well-known research problem due to such threats (Hong et al., 2014). Trust between SC partners remains a persistent issue between information sharing networks (Arnold et al., 2014; Rasiah et al., 2017; Azmat et al., 2022). While current implementations are not adequately placed to provide technological facilitation of trust between SC partners (Lu et al., 2018), BC technologies might support many use cases to enhance transactional trust by providing data assurance and auditability etc. (Kokina et al., 2017). However, trust is also a multidimensional construct and there is more to it than the aspect of transactional trust (Ring & Van de Ven, 1992). Therefore, a pertinent research area to be to understand the concurrence of the trust dimension of SCC with the BCT.

Further, the decentralized open-network approach adopted by BCT also promotes newer business processes that can enhance SCC by providing safer information exchange and auditability (Treiblmaier, 2018). There are some apparent research issues in these newer ways of information exchange (Wamba & Queiroz, 2020), as they tend to diminish the information asymmetry and might impact various SC partners in diverse ways. Additionally, each SC partner in the network might be differently inclined to submit to the practices of BC technologies; because such practices influence the social variables like trust, power and information exchange that go a long way in deciding whether the SCC is successful or not in terms of the actual benefits accrued (Pan et al., 2019).

While there is a plethora of research on how BCT might benefit the SCC and the performance of the SC network, however there is a perceptible lack in the literature about the ways in which BC technologies explain the multidimensional nature of SCC. The gap in the literature in terms of how exactly BC technologies deliver those benefits or why it is not able to deliver in some cases. It remains to be understood that there may be an interplay of the key characteristics of the BCT with the factors or antecedents of the SCC that results in the probable success or failure of the implementation of the BCT in the supply chain networks. This chapter will attempt to bridge some of these gaps in the supply chain collaboration enabled by BCT by re-examining the antecedents of SCC in the light of the BCT characteristics. It will also shed some light on the key opportunities and challenges for BCT implementation in the SCC process.

5 Interplay of Supply Chain Collaboration and Blockchain Technologies

The antecedents of SCC have been studied by many researchers and have been summed up in various forms. The antecedents offer an insight into the process of successful collaboration among supply chain partners. This section leverages a SCC framework that studies the antecedents of SCC, and broadly divides them into two categories (Tuli, 2018). Both these categories complement each other. One is the “Process and system aspects” and the other is the “Relationship aspects”. The process and system aspects comprise the inter organizational systems (IOS)

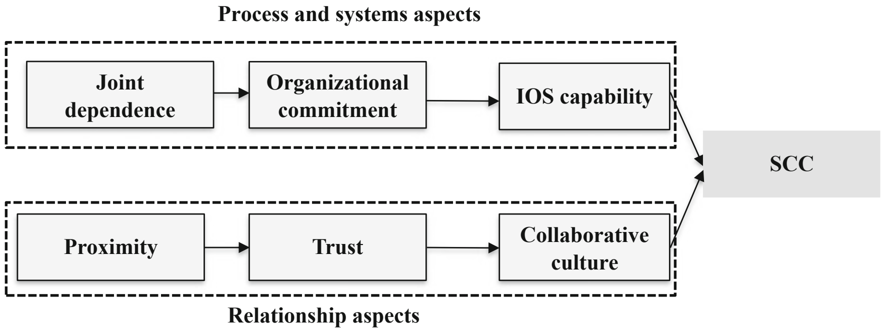

Fig. 1 Antecedents of SCC

capability of the SC partners to enable the exchange of information across the organizational boundaries. This is the key capability for being able to exchange the required information with the required partners at the required time. These systems are promoted by the organizational commitment towards the process of SCC, which in turn, is supported by the perceived level of joint dependence that SC partners have over one another.

The second category i.e., the relationship aspects are largely the softer aspects of collaboration e.g., collaborative culture embedded in the SC partners, which is a result of the mutual trust that they place in each other. This is promoted by the organisational proximity between the SC partners i.e., the cultural fit between the organisations demonstrated by the fit between their organizational process, systems, and the outlook that they share. A schematic is shown in Fig. 1 to indicate how both these aspects might complement each other to promote the collaboration among the SC partners.

The next sections examine each of these antecedents to understand their interplay with blockchain technologies to explore their impact on the BCT implementation. It also lists the potential opportunities and challenges to the process of BCT implementation due to each of these factors. The subsequent sections will summarize and discuss the observations and present a way forward.

6 Interorganizational Systems Capability and the BCT

Firms use inter organizational systems (IOS) to develop collaborative relationships with their partners (Ragatz et al., 1997; Bagchi et al., 2005; Hong, 2002). Integration through shared information leads to SC partners working effectively as a single enterprise. IOS includes the information sharing systems between the SC partners (Barret & Konsynski, 1982). Researchers have viewed them as IT applications shared by two or more firms that are used by the supply chain partners to mediate transactions or manage interdependencies between them (Subramani, 2004; Cash & Konsynski, 1985; Chi & Holsapple, 2005). IOS, by definition, cross organizational boundaries and are designed to benefit the participating firms (Johnston & Vitale, 1988). However, the deployment of IOS may be motivated by multiple goals like regulations, systems for increasing efficiency or control. Despite the similar underlying structure and technology, the adoption of IOS with different motivations can lead to different outcomes for the individual firms (Subramani, 2004).

IOS capability has been viewed as the enabler of information exchange between partners, and a facilitator of the transactions pursued for mutual benefits (Tuli, 2018). It views three main components of IOS capability as Information systems (IS) capability, IS flexibility and IS synergy. These support real time information exchange among the collaborating partners. Information systems (IS) capability may be viewed as the availability of the required IT systems to enable information exchange among partners. and enhance the information processing capabilities to enable a better interfirm cooperation in addition to reducing uncertainty (Subramani, 2004). Additionally, IS flexibility refers to the extent to which the systems, including IT resources and skills, may be scaled to handle increased information exchange effectively (Ross et al., 1996; Bharadwaj, 2000). to allow firms to respond to emerging requirements and provide for future integration. Further, IS synergy refers to the adoption of systems that meet defined standards in terms of usage, scalability and compatibility and facilitate information exchange between supply chain partners. Shared knowledge between managers and tight coupling of processes determines the strategic use of information systems and enable partners to cooperate (Rockart, 1988).

Research indicates that IOS capability supports exchange of information and resources, thereby facilitating the process of collaboration. This fits well with the notion that BCT have their backbone in the concept of private or restricted blockchains, wherein the SC partners may take up collaborative practices like information and resource sharing, joint knowledge creation or product development without the concern for information leakage. However, the challenges that BCT might face, in the context, are that the firms may need to enhance their systems and couple them with their SC partners tightly and use shared data structures so that they can make better use of the BC technologies. Creating requisite systems that have the capability and flexibility to participate in the collaborative processes and are aligned to leverage the benefits of the SCC is a basic requirement for BC technologies. Such requirements might transcend geographies due to the location of the SC partners thereby presenting concerns about legal framework of varied geographies that might support such technologies. Further, information sharing is a consequence of each stakeholder's disposition towards sharing, and SC partners might like to be selective in information sharing in the network. Therefore, BCT must be designed while keeping this aspect in view that it should be realized with that minimum viability of information exchange in mind.

7 Organizational Commitment and BCT

IOS capability is said to be contingent on the organizational commitment (Tuli, 2018). Organizational commitment has been viewed as a combination of top management commitment to align the resources for facilitating collaborative activities between SC partners. The management needs to recognize and endorse the collaborative actions and agree to a governing system that can deliver collaborative advantage to its stakeholders. While it may be hard to achieve due to the concerns of top managements of participant firms about the possible benefits at the firm level; it echoes the concern that better relational rents might not get translated to superior individual rents i.e., there may be potential imbalances is the distribution of benefits resulting from information sharing between collaborative partners (Yu et al., 2001).

As a matter of practice, all SC partners should benefit proportionally from the sharing of information. The distributed ledger membership of the BCT in a SC network provides a considerable advantage as participants, who do not share the belief that it may benefit the SC partners, may not join the arrangement. It ensures that the SC partners, in the BCT enabled collaborative environment, are more inclined towards supporting the initiatives and are likely get the organizational commitment.

However, it requires the support of various functions due to the diversity of information and the various sources where it resides; and a broad-based functional support from various functions is required necessitating a governance mechanism to enable the cross functional activities. (Fawcett et al., 2006). Accordingly, it is a challenge to draw on the organizational commitment as the managements of the respective SC partners are wary of the extent of the organizational resources and information to be committed in the evolving setup of BCT. A partial support, though easy to come by, may not finally generate enough benefits for the management to make justifications to continue with the support. A fuzzy idea of the BCT implementation, which might appeal to the management on the paper, may actually be the reason of discontinuance of the same during the course of the implementation. Therefore, a long-term clarity of the BCT implementation plan is an important prerequisite for the respective managements.

8 Joint Dependence and BCT

The organizational commitment is a result of the perception of joint dependence among the SC partners (Tuli, 2018). Transaction cost theory indicates that transactions under uncertainty increase the costs, thereby motivating the firms to engage in relational partnerships to minimize costs (Dyer & Singh, 1998). While reducing transaction costs, it might increase the switching costs for the partners (Geiger et al., 2012) and enhance joint dependence. Resource-dependence theory (RDT) explains that uncertainty may be better managed through external resources (Casciaro & Piskorski, 2005), thereby supporting the dependence between SC partners. Keeping aside the dependence due to power asymmetry between the SC partners, the joint dependence may be understood as a zero-sum game (Emerson, 1962) as it emanates from mutual interdependence leading to the concept of essentiality, wherein it defines importance of a partner, and that of substitutability (Jacobs, 1974; Sriram et al., 1992), wherein it indicates the high switching costs of a SC partner due to relationship specific investments (Bourantas, 1989).

Blockchain, as a technology, has the potential to motivate SC partners to enhance the relational exchange as it offers the possibilities for the promotion of common goals and reduction of relational risks like opportunistic behavior (Schmidt & Wagner, 2019) as well as cheating and information distortion (Kshetri, 2018). Therefore, there is a likelihood of increase of relationship specific investments, and consequently, of the joint dependence even when firms are likely to face uncertainties due to that dependence. A right alignment of incentive structures of the collaborative arrangements using the BCT might help to allay these concerns, wherein the potential imbalances resulting due to mutual dependence are minimized (Pan et al., 2019).

However, SC partners have their own perception of dependence and might like to limit their dependence on the other members in the network. The implementation of BCT, in part, is also dependent on promoting the notion of mutual dependence and relational rents leading to the distributed ledger and transparency. The partners may confront the dilemma of enhanced dependence versus the individual interests thereby presenting challenges to successful implementation of BCT in the areas which the SC partners consider as their core strengths and invaluable to their competitive edge over others.

9 Collaborative Culture and BCT

Culture is an organizational trait (Hofstede, 1998) that has been viewed as the norms, patterns, beliefs of a firm in the context of collaborative partnerships (Nooteboom et al., 1997) and refers to the orientation of the firm to nurture relationships, despite temporary setbacks (Walls, 1993; Kumar et al., 1998). It promotes relationships based on mutual trust; and is an important factor in the organizational context for understanding SCC (Orlikowski, 1993).

Four dimensions that explain the concept of collaborative culture are- Collectivism, Long term orientation, Power distance and uncertainty avoidance (Hofstede, 1980; Cao & Zhang, 2011). It is pertinent to study these dimensions in the context of BCT implementation in the supply chain. Collectivism facilitates the firms to engage in collective partnerships with other firms while managing issues (Sako & Helper, 1998). Long Term Orientation refers to the willingness of the firm to develop long term relationships with partners (Sheu et al., 2006) and is demonstrated by committing resources to enable successful relationships despite diverging priorities (Holweg et al., 2005; Angeles & Nath, 2001). The partners expect future gains from cooperation out of mutual obligations rather than a binding contract. Transaction- or relation- specific investments based on long term orientation enhance the collaboration between partners and result in process efficiency and productivity (Dyer, 1996;

Bensaou & Anderson, 1999). Power distance refers to the unequal distribution of power among participating members (Hofstede, 1980). Low power distance implies that partners tend to favour equal say in the relationships and joint decisions through formal or informal engagements instead of authority (Wuyts & Geyskens, 2005). It also implies an equal balance of power and governance based on shared values. Power distance plays a great role in supporting more participative relationships and asymmetry may be addressed through development of trust in inter organizational relationships Uncertainty Avoidance implies the intent of the firm to pre-empt uncertain situations (Wuyts & Geyskens, 2005). Firms manage this through suitable rules and processes, and tend to engage more with their supply chain partners for exchanging relevant information to enhance certainty e.g., forecasting, inventory etc. (Steensma et al., 2000).

BCT may have a very important role to play in enhancing the collaborative culture. Incentive alignment necessitates the sharing of costs, risks, and benefits between SC partners (Simatupang & Sridharan, 2002). BCT has the potential to align incentives among SC partners through the formulation and enforcement of incentive schemes. This incentive alignment improves the collectivism and long-term orientation among the participants in the network, as other parties are expected to follow the rules (Cole et al., 2019). It encourages the SC partners to engage into transactions wherein they are not averse to mobilize resources and make functional commitments that might help in making and achieving common goals. Further, BC-enabled smart contracts align the interests of the different parties in the consortiums and help in reducing the power asymmetry among the SC partners.

However, BCT represents a significant shift to a decentralized network, that requires the buy in of its SC partners. The implementation of BCT promotes the reduction of power distance between the SC partners which might not be acceptable to some of the SC partners in the medium to long term. Alignment of incentives, though a possible mitigation of this issue, might not be a perfect solution to this issue of equity of power among the members of the network. Therefore, prior trust between the partners and the generic culture of the SC network are the initial impediments that need to be taken into consideration before embarking on a BCT enabled collaborative journey.

10 Trust and BCT

Trust is viewed as a mechanism to minimize the self-interest and opportunism, enhance cooperation towards meeting shared objectives (Barney & Hansen, 1994) to lower transaction costs for the partners (Bromiley & Cummings, 1995). In the context of collaborative relationships, it might be measured using the two main dimensions termed as credibility and benevolence (Ring & Van de Ven, 1992; Sheu et al., 2006). Credibility refers to the belief that the firms in exchange relationships fulfil the implied responsibilities in a consistent and reliable manner (Zaheer et al., 1998). It works by making it difficult for partners to resort to opportunism or focus solely on self-interests (Pavlou, 2002). Benevolence refers to the expectation that firms in collaborative relationships act in a fair manner without taking undue advantage of others (Anderson & Narus, 1990). It is an expectation resulting from goodwill and is based on goodwill rather than on rational calculation. It is a stronger representation of trust than credibility (Borys & Jemison, 1989) and may involve exchange of confidential information or key resources among partners (Pavlou, 2002).

BCT has the potential of enhancing the transactional trust in the SC network. It is the nature of the BCT involving immutability, smart contracts and distributed ledger that enhance the credibility of the SC partners in the process (Cole et al., 2019). The consideration that the network members will honor their commitments will work to reduce uncertainty, risk of opportunism, and enhance collaborative exchanges by providing a means of governance. Therefore, trust is a well anticipated consequence of the application of BCT in the SC network. However, trust is also an extraordinarily strong antecedent of the information sharing as envisaged in the BCT implementation. Therefore, it is particularly challenging to explore trust in the context of the BCT implantation. The requirements of BCT implementation necessitate that there should be high level of supply chain transparency and that may create challenges concerning data privacy issues (Bridgers, 2017) and can be perceived as a source of power asymmetry in the favour of a few powerful actor like a buyer who sets up the blockchain and invites other partners to join. This might deter the smaller firms from joining the BCT enabled SC networks. The benevolence aspect of the trust is not well supported by the characteristics of the BCT, and only the prior trust can have a positive effect on this. Therefore, the challenge for BCT implementation is to identify the potential SC partners who would have the requisite trust in the process despite the potential concerns.

11 Proximity and BCT

The concept of proximity refers to the condition where interaction increases when partners exhibit similar attributes. It is viewed as a facilitator for exchange processes; thereby supporting collaborative engagements. Researchers have studied many dimensions of proximity; however, two dimensions are relevant to the SCC- organizational proximity and technology proximity. Organizational proximity relates to the similarity in the organizational routines and practices, culture etc. between two organizations. It tends to enhance the exchange relationship and reduce uncertainty between them. It enables easier exchange of information and personnel; and may reduce transaction costs of collaborative exchanges. Technology proximity represents similar knowhow of firms that supports knowledge exchange. It refers to the knowledge actors possess about the technology; rather than the technology itself. Therefore, the similarity and differences in knowledge bases contributes to the exchange relationship.

Since BCT implementation involves considerable interaction between the participating members, the organizational proximity is both an enabler and a result of the BCT implementation. The partners would set up systems that are shared across the organizations and similarities of the routines, processes etc. would enable the easier and superior implementation of the BCT across the network with higher proximity. Further, SC partners, who share technology proximity in terms of being able to understand and appreciate the BCT as an enabling technology, are more likely to succeed in its successful deployment in their network. The key aspects of BCT need to be enabled through relevant technologies and systems that span the organizational boundaries and the proximity between the partners has a positive effect on promoting the set up and deployment of such systems.

While it may enable the process of implementation of BCT; the similarities in organizational processes, practices and beliefs also implies similar outlook towards the information exchange and dominance that accompanies the transparency. Therefore, such firms might like to protect some selective information, and engage in information asymmetry to retain the keep competitive advantages in the SC network. Accordingly, proximity at its other extreme may result in a group of SC partners, who are all likeminded about the concept of BCT, but nevertheless might not implement or deploy the BCT in its desired format, thus restricting the benefits that each partner can draw from the implementation.

12 Summary and Conclusion

The prior sections have examined each of the enablers of supply chain collaboration in view of the implantation of blockchain technologies. A summary of the same is given in Tables 1 and 2, wherein they are classified in terms of the process and system aspects or the relationship aspects. It is noticed that BCT are well placed to manage the process and system aspects as they promote the process and system aspects. However, successful implementation of BCT is also contingent on the relationship aspects like collaborative culture, trust etc. These antecedents may sometimes challenge the strict notions of transparency, immutability and consensus as envisaged in the collaborative relationships. While BC technologies are expected to support the requisite processes and systems by providing a trusted platform and enabling the IOS; the relationship aspect also needs similar attention in the context. Further, blockchain technologies, by themselves, may be impacting these antecedents in various ways depending on their implementation. Therefore, it is pertinent to discuss the same to be able to better understand their interplay with the supply chain collaboration and its antecedents.

Hald and Mouritsen (2013) have applied Adler and Borys (1996) to explore the facilitating and constraining effects of enterprise resource planning systems in operations management. On the similar lines, it is pertinent to study both the sides of application of BCT in enhancing or constraining the collaborative practices. While the facilitating and constraining effects may both go in parallel, it might not be easy to perceive the same as the constraining effects may be located deep within the complex organizational structures that are the characteristics of the contemporary supply chains (De Leeuw et al., 2013). The extant literature generally mentions the facilitating or enabling effects, as Blockchain technologies are expected to support

Table 1 Interplay of BCT and the SCC antecedents related to process and systems

SCC antecedent (process and systems aspects)	Blockchain technology implementation	
	Opportunities	Challenges
IOS capability	– Use of BCT to cerate a reliable platform where SC partners can exchange the information without the concerns of information leakage etc.	– BCT to be flexible enough to meet the requirements of stakeholders to scale the systems for emerging needs – Implement BCT that offers alignment of the processes across the SC while keeping in mind the individual stakeholder's disposition towards information sharing
Organizational commitment	– Participating members in BC enabled SC networks are more inclined to provide functional commitment and support exchange from various functions and diverse information	– An implementation, not clearly visualized for the longer term, might not generate enough benefits for the managements of the SC partners to continue – The diversity of information and implementation across the SC might defeat the partial commitments
Joint dependence	– BC, as a technology, has potential to enhance relational exchange and relationship specific investment	The perception of dependence and the dilemma of dependence vs the individual interests may be a potential barrier in the implementation of BCT in the core areas

most of the antecedents of SCC and enhance the collaborative activities. However, implementation of BCT can also result in constraining effects when the implementation of BCT results in coercive formalization of its characteristics in the supply chain. The very characteristics, which promote the various antecedents, might abate them depending on how these are implemented and perceived by the SC partners. The key characteristics of BCT i.e., immutability, consensus, and smart contracts may be viewed as either enabling or coercive implementations of the concept of BCT depending on how they interplay with various antecedents of the collaboration.

In its enabling embodiment, the design and implementation of the BC is crafted with usability and an upgrading rationale. Therefore, it promotes the collaborative activities in the supply chain network by leveraging the skills inherent in the SC partners and the joint processes that tie the SC network together. Respective SC participants are seen as sources of skills and intelligence to be supported with the intelligent interventions of BCT in the existing SC network. Therefore, block chain technologies transform and enable the organizational processes in the desirable directions to enhance the collaborative activities and optimize the SC activities at the network level for a enabling a better supply chain performance.

Table 2 Interplay of BCT and the SCC antecedents related to relationship

SCC antecedent (Relationship aspects)	Blockchain technology implementation	
	Opportunities	Challenges
Collaborative culture	– BCT has the potential to align incentives and improve the collectivism and long-term orientation among the participants in the network	– Reduction of power distance and promotion of equity are possible initial barriers to be considered before implementation of BCT enabled SC networks
Trust	– BCT enhances the credibility of SC member about the other members on honoring their commitments – The information sharing among SC partners is enhanced by the characteristics of BCT e.g., the immutability and distributed ledger	– The overarching aspect of transparency might promote information asymmetry by some SC partners to retain the power distance. This might deter some smaller partners from joining the BCT enabled SC networks. – Prior trust between the SC partners might be more important in BCT implementation than the transactional trust created by the BCT
Proximity	– Easier to implement BCT when the SC partners have similar processes, routines and systems leading to a better system for exchange of information and resources	– The similar beliefs of SC partners towards information exchange and transparency might lead to inadequate implementation of BCT despite the capabilities

However, often the processes tend to take precedence over the rationale on which they are built. Accordingly, when the implementation of BCT gets burdened with the rationale of fool-proofing and deskilling the SC participants in the favor of processes; it starts substituting the relationship constructs like collaborative culture, trust etc. with the transactional constructs like smart contracts etc. As a result, the commitment tends to get dominated by procedures, and coerces efforts and compliance from SC participants while viewing them as the source of the issues rather than assets for the implementation. It might constrain the SC participants by inhibiting them from utilizing their potential leading to reduced collaborative advantage.

13 Conclusions

The chapter asserts that supply chain collaboration is likely to be impacted by the advent of the BCT. It might be facilitated and challenged at the same time. The chapter investigates the influence of blockchain technologies on the SCM in the context of the supply chain collaboration between the SC partners. It considers each of the enabling antecedents of SCC and attempts to predict the manner in which collaboration among SC partners might get impacted by introduction of BCT in the SCM. The opportunities of BCT stem from its characteristics of transparency, immutability and shared contracts that can enable improved processes, better functional commitment, and alignment of incentives etc. This can strengthen the collaboration process by enhancing the information exchange and establishing the robust frameworks. Concomitantly, the social aspects like trust, dependence etc. might be impacted in multiple ways depending on the attitude of SC partners, the equations of power distance and the prior trust etc. It is noticed that BC technologies, with their key characteristics of supporting information exchange with shared responsibility, might constrain some of the SC partners due to the barriers of reduced information asymmetry and power distance.

While the chapter uses the SCC framework based on the experience of automotive industry as its theoretical basis of the inquiry; nevertheless, the observations or opinions evolved may be generalized to understand the effect of BCT on collaboration. Such observations suggest that BCT should be perceived to have a diverse impact on SCC and the performance depending on the implementation and the relationship among the SC partners. Specifically, the chapter delves deeper into each of the antecedents of SCC to develop an understanding of its enabling and constraining effects and how these impacts might manifest in the collaborative advantage generated by the SC partners. In doing so, the chapter imparts a different perspective to view SCC in the era of blockchain technologies by the academic and managerial community; and presents further opportunities for a deeper enquiry into the subject of SCC in conjunction with the implementation of blockchain technologies.

14 Managerial Implications and Way Forward

The chapter has attempted to correlate the various blockchain characteristics with the antecedents of SCC and explained the possible interplay between both. Academicians may like to take note of the potential of interplay between the BCT characteristics and the process of SCC, whereas practitioners can benefit from some of the observations that the chapter makes about the constraining effects of BCT. Such observations have the potential to serve as a set of guidelines that might interest supply chain managers in understanding and mitigating the constraining effects of embedding BCT in the SC network. Conversely, supply chain managers seek to enhance the enabling effects of the blockchain, and the awareness of the interplay will promote that intention. Further research in this area might investigate the interplay of BCT with the SCC for various industries, operational characteristics, and levels of maturity of the SC participants.

Further research might focus on formulating and testing various hypotheses to examine the enabling and constraining roles of BCT on the SCC and develop frameworks concatenating the domains of BCT and SCC. Such framework may shed more light on how blockchain technologies impact the “process and system aspects” and the “relationship aspects” of the collaboration, and whether any of these is impacted differently by BCT characteristics thereby providing an insight into their implications for SCM. In general, possibility of further research is foreseen focussing on various characteristics of BCT and their constraining dimensions e.g., the distributed ledger which might realign the power distance among the SC partners in the network or the immutability that may enhance the credibility etc. Additionally, it may be worthwhile to focus on BCT as an enabler of relationship aspects. This might yield important insights into BCT to enable and empower blockchain characteristics to manage softer aspects of SC relationships like trust, culture etc.

Further, it is foreseen that various aspects of collaboration e.g., the process and system aspects, and relationship aspects will need to undergo the evolution to stay relevant in the era of BCSCM e.g., Trust might need to be understood more in terms of transactional trust that is a consequence of the successful implementation of BCT, rather than an abstract and complex factor that appears as a barrier to BCT. Such understanding may be developed only after a careful consideration of the various factors that promote SCC, and how blockchain technologies interact with them. Such evolution will enable the practitioners to implement the BCT in ways that are more amenable to the basic construct of SCC and its antecedents. The SC partners need to appreciate this evolution and make required efforts to extend the opportunities from implementing BCT in the supply chain processes. Such understanding is a resource both for the practitioners and the academia as it enables the successful collaborations in the BCT enabled environment.

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Developing Resilient Supply Chain Networks through Blockchain Technology: Strategies and Implications

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1 Introduction

The advent of disruptive Industry 4.0 technologies is staggeringly changing the business landscape (Mubarik et al., 2021a, b, c; Kusi-sarpong et al., 2022). This is resulting in the development of digital business environments for value co-creation using information and communication technologies (ICT) in supply chains (Deepa et al., 2022). This in contrast to traditional business environments, represents an innovative approach for collaborative organizations across multiple industries to effectively leverage technological and service resources (Senyo et al., 2019) such as collaborations with suppliers and customers. Businesses that are adopting these disruptive technologies are becoming cost effective and resilient. These technologies help transition from uncoordinated silos to integrated operational improvement focused on end-to-end internal processes and external consumer interactions. Nevertheless, the use of technology and operational skills would need to be coordinated and sequential to produce a holistic and compound effect (Novak et al., 2021). Today's business world, in which everything is linked, provides a digital imperative for businesses to facilitate changes through technology, which in turn serve as facilitators for new types of innovation such as supply chain innovation (Dutta et al., 2020).

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In the pursuit of better supply chain integration, efficiency, resilience, various businesses are adopting Industry 4.0 technologies, especially block chain technology (Mubarik et al., 2021a, b, c). Further, given the catastrophic impacts of COVID19 on the supply chains across the globe, now the firm are striving more than ever to adopt industry 4.0 technologies, especially blockchain, to build their supply chain resilience (Alzoubi et al., 2022). Likewise, the COVID-led SC disruptions has aggravated the need of strategies and ways to make supply chains more prepared, responsive, and agile. Further, as organizations are competing based on their supply chain networks, they are trying to transform their supply chains to stay ahead of the game (Hassan & Abbasi, 2021).

Recognizing this, though recent literature has emphasized the critical role of digital technologies in operations and supply chain management, including cloud computing (Gonul Kochan et al., 2018; P. Gupta et al., 2013; Novais et al., 2019), big data analytics (Govindan et al., 2018), and artificial intelligence (Büyüközkan & Göçer, 2018; Kshetri, 2018; Queiroz & Fosso Wamba, 2019) while the sufficient empirical evidences are yet to be established especially in the case of high-tech sectors such as electrical, electronics, and ICT. As noted by Khan et al. (2022a, b, c), Mubarik et al. (2021a, b, c) and Kusi-sarpong et al. (2022), there is a dearth of study on as to how the businesses can capitalize on blockchain technologies to uplift its supply chain resilience. The extant literature lumps blockchain as part of Industry4.0 technologies and does not focus on it explicitly (Chen, 2018; Kshetri, 2018; Chen et al., 2017; Viriyasitavat et al., 2020; Mubarik et al., 2021a, b, c).

Review of the recent literature (e.g., Mubarik et al., 2022a; Khan et al., 2022a, b, c; Azmat et al., 2022; Ali et al., 2021a, b; Qader et al., 2022; Kusi-Sarpong et al., 2022; Piprani et al., 2022) clearly illustrates an instrumental role BC in SCM. This research views blockchain as a technology advancement that has the power to contribute a number of supply chain management objectives, including cost, quality, speed, reliability, and risk mitigation (Kshetri, 2018; Dutta et al., 2020). A blockchain-based digital Supply chain allows information to be shared across the value chain in a secure, reliable, and trusted way (Dmitry et al., 2019). It has established new trends in productivity through the digitization of key business processes and enhancing by intra and inter-enterprise integration (Hines, 2014; Sadouskaya, 2017; Ozdemir et al., 2022). Due to its inherent efficient structure, blockchain-based digital supply chain is replacing traditional operations, and many of the businesses are now working to adopt it (Milani et al., 2016). Studies (e.g., Milani et al., 2016; Chichoni & Webb, 2018; Dmitry et al., 2019) suggests that for competing in the environment of disruptive technologies, businesses need to relook at their supply chain strategy to adopt digital supply network (DSN) driven by blockchain technologies in order to synchronize the physical product's flows, information, talent, and finance (Chichoni & Webb, 2018). BCSCM is more connected, intelligent, scalable, and swift than old-style supply chain management (Heiskanen, 2017; Dujak & Sajter, 2019; Kusi-sarpong et al., 2022). BCSCM network enables organizations, customers, suppliers, and other stakeholders to connect in real-time environments through the extended enterprise. Such networks develop a new level of collaborations, link more directly with customers, and grasp new markets rapidly and build and scale new offerings quickly. The best supply chains of today use state-of-the-art information and technologically enhanced communication systems such as PDAs, GPS, scanners, and tagging methods as RFID and barcodes (Kusi-sarpong et al., 2022). Digital technologies are progressively ousting paper-based supply chain reports. Businesses need to project and forecast variations in their customers' demand in order to cater to them effectively. In such a situation, transparency, extended collaboration with suppliers and customers are essential for meeting the demand fluctuations (Pirvulescu & Enevoldsen, 2019) and such projections and forecasting can be managed effectively through blockchain based technology.

In short, owing to the innate complexities and sluggishness of traditional supply chains and due to the agility, security, and effectiveness of BCSCM, the majority of the firms are either in the process of digitalizing their supply chain operation or have already adopted it. Further, firms are increasingly adopting technological developments like predictive analytics and robotics, which make them more resilient to have better movement of products and keep inventory inflow in warehouses and distributions centres (DCs) (Chichoni & Webb, 2018; Dujak & Sajter, 2019). Even though there are profound ways for accomplishing competitive advantage based on advanced supply chains. Against the above discussion, the basic premise of the present study is that that blockchain technology based supply chain (BCSCM) can play a significant role in uplifting the supply chain resilience of a firm. It helps firms to collect real time data and improves its end-to-end SC visibility, allowing the firm to access a vast volume of data for effective decision–making. (Queiroz & Fosso Wamba, 2019; Kusi-sarpong et al., 2022). Number of scholars argue that transition toward BCSCM is slower because of the absence of comprehensive framework, backed by scientific research, illustrating as to what can be the impact of BCSCM on the various aspects of SCM like SC resilience, agility, and performance (Büyüközkan & Göçer, 2018; Mubarik and Naghavi 2019; Mahmood & Mubarik, 2020; Mubarik et al., 2021a, b, c; Ahmed et al., 2021).

Further, organizations face many issues in the digitalization of their supply chain processes due to various strategies void as well. Such as strategies to improve the visibility, supplier sourcing and integration amongst multiple layers of suppliers and customers. These issues can be catered with the help of supply chain mapping and multi-tier channel integration strategies (Rasiah et al., 2017; Mubarik and Naghavi 2019; Mubarik et al., 2021a, b, c).

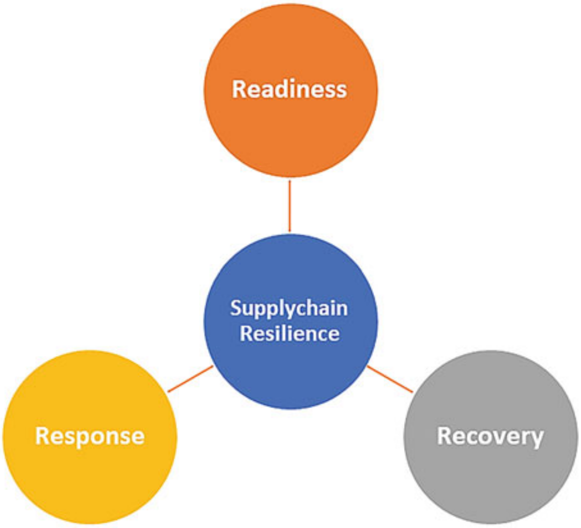
2 Supply Chain Resilience

In the physics term resilience is often considered as the ability of an object to return to its original states after deformation state. In the ecological studies it is referred to as the ability of the living systems to bounce back after some disturbance (e.g., Holling, 1973), Psychological and sociological research refer resilience as the ability to respond any extraordinary situations and bounce back after certain setbacks. In the business management literature the term resilience is considered as the capability of an organization to compete any known and unknown disruptions and to return to its original position afterward (Sheffi & Rice, 2005; Ponomorov and Holcomb 2009; Tukamuhabwa et al., 2015; Khan et al., 2022). Within the business domain, supply chain resilience has resumed an apex role. Given the turbulent business environment and lack of comprehensive risk management approaches, firms heavily rely upon their SC resilience (Ali et al., 2021a, b; Wieland & Durach, 2021). Further due to the multi-tier their multi-tiered nature, supply chains are becoming increasingly complex and intertwined. This complex nature of supply chain requires more resilient and flexible response, which can only be achieved by making the supply chains resilient (Ozdemir et al., 2022). This is the very reason that majority of the firms recognize the importance of SC resilience to combat volatile business environment and other unknown disruptions (Ponomorov and Holcomb 2009; Kusi-sarpong et al., 2021; Wieland & Durach, 2021). Further, a focal firm in the supply chain heavily relies upon its upstream and downstream partners (Mahmood & Mubarik, 2020; Mubarik & Bontis, 2022). Dealing with the organizations which are not in direct control of the focal firm can pose any disruption or risk, which can only be responded when the organization has a resilient supply chain. Likewise, the limited capacity of conventional risk management practices also require organization to foster resilient firm's supply chain operations (Revilla & Saenz, 2017; Piprani et al., 2022).

Before explaining as to why SC resilience is important for the firm it is essential to have a detailed review of its definitions and operationalization. Scholars like Barroso et al. (2011), Mubarik et al. (2020) define SCR as the ability of a supply chain to keep it operational under an extremely disruptive environment. It is an inevitable ability of a firm to cope with a disruptive situation and bounce back efficiently. That is directly connected to the SC disturbance, "a consequential situation that significantly threatens the normal course of operations of the affected supply chain entities" (Barroso et al., 2011). Adding to this Gunasekaran et al. (2015) and Singh et al. (2019) defines SCR as the adaptability and flexibility of a firm to adjust to the new environment. They are also of the view that a firm's operational flexibility is defined through its SC resilience (Singh et al., 2019). In other way, SCR is defined as the capability of a firm to recover from disturbance quickly in accordance with the adversities or disturbances (Singh et al., 2019; Khan et al., 2022a, b, c).

Various definitions of Supply chain resilience evolved from early research, however researchers. For example some of the authors (e.g., Fiksel, 2006; Tukamuhabwa et al., 2015; Ivanov & Dolgui, 2020; Ozdemir et al., 2022) define resilience as the capability of an organization to survive in the disruptive conditions, adapt the capacity for an enterprise to survive, adjust, and grow in the face of disruptions. They denote that building SCR requires a systematic approach. Likewise, few of the researchers have also defined SCR as "the measure of the persistence of systems and of the ability to absorb change and disturbance and still maintain the same relationships between state variables". In a nutshell, the ability of a supply chain to prepare for, respond to and bounce back after any unforeseen disruption is SC resilience shown in Fig. 1.

Fig. 1 Dimensions of supply chain resilience



2.1 Dimensions of SCR

2.1.1 Readiness

It refers to as the ability of a supply chain to pre-empt any unforeseen situation and prepare accordingly (Mubarik et al., 2021a, b, c). Even if the firm is not able to pre-empt any future disruption yet "Readiness" demands a concrete back-up contingency plan to respond to any unforeseen situation (Ozdemir et al., 2022; Pettit et al., 2019). A supply chains with greater degree of readiness have the adaptability and flexibility of arranging elective systems to diminish vulnerabilities (Pettit et al., 2013; Ponomarov & Holcomb, 2009; Ivanov & Dolgui, 2020). Studies on SC resilience highlight various pre-emptive abilities like flexibility, collaboration, redundancy, market strength, visibility, financial strength, diversity along with efficiency to determine resilience (Fiksel, 2003; Pettit et al., 2013; Ivanov & Dolgui, 2020). Chowdhury and Quaddus (2016) define the pre-emptive flexibility ability of a system as the capability to perceive, to expect and to protect against the changing state of risk before unfriendly consequences happen. In the comparative vein, a supply chain network needs to forecast, identify, assess, monitor the risk, and sense early warning signals to prepare for alleviating disruptions (Pettit et al., 2013; Wieland & Durach, 2021). Likewise, preparations and precaution can be taken ahead of time to recover from upcoming disaster if disaster has been predicted through forecasting (Sheffi & Rice, 2005; Spieske & Birkel, 2021). In advance prediction of disruptions is very effective for firms to identify risk in a timely manner. Such kind of initiative of risk identification in advance helps firms to know about the root cause of risk or disruption (Ali et al., 2021a, b).

Thus, one can avoid potential risk against the disruption by taking precaution. Essentially, "pre-emptive approaches", for example, early warning cautionary signal assessment is significant as ahead of time information can be acquired about the probability of disturbances (Pettit et al., 2013; Khan et al., 2022). Firms need pre-emptive abilities to defeat vulnerabilities in business conditions. Such abilities can likewise be appropriate for supply chain readiness in face of disturbance. Therefore, Supply chain readiness is vital to face and overcome disruptive events and to foster the resilience capability. In accordance with the extant literature as talked about above, sub dimensions of readiness are chosen as: disaster preparedness, flexibility/adaptability, visibility, redundancy or backup capacity and Collaboration.

2.1.2 Responsiveness

It represents the ability of a firm to combat SC disruptions. It reflects the strength of a supply chain to compete any unforeseen situation. As noted by Mubarik et al. (2021a, b, c) the real test of SC resilience is at the time when it is facing disruptions. Majority of the firms could not survive to the disruption due to the poor responses. Choi et al. (2020) explaining the situation mentioned that during COVID the response of the majority of the firms were subtle and unorganized. This was the very reason that number o firm were not able to keep their supply chain afloat (Khan et al. 2022; Kusi-Sarpong et al., 2021). A late response towards disastrous situation may cost unprecedented losses to organizations. For instance, a late reaction during fire in the Ericsson's supplier plant accounted for loss of $400 million. On other hand, a fast reaction from Nokia after the event of fire in same supplier's plant assisted Nokia to face and overcome the disruptive event and emerging from chip supply shortage to acquire competitive advantage in market (Novak et al., 2021). The capability to "response and recovery" is necessary for creating SCRE. Various researcher (e.g., Wang et al., 2010; Shen & Sun, 2021) consider ability of a firm to respond to any unforeseen situation as the major constituent of SCR. In a nutshell the ability to face the disruptions and keep supply chain operations intact during disruptions reflect an organization's SC responsiveness.

2.1.3 Recovery

Recovery represents the post-disruption ability of a firm to return to its original performance or operational level (Wieland & Durach, 2021). The organization that recovers and bounce back quickly after facing disruptions can outclass their competitors (Novak et al., 2021). As in literature, resilience is for the most part estimated as far as recovery time (Khan et al. 2022). Added that cost as a boundary to quantify resilience. Hence, resilience can be evaluated by the degree of recovery time, cost, ingestion of disturbance and capacity to lessen the effect of misfortune which centres around the post interruption ability of a system. Following Figure 2.2 summarized the dimensions of supply chain resilience.

3 Block Chain Driven Supply Chain Management

Before explaining the role of blockchain in supply chain management, it is essential to briefly provide an overview of blockchain per se and its various capabilities. Having explain supply chain management in details, now a brief discussion on the block chain driven supply chain management has been undertaken in the following lines. It is obvious from its name that BCSCM is infusion of block chain technology in the supply chain processes or adoption of blockchain technology to execute the supply chain activities (Dutta et al., 2020). In this context, to accomplish customer's satisfaction and to enhance firm's performance, use of digital technology such as internet of things, physical use of robotics, big data analytics, censoring all processes and connection of all aspects in Supply chain processes of firm is increasingly becoming part of present-day supply chains (Alicke et al., 2016; Mubarik et al., 2021a, b, c). Along with digital technologies, the blockchain technologies are revolutionizing the way businesses are being performed. So blockchain technologies, together with digital technologies, have laid the foundations of the blockchain-based digital supply chain (BCSCM), which can increase the supply chain performance by manifold and can improve overall business performance (Leong et al., 2018). The proceeding section is dedicated to explaining the artifacts of BCSCM and the way it works.

3.1 Blockchain Technology in Supply Chain

A blockchain, at its core, is a distinctive kind of information system that keeps up and records information in a manner and enables countless stakeholders to confidentially share and access to similar information and data (Dutta et al., 2020; Kusi-Sarpong et al., 2022). The latest transactions are added in a chronological way to increase the chains of data (Kewell et al., 2017; Dasaklis et al., 2022). The information entered in the blockchain can nor be changed nor erased. Besides, it works both as a safe/secure and integrated route just as a network and data set or data base as its capabilities are based on characterized rules programmed and customized mathematically and enforced them automatically through sophisticated technology (Nakasumi, 2017; Dutta et al., 2020). Since the blockchain encompasses numerous dimensions, including operational, technological, and legal, researchers and technologists are not agreed upon any one definition of blockchain (Kewell et al., 2017; Kusi-Sarpong et al., 2022; Dasaklis et al., 2022). Blockchain technology may be thought of as a hybrid database/enterprise system that records all types of transactions that can be used and shared concurrently across a large and decentralized network and can be accessed effectively by authorized stakeholders (Alzahrani & Bulusu, 2018). Additionally, it is described as an incorruptible digital ledger that is applicable to almost anything, including tangible and intangible items and processes (Archa et al., 2018; Dutta et al., 2020). All supply chain processes including inventory system for recording, tracking, monitoring, and transacting of all assets can be managed with greater efficiency by blockchain based supply chain

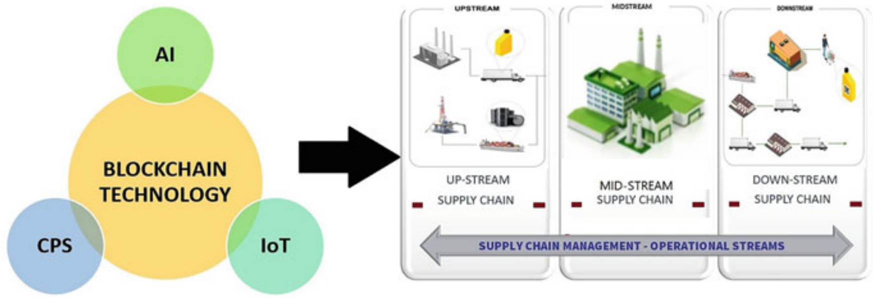


Fig. 2 Blockchain technology in supply chain

networks (Chen et al., 2017; Swan, 2018). Regarding the data in the blockchain, there is consensus in the chain about the transactions because all entities on the chain have the same version of the distributed digital ledger (Kano & Nakajima, 2018; Pimenta et al., 2022). The ledger records transactions in a series of blocks, and it exists in the form of multiple copies disseminated over the numerous computers, typically called the nodes (Li et al., 2018). In the blockchain operations, transactions are generated in a peer-to-peer network in a discrete way (Chen, 2018). Its features enable the ability of the advancement of distribution and permanency of information globally available, which is a paradigm that is drawing the attention of various industries (Sadouskaya, 2017; Wamba & Queiroz, 2022) such as Oil & Gas and Diamonds industries. Being an internet-based technology, blockchain valued for having the ability to record, validate, and process distributed transactions in unchallengeable, encrypted ledgers. In Fig. 2 shown impact of blockchain technologies on operational streams (e.g., upstream, midstream & downstream) of supply chain management.

3.2 Block Chain-Based Supply Chain Vs Traditional (Technology) in Supply Chain

Blockchain technology has distinct attributes as compared to the existing ERPs of information systems by comprising the four key characteristics: security, non-localization (decentralization), audibility, and smart execution (Steiner & Baker, 2016; Deepa et al., 2022). Block chain technology initially invented to process digital bitcoin transactions. According to the users of Bitcoin, Block-chain technology is pivotal to enhance the productivity and efficiency in many businesses (Kano & Nakajima, 2018; Deepa et al., 2022). Blockchain technology has the potential to change business productivity positively as the turtle turn. Particularly, block-chain has the potential to increase the efficiency and transparency of supply chains and impacts positively on everything from warehousing to delivery to payment (Hendrick, 2017; Dutta et al., 2020). The complexities of contemporary SCM have increased manifold in the last few decades due to the globalization, digitalization, virtual markets (Casino et al., 2019). In several Cases, supply chains extend and envelop in so many types of businesses that, because of their unprepared processes for this, and shared information isn't constantly from one end to another, leaving gaps of information in the middle of the links that join every business. Due to this, uncertainty and chaotic effect created toward the key items in supply chain network (Treiblmaier, 2018). It is difficult to examine the responsibility or accountability of illegal incidents related to the supply chain network. In view of these complexities and challenges businesses are facing problems like forgery and counterfeiting, unfree/forced labor and poor conditions in manufacturing plants (Malets, 2019). In such situation, blockchain can play an instrumental role in controlling and effectively managing these supply chain complexities (Dobrovnik et al., 2018). Primarily blockchain, as a guarantor of security and transparency, is the right solution to fix supply chains. Even the most straightforward blockchain technology-based application can bring greater benefits to supply chains. Registering the products transfer on digitalized ledger as transactions allow to identify primary data related to supply chain network.

To this day, there have been made several efforts to use blockchain for improving Supply Chain Management. IBM is a pioneer in this sphere; they have endeavored to streamline the leverage of blockchain in the supply chain. The main features of blockchain could be beneficial for application in the supply chain. First public tracking of products from the place of origin to end consumer. Second, it enables the participation of all stakeholders of the supply chain due to the decentralized structure. Third, enhanced security due to the immutability and cryptography of data. Likewise, the blockchain is also providing a platform for digitalization. Blockchain, when combined with digital technologies (e.g., Internet of things, robotics, and Cyber-physical systems) becomes a lethal weapon to transform the efficiency of the business processes. In this context, blockchain-driven digital supply chain management (BCSCM)—the supply chains with the base of blockchain technology, driven by the internet of things, big data, artificial intelligence, and predictive analysis—is the best alternative for overcoming the present-day challenges (Li et al., 2018; Choi & Siqin, 2022).

4 Block Chain Driven Supply Chain and SC Resilience

In a gradually disruptive context, information sharing, and enhanced coordination not only prepares companies to deal with the overwhelming effect of crises but also reduces the impact of disruption significantly. Scholars (such as Mubarik et al., 2016) have established that firms that tend to transform their supply chain processes through advanced digital infrastructure gain access to accurate market information that assists them to devise timely planning and deploy resources in advance with a proactive approach (Martín-de Castro, 2015). This proactive configuration and supply chain resources helps firms to maneuver disruptions and unexpected shocks. In addition, "firms that have transformed their supply chain with digital integrated systems have a common language, codes, and understanding towards the same issues and follow similar rules and norms with partners". In this way, firms perform much faster, precise, and accurately that make them more resilient, – which is, in fact, back or stimulated through improved communications, coordination and integration across supply chain networks (Craighead et al., 2007). Supply Chain Resilience (SCR) is defined as a capability that helps operate a supply chain in a disruptive and turbulent business environment with or without a slight decrease in performance (Tukamuhabwa et al. (2015, p. 8). When disruptions occur, information exchange and increased coordination not only mitigate the disruption's impacts, but also help companies to overcome the crisis's long-term repercussions. According to researchers (e.g., Mubarik et al., 2019), organizations that transform their supply chain processes through appropriate technologies can gain improved access to market information, which enables the organization to make proactive resource allocation decisions (Martín-de-Castro et al., 2011).

Proactively deploying and reconfiguring supply chain resources enables a company to respond to unanticipated shocks and interruptions. Additionally, "firms that have revolutionized their supply chains via the use of integrated digital systems share a common language, protocols, and awareness of comparable challenges, and adhere to similar rules and standards with partners. This enables businesses to enhance communication throughout the supply chain and so execute more quickly and correctly, thereby increasing their resilience (Craighead et al., 2007). SCR is described as a supply chain's capacity to function in the face of major interruptions and disturbances with or without a significant reduction in performance. Tukamuhabwa et al. (2015, p. 8). While recent academic studies have emphasized the critical nature of SCR (e.g., Stone & Rahimifard, 2018; Pettit et al., 2019), the COVID-19 pandemic provided a unique research setting that focused on organisations' capacity to deal with the devastating effects of disruption. Developing SCR implies that businesses can swiftly recover from a disruptive incident, either by returning to normalcy or improving their operational performance even more (Mandal, 2012). Businesses with a flexible and robust supply chain have already demonstrated their capacity to recover from the devastation caused by the COVID-19 epidemic (Choi et al., 2020). A business that benefits from highly collaborative relationships with its key suppliers and customers (i.e., relational capital) while also maintaining a well-integrated business process (i.e., structural capital) may have a more resilient supply chain, allowing it to mitigate the negative impact of a massive disruption such as the COVID-19 pandemic. Regrettably, the academic literature is devoid of any analysis of how supply chain digitalization may aid a firm's SCR, particularly during a moment of major upheaval. From a supply chain viewpoint, greater digitalization of the supply chain translates into improved collaboration and stronger relationships with key suppliers. These partnerships enable a business to enhance its supply chain learning. Additionally, trust between businesses and their suppliers significantly aids companies in acquiring and implementing important insights from consumers and suppliers (Khan et al., 2022a, b, c; Mubarik et al., 2019). Through a trustworthy platform, BCSCM can assist the company in

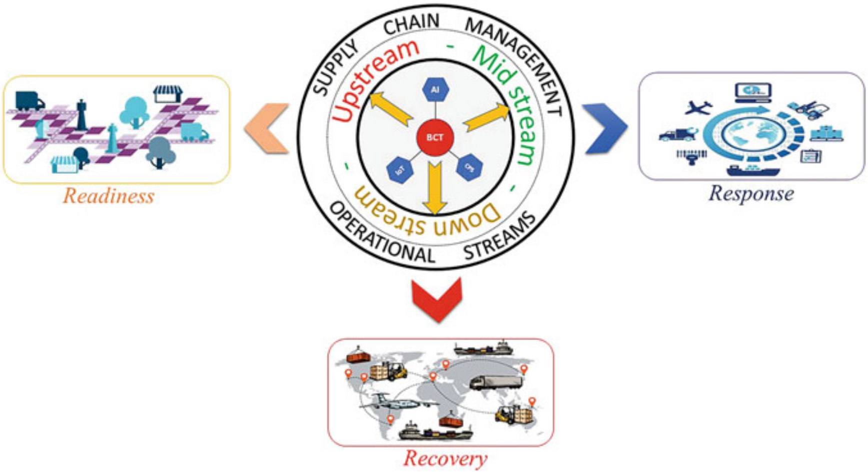


Fig. 3 Blockchain based supply chain management & supply chain resilience

collaborating with consumers and suppliers (Kusi-Sarpong et al., 2022). According to researchers (e.g., Mubarik et al., 2019; Mubarik & Bontis, 2022), companies with defined procedures, routines, systems, and databases are more resilient to disruptions in their SC. Similarly, advanced information systems and databases may significantly improve an organization's agility, analytical capabilities, and responsiveness. Additionally, these aspects of digitalization strengthen the flow of information with external supply chain partners, enabling a business to take pre-emptive actions to mitigate the consequences of interruptions. SCR demands a business to utilize its SC in a way that enables it to adapt effectively to a disruption. In Fig. 2 shown relationship between BCSCM and SCR (Fig. 3).

5 Concluding Remarks

This study offers two major dimensions of managerial implication, drawn from this study. First is related to the role of block chain driven supply chain. According to a recent IBM Institute Expert Insights research (2022), blockchain technology has been identified as a technology that will be deployed in a variety of supply chains to maximize visibility, optimization, and forecasting (Lieber, 2017). Additionally, businesses could leverage blockchain technology to develop effective connections with their partners, increase consumer transparency, and eliminate countless supply chain mistakes.

Inferring from the finding of the study, it is strongly suggested to the firms to develop the strategy to adopt the block chain technologies in their supply chain management processes. Adoption of BCSCM is not straightforward and may require firms to take following important strategic steps. First is the mapping the present position of the firm in term of technologies being used in managing supply chain.

This mapping can help firm introspect and realize its present position in term of technological adoption. If firm's find itself at the lower level in term of technological adopting in SCM, it may not directly plan to adopt the block chain driven supply chain management. Such firms would require to first improve the technological orientation and infrastructure to bring it to the level that it can absorb the BCSCM. It implied that firm must look into uplifting its technological absorptive capacity to adopt block chain based SCM (Mahmood & Mubarik, 2020). Once the firm attains level of technological adaption and a capacity to absorb the block chain based SCM than it can move to the next step. In the case where firms have sufficient level of technological orientation, IT infrastructure and IT absorptive capacity, such firms must immediately plan to adopt BCSCM. These firms can make the process of adoption phase wise where few selected key business processes may be replaced with BCSCM measures in first phase followed by replacement of other processes. The phase wise adoption can help to absorb the adoption easily. Blockchain technology has the potential to resolve issues surrounding the transparency of processes and information (Lieber, 2017).

To develop a cross-company supply chain and collaborative strategy, it is critical to understand your company's existing plans and related strategic objectives, as well as those of your supply chain partners. If a company's supply chain strategy is not connected with its corporate and sustainable objectives, as well as with cross-company supply chain strategies, the supply chain will be unsustainable in the long run. If the supply chain is designed in a manner akin to a "black box," with management unaware of what is occurring throughout their supply chain, it is impossible to effectively apply any improvement plan aimed at achieving long-term sustainability. Understanding your supply chain enables you to connect your company strategy, supply chain strategy, and sustainable plan with your chain partners. With natural catastrophes, industrial fires, CSR concerns, and health and safety failures increasingly affecting global supply chains, mapping the supply chain down to the lowest tier is the only way to minimize a rising risk load. Corporate purchasers' claims of ignorance are no longer acceptable to politicians and consumers in an increasingly connected world where information is instantaneous, and views are everywhere. Block chain-driven supply chain management and supply chain mapping could be important prerequisites for the development of multi-tiered integration. The implementation of BCSCM can help better to collaborate and communicate with the suppliers whereas the comprehensive supply chain mapping can allow to investigate the supplier's processes and best practices.

Acknowledgement This research is funded by Research and Management Centre of University Tun Hussein Onn Malaysia (RMC–UTHM), and FRGS grants vote number K0417 under Ministry of Higher Education, Malaysia (MOHE).

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Relationship and Impact of Block Chain Technology and Supply Chain Management on Inventory Management

Muhammad Irfan Khan, Syed Imran Zaman, and Sharfuddin Ahmed Khan

1 Introduction

Blockchain technology, also known as BCT, is quickly becoming one of the most talked about topics in the world today. Because digitization is so ubiquitous (and most likely necessary) in today's world, we have begun the process of digitizing our assets. The process of converting information into numbers (data) that can be saved, transferred, and analyzed by a computer system is referred to as digitalization. We have started looking at several methods that may help us safeguard all of the resources that this technology will allow us to digitize (turn into data). Therefore, the technology known as blockchain was first designed to protect digital assets (i.e., cryptocurrency). Blockchain technology is viewed with skepticism by businesses owing to the fact that it is innovative and unpredictable. As a consequence of this, businesses may feel that the investments they have made in this technology are laden with a significant amount of risk (Meidute-Kavaliauskiene et al., 2021).

Businesses have the potential to boost customer satisfaction and, as a result, customer loyalty by introducing greater openness into their supply chain operations. In addition, more transparency in the supply chain may improve supply chain collaboration by fostering a greater level of confidence between businesses (Mubarik & Naghavi, 2020; Khan et al., 2022a, b, c). The adaptability of a company's supply chain may be an essential component in the achievement of a long-term competitive

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_4

advantage for the company. Blockchain is a technology that can offers significant benefits in all three categories of customer satisfaction, customer loyalty and greater openness. The present chapter is aimed to address the concerns about the blockchain technology in general and particularly in the context of supply chain. There are various studies (e.g., Rasiah et al., 2017; Mahmood & Mubarik, 2020; Mubarik et al., 2021; Ahmed et al., 2021; Khan et al., 2022c; Zaman et al., 2022), which have highlighted the need for advance technology that can help firm to strike balance between its explorative and exploitative activities (Alexopoulos et al., 2019; Khan & Zaman, 2023).

The next sections of the book chapter are organized as, the second section discusses about blockchain management, its importance, elements, functions, types and benefits. The third section discusses about supply chain management, its importance, components, types, benefits and impact on inventory management. The fourth section discusses about blockchain and inventory management, its benefits, role, aspects, benefits, limitations. The fifth section discussed the recent developments, limitations, summary and conclusion.

2 Blockchain Technology

The blockchain is a decentralized, immutable database that makes it possible to record transactions and keep track of assets inside a business network. Both physical and intangible things, such as bank accounts, reputations, and patents, may be considered assets. Examples of material assets include a house, a car, cash, and a plot of land (intellectual property, patents, copyrights, branding). On a blockchain network, nearly anything of value may be recorded and traded, which lowers the risk for everyone and brings down prices (IBM, 2022). Some basic benefits of blockchain management are shown in Fig. 1. Basic blockchain management works as below.

2.1 As each Transaction Occurs, it Is Recorded as a "Block" of Data

These dealings include the exchange of either a tangible (a product) or intangible (a service) asset (intellectual). The data block is capable of storing the information that you specify, such as who, what, when, where, how much, and even the condition, for example the temperature at which a food shipment was kept (IBM, 2022).

2.2 Each Block Is Connected to the Ones before and after it

When an asset moves from one place to another or when ownership is changed, these blocks create a data chain to reflect the movement of the asset. The blocks perform a

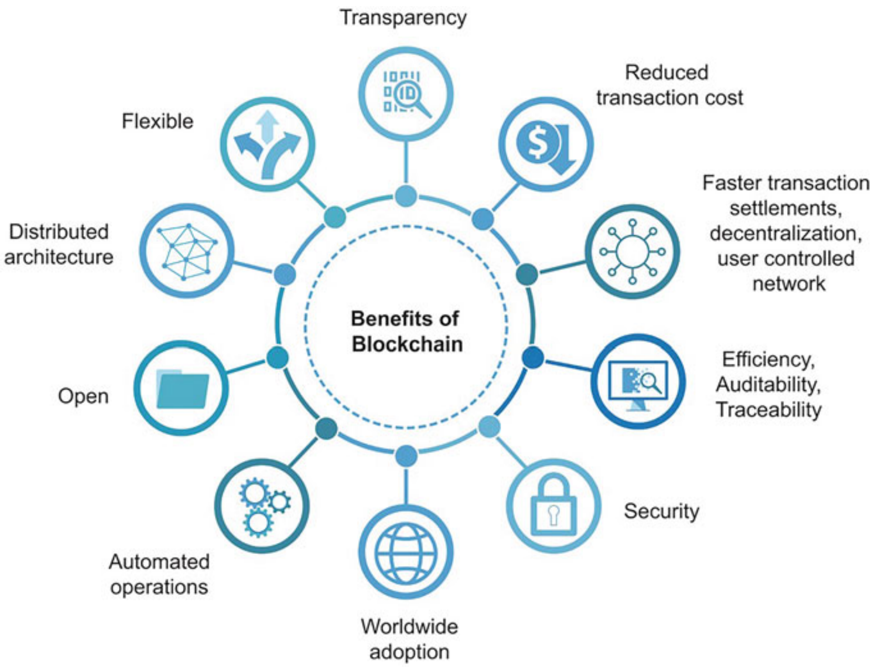

Fig. 1 Benefits of Blockchain management. Source: cloudcredential (2022)

timing and order check on the transactions, and the fact that they are securely connected to one another makes it impossible for any block to be altered or inserted in the space between two already existing blocks.

2.3 Transactions Are Blocked Together in an Irreversible Chain: A Blockchain

The verification of the chain as a whole is strengthened with the completion of each subsequent block, which in turn strengthens the verification of the block that came before it. The blockchain is so rendered tamper-proof, hence delivering the immutability that serves as the fundamental property of this technology. This removes any possibility of manipulation and generates a record of transactions that you and the other people who participate in the network can rely on (IBM, 2022).

2.4 Importance of Blockchain Management

The verification and tracking of multi-step transactions, which are often difficult to do, may be simplified using blockchain technology. It is possible that it will make transactions more secure, reduce costs associated with compliance, and speed up the processing of data transfer. The management of contracts and the verification of goods origins might both benefit from blockchain technology. In addition to that, it may be used for the maintenance of titles and deeds, as well as voting platforms.

2.5 Key Elements of a Blockchain

There are a number of key elements of blockchain as below.

2.5.1 Distributed Ledger Technology

Every member of the network has access to both the distributed ledger as well as the immutable record of transactions it maintains. Because just one copy of each transaction is kept in this shared ledger, the effort duplication that is typical of more traditional business networks is significantly reduced.

2.5.2 Immutable Records

Once a transaction has been entered into the communal ledger, none of the participants are permitted to change it or otherwise interfere with it in any way. In the event that a record of a transaction contains an error, it is necessary to record a new transaction in order to correct it, and both of these transactions must then be accessible.

2.5.3 Smart Contracts

For the purpose of expediting transactions, a predetermined set of guidelines is digitally signed and stored on the blockchain in the form of a "smart contract." A smart contract may specify the requirements for the transfer of corporate bonds, the conditions of payment for travel insurance, and a great deal more.

2.6 Types of Blockchain

There are four different sorts of structures that may be used for blockchains, and they are as follows (Fig. 2):

2.6.1 Public Blockchain

Public blockchains are distributed ledgers that do not need any special authorization to use and are open to participation from anybody. A public blockchain provides all nodes with the same opportunities to access the blockchain, create new data blocks, and validate existing data blocks. At this point in time, the majority of bitcoin trade and mining takes place on public blockchains. It's possible that you're already aware with popular public blockchains like as Bitcoin, Ethereum, and Litecoin. Nodes on public blockchains "mine" cryptocurrencies by solving cryptographic equations in order to produce blocks for transactions required by the network. This process is known as "block generation." Miner nodes are rewarded with a token amount of bitcoin for the computational work they do. The miners serve much the same

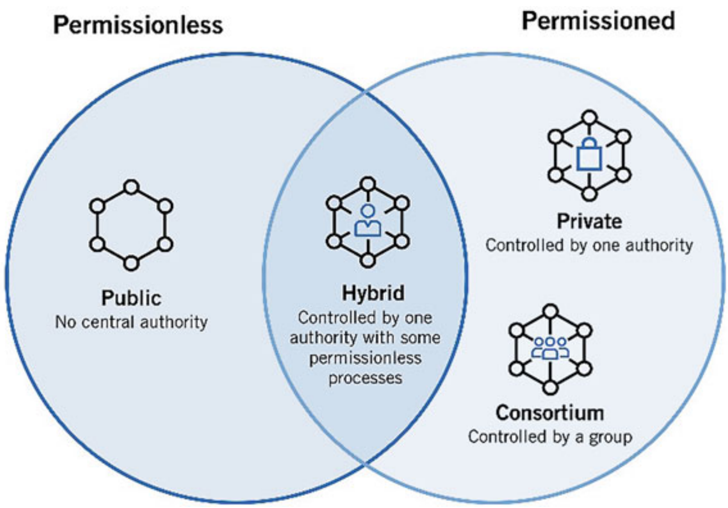

Fig. 2 Different types of blockchain. Source: Nadeem and Shah (2021)

purpose as bank tellers in today's world, since they are responsible for facilitating transactions and "mining" pay for their efforts (Wegrzyn & Wang, 2021).

2.6.2 Private (or Managed) Blockchain

Private blockchains are permissioned blockchains that are maintained and controlled by a single entity. These blockchains are also referred to as managed blockchains. A central authority will decide who may participate as a node in a private blockchain and who cannot. In addition, the permissions to carry out functions that are granted to each node by the central authority are not necessarily on an equal footing. Due to the restricted access that the general public has, private blockchains may only be considered partially decentralized. Both Ripple and Hyper ledger, which is an umbrella project for open-source blockchain applications, are examples of private blockchains. Ripple is a business-to-business virtual currency exchange network. Hyper ledger is an umbrella project (Kusi-Sarpong et al., 2022).

2.6.3 Consortium Blockchain

Consortia blockchains are permissioned blockchains that are controlled by a consortium of companies, in contrast to private blockchains, which are administered by a single firm. Consequently, consortium blockchains are more decentralized than private blockchains, which results in an increased level of security. Consortia formation, on the other hand, might prove to be a challenging endeavor since it requires cooperation between a number of companies, which brings up both logistical challenges and potential antitrust violations (which we will examine in an upcoming article). In addition, some participants in supply chains might not have the necessary hardware and software to implement blockchain technologies. Even those who do might conclude that the upfront costs of digitizing their data and establishing connections to other participants in the supply chain are too high to justify the investment.

2.6.4 Hybrid Blockchain

One kind of blockchain known as hybrid blockchains is run by a single entity, but they are still subject to some level of oversight by the public blockchain. This oversight may take the form of auditing or monitoring. This monitoring is necessary in order to carry out the necessary validations for certain transactions. IBM Food Trust is an example of a hybrid blockchain that was designed with the intention of increasing efficiency across the whole of the food supply chain. This system was created by IBM. One of the topics that will be discussed in further depth in an upcoming post that is a part of this series is the IBM Food Trust (Wegrzyn & Wang, 2021).

2.7 Benefits of Blockchain

Time is often wasted in operations due to duplicate record keeping and validations performed by third parties. Fraud and other forms of cybercrime are easily perpetrated against information management systems. It's possible that a lack of transparency will make it more difficult to verify data. And because of the Internet of Things, the amount of transactions has increased dramatically. Because of all of this, company is slowed down, earnings are reduced, and a new strategy is required. Bring up the topic of blockchain (Hughes et al., 2019).

2.7.1 Greater Trust

Using blockchain will give you the assurance that the data you are receiving is accurate as well as up to date, and that the other members of the network will only have access to your confidential blockchain records if you give them that authorization explicitly. This will give you the peace of mind that you need to feel comfortable using blockchain. Using blockchain will provide you with the assurance that the data you are getting is correct and up to date if you are a member of a network that is only available to members.

2.7.2 Greater Security

Once a transaction has been confirmed, it can never be modified again since it is kept permanently; this is one of the requirements that every member of the network must fulfill in order to achieve a consensus on the authenticity of the data. Nobody, not even the person in charge of managing the system, will ever be able to wipe out a transaction (IBM, 2022).

2.7.3 More Efficiencies

By using a distributed ledger that is shared across all of the users in a network, time-consuming record reconciliations may be eliminated completely. This would result in significant time savings. Additionally, in order to speed transactions, a preset set of instructions, also known as a “smart contract,” may be recorded on the blockchain and then automatically carried out. This practice is known as “smart contracting.”

3 Supply Chain Management

Supply chain management refers to the administration of the transportation of products and services, including the transformation of raw materials into completed commodities. It involves making a concerted effort to streamline the supply-side operations of a firm in order to maximize the value provided to customers and gain a competitive edge in the market (Fernando et al., 2022).

It is essential that two requirements be satisfied for the supply chain of a firm to be successful. First, the supply chain must be cost-effective, and second, it must give results on time. Both of these factors must be satisfied. We began out with an explanation of how management of the bread supply chain works. It is not very complicated. There are many different sophisticated techniques for managing supply chains, and these procedures vary according on the size of the organization, the intricacy of the chain, and the number of goods involved in each step. Therefore, the management of the supply chain begins at the point of origin of the product or service and continues all the way through its distribution and the consumption of it by end users.

3.1 Importance of Supply Chain Management

It is possible for a firm to increase its profits if it is able to reduce its operating costs, which is something that may be done via efficient management of the supply chain. This level of efficiency is observable at each stage of the process, from the very beginning, when the idea is conceived, all the way until the very end, when the product is put on the market (Indeed, 2021).

- The consumer is entitled to the expectation that the product selection that is offered to them will be true, as well as the quantity.
- The consumers have the right to anticipate that the things they purchase will be easily available in the designated area. (That instance, if an auto repair shop does not have the proper components in stock and cannot service your car for an extra day or two, the level of customer satisfaction will decline.)
- Appropriate Delivery Timing - Customers anticipate that items will be delivered at the given time, and they expect that things will be delivered on time (i.e., customer satisfaction diminishes if pizza delivery is 2 h late or Christmas presents are delivered on December 26).
- Support Immediately After the Sale - Customers anticipate getting assistance with their purchases in a timely way when it comes to obtaining support right after the sale. (for instance, if a customer’s home furnace breaks down in the midst of

winter and the issue can't be rectified for a number of days, the customer's level of satisfaction will decline) (CSCMP, 2022).

3.2 Types of Supply Chain Management (SCM) Systems

Supply chain planning systems, also known as SCPs, and supply chain execution systems, also known as SCEs, are the two types of supply chain management systems. The functions that are carried out by the supply chain management systems serve as the criterion for classifying them into one of the two categories (Kukreja, 2022).

3.2.1 Supply Chain Planning Systems

Companies may find here data that is beneficial to them in the process of developing their supply chains, which is provided by these systems, and which can be located here. In the process of creating supply networks, the following are some of the most important jobs that must be filled:

- Developing a plan for acquiring the necessary resources and carrying out manufacturing for the commodities in question, as well as estimating the degree of demand for each item individually
- Formulating an estimate for the overall quantity of the product that will be produced in a certain period of time
- Determining the location where the finished goods will be stored and completing the necessary preparations for their warehousing.
- Determining the mode of transportation that will be used in the process of delivering the products in a manner that is efficient and cost-effective
- Figuring out how much finished product, intermediate product, and raw material to have on hand in the proper proportions
- Determining how much of a certain product or service a firm has to create in order to meet the requirements of all of its customers and ensure their satisfaction (Kukreja, 2022).

3.2.2 Supply Chain Execution Systems

These informational systems provide assistance to firms in the course of carrying out the phases that are engaged in their supply chains by providing data that is of use to those organizations (Azmat et al., 2022; Ali et al., 2021; Qader et al., 2022). When it comes to the execution of supply chain activities, the following is a list of some of the most significant duties that are carried out:

- Managing the flow of things from manufacturers to distributors to retailers and finally to consumers in order to guarantee the accurate delivery of products and ensuring that customers are satisfied with the service.

- Providing information on the current processing status of orders in order to enable vendors to give customers with realistic estimates of when their items will be delivered
- Keeping a record of shipments and giving an accounting of things that have been returned or are planned to be repaired and serviced in the future.

3.3 Drivers of Supply Chain Management

There are a number of components of supply chain management as below.

3.3.1 Planning

This is a very important stage in the process. Before beginning the whole supply chain, it is vital to complete and put into action the strategy that will be used. It is essential to investigate the product or service's demand, as well as its viability, expenses, profitability, and labor, among other factors. It will be quite challenging for the organization to achieve success in the long run if it does not have an appropriate plan or strategy. Therefore, this phase requires a substantial amount of time to be committed to it. It is impossible to go forward until all potential advantages and disadvantages have been weighed and the plans have been completed. Every company needs some kind of plan, whether it's a blueprint, a road map, or a strategy, on which to base its strategic decisions. The ability to recognize demand and supply trends in the market is one of the many contributions that planning makes to the establishment of a successful supply chain management system (iqualifyuk, 2017; Kusi-Sarpong et al., 2022; Piprani et al., 2022; Miao et al., 2022; Mubarik et al., 2022).

3.3.2 Information

The unceasing dissemination of knowledge is the driving force behind today's globe. In order for a company to be successful, it is very necessary for that company to have access to the latest information about every aspect of the product that it manufactures. If the information is given efficiently and in a timely way to all business levels, then the market patterns of supply and demand for a particular product may be grasped most effectively. This may be the case if the information is shared throughout the firm. In a global economy that is dependent on the accumulation of knowledge, information is very important, and ignorance on any aspect of a business may literally spell doom for the company's future (iqualifyuk, 2017).

3.3.3 Source

The suppliers are an essential component of the management systems for the supply chain. When developing goods and services for final consumers, many sets of raw materials are put to use in the production process. As a result, it is very necessary to get raw materials of an acceptable quality at rates within a reasonable price range. If a supplier is unable to meet both the deadline and the established budget for delivery, the company may suffer financial losses and suffer a horrible public image.

3.3.4 Inventory

A well-kept inventory, which is painstakingly maintained, is an essential component of a supply chain management system that achieves a high level of success. A list of the things, raw materials, and other essentials that are required for the manufacturing of a product or service is referred to as an inventory. This list has to be updated on a regular basis so that we can differentiate between the existing inventory and the required inventory. The management of inventories is a crucial part of the supply chain management function. Without it, neither the production nor the sale of the product would be possible, hence inventory management is absolutely necessary for this function. Businesses have started paying a larger amount of attention to this element as a result of the impact it has on the supply chain (iqualifyuk, 2017).

3.3.5 Production

The production stage is one of the most important parts of the whole system. It is only possible if all of the other components of the supply chain are working in tandem with one another. It is essential that proper planning and supply of commodities, in addition to the maintenance of an accurate inventory, be carried out before the production process can get underway. Following the completion of production, products are examined, packaged, and given their last touches before being sent out for delivery.

3.3.6 Location

Any firm that has the desire to continue existing and even thriving will want a location that is profitable for the business. Take, for instance, the construction of a facility to produce carbonated beverages in an area with a restricted availability of water resources. A corporation of this kind has an essential need for water. It is possible that the lack of available water may impede operations and have a detrimental effect on the company's image. A company will not be able to grow if it is required to split a scarce raw resource with the community. Because of this, it is essential for a company's success to choose a location that is beneficial, well-connected, and located in close proximity to the source of important production supplies. When developing a business unit, it is important to consider both the availability of and the demand for human labor (iqualifyuk, 2017).

3.3.7 Transportation

Transportation is very necessary in order to get unprocessed resources to the manufacturing unit and completed goods to the market. It is imperative at each and every level that products be transported in a timely manner in order to keep the flow of the business process uninterrupted. Any business that gives this component the attention and care it deserves will be rewarded with timely production and delivery of its products, which will lead to increased profits.

3.3.8 Return of Goods

A strong supply chain not only includes a mechanism for the return of things that are faulty or do not perform as intended, but it also includes a customer grievance resolution unit that is very responsive. Nobody is without flaws. It's possible for a machine to break down only once, or over a million times. It is possible to plan for the possible return of products under a variety of circumstances as part of a strong business operation. Even the most meticulous quality control procedures might sometimes miss flaws due to unanticipated circumstances. In the case that such violations do place, which are always followed by complaints from customers, a corporation is required to recall the product (or products) in question and provide an apology. This not only helps to cultivate great connections with customers, but it also helps to maintain goodwill over time (iqualifyuk, 2017).

3.4 Benefits of Supply Chain Management

The following are some of the benefits that are made possible by effective supply chain management (SCM) systems, which also contribute to an improvement in the company's overall performance.

- Improve the quality of service provided to customers by delivering to them the relevant products at the suitable time and in the appropriate location. This will eventually lead to a rise in income for the company (Mubarik et al., 2021).
- Provide the companies with the capacity to quicken the process by which they bring their products to market in order to better compete. Because of this, the companies get their payments in a timelier manner compared to their rivals who do not have an efficient supply chain.
- Decrease the entire costs associated with the supply chain, including the costs associated with obtaining materials, the costs associated with shipping, the costs associated with carrying stocks, etc. The reduction in the costs associated with the supply chain has contributed to the expansion of the profitable operations of the firm (Kukreja, 2022).

3.5 Blockchain Technology in Supply Chain Management

Blockchain is more than just electronic data exchange (EDI); it is the backbone of supply chains, giving substantial benefits over the traditional IT infrastructure and analytical capabilities of today's supply networks. BCT is scalable, which means that any number of participants may be added to the blockchain without the integrity of the data being compromised. Since blockchain is independent from both its immediate surroundings and previous systems, it enables speedy installation. Once information has been recorded in a block, it cannot be changed, and the use of distributed storage makes it very difficult to launch a cyberattack. Every person that is a member of the chain has their own complete copy of the data. Participants, on the other hand, have the ability to maintain the confidentiality of firm information provided they precisely define their access rights. (Lierow et al., 2017). Because businesses may digitize physical assets and generate a decentralized unchangeable record of all transactions using blockchain technology, it is feasible to trace assets from the moment of manufacture all the way through delivery or usage by the end user. Blockchain technology may enable end-to-end tracking in the supply chain more transparent and accurate. Both enterprises and consumers gain from the better visibility of the supply chain because to this increased openness (Laaper & Fitzgerald, 2021).

Increased supply chain transparency may be driven by blockchain technology, which may aid in the battle against fraud for high-value products such as diamonds and prescription drugs. The use of blockchain technology could assist businesses in gaining an understanding of the process by which raw materials and finished products are moved from one subcontractor to the next, thereby lowering the risk of profit losses due to counterfeiting and gray market trading and boosting end-user confidence by lowering or eliminating the impact of counterfeit products.

In addition, firms are able to have a better degree of control over contract manufacturing that is outsourced. All of the parties in a supply chain have access to the same information through blockchain, which has the capacity to decrease the amount of errors that occur during data transfer or communication. It is feasible to spend less time checking data and more time offering goods and services, which may result in either an increase in quality or a decrease in cost, or both (Laaper & Fitzgerald, 2021).

Some other benefits of blockchain driven supply chain are:

- Enhance the material supply chain's ability to be monitored in order to ensure compliance with corporate needs.
- Decreased losses caused as a consequence of dealing in counterfeit products or gray markets
- Strive to attain improved visibility and compliance with reference to outsourced contract manufacturing.
- Decrease the quantity of paperwork as well as the costs of administration.
- Additional potential for benefits.
- Improve the company's image by being open and clear about the sort of materials utilized in the creation of items.
- Increase the data's creditability as well as the public's faith in it.
- Take actions to limit the prospective harm to your public relations caused by supply chain malfeasance.
- Engage stakeholders.

3.6 The Impact of Supply Chain Management on Inventory Management

The supply chain would not function properly without proper management of the inventory. It covers a number of different issues, including the management and supervision of purchases made from suppliers and consumers, the control of the amount of product that is available for sale, the maintenance of storage space for stock, and the fulfillment of requests (Waller & Esper, 2014). The management of connections with both customers and suppliers is an essential component of supply chain management. The idea of working together to solve problems has been seen as the essential component of supply chain management in a few different contexts. On the other hand, a more in-depth analysis of supply chain connections, in particular those involving product flows, reveals that inventory movement and storage are at the heart of these interactions. The process of acquiring, transferring, or administering inventories makes up a significant amount of the tasks that are involved in managing relationships. Due to the fact that it is the pivotal node in supply chains, inventory plays an extremely important part in the logistics of supply networks. One of the most fundamental roles that inventory plays in supply networks is ensuring that demand and supply remain in a state of balance with one another. When it comes to effectively managing forward and reverse flows in the supply chain, businesses have to deal with upstream supplier exchanges as well as downstream customer requirements. Because of this, a company is placed in the situation of having to find a way to meet the often unpredictable demands of customers while also ensuring that it has an adequate supply of resources and products. Inventory is often used to accomplish this equilibrium-setting task. For example, the use of sales and operations planning (S&OP) strategies is becoming more popular as a trend. The major goal of S&OP is to match strategic plans between the company's demand management activities (such sales forecasting and marketing) and its operational divisions. This is the core purpose of S&OP (such as manufacturing, supply chain, logistics, and procurement). This often necessitates in-depth discussions on the on-hand inventory, inventory that is in route, and inventory that is currently being processed by the firm (Waller & Esper, 2014). Some of other impacts of supply chain management on inventory management are below.

3.6.1 Decreases Purchasing Cost

Retailers are depending on supply chains to swiftly deliver expensive things so that they may reduce the length of time that they are obliged to maintain expensive inventories in their stores. For instance, in order to cut down on unnecessary inventory expenses, consumer electronics merchants want prompt delivery of 60-inch flat-panel plasma HDTVs (Waller & Esper, 2014).

3.6.2 Decreases Production Cost

It is depending on supply networks whether or not manufacturers are able to reliably move materials to assembly plants. In the absence of these systems, there is a possibility that production may be interrupted due to a scarcity of materials. For example, if a vehicle assembly factory is forced to shut down because of an unforeseen delay in the delivery of components, the consequent lost pay might amount to millions of dollars each day and $20,000 per minute.

3.6.3 Decreases Total Supply Chain Cost

The design of networks that meet the needs of the customer service while incurring the least amount of total cost is the responsibility of the managers of the supply chain. These managers are vital to the success of both manufacturers and retailers. Companies who are able to maintain seamless operations across their supply chains have a greater ability to compete successfully in the market. For instance, the innovative approach to the computer supply chain that Dell utilized involved the production of each computer according to a specific order placed by a client, followed by the shipment of the computer directly to the consumer. This was accomplished by placing the production of each computer directly after the order was placed by the client. Because of this, Dell was able to avoid having substantial stockpiles of computers sitting in warehouses and retail locations, which resulted in a cost savings of several millions of dollars (Prologis, 2022).

Since the focus of this chapter is on inventory management the next section will focus on blockchain integration with inventory management in supply chain.

4 Blockchain Technology and Inventory Management

Participants in a blockchain supply chain may find it easier to enter pertinent information, such as price, date, location, quality, and certification, using the ledger to facilitate more efficient supply chain management. The accessibility of this information within blockchain has the potential to improve the traceability of the material supply chain, reduce losses incurred as a result of counterfeiting and the gray market, enhance visibility and compliance regarding outsourced contract manufacturing, and possibly strengthen an organization's position as a leader in responsible manufacturing (Laaper & Fitzgerald, 2021).

4.1 Role of Blockchain Technology in Different Aspects of Inventory Management

There are a number of roles blockchain technology can play in different aspects of inventory management as below.

4.1.1 Blockchain in Inventory Management

Blockchain technology was not initially developed to assist warehouses in improving and optimizing their inventory management; however, this is something that the technology does very well. By keeping a permanent record of each transaction, blockchain technology makes it possible to link warehousing facilities, factories, suppliers, distribution hubs, production locations, and retail partners. After then, the data are saved and made accessible to everyone who uses the network (Prologis, 2022).

4.1.2 Blockchain in Inventory Costing

When the distributed ledger technology (blockchain) is used for record keeping, various assets, such as units of inventory, orders, loans, and bills of lading, are each given a one-of-a-kind identification that also functions as a digital token. This ensures that each asset can be traced back to its original owner. In addition, participants in the blockchain are each given a one-of-a-kind identity, which is also referred to as a digital signature, that they are required to use in order to authenticate the blocks that they contribute to the distributed ledger. This is done in order to prevent tampering with the data in the distributed ledger. After that, the blockchain makes a record of every single step of the transaction as a transfer of the corresponding token from one party to another participant (Gaur & Gaiha, 2020).

4.1.3 Blockchain in Warehouse Inventory Management

Even in the field of warehouse operations, blockchain technology is still in its infancy; yet one cannot ignore the enormous potential that it has for the industry as a whole. Warehouse operations are one of the most important parts of the supply chain. It has the potential to revolutionize everything, from the administration of inventory to the tracking of transportation to the logistics of relocating objects from one place to another. Because of the use of blockchain technology for the purpose of data authentication, the whole supply chain is able to contribute data and validate that data. Because of this, it is impossible for the data to be changed in any manner (Prologis, 2022).

4.1.4 Blockchain in Inventory Accounting

The necessity to enter accounting information into a large number of databases is eliminated by BCT's use of a technology known as distributed ledgers, which makes this task unnecessary. In addition to this, the necessity that auditors reconcile several ledgers may be eliminated as a result of this change. As a result of this, large amounts of time may be saved, and the possibility of mistakes brought on by people may be considerably reduced (Gaur & Gaiha, 2020).

4.2 How Manufacturers Can Use Blockchain for Inventory Management

When it comes to managing their inventories, most retailers and enterprises have always operated under a reactive paradigm. If manufacturers managed their inventories with the use of blockchain technology, they may see significant reductions in the imbalances and inefficiencies they now face. It is reasonable that blockchain is becoming increasingly popular for use in inventory management given that it enables businesses to link every aspect of the supply chain with a safe, transparent, and permanent ledger of transactions, thereby resolving the greatest challenges that inventory management teams face. According to the findings of some studies, the adoption rate of blockchain technology for inventory management was somewhere about 5% in 2018. It is expected that it will reach 54 percent during the course of the subsequent 5 years. It is easy to understand why blockchain technology is becoming increasingly popular for use in inventory management. Blockchain enables businesses to connect every aspect of their supply chain with a secure,

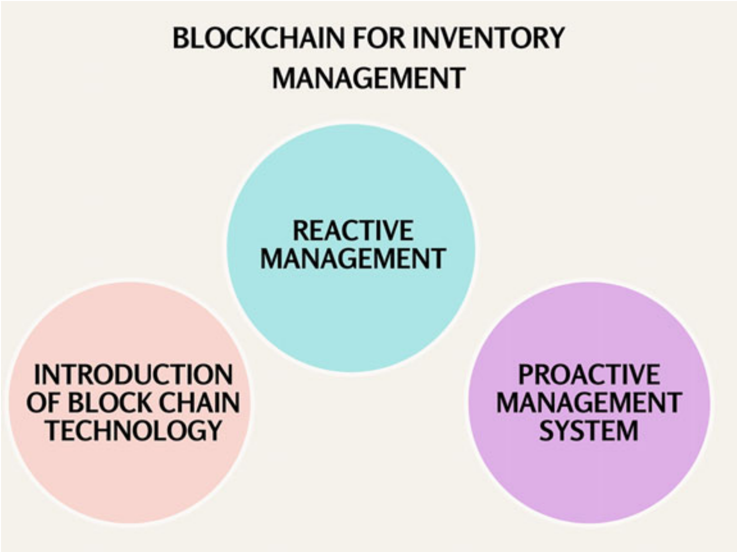

Fig. 3 Different types of blockchain. Source: Allerin (2022)

transparent, and permanent ledger of transactions. This helps inventory management teams overcome the most difficult challenges they face (Joshi, 2019) (Fig. 3).

4.3 Proactive Inventory Management with Blockchain

Using blockchain technology, each player in the supply chain is able to communicate with one another. It helps to improve communication between partners in the supply chain, which in turn cuts down on the amount of errors that are made. The fact that the data can be accessed in real time makes blockchain an invaluable tool for streamlining processes and ensuring that the system always provides correct results. Blockchain is a decentralized ledger that offers complete safety and transparency for all transactions that take place throughout the supply chain. The records of the transactions are saved, and they may be accessed by anybody who uses the network. Once data is recorded, it cannot be changed without the approval of all participants, and every transaction and alteration that takes place on a blockchain can be tracked back to its original source. This helps to decrease fraud committed by employees and gives a mechanism of traceability that saves time in the event that fraud does take place. Businesses are able to more accurately forecast the demand in the market when they use blockchain technology. As a consequence of this, the personnel responsible for inventory management are able to pro-actively prepare for refilling, rather than just reacting to stock-outs (Ishizaka et al., 2022; Joshi, 2019).

4.4 Blockchain Basics for Inventory Management, Logistics and Warehousing

A manufacturer may record and see transactions made at each level of the supply chain if they are using blockchain technology. Because of its decentralized character, distributed ledgers provide companies with access to a single, immutable truth that may be used not only for the settlement of disputes but also for the planning, administration, and operation of logistics and storage facilities. The fact that the Blockchain technology is incredibly secure is another benefit for companies to take use of. Hackers would have a very difficult time targeting encrypted information that is maintained on blockchain because to the immutable and decentralized nature of block chain. Hackers would have a very difficult time targeting blockchain-stored information (Wegrzyn & Wang, 2021).

4.5 Blockchain Benefits for Inventory Logistics and Warehousing Management

Both the absence of visibility across contemporary logistics networks and the continued use of antiquated paper documentation techniques are contributors to the complexity and inefficiency of these systems. Blockchain technology offers a solution to each of these issues.

4.5.1 Lack of Visibility

Because of the complexity of their logistics networks, businesses often have blind spots in their supply chains, which makes it more difficult to locate things at any given time. Because of this lack of visibility, firms sometimes have a difficult time identifying performance issues. The inability of firms to maintain accurate delivery schedules and make efficient use of corporate resources is hampered by the absence of real-time monitoring (Gaur & Gaiha, 2020).

4.5.2 Paper-Based Systems

Paper-based records are the standard for logistics networks; as a consequence, each entity that handles a product is required to manually keep records on that commodity; this might result in duplicate information or information that is in contradiction with other data. In addition to this, dishonest individuals may easily fabricate paper documentation since it is so easy to do so. In conclusion, it's possible that the players in the supply chain may provide and process paper documents more slowly than digital documentation. In the present logistics supply chain, there is a possibility that cargo containers may be held up at the port while authorities wait for the receipt of the paper bill of lading (which functions as the contract of transport, certification of product reception, and title document) (Gaur & Gaiha, 2020).

4.5.3 Blockchain Benefits for Warehousing

The growing need for storage space in general has brought to the forefront some of the challenges that are connected with managing and keeping track of warehouse inventories. Utilizing blockchain technology may assist in alleviating some of the challenges connected with regulating and keeping track of inventory.

4.5.4 Moving beyond Reactive Inventory Management

In most cases, companies manage their warehouses in a very reactive manner, which means that they only buy more inventory when stock levels are low or when predictive models (which might take some time to build) indicate the need to order additional inventory. This means that corporations only buy more inventory when stock levels are low or when predictive models (which might take some time to build).

4.5.5 Minimizing Manual Processes

The bulk of warehouse tasks, such as recording the location of goods, picking inventory, and monitoring inventory, are carried out manually. Smart warehouses may be able to increase their level of automation by adding blockchain technology as firms continue to phase out human processes as a result of the development of advances in warehouse automation (such as inventory-counting drones and picking robots). Stocking, replenishing, selection, and packaging are all more efficient thanks to the usage of blockchain technology, which facilitates digital recordkeeping and the creation of smart contracts (Kukreja, 2022).

4.5.6 Smart Contract Solutions

Computer programs known as “smart contracts” are designed to carry out activities automatically in accordance with a pre-established set of guidelines. The technology that supports blockchain enables the execution of what are known as “smart contracts.” Transactions that take place between participants in a supply chain may become simpler as a result of this function, which also produces a paper record of the transactions that take place. It is possible that participants in the supply chain will get their payments in a timelier manner, which will result in a reduction in administrative costs. The following are some of the ways that businesses engaged in logistics and storage may utilize smart contracts:

- Put in place a program that will make the recording of delivery times and the receipt of items into inventory fully automated.
- Utilize an automated method to process payments for the inventory that was received.
- In the event that a product that is currently held in inventory is likely to go out of date or if the price of a product that is currently held in inventory has reached a “strike price” that was previously decided, the necessary parties should be notified.

- Collaborate with devices that are connected to the Internet of Things in order to send out alerts whenever the conditions of a warehouse or shipping container, such as temperature and humidity, suffer a change.
- Put in place a program that will remove credits automatically in the event that the Service Level Agreement (SLA) and Key Performance Indicator (KPI) metrics are not satisfied.

It is important to automate the process of recording product transfers across members of the supply chain, beginning with the manufacturer and ending with the final consumer. Establishing a link on the blockchain between importers, exporters, and each party's bank may help to automate the execution of commercial transactions between the two parties. Because of this, we will be able to reduce the amount of paperwork and quality control processes that are unnecessary (Kukreja, 2022).

4.5.7 Blockchain for Digital Inventory Logistics and Smart Warehouses

The handling of inventory logistics, which is the management of incoming and departing flows of products, as well as inventory warehousing, both cost businesses a large amount of money. Inventory logistics refers to the management of incoming and exiting flows of items (the receipt, storage, and distribution of goods). Even when business is booming, it may be difficult to maintain a handle on the costs associated with logistics. During times of extensive disruption, the costs may go perilously close to becoming unsustainable, which would be a terrible situation. Only COVID-19 was to blame for the widespread shortages of consumer products and the accompanying hikes in prices (Wegrzyn & Wang, 2021).

5 Recent Developments and Future Outlook

Some recent developments in blockchain are Bitcoin, the first blockchain application, inspired substantial blockchain testing, mainly in the financial services industry. In 2015, Nasdaq and OMX Group Inc. worked with Chain, a blockchain business, to test and assess blockchain technology for share trading on Nasdaq Private Market. Visa Europe, the Commonwealth Bank of Australia, RBS, and a number of UK high street banks have all claimed that they are constructing their own blockchain-based proof-of-concepts (Laaper & Fitzgerald, 2021). Large corporations and startups are examining uses for blockchain outside of the financial services industry as the technology gains prominence. Numerous organizations are currently experimenting with blockchain technology to satisfy a range of objectives. Provenance, a firm focusing on supply chain transparency, has conducted a six-month test for tracking the ethical origin of tuna in Indonesia using blockchain technology. Monegraph, a startup created in 2014, leveraging blockchain technology to guarantee the use and sharing rights of digital media such as video snippets and brand-sponsored content, and to allow revenue sharing among media creators, publishers, and distributors. Skuchain provides blockchain-based B2B trade and supply chain finance solutions for the $18 trillion global trade finance industry, which is composed of various actors, such as buyers, sellers, logistics providers, banks, customs, and third parties (Jiang et al., 2021; Laaper & Fitzgerald, 2021).

5.1 Current Limitations Faced in Inventory Management

The supply-and-demand model serves as the foundation for the present-day inventory management system. When using this method, businesses confront a significant obstacle when attempting to manage the network of their supply chain. The lack of visibility that exists farther down the supply chain makes it difficult to accurately gauge the level of demand from customers. These supply chains include a wide variety of partners, including wholesalers, distributors, and retailers working together. Each of these organizations operates according to its own procedures and frameworks in order to efficiently manage financial transactions and the flow of commodities (Joshi, 2019).

5.2 Concluding Remarks

In this chapter, we have investigated the principles of blockchain technology, as well as its history and how it might be used in supply chain management. We demonstrated how blockchain technology may be connected with supply chain management to provide more efficient inventory management. We address the significance of blockchain technology in supply chain management technologies as well as the advantages it offers in terms of the integration and adaption of inventory and cost. Blockchain technologies have the potential to provide additional answers to issues relating to supply chain management, which will enable a wide variety of applications. The global business will see an improvement in blockchain management for supply chain operations as a result of more research into the domains and applications discussed in this chapter.

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Road and Destiny Are Not Same: Leading to and Leading in Blockchain Driven Supply Chain

Muhammad Mumtaz Khan

1 Introduction

> *"The world outside is too crowded, too fast, and too complex. What I see a moment ago goes into oblivion leaving a space for the new that comes and goes in no time. I will settle a bit and wait for things to come to rest then I would start my learning," said the son to his father. "In that case, don't wait a bit but wait till the end as the change would go on till the end," replied the father, "Your learning, at least, needs to keep pace with the change, or move to the back seat and allow someone else to be your guide."*

The unprecedented pace of change is mesmerizing. Born and raised in the third world country in the last quarter of the twentieth century, I experienced a life whose slow pace was even exasperating for a person like me who did not have the luxuries available to the people of the developed world. I remember to this day, back from school, my mother would give me an electricity bill along with the billed amount to deposit at a nearby bank which was approximately a mile away from my home. For a twelve-year-old boy, this was a big task not in terms of a long and tiring walk but an equally long and tiring wait in the long queue formed by people outside the bank. Today, I see my son, performing the same task from the comfort of his room through a mobile app within a few seconds. It is not just the bill payment that has become digitalized, the transformation is all-encompassing and fast-forwarded by the COVID-19 pandemic (Paul et al., 2022), world has moved from real to predominantly virtual. Today, I am once again exasperated. This time it is not the slow pace of life but the fast pace of change that has taken the world by surprise.

The force behind this leapfrogging is provided by computers and mobile phones connected through the internet. Today, internet connectivity is as vital as electricity

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_5

was in the twentieth century. New generations readily show their disquiet if the internet link is down for a few minutes. With the unabated Omni-connectivity, new business models have emerged where business is managed through platforms operated on the internet. Uber, Airbnb, and M-Turk are some examples of these changes (Kenney & Zysman, 2019). These mentioned changes are not ends in themselves. They are the ones that need a third party to establish a connection between the customer and the service provider. The futuristic technology known as Blockchain envisions a world where consumers and producers will be connected through a seamless joint eliminating the intermediaries.

Change initiated at one point does not remain confined to that epicenter. The ripples caused by change travel in all directions creating possibilities that were not originally visualized. One such corollary of blockchain-driven technology is the ability of employees to loosen the noose around them that had bound them since the beginning of the industrialized economy. Being the sole provider of financial capital, owners and managers had a large sway over their employees (Khan et al., 2021c). Words of managers were commands to be followed by the subordinates. The deviation was undesired and even reprehensive. Employees, well aware of their substitutability, knew saying nay was not an option. So, for almost a century, employees experienced a varied level of disempowerment in which their degree of freedom was determined by their usefulness to the cause of the organization. With the explosion of knowledge, the power of production shifted from financial capital to knowledge capital (Khan et al., 2021a). Employees, the owner of this new capital known as intellectual capital, would be the ones in command (Mládková, 2012). With this change of power, the rules meant to manage and lead employees of the manufacturing economy would have to be replaced.

Another change brought by the supply chain was the change in the process of maintaining trust, the idea that binds multiple interacting parties. Internet without blockchain provided connectivity with questionable trustworthiness (Mubarik et al., 2022; Khan et al., 2022, b, c). The absence of trust compelled the interacting parties to involve intermediaries resulting in an increased cost of using the internet for business. Blockchain through its digitalized ledger addressed the issue of trust. Ease of traceability, verifiability, and accessibility reduce the need for intermediaries thus decreasing the cost of e-business. The overwhelming reason for the adoption of blockchain would be its facile verifiability (Khan et al., 2022a; Azmat et al., 2022; Ali et al., 2021; Qader et al., 2022). The ability of blockchain to drain distrust from working online paves the way for universal adoption of e-commerce. Supply chain sustains on trust, in a traditional supply chain trust comes from the relationship built over time between interacting parties (Mubarik & Naghavi, 2020; Mahmood & Mubarik, 2020; Mubarik et al., 2021; Mubarik & Naghavi, 2020; Ahmed et al., 2021). This traditional supply chain does not allow an individual firm to connect with all customers directly. Its way of working is to involve intermediaries. Wholesalers and retailers are the essential components of the traditional supply chain that cannot be excluded. Blockchain-driven supply chain benefits the supply chain in two ways. First, it allows the traditional supply chain to work transparently. Second, the use of blockchain allows producers and consumers to interact without the support of intermediaries. Technology with the potential to revolutionize the supply chain needs a change in mindset on the part of leadership. Leadership has two tasks at hand. First, leaders are supposed to promote and facilitate the adoption of blockchain by employees. Second, once blockchain becomes a new normal, leaders would be required to do away with their erstwhile leadership style assuming an elated status. With the democratization of knowledge, leaders would have to be transactional in their interaction and serving in their intent.

The main goal of the current chapter is to explain a monolithic form of leadership may not serve us in our pursuit and use of blockchain technology (Rasiah et al., 2017). The journey to implement blockchain technology has its challenges ranging from employees being unwilling and incapable of readily accepting the change. On the contrary, once blockchain has been implemented and the knowledge difference has fizzled out, employees would be in possession of new knowledge and skills enhancing their productive potential along with their clout. Such an eventuality raises the stature of employees and they would expect different treatment thus necessitating a different leadership. In this chapter, we propose the use of transformational leadership for the adoption of blockchain technology. For the world resulting from the adoption of blockchain for the supply chain, we propose that employee-centered servant leadership will be more appropriate (Kusi-Sarpong et al., 2022; Piprani et al., 2022; Mubarik et al., 2022).

The chapter will proceed as follows. It will discuss blockchain and its applications in the supply chain. Next, it will discuss the relevance of leadership in a blockchain-driven supply chain. Finally, it will discuss the role of leadership in a blockchain-driven supply chain.

2 Blockchain: An Overview

Accustomed to working in the physical world when people wanted to develop protocols to design mechanisms to transfer rights and fulfillment of the obligation, they had the process in the physical world as an ideal type. For them, the physical connection provided a base to judge the trustworthiness of the one they were transacting with. In case, trust was high, verbal consent was as good as a written agreement. Otherwise, it was necessary to take steps to ward off the chances of fraudulent behavior. One of the ways to ward off such an occurrence was to seek a guarantee from a third party. To clarify the process, we suppose two parties; one buyer and the other seller are ocean apart. One party located in New York wants to buy a generator from a firm located in Germany. German producer happily wants to deliver the ordered generator to the customer, but it is apprehensive if the customer may not keep its promise. Similarly, the buyer has his reservations as well. What if the product does not turn out to be what the seller has promised? To facilitate them, there is a need to involve a third party. In this case, two parties would be required. One would be the bank which would issue a letter of credit guaranteeing payment when the product is delivered. The second third party would be a buying house that would check the product for the agreed-upon specs before the shipment.

Working in the virtual world would bring the masses to interact with the masses. Such large-scale commerce would soon be paralyzed if third parties were asked to guarantee the transactions. The sheer volume of transactions could not be managed. Additionally, the documentation would also be a mammoth task. The question at hand was how to make virtual transactions as good as the one between two physically interacting individuals. The answer turned out to be blockchain technology. Blockchain was not only able to build trust in the virtual transaction, but it also excluded the need for intermediaries (Xu et al., 2019). All this was possible through the smart contract. A smart contract is an algorithm-based contract that ensures the interacting parties fulfill their obligations when the other party has done its part of the agreement (Singh et al., 2020). Blockchain also provided additional benefits that included safety. The record maintained for the transaction was safer than the one in the physical world as the physical ledger was recorded at one place that could be tempered or got destroyed. The one maintained in the virtual world was recorded at one place, it was stored at multiple locations so any mishap at one place could not erase the record that was recorded at multiple dispersed locations. Additionally, the record initiated by a person would be there with his virtual signature. In case, he tries to change it, it would not be possible as it cannot be changed. Every attempt to bring a change would be recorded as an additional entry thus maintaining a track record of all changes. In case the record has to be reversed. A new entry describing the previous one to be void would have to be passed. The new entry would be there with the virtual signature of the one undertaking such a change that would be visible to all connected to the record. This feature of being known to multiple individuals connect to the blockchain furnishes a new base for validation. In a contract signed between two physically interacting parties, the validation is provided by the legal framework. In the blockchain, even the central authority is circumvented as the validation comes from the multiple individuals connected to the blockchain. Finally, despite being decentralized, the ledger at the back of the blockchain is encrypted so the real information remains known to the interacting parties and not the journal public.

3 Applications of Blockchain

Blockchain, through its smart contract, has the potential to connect transacting parties without any need for intermediaries. Additionally, the safety feature of blockchain makes it a viable and efficient alternative to the existing process of the transaction. Some of the applications are discussed here.

Exclusion of the Fake Items: As the movement of the product is synchronized with the flow of information, a product with no verification on blockchain stands out be clearly pinpointed as an item with an unknown identity. The fake or counterfeit is sometimes an acceptable product category and customers readily accept them. However, fake items sometimes turn out to be extremely dangerous. One such field where fake items may cause considerable trepidation is the pharma industry.

A product with no verification on blockchain identifies to be fake thus it can be easily detected and removed.

E-Governance: Governments both transparent and corrupt have problems with governance. Corruption-infested countries are power-driven. Information is shared with preferred quarters to benefit them. Similarly, services are more accessible to those with clout. On the other hand, the countries which are relatively transparent face the problem of timely response as the bureaucratic system is inherently slow. The use of Blockchain technology has the potential to answer both issues. The decentralized, distributed, and secure mechanism of blockchain enables individuals to access government services and register their complaints. The time-sequenced record and smart contract have the potential to eliminate preferential treatment to the influential ones as the order is determined by time and urgency which would be defined by consensus among citizens thus eliminating any chance to deny or delay services to the public.

Supply Chain Efficiency: A firm while dealing with its supplies of multiple raw materials and processed goods interacts with multiple firms. Sometimes, the number of firms, it needs to deal with goes into the thousands. In such a situation, lack of visibility or expanded lead time causes production headaches for a firm. In this regard, the use of blockchain provides visibility of the product in flow thus enabling firms to manage their production better. If different firms can agree to share their data online, there is a possibility that a firm with an excess of one inventory can divert its excess inventory to the one with the shortage.

4 Is Leadership Still Relevant in the World Run through Blockchain Technology?

Influence is at the core of leadership (Northouse, 2015). In physical interaction influence stems from a person or position or a mix of both. When the world is in a drift from physical to virtual, physical interaction would be minimized and positional power would be captured by algorithms. The idea of minimized physical interaction is easy to understand as the one submitting your tax return would never interact with you physically. The erosion of personal power is not easy to understand. To clarify the point, we move to a bureaucratic organization. In its ideal form, bureaucracy ensures compliance with rules (MacKenzie, 2011). Once requirements have been met, the next step is the logical culmination that cannot be stopped. If through mutual consensus, a smart contract is reached, now, when one party has performed its obligation, the other interacting party would be required to do its part. In such a situation, the need for positional power is greatly minimized.

With the envisioned change ensuing from blockchain, leadership has to undergo a transformation as well. Here, we attempt to explicate the issue of leadership from two angles. The first one is to explore the role of leadership in motivating employees to learn and champion blockchain technology. The second one is how leadership will manifest itself once blockchain technology becomes a dominant way of working in society.

4.1 Leadership for Promoting and Facilitating Blockchain Technology

Living in the world is really puzzling. We strive to give it a structure; however, we end up with something that undermines the existing structure. The comfort of the existing system and the choices offered by the new one may make us ambivalent. On one hand, comfort with the existing system retard our movement toward the new. On the other hand, new choices provided by the emerging alternative entice us. As an individual, we may afford to select the timing of adoption on our own. Least motivated to accept new ways of living, the laggards find themselves compelled by the emerging norms to say goodbye to the old way of living. Unlike the life of an individual, organizations live in an extremely competitive world. The urge and compulsion to survive and grow do not allow them to show any slackness in the adoption of a new technology that can give them a competitive edge over their competitors. In case of delay, the consequences can be catastrophic. Nokia, unable to respond to the challenge presented by the Android operating system, had to unceremoniously relegate its coveted position of the market leader in the mobile phone industry (Lamberg et al., 2021). Organizations, along with being on the lookout for emerging useful technology, have to motivate their employees to expedite the adoption of a technology that they consider to offer a competitive edge. Once an organization has found a technology to benefit it, its adoption by employees is a sine qua non for its future performance. Employees unwilling to adopt the change would retard the process of change, and the ensuing problems would lead to acrimony thus denting the current performance.

Motivating employees to learn and use new technology is a hard idea to sell. Accustomed to old methods of doing, employees do not show a proclivity to do away with their time-tested methods. Faced with such a quandary, leaders cannot enter into a transaction to offer a reward for the change as it has little chance of success. Instead, leaders have to sell the idea emphatically convincing followers that the pain of transition is worth a try. To do such convincing, transformational leadership can do wonders. Before explaining how transformational leadership can be useful for motivating and facilitating employees to embrace blockchain, there is a need to understand transformational leadership itself. Transformational leadership changes the idea of interaction between leader and follower. In transactional leadership, leaders are bound to fulfill their part of the agreement contingent on followers' fulfillment of their part. Such a short-run interaction does not give a reason for employees to grow themselves. Instead, transformational leadership embraces idealized influence to motivate employees (Bass, 1985). Contingent reward creates short-term orientation of employees. They adjust their effort contingent on the previous fulfillment of a transaction. On the contrary, in transformational leadership, employees are given inspirational motivation. For them, it is not a one-time activity that counts because of the attached reward, the real motivation is the long-run goal of learning and growth. To infuse employees with inspirational motivation, leaders are required to be well aware of the goal and challenges in way of that goal. This clarity is only possible when leaders have a complete understanding of the change they propose. In the context of shifting to the blockchain, leaders need to have a thorough understanding of blockchain. Those in lead must also be clear about how followers can be led on the path towards the acceptance and adoption of blockchain. The knowledge base of leaders will work as the idealized influence that will give inspirational motivation to employees. Additionally, the same knowledge base enables leaders to be more convincing in persuading followers to go for blockchain. Of course, once you convince people to follow a path, the convinced individuals may ask you to show them the path to follow. In case, you fail to elaborate on the path and the process, the idealized influence would vanish thus leaving followers unmotivated. So, the knowledge base of leaders will help them not only in establishing their idealized influence, but would also succeed in translating it into inspirational motivation. Won over by transformation leaders, leaders can push followers to question the existing processes they follow. Blockchain provides an alternative that changes the existing supply chain completely. With the elimination of intermediaries, the direct link between producer and consumer is going to be a reality very soon. Such a change would improve the quality of goods, it will also reduce the cost. Finally, transformational leadership is well aware of individual differences. They know how people differ in their skills, attitude, motivation, and contexts. With this realization, transformational leadership shows a proclivity to design a different path for different followers. Transformational leaders can come up with different strategies for different employees. Those lacking in willingness would be encouraged through personal and collective benefits ensuing from the adoption of a blockchain-based supply chain. Those lacking in capabilities would be given training. Finally, those who lack both skills and willingness would be dealt with using a mix of motivation and training.

4.2 Leadership Once Blockchain Is Adopted

The shift of paradigm is nothing new for us. For instance, the industrial revolution of the eighteenth century gave us new capabilities, similarly, it gave us new problems. Catapulted by machine power, employees gathered on the job floor were having new types of problems. They might have eliminated the previously lurching hunger, it landed in the world where boredom and ennui were there to lead them to misery in a different way, yet the end was no different from what had been caused by hunger. Previously it was the pang coming out of an empty stomach, this time, it was the pain coming out of an empty being. Hunger had just changed its shape. From the stomach, it had moved to the inner being. Hunger is just an unmet need. In the case of the inner self, it was even more gnawing and the resulting pain was more excruciating. Soon, it was found that scientific management intended to improve efficiency had limited application. Once physiological needs were satiated, money lost its motivational prowess. The internal void caused by the loss of meaning was resulting in a loss of motivation and a rise in ennui (Khan et al., 2021b). If scientific management could not sustain its luster in the industrialized world, leadership that ensured the successful transition to the adoption of blockchain may not work well once blockchain becomes a new norm. If the industrial revolution was the change in the production system, blockchain technology has revolutionized the way products and services would be exchanged. If the machine had taken the toil out of work, blockchain would drain interaction out of transactions. In the industrial economy, leaders were responsible for motivating employees along with providing vision to the organization. In a blockchain-driven world, algorithm-based rules would leave no room for leaders to play any role. Smart contracts would eliminate any chance of ambiguity; thus, the idea of using a leadership type intended to sort out differences had little chance of success from the onset.

We suggest that there is a need for more employee-centered leadership once Blockchain becomes operational. There are two reasons for being more employee-centered. One of the reasons is from the context and the other is from the blockchain technology itself. The idea of blockchain is born in an era which is known as a knowledge economy. In the knowledge economy, the source of competitive edge is not financial capital as was the case with the manufacturing economy. In the knowledge economy, employees determine the competitive edge of a firm. Organizations possessing top-notch talent maintain their competitive edge by making good use of it. These talented employees come up with new ideas to improve the working of the firm through incremental innovation. Additionally, by indulging in radical innovation, these talented employees come up with new products and services enabling the firms to earn an abnormal profit (Khan et al., 2021a). Despite the possible benefits, there is a flip side to the case of knowledge workers. They do not let themselves be commanded. They love independence. So, if they are treated as managers treat employees of the manufacturing economy, they would balk. Knowing they are in high demand, knowledge workers easily switch to new jobs if they are not pleased. In this context, organizations need to use employee-centered leadership (Khan et al., 2021c).

Along with the dominant position of employees, blockchain itself provides an impetus to bring a change to leadership. Blockchain democratizes information. The resulting information symmetry brings us to perfect competition where nobody can sustain their competitive edge by holding back information. The possibility of arbitrage would wane as the imbalance between demand and supply would not take too long to be restored. Bottlenecks in the supply chain would be known to all interacting parties. These instances are not the exhaustive list of information symmetry promised by blockchain technology. Similarly, employees will also have symmetric information. From HR policies to performance appraisal all would be visible to employees. In such a scenario, the processes would have to ensure fair play. In case, employees find any foul play they will flagrantly show their reaction in no time which may vary from reduced commitment to quitting the job. In light of these changes, we propose leadership in the era of blockchain technology use servant leadership to deal with their followers. Servant leadership is employee-centered leadership that intends to change employees into servant leaders to benefit the overall community (Eva et al., 2019; Khan et al., 2022). Servant leadership is one of the leading contenders for being adopted in a blockchain-driven economy as it caters to individual, organizational and societal objectives. Blockchain enables us seamlessly connect all interacting parties thus establishing a community that transcends the boundary of organizations. Servant leadership had the intent and blockchain gives it the capacity to do so. Servant leadership is employee-centered from its philosophy to practices. For it, service is the source of influence (Greenleaf, 2002). It helps employees grow so they can better serve the firm they work for and the society they live in (Khan et al., 2021b). Giving employees opportunities to learn, staying at the back when help is needed, and showing themselves to be ethical beings (Barbuto & Wheeler, 2006; Sendjaya et al., 2008) help employees learn and grow. The imminent prevalence of blockchain technology would pave the way for servant leadership. Blockchain technology would enable peer-to-peer relations at the mass level. By doing so, employees would know about the changes taking place at the time of their occurrence.

There is another level of leadership that is ecosystem level. As blockchain technology allows firms to each other across the industry, there would be a need to have a collective mindset where instead of following the firm-centered organizational goal, organizations would be required to follow a collective mindset. Such a mindset is the hour of need as the world is moving from a single bottom line to a triple bottom line. The previous single bottom line, focusing just on profit, inculcated a mindset that regarded others as competitors working to win a maximum number of dollars. For the managers, following profit, the dollar gained was the relative measure of success. Driven by the desire to win more dollars, managers treated others in their field to be their rivals and they usually followed strategies causing harm to others. In a world where firms are required to follow the triple bottom line, such a parochial approach may give increased profit to a firm, but incurs a great collective cost. To promote collective thought, servant leadership can be useful. Having community development as its ultimate goal through the growth of employees, servant leadership serves the idea of a triple bottom line.

5 Implications and Concluding Remarks

The world is slowly drifting towards its virtual manifestation. For future generations, the luxury of time may allow them to use their education to enable them to adopt blockchain technology. For those, who are already part of the labor force, this luxury does not exist. Instead of education, there needs to be a quick fix to the prevailing knowledge deficit in blockchain. So, on the job training may be one of the options. Yet, this strategy will work when leaders pushing for the change have an intent, vision, and ability to do so. To achieve this end, leaders need to spearhead the change process. Leaders employing transformational leadership can bring the desired change. Managers working in organizations need to develop a clear idea as to how blockchain can be useful for blockchain. With this clarity, they can sell their ideas to their subordinates. The technical nature of blockchain may necessitate training of employees so their basic understanding of blockchain can be boosted. Of course, training affects the capacity of employees, but not their will. To make them willing to adopt blockchain, transformational leaders using their inspirational motivation can convince employees to adopt the mechanism that is going to be a new normal in the coming days. Of course, the diversity of employees makes it necessary for leaders to adjust their strategy according to the needs of employees. One fit for all strategy will hamper the change process instead of facilitating it. So, in short, leaders with clarity can convincing foster the willingness of followers and enhance their ability towards the adoption of blockchain-driven supply chain.

Once blockchain has been adopted, the ensuing democratization of information brings all to the same level of information. With this information symmetry, old ways of leading where leaders assume a higher status for themselves would not be applicable anymore. Easy accessibility of information provides employees with an opportunity to enhance their knowledge and understanding in no time. Working with employees in such an enabling environment requires leaders to adopt employee-centered leadership. Managers will be better off if they change their mindset from individual to collective wellbeing. With this mindset, managers would promote a collective mindset among their employees. Global concerns for sustainability are better addressed if managers change their mindset and guide their followers in the same direction.

Currently, the field of leadership is completely barren when it comes to the blockchain-driven supply chain. Supply chain itself is risk prone and when technological shift is added to its riskiness, the vulnerability increases manifold. Academicians need to address how the change process can be led. One area of concern is to explore the role of leadership in increasing the readiness of employees towards the adoption of blockchain-driven supply chain. Additionally, academicians can explore the difference between tech-savvy and tech-naïve needs for learning to be ready for blockchain caused changes in supply chain. Finally, researchers can address the issue of leadership mindset in technology driven supply chain. Researchers can address the issue of leadership mindset and style not only at operational level but also at strategic level.

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Role of Leadership for Blockchain-Driven Supply Chain Management

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1 Introduction

Blockchain is believed to be a ground-breaking, revolutionary platform that is expected to alter supply chain operations (Carter & Koh, 2018; Ksherti, 2018). Global supply chain management might be transformed as a result of blockchain. The traditional supply chain typically comprises of suppliers, manufacturers, logistics firms, wholesalers, and retailers that collaborate to deliver goods to the end-users. However, supply networks get increasingly intricate as they grow. Through blockchain technology, supply chain management has become more well-organized because parties can keep track of price and date as well as the location, quality, certification and other relevant data (Korpela et al., 2017). Participants in the supply chain must be of a unified view of the data while still separately and privately confirming transactions, such as manufacturing, shipment, delivery, and sales, in order to handle the problems. A company's supply chain traceability, losses due to fake and grey market goods, and compliance with the outsourced contract might be improved by the availability of this data via blockchain technology (Korpela et al., 2017; Ali et al., 2021; Qader et al., 2022; Kusi-Sarpong et al., 2022; Piprani et al., 2022).

Large companies and start-ups are experimenting with blockchain technology as it has gained popularity outside the finance sector. Many firms are actively using blockchain technology to meet their needs. Provenance, an Indonesian supply chain transparency start-up, has been utilizing blockchain to monitor Indonesian tuna

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_6

procurement for 6 months. The blockchain system pioneered by the 2014 start-up Nakamoto (2008) protects and freely shares digital material, such as video samples or sponsored content. Abeyratne and Monfared (2016) propose that blockchain-based solutions for intercompany trade and supply chain finance benefit all supply chain parties, including buyers, sellers, logistics providers, banks and customs authorities.

The right leadership plays a crucial role since the adoption of blockchain technology would not go swiftly without a change in management that is instigated by the leadership to adapt their strategies in alignment with the changing times. Scholars and business executives do not fully comprehend the precise leadership characteristics that supply chain management practitioners use to propel their organizations to success. To completely identify the findings about the leadership traits that make for the most effective supply chain management, further research is required (Wang & Cruz, 2018). We also draw on the findings from Akhtar et al. (2016) study which proposes that the business management curriculum should include data-driven decision-making techniques in order to produce managers who are prepared to handle future business difficulties. Studying how a leader responds to uncertainty in the workplace and the procedures they would use to reduce risk might be another area of research.

Blockchain driven supply chain management (BCSCM) has the ability to significantly increase a company's value by supply chain transparency, minimizing risks, and enhancing efficiency and management. Using blockchain technology, it is feasible to boost supply chain transparency while simultaneously lowering costs and risk (Dutta et al., 2020; Hackius & Petersen, 2017; Khan et al., 2022a; Azmat et al., 2022; Mubarik et al. (2022). Traditionally, the industry used to be responsible for promoting innovation and technical progress, but that role has completely changed in the modern days. To be successful in today's world, the leader must not only keep track of practices but also direct the subordinates to uplift the organization to maximum potential. The leaders must ensure that technology has not become outdated as a consequence of technology's constant revolution (Queiroz et al., 2019; Mubarik et al., 2022; Khan et al., 2022b, c). In recent years, the concept of "blockchain" has most commonly been reported and discussed in the news, which outnumbered all other terms (except maybe Fake News) (Sternberg et al., 2021). Blockchain is a decentralized, peer-to-peer ledger of value transactions that is changing the way businesses distribute products and services to their consumers. It enables all leaders to have an eye on all transactions, which ensures transparency in transactions and practices. Due to the lack of motivational and empowering role models in the industries of Pakistan, participation is minimal. In other words, there is an unparalleled absence of leadership in our culture. Given all of these drawbacks, this research considers the possible effects of deploying a blockchain infrastructure in any form of organization, particularly in the context of management. Furthermore, blockchain technology appears to be able to address such problems since it offers security, transparency, and decentralization through its distributed and unchangeable ledger (Chartier-Rueg et al., 2017). Employees who are working under competent leadership use resources effectively and efficiently. It boosts employees' productivity, which eventually results in satisfactory management of the supply chain. Employee commitment to acknowledge the change is the most critical factor in any business. Leadership is only effective if the employees desire to accept change and are dedicated to doing so (Herscovitch & Meyer, 2002; Rasiah et al., 2017).

In a nutshell, blockchain technology removes the need for managers as a middleman. Implementing a blockchain database helps construct precise records and verifies accounts in real-time, removes the need for banks, eliminates the need for lawyers, and gives an alternative to accounting firms with self-updating smart contracts (Queiroz et al., 2019; Mubarik & Naghavi, 2020; Mahmood & Mubarik, 2020; Mubarik et al., 2021; Mubarik & Naghavi, 2020; Ahmed et al., 2021). Whether or not you believe in the blockchain revolution, it has negated the fundamental underpinnings on which conventional business methods are built.

This chapter will aid practitioners in understanding how leadership behaviors affect the supply chain. The top management and CEOs ought to be the ones who learn the most from this study. The chapter makes recommendations for the top management's degree of engagement and support in organizational and supply chain operations. CEOs are advised to adopt a leadership style that combines blockchain elements in order to get the most remarkable results.

2 The Ideology of Blockchain-Driven Supply Chain Management

According to the World Economic Forum, increased supply chain transparency potentially contributes to the reduction of fraud in high-value items. It is possible to gain a better understanding of how ingredients and finished goods are routed through subcontractors by utilizing blockchain technology, thereby reducing profit losses from counterfeit and grey market trading and increasing end-user confidence by reducing or eliminating the impact of counterfeit products (Azzi et al., 2019).

As a result of these advancements, businesses may be able to exert greater control over outsourced contract manufacturing. Because all supply chain stakeholders have access to the same data, data and communication flow issues may be eliminated. Spending less time confirming data and more time offering goods and services, either by raising the quality of the products or by lowering the price, or by combining the two strategies at the same time, would boost the business. The participants that have begun experimenting with blockchain technology should be kept under close observation by organizations as the technology gets momentum in the marketplace (Longo et al., 2019). For example, the more people participate in a supply chain, the network effect makes it easier for others to join and reap the benefits of blockchain technology. When developing a blockchain prototype, businesses should consult with other stakeholders in their supply chain, as well as competitors.

3 Leadership Role for Blockchain-Driven Supply Chain Management

Leaders influence how supply chain stakeholders interact with a variety of interdependent, geographically dispersed partners who rely on timely and accurate data transfer to function effectively. Even yet, there are a lot of international organizations without a centralized worldwide monitoring structure (Wamba & Queiroz, 2020). Since, most times, centralized financial institutions or arbitrators are either inaccessible or incompetent, leaders' motivation offers excellent direction for using blockchain technology. Leaders, therefore, view a globally dispersed system that may offer insight as both unique and intriguing.

Despite its potential, blockchain technology is still in its early stages, and users should proceed with caution. Leaders may use these five activities that assist in achieving the BCSCM objectives (Fig. 1).

3.1 Procedural Stipulation

3.1.1 Blockchain Supply Chain Induction

The most basic stage is based on an internal Material Requirements Planning (MRP) system and is driven by the lead-time requirements of blockchain. This category only includes both (one-tier and two-tier) suppliers using blockchain structure. With the exception of status reporting, the vast majority of planned vendor interactions are handled through documentation. Quotes, purchase orders, and information releases

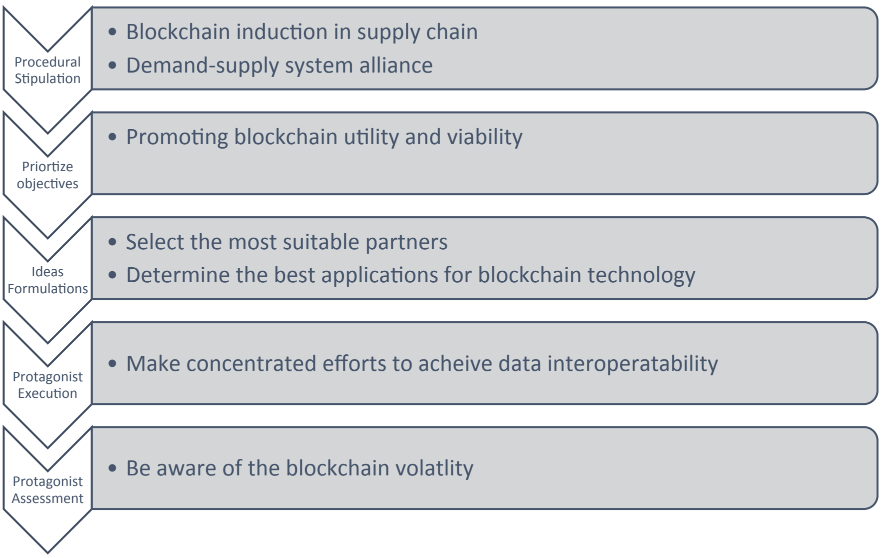

Fig. 1 Blockchain process

are examples of transactional communications (releases). Furthermore, there is an increase in the complexity of interrelationships, as well as a growing interest in status reporting and some data sharing among participants.

3.1.2 Demand Supply System Alliance

The foundations for cooperative interaction and proactive behavior are laid by the free and simultaneous flow of critical information throughout the supply chain. In some circles, it is also known as the glass pipe.

Visionary supply chain leaders will share and coordinate their roadmaps with the rest of the channel at the end of the day. Partners and suppliers will develop complementary independent roadmaps that not only support their partners' initiatives but also create new business dynamics that protect their own. By definition, those who do not participate in the plan and thus do not contribute to the solution of the problem are excluded from the roadmap.

3.2 Prioritize Objectives

3.2.1 Promoting Blockchain Utility and Viability in the Supply Chain

A compelling business case must be developed to encourage blockchain adoption and deployment throughout the supply chain. It might help organizations figure out if blockchain technology is a good fit for the company. In addition to the contemporary technology, a use case must be upgraded that illustrates the consequences [and] suggests behaviors (Treiblmaier, 2018). Keep in mind when assembling a team of collaborators that the implementation's goal is to obtain accurate data, which is the key point of blockchain technology in the supply chain. What works and what does not in blockchain technology should be addressed in the blockchain proof-of-concept (Shen et al., 2022). It is vital to determine whether the process was successful in achieving the efficiency goal. Close attention ought to be paid to the results obtained in the pursuit of transparency if that was the goal.

3.3 Idea Formulations

3.3.1 Select the most Suitable Blockchain Partners

By definition, integrating blockchain technology into the supply chain is a collaborative effort that requires third-party data contributions, validation, and sharing (Yin & Ran, 2021). Finding business partners who are interested in exploring the benefits of collaborating, even if only for a proof-of-concept implementation, is recommended by Leng et al. (2018). There are some tasks that are simply impossible to complete independently. Blockchain, according to Kim and Laskowski (2018), necessitates a large number of diverse and autonomous partners to embrace a novel and unproven technology that currently has limited utility.

Visionary supply chain leaders believe that the true benefits of blockchain grow in direct proportion to the number of participating partners. Because there is no third party to mandate or guide adoption, such as a government or large association, and no startup to drive adoption, adoption and governance are frequently extremely difficult to achieve (van Hoek, 2019). The quality of the data entered determines the dependability of ledger entries.

The absence of effective leadership in blockchain causes supply chain security issues that exist in reality because it is impossible to rely on all potential partners or their data. The integrity of ledger entries is only as good as the data that is entered. If there are a large number of participants, some of whom may be dishonest, and a sufficient level of acceptance of, or disregard for, the data that is passed along, a blockchain may not be of significant benefit to the business.

3.3.2 Determine the Best Applications for Blockchain Technology

If businesses want to get started with blockchain technology in the supply chain, they should start by looking for areas that have all of these characteristics:

(a) Information is exchanged between people from all over the world.
(b) It is impossible to place undue reliance on a single entity due to the lack of a central authority.
(c) There is a well-defined data standard and a simple, consistent electronic data interchange (EDI) process.

Because everyone in the partnership benefits from the value proposition, everyone has an incentive to adopt new technology and processes. Due to its inherent value, an electronic letter of credit, for example, is classified as a digital asset on the blockchain.

3.4 Protagonist Execution

3.4.1 Make Concentrated Efforts to Achieve Data Interoperability

In order to get the most benefits from blockchain technology, it must be tightly integrated into the existing technological environment. The data governance strategy must include parts of blockchain technology. Fluree, a blockchain-based data management platform, is an excellent example.

According to Kumar et al. (2020), blockchain technology should include data management in order to be interoperable with the organization's standard ERP systems.

3.5 Protagonist Assessment

3.5.1 Be Aware of the blockchain's Volatility

Technological changes must be planned for and adapted by businesses.

In contrast to this, although the underlying technology and structure are vital, they are also developing at a breakneck pace. It is likely that the majority of blockchain solutions will go through technological changes before becoming widely adopted.

The blockchain platform market, according to Köhler and Pizzol (2020), is massive but fragmented. Tokenization or universal computing may be more important than confidentiality in some of the current blockchain services being offered. According to Cai et al. (2021), the majority of blockchain offerings, as well as supporting systems and security, are not yet mature enough for large-scale production work. However, these issues will be resolved within the next 3–5 years.

Not to mention, as the blockchain evolves, keep an eye out for changes in governance. A set of governance rules must be in place to avoid coalitions from collapsing in the manner in which so many early blockchains collapsed as a result of hard strikes that divided their stakeholder base.

Cai et al. (2021) suggest assessing your company's digital networks, processes, and transactions, focusing on the intersections between digital readiness and maximum business value. There is no such thing as a one-size-fits-all when it comes to blockchain. One needs to make sure that blockchain technology is a good fit for their application. Blockchain is capable of delivering capabilities that other technologies cannot do for supply chain networks. Before making any decisions, many businesses would be wise to wait and see how blockchain benefits develop and how current implementation challenges result in best practices. The majority of other supply chain technology initiatives are not nearly as complicated as blockchain installations. Blockchain installations remain among the most difficult to complete. It is unsurprising that only a few of these initiatives are gaining traction and broadening their scope.

4 Blockchain-Driven Supply Chain Management in Contemporary Organizations

A blockchain-based network's primary feature is decentralization. It enables individuals (i.e., peers) to communicate directly with one another without the need for an intermediary to coordinate and verify the transactions, who would then charge a fee for their services.

4.1 Distribution

The system and data on the blockchain are very durable in the face of technological failures and malicious assaults since they are usually kept on hundreds of devices that are linked through a distributed network of nodes. In the event that a network node fails, the network's availability and security are not affected since each node has the capacity to replicate and keep a copy of the database (Kshetri, 2021). On the other hand, traditional databases are more vulnerable to technical failures and cyberattacks because they rely on a restricted number of servers.

4.2 Stability

It is almost hard to delete or change data after it has been recorded on the blockchain. As a distributed and public ledger, a blockchain is an excellent choice for storing financial records and other information that needs an audit log since each transaction is monitored and continuously documented on a distributed public ledger (Wu et al., 2021). For example, a company may utilize blockchain technology to prevent its workers from engaging in fraudulent behavior. In this instance, the blockchain may be used to record all financial transactions inside the company in a safe and secure manner. It would be more difficult for employees to conceal illegal transactions.

4.3 Technological Benefits

Traditionally, the vast majority of payment systems rely on an intermediary to complete transactions. Intermediaries include financial institutions, credit card firms, and payment service providers, to mention a few. This is no longer essential with blockchain technology since transactions are confirmed by a distributed network of nodes via a process known as mining, which is done by a central node (Shahid et al., 2020). As a result, blockchain is frequently referred to as a “trustless” system. Therefore, a blockchain system reduces the risk associated with relying on a single corporation while also decreasing total costs and transaction fees by eliminating middlemen and third parties from the transaction process.

4.4 Advanced Transparency

Above all, the purpose of blockchain is to maximize transparency. It will have a significant influence on how businesses adapt over the coming decades, whether via the use of smart contracts to create trust between employees and employers, or through the use of trusted ledgers to ensure accurate data (Perboli et al., 2018). More rigorous data administration will significantly reduce human error, eliminate financial impropriety, and boost customer confidence in huge organizations. As they work to strengthen their connection with their customers, leaders will develop a culture of trust and candor in their team.

4.5 The Next Generation

Regardless of professional experience or industry, it is evident that all leaders must cultivate a culture that attracts the greatest and brightest minds and promotes an atmosphere in which these brains are encouraged to push their businesses to new heights of success and creativity in BCSCM (Moosavi et al., 2021). Despite the fact that the vast majority of those who have succeeded in ‘jumping on the block’ early did so without a formal education, schools are already developing Blockchain and

Bitcoin-specific courses and degrees, teaching the next generation of project managers, entrepreneurs and CEOs.

The BCSCM novel method has the potential to be a potent tool for organizing a company and engaging the staff and customers. The awareness of the blockchain supply chain, like with other digital technology, is the first step towards learning its use and integrating it into the professional portfolio.

5 Blockchain-Driven Supply Chain Management Challenges

Many business leaders are eager to adopt blockchain technology, but they are also concerned about the challenges and risks associated with its implementation and use.

Peer-to-peer ledger systems, such as blockchain, are capable of recording transactions between two parties in an efficient and permanent manner, allowing them to be tracked. An excellent example of how this new technology has the potential to change a wide range of applications is smart contracts, which are just one example of how this new technology has potential to change a wide range of applications.

5.1 Lack of Adoption

The success of blockchain ecosystems is dependent on their ability to gain widespread adoption. If a company wants to implement supply chain tracking and tracing capabilities, both the company and its suppliers must become members of a blockchain network. Despite this, the APQC (American Productivity & Quality Center) reports that just 29% of firms are either piloting or completely using blockchain. Without broad acceptance, blockchains' use and scalability will be severely constrained.

Although this is the case, there are compelling reasons to be optimistic about the adoption of blockchain technology in the coming years. This could be achieved by collaborative efforts across enterprises, as well as the development of blockchain working groups to solve common concerns and discover solutions that benefit everyone while securing sensitive data (Kumar & Iyengar, 2017). Many businesses have formed collaborative blockchain groups in order to solve common problems without disclosing sensitive information about their operations.

It was established by a number of large pharmaceutical companies and is now in its second year, following a partnership with Deloitte prior to the COVID-19 pandemic. The blockchain for the Clinical Supply Chain Industry Working Group is now in its second year. KitChain is a blockchain-based application developed in collaboration with Ledger Domain, a blockchain developer. Additionally, it enables firms to trace the transportation of packaged medications. It not only aids supply chain security but also removes the need for paper records and guarantees the confidentiality of medical trial data, among other advantages.

5.2 Skills Gap

Blockchains encompass complex networks that need fast adoption in order to work properly. A corporation and its suppliers, for example, must both adopt a blockchain network in order to deploy track-to-trace capabilities in supply chains.

5.3 Trust among Users

A significant roadblock to the widespread adoption of the blockchain is a lack of trust among its users. Two sections make up this challenge: Confidence in blockchain technology and the other participants in a network may be a concern for businesses (Yadav et al., 2020).

Every transaction is made more secure and private, thanks to blockchain technology. The fact that the network is decentralized and does not have a single authority to validate and check transactions ensures that this holds true even in the absence of a central authority to approve and verify transactions. It is critical to have consensus algorithms in place on a blockchain network because they ensure that everyone on the network is in agreement on what is happening with the distributed ledger at any given time (Jamil et al., 2019). It ensures that each new block added to the blockchain is the only truth that has been unanimously agreed upon by all nodes in the network, which is called convergence. According to business executives, blockchain networks that do not include anonymous users foster a greater sense of trust.

When peers and competitors work together to solve common problems in order to foster customer trust, TradeLens (a global logistics network founded by Maersk and IBM on the IBM Blockchain Platform) serves as an example of what can happen when customers and competitors work together to solve common problems. In contrast to anonymous public blockchains, private blockchain members, known as "Trust Anchors," have cryptographic identities that are known to the network, as opposed to anonymous public blockchains. To ensure that shipping documentation is unalterable, private, and trackable, TradeLens has developed a permission blockchain that can be used to track and trace shipments.

5.4 Financial Resources

According to respondents to an APQC study, the most significant barrier to the widespread adoption of blockchain technology is the lack of financial resources. It is not expensive to use blockchain technology, and many businesses are experiencing financial difficulties as a result of the pandemic and disruption that will occur in 2020. The outbreak, on the other hand, has demonstrated that corporations, particularly information technology departments, are capable of responding far more quickly than was previously believed possible.

A closer look at this stumbling block reveals that it is the result of a widespread lack of competency and knowledge in the area of blockchain technology throughout the organization. We have found that when individuals become more aware of new technologies, their ability to construct a compelling business case for their adoption increases in lockstep (Zhu & Kouhizadeh, 2019). This will also be true for blockchain technology if proponents focus their efforts on establishing a business case that demonstrates how the technology's benefits surpass the adoption costs.

6 Blockchain-Driven Supply Chain Management Interoperability

As more businesses use blockchain technology, more businesses are developing their own systems with a range of features (governance rules, blockchain technology versions, consensus models, etc.). This network of autonomous blockchains is currently interconnected, and there is no common standard allowing various networks to communicate with one another.

Interoperability across BCSC networks refers to the ability to trade, review, and access data across many blockchain networks without the involvement of a mediator or central authority (Reddy et al., 2021). Without compatibility, widespread adoption is almost definitely unattainable. Interoperability transversely BSCS is critical in a post-pandemic business environment where communication between divisions, as well as with suppliers and consumers, is required. Only in this way will businesses be able to maximize the value of their blockchain investments. Interoperability initiatives have increased substantially over the past year, with the goal of bridging the divide between multiple blockchains. They are all intended to connect with private networks or public blockchains, which explains their widespread use (Madhwal & Panfilov, 2017). In the long run, these solutions are projected to be more beneficial to corporate leaders than prior projects that focused only on public blockchains and cryptocurrency-related technology.

7 Conclusion

The critical component of performing valuable transactions in the organization stands out on trust. Our potential to communicate any form of values or make decisions depends on trust, especially in an uncertain work environment. In this situation, leadership is simply seen as an add-on to virtuous management, which is contrary to the conviction of great leaders who consistently emphasize inspiration and trust as necessary conditions for an organization to work effectively. The key objective of this chapter is to examine the effects of adopting blockchain technology on organizations and, while doing so, to create a thorough assessment of how these effects will be affected by leadership and manage the supply chain. This will be accomplished by outlining the broad scope of blockchain technology and what it means for an organization to utilize it.

Aside from banking and finance, industries such as real estate, supply chain, and healthcare have begun to incorporate blockchain technology into their daily operations, and it appears that it will be around for a long time due to the immediate improvements in transparency and efficiency that it has brought about. While many businesses are waiting to see whether BCSCM will have a long-term influence on their industry, some start-ups are using the technology to gain a competitive advantage.

It will be difficult, though not impossible, to implement blockchain supply chain management because of the numerous issues that are currently being experienced by the leaders. Many of the major challenges faced by blockchain are typical of those faced by any new technology in its early stages. In order to make the business case for adoption, visionary leaders must persuade their organizations to take risks, build relationships, and make tradeoffs that are common in other industries.

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Tractability, the Mantra of Block Chain Technology in the Food Supply Chain

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1 Introduction

The entire value of the global food service was 2323.29 billion USD in the year 2021. The market is predicted to expand at a compound annual growth rate (CAGR) of 10.76%, moving from USD 2540.05 billion in 2022 to USD 5194.60 billion in 2029. However, this industry's natural, unprocessed food segment is losing ground to the processed food sector, which is a sign of consumers' shifting preferences. Despite its success, the processed food sector is challenged by rising consumers' quality and safety concerns, and the failure to adopt stringent monitoring and traceability protocols (Casino et al., 2021).

Recently, many restaurant franchises have been the focus of food safety investigations Food fraud is one of the most common food safety issues. The global food industry is estimated to lose between $10 billion and $15 billion each year owing to food fraud: "the fraudulent, intentional substitution or addition of a substance in a product to increase the apparent value of the product or reduce the cost of its production.". If consumers are unsure about the safety and sourcing of the food they are consuming, they are likely to shop elsewhere, which can profoundly impact a business's bottom line. Food safety, and more specifically food fraud, is linked with tractability which is highlighted in the well-known cases discussed below: horse meat in Europe in 2013, donkey meat in 2017, dead chicken in 2022, and contaminated milk in 2017 in South Asia. The counterfeit vine case of The Chateau Lafite Rothschild, a French wine estate, is presented as a case where consumers faced difficulties in buying genuine and original products.

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_7

At this point, it is necessary to discuss the critical importance of traceability in the food supply chain. It is a considerable challenge to keep food safe at all supply chain links. Unlike other supply networks where product quality remains unchanged during its flow in the supply chain, the quality and the form of the food material are prone to alter between the point of origin and consumption (Ehsan et al., 2022; Zhou et al., 2022). Therefore, it is necessary to trace food products through the supply chain to ensure that problems with quality, origin information, transparency, and tracing are effectively controlled. However, food traceability cannot be made possible without digital and standardized information dissemination. In this context, various studies (e.g., Rasiah et al., 2017; Mahmood & Mubarik, 2020; Mubarik et al., 2021; Mubarik & Naghavi, 2020; Ahmed et al., 2021; Mubarik & Naghavi, 2020) discuss and recommend cutting edge technological adoption.

Traceability in general and food traceability essentially requires accurate and efficient information dissemination in a consistent format to all parties involved in the supply chain (Kusi-Sarpong et al., 2022; Mubarik et al., 2022; Qader et al., 2022; Terzioglu et al., 2022). The information can be transferred through paper-based systems or digitally. Commonly, paper-based systems are utilized in many small and large enterprises due to the high operational and maintenance resource requirement of digital systems (Karippacheril et al., 2017). Nevertheless, paper-based solutions suffer from several drawbacks. The expense involved in the implementation of digital traceability systems obstructs food tracking across the supply chain, especially for small-scale manufacturers (Conti, 2022). Eventually, the costly administration of blockchain technology inflates food prices.

In addition to digitalization, food traceability needs cost-effective systems that can provide accurate, up-to-date, and reliable information in a standardized format to all the stakeholders involved in the food supply chain (Raj et al., 2022). However, standardization at each stage is challenging since the participants involved have unique characteristics (Wognum et al., 2011; Ali et al., 2021; Khan et al., 2022b, c). These stakeholders lead to a myriad of variations presenting unique barriers in establishing traceability systems for processed food. First, the food sector uses a wide variety of natural and synthetic components, necessitating the development of a system that allows for easy, cheap, real-time, and multiple-user authentication at any point in the supply chain (Khan et al., 2022a; Azmat et al., 2022; Piprani et al., 2022; Mubarik et al., 2022. Secondly, the inter batch variations pose a challenge. The existing system heavily relies upon the batch numbers or bar code system, tracing each ingredient from the source to the manufacturer and consumer. However, this system can only store and pass limited data to its users across the supply chain. Further, when several batches with different expiry dates, etc., are simultaneously used, the existing system fails to trace each overlapping batch to share the information in real time with several stakeholders. The difference between the supply chain of processed food and other products is quite significant, yet not highlighted.

2 Why Traceability? Global Cases

To set the backdrop of the research and explain why traceability is essential, five cases from different parts of the world are illustrated below as examples. These cases present typical problems faced by consumers in the global food industry and their stainable solution via blockchain technology.

2.1 Case 1: Horse Meat

The horse meat scandal (2013) rocked the food business in several regions of Europe. The information made its way to public on January 15, 2013, when it was revealed that frozen beef burgers sold at several Irish and British retailers had horse DNA. In some cases, horse meat made up as much as one hundred percent of the food's total meat composition. Some samples even included other unreported meats, like pork. According to the analysis, pig DNA was also found in 23 out of 27 samples of beef burgers. The incident raised a huge uproar as several religious groups worldwide are prohibited from eating pork. The scandal brought to light a significant breach in the traceability of the food supply chain. The possibility of harmful substances being added to food alarmed the authorities, although the presence of undeclared meat was not a huge concern public health standpoint. For example, racehorses may have made their way into the food supply chain while carrying the banned veterinary medication phenylbutazone. Later, the issue expanded to 13 additional European nations, prompting European authorities to decide on an EU-wide approach. Ultimately, this incident confused the consumers if what they were receiving in the name of beef was horse meat, pork or a mixture of all?

2.2 Case 2: Donkey Meat

Faraz Khan published a report in Tribune newspaper in Pakistan on April 27, 2017. The police in Lahore conducted many raids on illegal slaughterhouses. According to the Karachi police, donkey meat was consumed by Lahore residents, and the skins were found in Karachi. Again, the customer suffers due to the lack of a mechanism identifying the source of meat sold at the retail market. As a result, the raw meat industry also lost its credibility in the eyes of the customers.

2.3 Case 3: Dead Chicken

Another case was reported in Business Recorder Newspaper titled "Butcher held for selling dead chicken meat", APP published on tenth April 2022, in Lahore, Pakistan. Based on a tip-off, Officer in Chief MC raided a chicken shop to find 2.5 mounds of dead chicken meat which was later disposed of. Although the crew managed to capture the butcher and file a complaint against the accused, the consumer remained at the losing end.

2.4 Case 4: Contaminated Milk

A report on the issue of adulterated milk in Pakistan came into the press with the headline "Sale of adulterated milk goes on unchecked" by Tahir Hussain on January 12, 2017, in The News. The Punjab Food Authority were afraid that consumption of unclean milk might cause Cancer and Hepatitis C. Only 27 out of 52 samples tested were found suitable for human ingestion, and the rest were found to be contaminated. Unfortunately, Pakistan lacks laboratories equipment necessary to detect chemical contamination in milk and water. Therefore, the only available source of verification of milk quality is the manufacturer's certification. If that is tampered with, the consumer has no independent source to countercheck the manufacturer's claim. Again, the consumer suffers the consequences.

2.5 Case 5: Counterfeit Vine

The Chateau Lafite Rothschild, a French wine estate specializing in Bordeaux wine located in Pauillac in France, is reputed for producing some of the most premium wines in the world. Because of this high price, the business is endangered by counterfeits causing a lost sales and dissatisfied customers. The company reports millions of euros lost sales to the dupes annually. The Chateau Lafite Rothschild has deployed several anti-counterfeiting measures, including the appointment of officers for random audit of the supply chain. It also implemented various technology-based solutions available to trace non-genuine products. These included RFID, bar codes, and blockchain technology. The brand credibility suffers, and the customer is robbed of huge amounts of money for the fake products.

3 Who Suffers?

In all the cases above, the consumer is the final victim. Usually, consumers are unaware of the actual ingredients in the product they are consuming. For example, in the case of the sale of horse meat in Europe, the consumer never would have suspected that beef could contain horse flesh residues. In the case of the donkey meat sale, the consumer could not differentiate beef from donkey meat after the meat was cooked with various spices. Similarly, it was exceedingly impossible to know if the chicken was alive or dead at the time of slaughter, in the case of a dead chicken sale. For milk, also, consumers can hardly ever tell whether fresh milk is contaminated or adulterated. When consumers buy wine labeled Chateau Lafite Rothschild, they cannot check its authenticity, so they consume a knockoff brand under the pretense that it is genuine. The issue is based on a single factor:

traceability. The final consumer cannot trace the entire food supply chain from the source to the table. The dilemma faced by the consumers in tracing the backend supply chain can be resolved through the alternative solutions proposed below. The suitability of blockchain technology over other alternatives, such as manual certifications, barcode systems, RFID, and QR code, are debated in the next section.

4 Issues in Existing Technology Based Solutions

Blockchain-driven developments are arguably the most effective methods of overcoming traceability issue. Nevertheless, few other alternate tools and technologies are also routinely adopted in the food sector to address the traceability problem. The subsequent portion of this chapter presents a balanced argument pros and cons of each alternative followed by discussion on blockchain as the best solution for traceability.

4.1 Bar Code

A barcode is commonly used mode of data assimilation and dispersion. The code is made-up of machine readable, one-dimension visual representation of data through varying width of monochrome bars. A typical machine-generated bar code used at farms is illustrated below (Fig. 1):

In this barcode, the number of the farm is represented by the first four digits, while the remaining digits are all zeros. When an animal is moved to the slaughterhouse, a new bar is created to reflect the location. The second bar code displays the number of the slaughterhouse and the date when the animal is slaughtered. Later, a another bar code with the date is generated when the meat is eventually delivered to the retail outlet or store. After that, meat is prepared for slicing or packaging in a store or outlet. Additional bar code with the date and information about the outlet will be generated here. Consequently, the tag now contains information regarding the farm from which the animal was produced, the identification number of the slaughterhouse, the day the animal was slaughtered, the packing date, and the information regarding the shipment. The code allows adding more data, such as information about the retailer, the warehousing location, the distributor ID, and the delivery date. The device can even track the eventual consumer by recording each transaction in detail at the retailer's checkout. Although the information on the barcode can be updated at each stage, the system is not flexible enough to identify and communicate data to all stakeholders in the supply chain in real-time.

1111-0000-000000-000000-00000

Fig. 1 Bar Code A

4.2 QR Codes

QR code, which stands for "quick response code," is a matrix represented as a two-dimensional, machine readable code. It is a trademark for a square barcode that can be scanned and allows smartphone users to access website directly. In the case of meat, it may trace the information from the farm to the consumer. A QR code is made available throughout the supply chain, and the slaughterhouse is responsible for keeping track of it. Several four-digit codes can be assigned to the company. For example, the farm has the number 9999 assigned to it. The farm's location can be found in the first column. Each slaughterhouse will be assigned a number that is one of a kind, and the remaining columns will be filled with zeros (Table 1).

The animal is then taken to a slaughterhouse, and the image is captured along with the slaughter. A date is appended to the QR code following the slaughter, and the date is added to the image. It guarantees the individual animal as well as the batch tractability. Because the head of the animal is removed after the skin is removed, the label should not be affixed to the horn or the head of the animal. Rather, it should be attached to the portion of the body that remains attached until the animal is sold at a retail store. Following the scanning, just one date will be displayed, while the others will be set to zeros.

After that, the meat is brought to the place where it will be sliced or packed (shop or sales outlet). Here, another QR code that includes the time and location of the outlet will be generated for you. As a direct consequence, the tag now contains information regarding the farm from which the animal was produced, the identification number of the slaughterhouse, the day the animal was slaughtered, the packing date, and the information regarding the shipment. The code allows adding more data, such as information about the merchant, the warehousing location, the distributor ID, and the delivery date. The device can even identify the end user by capturing the specifics of each transaction at the store's checkout counter. However, if the animal's body is cut into several pieces or chopped into minced meat, it is not easy to label and trace each piece. The situation further complicates if meat from several sources comes together in one place and is redistributed to several locations for retail sales.

4.3 Radio Frequency Identification (RFID)

Radiofrequency identification, a form of wireless communication that operates in the radio frequency part of the electromagnetic spectrum, is used in conjunction with electromagnetic or electrostatic qualities to identify an item, animal, or person. An RFID system comprises a reader and a transmitter & receiver-embedded tag or label. The RFID tag is made up of two parts: The an antenna for signal communication and

Table 1 QR Code data

Farm	Slaughterhouse	Slaughter date	Packing date	Outlet
9999	0000	000000	000000	00000

a microchip for information storage and processing. All tags are labelled with unique serial number.

The radio communicator transmits the signal to a tag through an antenna that reads the recorded data. The information saved in the tag's memory bank is returned in the response. After that, the results are relayed from the interrogator (aka reader) to the software that runs on RFID computers. The RFID tags can be passive or battery-operated. Passive RFID tags do not require batteries. Using the radio wave energy that the interrogator emits, the data captured on a passive RFID tag is transmitted back to the tag that originally recorded it. The battery-operated RFID tag contains a little battery that provides power to the information relay.

The RFID tags attached to the animals contain all the information regarding the supply chain: the farm at which the animal was raised, the identification number of the slaughterhouse, the slaughtering date, the packing date, and the information regarding the shipment. The code allows adding more data, such as information about the merchant, the warehousing location, the distributor ID, and the delivery date. The device can even identify the end user by capturing the specifics of each transaction at the store's checkout counter. However, the data cannot be communicated live among all supply chain partners.

4.4 DNA-Based Traceability

DNA (deoxyribonucleic acid) technology makes it possible to recognize every animal's one-of-a-kind DNA code. This code is eternal and remains the same throughout an animal's life, whether alive or dead. It is present in fresh foods and even cooked meat in some cases. Because the consumption of genetically modified food is forbidden following Section 5.10 of the Pakistan Halal Authority (PHA) Act of 2016, it is essential to identify the breed of the animal (GM F). On the other hand, this testing might only be recommended if the regulations of the country that imports the animal necessitate it. Since all locations do not house facilities for animal DNA testing, it pushes up transportation prices and can occasionally cause delays. Due to this reason, the practice is not very common and is only used in exceptional cases.

4.5 Certification

Certifying bodies, verify material quality at the point of input and output during the production stages is a common practice in the industry. Commonly, the self-endorsing statements made by the company on the quality of the material used are supported by several material certifications of the external, independent agencies. The ISO certifications of various codes are among these authorities. For the quality of the materials being used, SGS and Cotecna issue ISO 9001, 9002, etc. are commonly used. Halal certificates are issued by specialized certification organizations such as SANHA and JAKIM. Since each Halal certification body has its own criteria, no single organization exists to verify a universal norm.

Consequently, free trade across Muslim nations is hampered as a product may be certified halal by one authority but not the other. As a solution, groups of countries have formed that trade within the group accepting halal certification from member countries' authorities. The problem becomes more severe when halal-certified products are imported into non-Muslim countries. The issue of universal halal certification will persist until and unless all these agencies agree on a standard. Currently, two limitations of Halal certification are the complexity of international markets and the offshore manufacturing plants, which makes mapping and control more challenging at the logistical level.

These authorities are constrained by the fact that the scope of the audit is frequently restricted to the entity seeking certification. The data and scope of information are also restricted by the supply chain point as specified by the contract's terms. Supply chain are rarely audited end-to-end, from the raw material sellers to the final consumer, as data collection from all often-uninterested stakeholders can be difficult.

4.6 Specialized Certification Bodies (Halal Certifications)

On the flip side of halal certification, some limitations have been found, most of which are tied to the complexity of global marketplaces and the offshoring from multiple manufacturing sites, which makes mapping and controls more difficult. An exceptionally high level of security is provided by blockchain technology in the form of independent verification procedures that take place across all participant computers in a blockchain network. In situations involving digital currency, this verification is used to approve transaction blocks before their inclusion in the chain. This approach could be used in various applications, including identity verification and other verification processes.

5 Blockchain-What and Why

A robust and effective supply chain is essential to the success of numerous companies in various industries. Multiple businesses have already adopted blockchain technology to monitor supply networks and guarantee their effectiveness. This might take human labor and the chance of error out of a complex and essential procedure. Supply chain management scenarios are typically mentioned while discussing traceability in relation to blockchain technology. Traceability is one of the promising benefits blockchain technology brings to supply chain management. It may be worth noting that although we have argued in the previous section that existing technologies fail to give a complete solution to the traceability issue in the food industry, it does not mean that they cannot be used in combination with blockchain technology to provide the best possible result.

Blockchain guarantees greater transparency into the specifics of a product's provenance, and a product's chain of custody from its origin to its place of consumption is implied by its provenance. Additionally, blockchain enhances asset tracking accuracy throughout a supply chain transaction.

The traceability based on blockchain technology is more reliable, transparent, and efficient. The requirement to track information about a product from manufacturing to the point of sale has grown in recent years. It helps the material and information flow more smoothly within the traceability business. Traceability solutions are a natural fit for the food business. Companies involved in the food supply chain must guarantee the safety of their goods. By detecting problems before they affect the final consumer, traceability lowers the risk of foodborne illness, contamination, and spoiling. Unsafe food can damage brands, trigger regulatory action, and even force the liquidation of certain enterprises when it manages to get past the system and end up in consumers' bellies. Traceability enables workers in the food sector to swiftly locate the cause of a problem and fix it before it significantly impacts public health.

For companies in the food industry, tracking and tracing food is essential. It enables them to track the movement of food items and their ingredients backward (first-mile traceability) and forward through all supply chain stages (last-mile traceability). Brands can verify product quality and spot and address problems in real time by linking product production, processing, and distribution at the ingredient level.

The first stage of preparing the product for the client or distribution point is called the "first mile" of traceability. The first mile includes product packing, goods validation, and transportation to the logistics center. Up until the product is placed in the customer's hands, there is last-mile traceability. Almost anyone can design a QR code for any piece of information because they are so widely used. A given QR code is simple to duplicate, and it's simple to swap it out with another one that has different data. It's not difficult to imagine that this attribute of counterfeit ability gives counterfeiters the go-ahead. Due to the complete reproducibility of the tags, counterfeiters may quickly reproduce QR codes from high-quality products and pass them off as genuine.

Fraudsters don't need specialized skills to fake a QR code, and creating any QR code is frequently as simple as using an online tool. Therefore, businesses desiring to guarantee product safety should choose to track products using non-counterfeit technology. This technology combines many sensor types to produce data that is then stored on a blockchain. So what characteristics place blockchain technology over and above all other systems mentioned above? The following section answers this question.

5.1 Blockchain -Optimal Possible Solution

The blockchain acts as an unchangeable ledger that enables decentralized transactions. Applications built on the blockchain have emerged in various industries, including financial services, rating management systems, the Internet of Things (IoT), and many more. Its exceptional characteristics include tractability, immutability, irreversibility, decentralization, persistence, and anonymity. For this chapter, since the above cases concern issues of sourcing material upstream of the food supply chain, the traceability feature of blockchain is highlighted in the next section of the chapter.

The persistently rising food adulteration, leading to significant economic losses and consumers' distrust, has become an urgent problem for food producers, academics, governments, consumers, and other stakeholders. Tracking and authenticating the food supply chain to understand better the food's provenance is necessary to locate and eliminate potential sources of food contamination around the world. Blockchain technology stores data in chronological sequence and provides stakeholders access to data. Consequently, it resolves traceability and transparency concerns. This section explores the possibilities that blockchain technology presents in terms of ensuring authenticity and traceability within the food supply chain context. It can possibly be regarded as the most innovative and appropriate method of collecting and managing data.

blockchain technology provides high level security and uses several independent verification procedures that run on all of the computers participating in a blockchain network. In situations involving digital currencies, the verification is performed to provide the green light to transaction blocks before their inclusion on the chain. This approach can be used in various applications, including identity and other verification processes.

A robust and effective supply chain is essential for the success of numerous companies in numerous industries. Multiple businesses have already adopted blockchain technology to monitor and guarantee supply networks' effectiveness. However, the role of well-trained human labor is required to prevent the chance of error out of a complex and essential procedure. Although blockchain has several unique features, the following section concentrates mainly on the traceability function of blockchain, being the focus of this chapter.

5.2 Traceability in Blockchain

The worldwide agro-food industry has seen growth in blockchain food traceability. Credibility, efficiency, and safety are improved when food products can be instantly traced from their point of origin through all the points of contact on their way to the consumer. Most of the debates on the blockchain technology would center on supply chain management scenarios, but traceability is one of the promising benefits that blockchain technology brings to supply chain management. Better traceability might be possible with the use of smart contracts and blockchain technology when business logic can be programmed. Although blockchain technology pools data from several users at the same time, each user only has limited access to the features.

Blockchain guarantees greater transparency into the specifics of a product's provenance, and a product's chain of custody from its origin to its place of consumption. Additionally, blockchain enhances asset tracking accuracy throughout a supply chain transaction. Blockchain applications in supply chain management can improve efficiency even in the technologically advanced world. In addition to preventing exploitative practices, blockchain can help in providing auditable asset tracking. This secured communication system is necessary between two parties throughout the complete supply chain.

The traceability based on blockchain technology is more reliable, transparent, and efficient as compared to any other method. As a direct consequence, there is now a more important requirement to track the information about a product throughout its entire lifecycle, from manufacture to sale; this requirement assists in the material and information movement within the traceability business. By using IoT-based devices for information gathering and persistence of agro-food products, blockchain technology will improve information security and transparency while also contributing to sustainable traceability management (Galvez et al., 2018). Blockchain technology does not just upgrade the information system from reactive to the current mode but also puts it proactively. This proactive approach is essential in today's fast-moving economy.

Traceability solutions are a natural fit for the food business. Businesses involved in the food supply chain must guarantee the safety of their goods. By detecting problems before they affect the final consumer, traceability lowers the risk of foodborne illness, contamination, and spoiling. Unsafe food can damage brands, trigger regulatory action, and even force the liquidation of certain enterprises when it manages to get past the system and end up in consumers' bellies. Traceability enables workers in the food sector to swiftly locate the cause of a problem and fix it before it significantly impacts public health.

5.3 Mechanism of Traceability in Blockchain

For companies in the food industry, tracking and tracing food is essential. It enables them to track the movement of food items and their ingredients backward (first-mile traceability) and forward through all supply chain stages (last-mile traceability). Brands can verify product quality and spot and address problems in real time by linking production, processing, and distribution at the ingredient level.

The first stage of preparing the product for the client or distribution point is called the "first mile" of traceability. The first mile includes product packing, goods validation, and transportation to the logistics center. Up until the product is placed in the customer's hands, there is last-mile traceability. The question arises: If blockchain has so many benefits, why is it not so commonly seen in the food industry?

5.4 The Reluctance of Organizations to Implement Blockchain

Due to their disparate motivations and limitations in information gathering and sharing, many supply chain stakeholders frequently resist complete traceability. Blockchain technology implementation problems include:

- Difficulties in transferring all data into digital form at each stage of the supply chain.
- Performing cost-benefit analyses, persuading management to approve the initial software capital expenditure, fostering a disruptive ecosystem throughout the entire company, and encouraging upstream/downstream vendors to exchange real-time data
- Blockchain technology has dramatically increased the security of data storage and transit, but the personnel handling the data must also be dependable. Some businesses are reluctant to utilize blockchain technology due to data theft by these operators.

The above issues need to be realized, addressed, and resolved to reduce the resistance to implementing blockchain in the food supply chain.

5.5 Levels/Dimensions of Traceability

Salah et al. (2019) identify four dimensions of the traceability level: breadth, depth, access, and precision.

- The breadth of blockchain technology includes the amount of attributes linked to the provided item is referred to as the traceability of the supply chain. These could come in the shape of products or batches. Perhaps this distinguishing quality of blockchain technology, which is hard to duplicate so thoroughly in other technologies
- The depth of blockchain technology includes full upstream and downstream product traceability throughout the whole food supply chain. The entire chain would become unreliable if it were to break or become weak at any point. The blockchain system's dependability would depend on how accurate the vendor's data was. The successful implementation of blockchain technology requires stakeholder confidence in information sharing throughout the supply chain.
- Access describes how quickly goods and information can be found among supply chain participants. The benefit of blockchain is that information may be shared live without needing a central storage system because it is saved in blocks across numerous computers and is available to all stakeholders with safe, traceable, and validated transactions.
- Precision refers to the tracing system's capacity to precisely identify product movement and changes to its characteristics at each level of the supply chain.

5.6 Implementation Challenges

Zhang et al. (2021) put out four groups of difficulties for a successful application of blockchain for supply chain traceability

Standard: The absence of standardized information formats and sharing platforms leads to problems with interface compatibility across stakeholders within departments and vendors.

Information: As with any other IT-based system, the efficient deployment of blockchain is hampered by the ease with which data can be accessed throughout the supply chain, its accuracy, the absence of complete information, and the lack of current knowledge.

Economic: Financial costs, such as the price of initial software and hardware, as well as the cost of human capital and training, become a barrier to the adoption of blockchain technology.

Lack of awareness: The system's adoption is hampered by management and executives not involved in information technology.

5.7 Blockchain and Food Supply in the Face of the Pandemic

The year 2020 brought with it opportunities and challenges never seen before. The global supply chains were disrupted due to lockdowns, resulting in production shortages. Consumer behavior also showed changes. Consumers shifted their preferences to necessities and lesser value-added products instead of luxury goods. Further, the point of contact shifted from malls and superstores to e-commerce platforms. The regulating authority's role increased as consumers preferred to purchase certified goods free of contamination. It has resulted in a higher demand for products traced throughout the supply chain. Global food supply chains were significantly affected. An alternate strategy is needed to find alternatives to the bottleneck and monopolistic areas in the supply chain, even if it means an increase in costs. It has opened opportunities for new supplier entries in the traditional markets. Since these new suppliers needed to be verified for their products and service, the need for digital technology increased tremendously. Another issue faced during the pandemic was that although the need for digital data increased, there was less opportunity to physically verify goods on location before being downloaded to a computer.

6 Theoretical Underpinning

The supply chain literature suggests applying six major theories related to blockchain in supply chain management. These theories are Agency Theory (Cole et al., 2019), Information Processing Theory (Martinez et al., 2019), Institutional Theory (Torres de Oliveira, 2017), Network Theory (Treiblmaier, 2019), Resource Based View (Morabito, 2017), and Transaction Cost Analysis (Schmidt & Wagner, 2019). Among the theories mentioned above, the information processing theory connects the issue of traceability in the blockchain.

6.1 Role of Information Theory in Blockchain

The study of information transformation, processing, extraction, and utilization is what information theory is all about. As a result, one way to think of information is as the solution to the problem of uncertainty. The information theory could be used to evaluate the difficulty of a supply chain for blockchain. More specifically, the information theory could quantify the difficulty of a supply chain system by providing information on each production process. It would be accomplished by providing information at each stage of production. This data access will ensure that information is fed, processed, and retrieved by all stakeholders in the supply chain in a manner that is free of errors and in real-time. Blockchain is the only technology that can verify this. For instance, Montecchi et al. (2019) investigated the applicability of blockchain technology in supply chains to help customers by providing access to more information, specifically, knowledge regarding the product's provenance. It was done to help customers make more informed purchasing decisions.

Overall, information theory can link any uncertainty and complexity within the supply chain, and providing more information could reduce the uncertainty and risks. Moreover, information theory provides a foundation for analyzing how blockchain can increase information-processing capabilities and transparency along the supply chain.

7 Future of the Blockchain

Although the year 2022 witnessed a post-pandemic phase, the re-emergence of new variants from time to time has not clearly defined a line to the end of the Covid-19 pandemic. Intermittent smart lockdowns created shortages and surplus supplies at various supply chain stages. Blockchain can assist in streamlining this fluctuation in supply by sharing the volume of inventory levels in real-time with all the upstream and downstream stakeholders.

Another dimension of the blockchain shows its potential use with other technologies, such as the internet of things (IoT) and artificial intelligence (AI). Although at a very initial stage, combining these technologies in the future not only would track the whole of the supply chain but also guide, predict and forecast the consumer action towards the product and service. With the application of 5G technology, this interface may see galloping expansion in the future. The use of blockchain will see its growth in the product markets, shifting from the current usage in cryptocurrency and the financial sector.

The current reluctance in applying blockchain technology will be eliminated with the maturity of the technology. It will improve user experience through a more user-friendly interface, well-trained operators, and refined regulation. The global supply chain needs to be regulated by international bodies such as UN World Food Program (WFP) to secure food supplies. Moreover, food supplies are predicted to be disrupted due to global warming and water shortage issues. With the expanded usage of the technology, the initial investment cost of implementing blockchain to enhance transparency and traceability in the supply chain is expected to come down. Availability of cost effective support resources, such as open source software and free data, will make smaller organizations willing to jump on the bandwagon, further filling the gaps in the supply chain.

8 Proposed RF Food Supply Chain Traceability Model

The RF (Rehan-Fahim) model reflects the focal importance of traceability for the ultimate consumer and other actors in the supply chain. The model suggests that all the food supply chain actors are linked via blockchain traceability, which is only possible in real-time with the help of 5G connectivity. Cloud-based IoT traceability and the use of artificial intelligence for forecasted projections will be the buzzwords in the sustainability of blockchain traceability. Hence, the traceability melts down to the real-time data sharing and transfer among the stakeholders right from the beginning till the tail end of the supply chain (Fig. 2).

9 Conclusion

The analysis of the cases mentioned at the beginning of this chapter reveals that the two cases are in a European context. It can be seen that even though European economies are well-documented and supply chain information is available at almost all the points in the supply chain, there is a gap in connecting the data in real time throughout the blockchain. In addition, when a link in the information chain is either

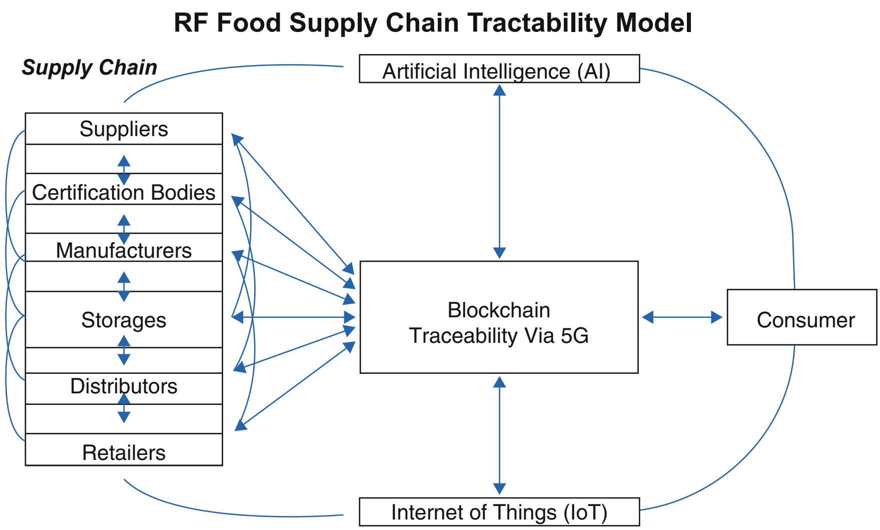

Fig. 2 RF food supply chain traceability model

damaged or missing, the entire supply chain loses its transparency and traceability. Other information technologies, such as RFID and barcodes, cannot guarantee the comprehensive coverage in terms of length, breadth, and flexibility necessary to cover information from the farm to the fork. For now, the adoption of blockchain is the most effective answer that technology can deliver. Blockchain technology may be further improved in the future by combining its use with other technologies, such as the internet of things (IoT) and artificial intelligence (AI), both of which can further facilitate the industry and consumer. The application of blockchain technology within the food supply chain presents an opportunity for Europe to take the lead globally.

The other three cases mentioned at the beginning of the chapter came from a developing countries in South Asia, where the documentation of the entire supply chain is difficult to attain. Therefore, deploying any supply chain digitalization is an uphill task. Additionally, for the same set of reasons, the importance of traceability increases not only in Asia but also in Europe. Since developing countries rely on exporting products to developed nations, the issue of traceability has become increasingly important. Blockchain is an ideal medium for transparency and traceability, even in domestic markets. A certifying body might sometimes be unreliable. The distribution of data protected by blockchain has the potential of becoming the most appropriate channel for distributing reliable data among stakeholders.

10 Concluding Remarks

While it can be challenging to digitalize data in developed and developing countries, legislative actions may ensure documentation. The legislature to implement documentation among food supply chains can be supplemented through the application of blockchain technology. Consequently, not only will blockchain make the whole system more transparent and traceable for the government authorities, but also for the consumers.

A mobile application may be originated at the end of marketing and supply chain managers, resulting in customer satisfaction. With the help of a mobile application, the customer will be able to check the details of each step in the supply chain. Once satisfied, it would hardly be willing to switch to brands devoid of supply chain documentation via mobile app.

Implementing blockchain technology in the food supply chain will speed up the understanding and adoption of blockchain, especially in the less developed part of the world. Mandatory use of blockchain by all the participants in the supply chain will help improvise the system requirements, thereby overcoming the barriers to adopting blockchain.

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Capability Framework to Support Supply Chain Open Innovation Networks

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1 Introduction

Since its inception, open innovation has changed most business processes including supply chain. Supply chain is considered a backbone of globalization and internationalization of modern-world businesses (Damert et al., 2020). In fact, firms compete on the basis of the resilience of their supply chains (Spieske & Birkel, 2021). To enhance integration, firms are now establishing supply chains where they collaborate and interact with various stakeholders, including other firms, partners, multi-tier suppliers, B2B customers, and several others (Aldrighetti et al., 2021). These networks enable these actors to exchange their information to perform process innovation in order to stay ahead of competitors while providing better services. In this way, they develop an open innovation (Chesbrough & Bogers, 2014) kind of supply networks where the purposeful flow of knowledge is made to gain access to the competencies, resources, and expertise of each other (Mubarak et al., 2021). Most large firms are affluent in acquiring resources and generating internal knowledge for innovation in their processes. However, small and medium firms (SMEs) are continuously seeking to obtain these resources and knowledge considering their assets, financial, and structural limitations (Leckel et al., 2020). Hence, firms and stakeholders form collaborative networks with each other to facilitate interactions

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_8

and collaborations related to learning and co-innovation. These open networks contain members across the world operating in similar industries, such as open networks of automotive manufacturers and suppliers, biotechnology, electrical and electronics, chemical, and many other sectors ranging from low-tech to high-tech. These networks are developed, operated, and managed through advanced technologies such as blockchain forming blockchain driven open innovation networks (Kusi-Sarpong et al., 2022). In this way, a significant number of collaborations are managed by integrating actors globally. However, various issues in their functioning led to disintegration and undermined their functions (Nestle et al., 2019). The main issue reported is the trust issue among stakeholders, as they come from diverse locations, different cultures, languages, and values (Mubarak & Petraite, 2020; Pratono, 2018). The element of trust is critical to succeed the collaborations in innovation networks (Brockman et al., 2018; Didenko et al., 2020). Researchers have confirmed that digital trust can be utilized to streamline such networks (Mubarak & Petraite, 2020); nevertheless, it is not a standalone solution, and other factors are also required to study. Hence, the need to study the interactive side of capabilities is vital for improving supply chain open innovation networks. In addition, collaborative innovation networks are highly technology intensive and need more attention on related competencies (Teodorescu & Korchagina, 2021), yet the literature has addressed this aspect with a generalized set of capabilities. However, the discussion of technological factors remains ambiguous and inconsistent with respect to such networks (Huggins et al., 2020; Lopes & de Carvalho, 2018; Urbinati et al., 2020). This study extends the dynamic capabilities view (DCV) that posits assimilating and continuously upgrading the capabilities of firms keeping in mind the rapidly changing and dynamic environment (Teece et al., 1997; Teece, 2020). Literature has focused on a generalized set of capabilities for innovation networks and firms (Adamides & Karacapilidis, 2020; Jun & Kim, 2022; Wu et al., 2022). However, the demarcation with respect to nature of capabilities largely remains unanswered. In doing so, this chapter discusses the technological and interactive dimensions of capabilities in order to enhance both tacit and explicit aspects of learning and knowledge sharing in the networks. By applying the multi-criteria decision making (MCDM) technique based on experts-based modelling, this study initiates a model to manage supply chain open innovation networks where the interactions and interdependencies of technological factors are extracted. In this process, first, the capabilities are ranked and prioritized with the help of European experts from industry and academia through analytical hierarchical process (AHP). Further, the dependencies and interdependencies of those ranked capabilities are identified by applying interpretive structural modelling (ISM). This study developed an interactive model of capabilities directing the improvement of supply chain open networks. This is one of the important contributions made by coupling and amalgamating the capabilities and their interactions with the function of SCOINET. Researchers have developed several capability frameworks related to capability maturity, digitalization (Ghobakhloo et al., 2022), Information technology (Curley, 2007), eGovernance (Iribarren et al., 2008), marketing (Moi & Cabiddu, 2021) and a few other concepts. In the realm of collaborative innovation framework for open innovation maturity (Hosseini et al., 2017) and service capabilities (Carroll & Helfert, 2015) related to open innovation developed. Podmetina et al. (2018) presented open innovation competencies and endorsed Mortara et al. (2009) and Salisu and Bakar (2019) view of interactive and technological skills implicitly at individual and firm level. However, they did not explicitly address the interplay of these capabilities sufficing the functionalities at network level. In this context, a critical void exists when it comes to the capability frameworks for SCOINET. In particular, focus on the technological and interactive capabilities (Mortara et al., 2009; Salisu & Bakar, 2019) needs attention. Therefore, we address this issue by zooming in the technological and interactive capabilities to support the functioning of SCOINET. We develop a framework by showing the interactions and inter-dependencies of capabilities as well as functions of SCOINET. This study will allow policy makers to upgrade these networks to enhance interactions within them. For researchers, a novel framework is presented by extracting the tech factors for technological upgrading and interactions management to fulfill the SCOINET functions to streamline them.

2 Supply Chain Open Innovation Networks (SCOINET)

Driven by industry 4.0 technologies, supply chain networks are transformed that facilitate various actors by integrating them (Queiroz et al., 2019). Before discussing open innovation networks, supply chain requires a brief introduction. Supply chain management is the process in which multiple streams of supply chain partners are managed and integrated to streamline functioning of businesses (Aldrighetti et al., 2021; Khan et al., 2022a, 2022b, 2022c). These streams include upstream where the suppliers and their suppliers are managed in a multi-tier approach. In the midstream, the production process of the firms is focused, and in the downstream, multiple layers of customers are catered. These streams are managed through multi-tier channel integration (Ali et al., 2021; Mubarik et al., 2022).

The open innovation networks enable interactions and collaborations amongst the actors in an open way, which means that stakeholders tend to open their knowledge and resources for other members of networks with mutual and agreed goals (Obradović et al., 2021; McGahan et al., 2021). Similarly, suppliers, firms, and customers share their supply capacity, demand forecast, and several other related information. In this process, suppliers share their suppliers and create a multitier supplier chain that is visible to other partners. Similarly, the customers (B2B) share their customer layers and form a multi-tier customer chain. In this way, the stakeholders perform demand and supply forecasting that helps streamline the production and supply processes. Besides improvement in the design and features are also exchanged between the firms, suppliers, and customers. Knowledge generated as a result of interactions and collaborations amongst supply chain network partners is utilized and channelized by applying a strategy of supply chain mapping (SCMp) (Donaldson et al., 2020; Mubarik et al., 2021). The supply chain mapping frames the multiple layers of the supplier and the customer to enhance visibility across the network. This framing is done in the form of mapping the information of multi-tier actors that is managed through blockchain technology. This technology enables real-time information management and tracking that cannot be deleted, nor can it be corrupted or edited (Dutta et al., 2020; Moosavi et al., 2021). Blockchain is the most sophisticated technology of the fourth industrial revolution, displaying the features of transparency, traceability, and immutability. Especially the decentralized type of blockchain instead of centralized system (Mubarik et al., 2022). These features enhance the information sharing, integration, and visibility on network that promotes trust amongst the actors (Kusi-Sarpong et al., 2022). In this way, the open innovation paradigm has significantly changed the way supply chain processes were managed. It has not only supported supply chain networks but also promoted the productive interactions taking place on them.

2.1 Functions of SCOINET

SCOINET facilitate collaboration through information sharing between network members. While doing so, decisions such as sourcing, demand and supply planning, and innovations in supply chain processes are supported that enhance value creation. Furthermore, the integration across the network stakeholders is improved by enabling visibility. The conventional supply chain networks focused on the limited scope of integration where internal, customer, and supplier were undertaken (Mubarik and Zuraida, 2019). These three areas of integration can be demarcated into two broader categories of internal and external integration; in which the internal integration is at firm level covering the various departments and divisions of a firm. Whereas the external integration with customers and suppliers focused on the direct customers and suppliers where the tier-I customers and suppliers were taken onboard. In this manner, the firms have a limited view and information about the further layers or tiers of customers and suppliers' firms that inhibited the sourcing and effective decision making in the supply network. To cater this issue, the concept of multi-tier channel integration was coined that explains that the spectrum of integration should be expand to tier-II and beyond stakeholders (Kusi-Sarpong et al., 2022). This will help to improve the visibility of the whole network that would support the collaboration and decisions related to ameliorating overall supply network while opening them. The strategy of supply chain mapping helps to map the multiple tiers of stakeholders that enhances the visibility across the network (Khan et al., 2022c). In this way, trust and collaboration between the network members can be increased with the help of complimenting role of open innovation approach. Therefore, multi-tier channel integration and supply chain mapping should be undertaken together in order to streamline the functions of supply chain networks. These two strategies are supported by industry 4.0 technologies such as blockchain technology to nurture and develop the supply chain networks (Mubarik et al., 2021). This technological infrastructure improves the overall functioning of supply chain open innovation networks by making them resilient (Ali et al., 2021). In a nutshell, the SCOINET functions such as integration (of multi-tier channels), visibility, and resilience are supported by various technological and interactive factors and capabilities that in return affects the SCOINET.

3 Capabilities for SCOINET

In order to improve SCOINET, the capabilities can play an important role. This study discusses two types of capabilities, technological and interactive. Technological capabilities are related to managing technological knowledge, processes, or equipment. While the capabilities associated with facilitating interactions of network members are termed as interactive capabilities. Technological capacity and technological orientation are technology-related capabilities; and digital trust and relational capital are considered as interactive capabilities.

3.1 Technological Capacity

Technological capacity is pointed out as a competence of firms to perform technical functions with its influence on overall performance (Teece et al., 1997). Technology capacity is deemed a critical factor for SMEs to remain competitive in dynamic markets. It is associated with activities related to knowledge, expertise, competencies, technology, and systems (Kim, 2018; Kim & Rhee, 2009). However, in SMEs, this capacity is conditioned by certain factors such as resources limitations, threats of market, and sector of activities (Estrada et al., 2019; Mayer-Foulkes et al., 2021; Mubarik & Naghavi, 2020). It is the ability to generate or acquire new technological knowledge, improve existing knowledge base, and innovating processes that indicates the ability of firms to respond with competitive and disruptive situations (Andrade et al., 2021). Technology capacity enables firms to reach new resources (Liao et al., 2020; Narimani et al., 2019), innovative processes, manufacturing, and technologies (Gedajlovic et al., 2012), configuring new knowledge and gaining technical mastery (Relaño et al., 2021; Wang et al., 2015). It encapsulates both kinds of resources including technological and human (Andrade et al., 2021; Barbosa Castro et al., 2022). Thus, technological capacity covers industry 4.0 led technologies such as blockchain that drives the supply chain open innovation networks (Kusi-Sarpong et al., 2022). Human resources cater to the firms, suppliers, and customers that collaborate with each other for supply chain innovation. Therefore, technological capacity can facilitate these networks to streamline their supply chain processes.

3.2 Technological Orientation

Technological orientation is the tendency or mindset of firms to acquire and advance their technology base or at least improve their technology-related knowledge (Bagheri et al., 2019; Gatignon & Xuereb, 1997). It is vital for firms operating in an open innovation paradigm that promotes knowledge and resource sharing with members or partners. In addition, it demonstrates the ability of firms to generate, adopt and apply technological knowledge in innovation processes (Borodako et al., 2022; Chang et al., 2020). Similarly, technological orientation can improve the interactions of firms, suppliers, and customers to exchange technological and procedural knowledge with each other to carry out innovation in production, as well as in processes (Mubarik & Naghavi, 2021; Zhang et al., 2018) which is essential for manufacturers and suppliers of technology-related products and services. Likewise, it can improve the open innovation networks of suppliers and customers by complementing the knowledge interactions between them.

3.3 Digital Trust

In the realm of open innovation where collaborative interactions take place for learning, trust holds a vital position (Mubarak & Petraite, 2020). It facilitates effective knowledge and information sharing among the partners and firms. Similarly, for open innovation networks where substantial number offirms, suppliers, customers, and other stakeholders participate, the presence of trust is crucial (Brockman et al., 2018). These networks are managed through advanced digital technologies of industry 4.0 that renders the conventional features of interorganizational trust obsolete (Lee et al., 2022; Salampasis et al., 2015). For such networks, both technology and human-centric dimensions of trust play an important role to support collaborations. However, the literature fell short until Mubarak and Petraite (2020) presented the notion of digital trust to improve open innovation interactions. The digital trust addresses both of these dimensions by undertaking technology-cum-human aspect for learning interactions. It has encapsulated the industry 4.0 technologies such as big data, the Internet of Things, blockchain, and cyber physical systems. In addition, it takes the conventional measures of trust and inter-firm trust that play complimentary role to facilitate technology-human interactions. This concept of trust is most suitable for open supply chain networks as they are highly technology driven, such as blockchain based supply networks. The members of these networks can effectively exchange their knowledge and information with each other to succeed in the innate functioning of supply chains. Therefore, we argue that digital trust is the most suitable dimension of trust required for industry 4.0 technology-based supply chain open innovation networks.

3.4 Relational Capital

Firms and partners share critical knowledge with each other while doing collaborations and supply chain innovation. The knowledge shared possesses both explicit and tacit types. The former includes codified knowledge that can be easily understood and transferred through knowledge-transfer processes (Nonaka & Takeuchi, 1995; Blackler, 1995). The latter, tacit type, refers to the knowledge that is not codified and cannot be transferred in a structured manner. This type of knowledge is necessary for innovation in processes and decision making, such as sourcing (Ritala et al., 2021). In fact, tacit knowledge is based on experiences, culture, and other interactive aspects that cannot be known otherwise. It is embedded in the relationships between firms and partners that can be acquired through relational capital. Relational capital refers to the relationships of firms with outside firms, suppliers, customers, and other stakeholders (Mubarik et al., 2021). Therefore, this category of social and interactive capital is inevitable for network members to obtain the tacit understanding necessary for supply chain improvements (Kusi-Sarpong et al., 2022). It also promotes trust between suppliers, customers, and firms by sharing tacit aspects such as experiences, feelings, cultures, and other informal interactions. In an nutshell, drawing upon from the most recent literature (e.g., Rasiah et al., 2017; Mahmood & Mubarik, 2020; Mubarik et al., 2021, 2022; Ahmed et al., 2021; Kusi-Sarpong et al., 2022; Qader et al., 2022; Khan et al., 2022a, 2022b; Azmat et al., 2022; Ali et al., 2021; Piprani et al., 2022), we conclude that there exists a need of framework that can explain the linkage of technological capabilities, interactive capabilities and supply chain opn innovation networks.

3.5 Conceptual Framework

This study extends the dynamic capabilities view (DCV) that posits assimilating and continuously upgrading the capabilities of firms keeping in mind the rapidly changing and dynamic environment (Teece et al., 1997). The conceptual model of the study shows that the capabilities, including technological and interactive types, improve SCOINET. The technological capabilities are technological capacity and technological orientation, while the interactive capabilities are digital trust and relational capital. The former is related to technology adoption, and the latter is applied to manage interactions among stakeholders on SCOINET. Nonetheless, in the further sections, we discuss how these capabilities are related to each other and with SCOINET. The conceptual framework is shown in Fig. 1.

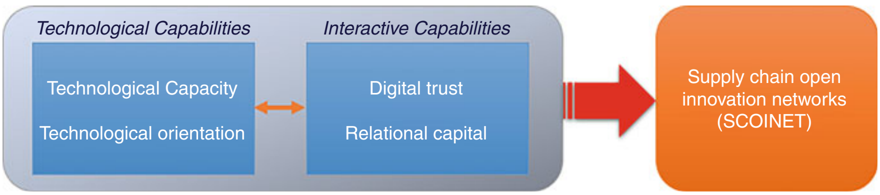

Fig. 1 Conceptual framework of study

4 Research Methodology

This study has adopted a three-fold research methodology. The first includes the identification of multiple factors to facilitate the supply chain open innovation networks. Followed by the second, in which experts-based decision making is applied by adopting analytical hierarchical process (AHP) in which the factors are prioritized. Finally, interpretive structural modelling (ISM) is applied to determine the interactions and interdependencies of factors obtained in the second step. For AHP and ISM, 13 experts from industry, research and academia participated in the study. According to the recommendations of Ghobakhloo et al. (2022), who involved 11 experts in their research, this number of experts is appropriate for this type of research where model or strategy development is required. The research process is illustrated in Fig. 2.

5 Findings

5.1 Analytical Hierarchical Process (AHP)

Through the analytical hierarchical process (AHP), four dimensions of the study were prioritized with the help of 13 European experts. These four dimensions include two categories of interactive and technological. The interactive dimensions

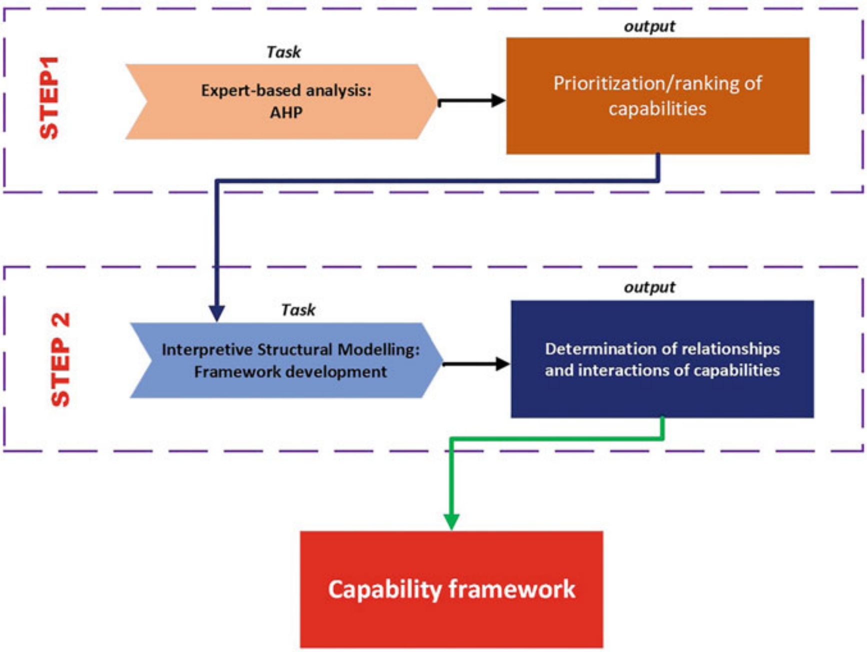

Fig. 2 Research design

Table 1 Ranking of dimensions

Dimensions	Ranking
Technological	
Technological capacity (TCAP)	3
Technological orientation (TO)	1
Interactive	
Digital trust (DGT)	4
Relational capital (RC)	2

include digital trust and relational capital, while technological ones are technological capacity and technological orientation. The most important dimension that emerged is the technological orientation of firms, followed by relational capital, while technological capacity is ranked as 3, and digital trust is lowest ranked among the four selected dimensions. The findings of prioritization are given in Table 1.

5.2 Interpretive Structural Modelling (ISM)

The relationships and interdependencies are identified with the help of experts after prioritizing or ranking the technological and interactive dimensions. The results reveal that all the four dimensions positively influence supply chain open innovation networks (SCOINET) showing as TO→SCOINET, RC→SCOINET, TCAP→SCOINET, and DGT→SCOINET. However, various relationships amongst those also exist. While impacting SCOINET (TO→SCOINET), technological orientation impacts the technological capacity of firms (TO→TCAP). Also, it moderated between technological capacity and open innovation. Moreover, relational capital and technological orientation are mutually dependent (RC←→TO). In addition, relational capital and digital trust are also mutually related (RC←→DGT), while relational capital impacts open innovation (RC→OI). Technological capacity also improves open innovation (TCAP→OI) and is dependent on digital trust as well (DGT→TCAP) that is dependent on relational capital (RC→TCAP). Finally, digital trust improves open innovation (DGT→OI) that leads to the enhancement of SCOINET (OI→SCOINET). Apart from these, all relationships are shown in Fig. 3. In this way, a brief version of capability framework for SCOINET improvement is developed in which two types of capabilities, technological and interactive ones, are taken, that improves the functions of SCOINET including multi-tier channel integration, supply chain mapping or visibility, and resilience of supply networks by improving its readiness, and re-configuration as per market disruptions. These functions lead to the overall enhancement of networks' operations including collaboration, information sharing, sourcing, demand and supply forecasting and process innovations.

For better understanding of interactions, the colored framework can be seen online by accessing Springer's official website.

The detailed explanations of relationships are given in table 2.

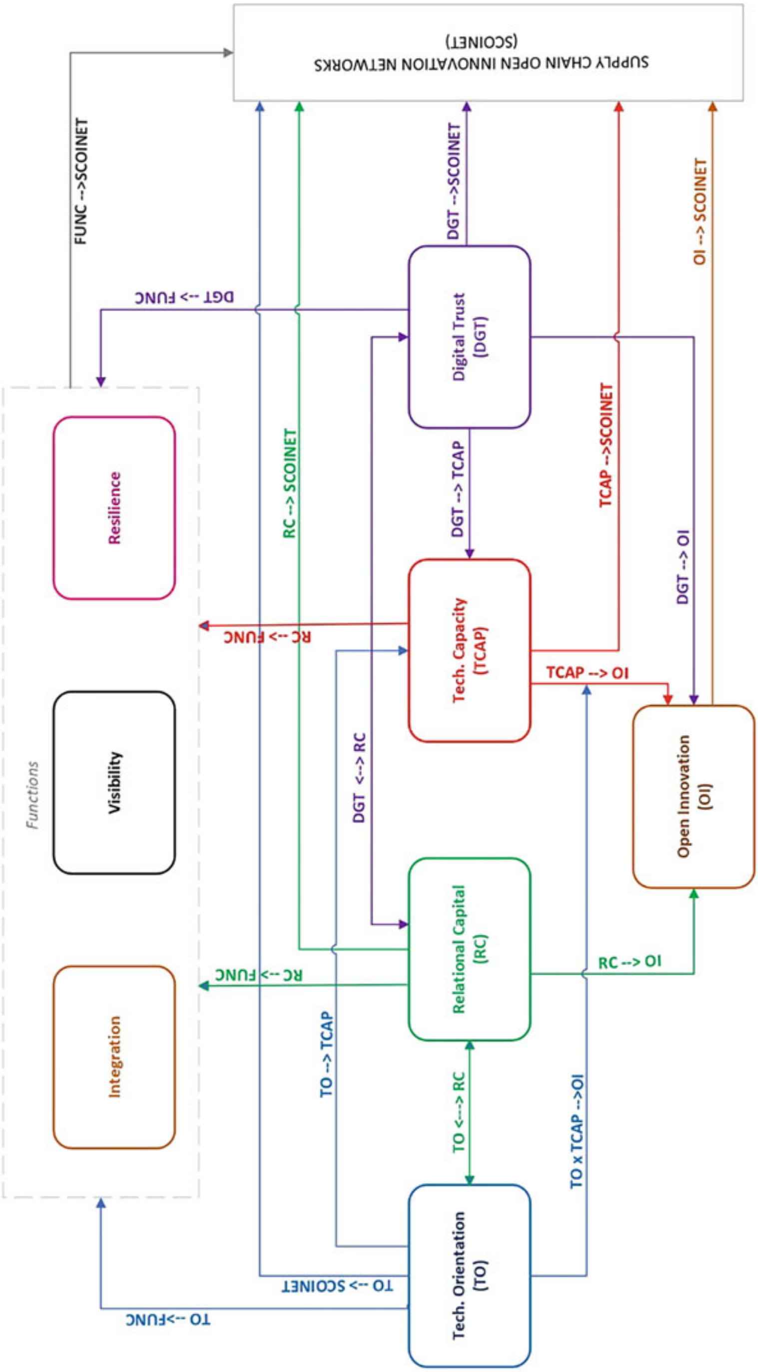

Fig. 3 Framework for SCOINET improvement

Table 2 Descriptions of relationships

Interactions	Descriptions
TO➔ SCOINET:	*Technological orientation impacts supply chain open innovation networks*
RC➔ SCOINET:	*Relational capital impacts supply chain open innovation networks*
TCAP➔ SCOINET:	*Technological capacity impacts supply chain open innovation networks*
DGT➔ SCOINET:	*Digital trust impacts supply chain open innovation networks*
TO➔ TCAP:	*Technological orientation impacts technological capacity*
TO x TCAP➔ OI:	*Technological orientation moderates the relationship between technological capacity and open innovation*
TCAP➔ OI:	*Technological capacity impacts open innovation*
RC←➔ TO:	*Relational capital and technological orientation are mutually related*
RC←➔ DGT:	*Relational capital and digital trust are mutually dependent*
RC➔ OI:	*Relational capital impacts open innovation*
DGT➔ OI:	*Digital trust impacts open innovation*
DGT➔ TCAP:	*Digital trust impacts technological capacity*
OI➔ SCOINET:	*Open innovation impacts supply chain open innovation networks*
TO➔ FUNC:	*Technological orientation improves integration, visibility, and resilience of networks*
RC➔ FUNC:	*Relational capital improves integration, visibility, and resilience of networks*
TCAP➔ FUNC:	*Technological capacity improves integration, visibility, and resilience of networks*
DGT➔ FUNC:	*Digital trust improves integration, visibility, and resilience of networks*
FUNC➔SCOINET:	*Functions including integration, visibility, and resilience of networks influence collaboration, information sharing, sourcing, demand and supply forecasting and process innovations in supply chain open innovation networks.*

6 Implications and Concluding Remarks

This chapter has discussed the capabilities to upgrade the supply chain open innovation networks (SCOINET). In doing so, two sets of capabilities, including interactive and technological, are identified. Interactive elements contain digital trust and relational capital, while technological elements are technological capacity and technological orientation. After applying the analytical hierarchical process (AHP) to prioritize those dimensions, technological orientation is ranked first, relational capital second, followed by technological capacity, and finally, digital trust at lowest rank. The findings reveal that there is no linear approach for developing capabilities for the improvement of SCOINET. Both interactive and technological capabilities must be simultaneously developed in order to make SCOINETs robust. Furthermore, interpretive structural modelling (ISM) was applied to check the interactions amongst those dimensions towards SCOINET advancement. The selected dimensions directly and indirectly contributed to the development of SCOINET. In this context, technological orientation and relational capital; relational capital and digital trust; and digital trust and technological capacity are mutually dependent.

Therefore, these should be focused on accordingly. Technological capacity and digital trust neither perform mutual interactions nor perform other interactions. However, both converge to improve open innovation of firms. The capabilities support the functions of SCOINET that are to integrate them, make them visible, and achieve resilience to manage disruptive situations. Conclusively, a framework is presented to navigate the capability development for SCOINET development. This study will help policy makers to foster open networks, SCOINET and others. Moreover, the most relevant interactive and technological capabilities dependencies and inter-relationships will guide to achieve micro-objectives in firms and networks. As a research contribution, a framework based on interactive and technological capabilities is presented to improve open innovation networks. This framework can be applied to open networks other than supply chain related. Future researchers are recommended to test the modelled relationships in order to validate the model by deductive approach. In doing that, the relationships can be tested by applying PLS-SEM approach after developing the related hypothesis. Besides, as this chapter opens the discussion on capabilities framework for supply chain open networks hence it is suggested to study its dimensions and capabilities compehensivley in order to enrich the understanding developed by this study.

Acknowledgements This project has received funding from the Research Council of Lithuania (LMTLT), agreement No S-MIP-19-44 and has been performed in cooperation with the European Union's Horizon 2020 research and innovation programme under grant agreement No 810318.

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Blockchain-Driven Supply Chain Management and Open Innovation

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1 Introduction

Innovativeness is continually observed as the progression which usually absorbed within the boundaries of the firm. Whereas, the approach to innovativeness in businesses has been changing widely, as the domain of innovation is altering and extending the boundaries of the company's innovativeness prospects. Therefore, businesses are moving from the traditional conception of the closed innovativeness model to open innovation prospects (Elmquist et al., 2009). In the era of change and progression of systems and approaches is the demand for industry 4.0 which shapes the need for prospective business strategies. This need for change is the forceful truth of today, which disturbing the conventional business procedures, systems, and market forces (Fragapane et al., 2020). Innovativeness is one of the classic patterns of activities that businesses plan for involving consumers and suppliers.

In recent years, the conception of open innovation is attracting the attention of experts in the innovation and management field (Costa et al., 2007). Which intensifies the innovative attitude and outlook concerning research and development management prospects, and presumes that businesses must utilize the outside conceptions and philosophies along with the internal knowledge, information, and ideology. Where at the same time businesses also look for internal and outer paths

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_9

toward markets for the progression of the technological domain (Chesbrough, 2006a, 2006b).

Industrial 4.0 philosophy is encouraging the conception of open innovation for industrial growth and to achieve competitiveness within the market against rivals. The need for concerted innovation is gaining massive attention within academia and the industrial domain, as the worldwide competitiveness amongst businesses and the revolution in technology prospects are the key antecedent of the need for open innovation (Moreira, 2005).

The conception of the supply chain is associated with the complex dominion which is connected with a variety of initiatives and founded on the information float to understand the business concerned alliances of all the linkages among business initiatives (Leng et al., 2018; Kusi-Sarpong et al., 2022; Mubarik et al., 2022). This domain of supply chain is a multilevel organization system of association intended to advance the rotation competence, were at the same time developing a business system focusing on value-adding as a primary focus, comprising the info, logistics, and investment flow (Xue et al., 2020; Qader et al., 2022; Khan et al., 2022a).

The overall industrial revolution or industrial 4.0 domain represents the transformed level of businesses and mechanism of the whole value creation in aspects of the supply chain and improved life cycle of produces (Bigliardi et al., 2010; Rasiah et al., 2017; Khan et al., 2022b; Azmat et al., 2022; Ali et al., 2021). There are numerous setups for establishing the connection between the supply chain bodies, which include the improved incorporation of basic suppliers within the domain of collectivism. Which encourages the serious assurance bond between the parties, especially in the form of a mutual competitive approach (Bigliardi et al., 2010; Piprani et al., 2022; Mubarik et al., 2022).

This arrangement stresses the high-tech approaches and systems of industrial aspects, existence of the end-to-end value chain, and smart business interaction systems (Mubarik et al., 2021). The outdated and old system of the supply chain is not competent in meeting the innovative economic, scientific, and customer stresses. The supply chain management system is developing in terms of its extent of involvement, comprising several levels and several participants on different levels. Consequently, businesses are indulged to join in their various actions with consumers and suppliers for continuing in the market (Bigliardi et al., 2010; Mubarik & Naghavi, 2020; Mahmood & Mubarik, 2020). The supply chain system today consists of strong complications and a diversified environment.

Where the system was founded on the modification of market arrangement, environmental concerns and supply chain mandate also included intangibility (Campos et al., 2019). Though, the old-fashioned supply chain system is relatively low in terms of adaptability according to the demand of consumers and modified systems. Therefore, it has less ability to meet the necessities of modified environmental concerns (Yu et al., 2018). Whereas, to encounter the growth of competitiveness among businesses and adaptation aspects in customer's needs, old school supply chain system is facing challenges (Kshetri, 2018; Mubarik et al., 2021; Mubarik & Naghavi, 2020).

This whole developed system includes all the levels from customized consumer demands, supply chain systems, industrialized processes, and providing the products to consumers (Sendler, 2017). This transformation not only focusing the domain of manufacturing, delivery, and supply chain but at the same time also includes transparent processes and networking of manufactured items and services in a digital way (Pfohl et al., 2015; Ahmed et al., 2021). This arrangement of transparency, networking, and the digital world affects the overall business setting to develop transformed business models and supply chain systems according to the demand of change. Which affects the partnership and communication level to provide an enriched level of trustworthiness, quickness, and efficiency (Kern & Wolff, 2019).

1.1 Open Innovation and Supply Chain Management

The dominion of innovation within the arrangement of business started in the initial human settlements and widely influenced the prospects of evolution and progression of cultures. The origination of the latest and innovatively developed tactics of production and approaches for supplying has been critical for the persistence of societies within the challenges of competitiveness (Ghouri et al., 2021; Gul & Khan, 2020). Where an insignificant number of innovators headed towards agricultural and industrial advancement, along with their huge and continuous impression on overall communal systems (Inauen & Schenker-Wicki, 2011).

In a current scenario, innovativeness is one of the priority stratagems of businesses, and view as a fundamental aspect of the success and survival ability of firms (Khazanchi et al., 2007). Innovation is inevitable for businesses to achieve competitiveness and face challenges effectively (Stock et al., 2002).

In the earlier mid-twentieth century, fundamental technological systems were established by giant firms' industrialized research sections, which they applied to the concerned production methods, production, and services domain (West & Gallagher, 2006; Bruland & Mowery, 2006). Vertically integrated prospects of firms were the basic practice of obtaining the latest technological upgrades to ensure the firms with a competitive edge over other competitors in the market (West & Gallagher, 2006). However, in customary and old-style business arrangements, innovative methods and products were established within the firm's limits (Bruland & Mowery, 2006), which Chesbrough (2003a, 2003b) called a closed innovativeness approach, where successful innovations needed regulators and businesses to be self-sufficient as they would not firm on the excellence, accessibility, and aptitude of the related parties.

The businesses would maintain all the regulations concerning research and development accomplishments and these all prospects excluded any outside knowledge or technological incorporation. However, the conception of a closed innovativeness arrangement is coming to its limits. As for businesses to be effective in innovative approaches and tactics irrespective of the industrial focus significantly depends on interaction with outside the firm boundaries and including outside important bodies (Laursen & Salter, 2006), which contains smart interactions with consumers and supplying bodies (Song & Di Benedetto, 2008).

Combining flexibility of knowledge and skillful workforce, rapid changes in the consuming and manufacturing utilities, and smaller product life cycles are the key elements of prototype modification of industrialized research and development domain and encouraging the demand for open innovation (Afuah, 2003; West, 2006). Whereas, the expansion in the interchange of technological and intellectual assets backs this modification from a closed innovativeness arrangement to an open innovation arrangement.

The rise in technological markets has militarized technological and intellectual assets (Arora et al., 2001). The fundamental reason behind this shift is that useful knowledge is not limited to a small number of giant entities, the necessity for opening the research and development domain becomes critical for firms (Gassmann, 2006). Consequently, the prospects for attaining knowledge and technological basis from the external environment and beyond the limits of organizational boundaries are considerably improved. Open innovation pressurizes the prominence of capturing this outer knowledge or technological base to transform them effectively for the progression of advanced merchandise and services (Gassmann, 2006; Afuah, 2003).

For the domain of ensuring open innovation, overall activities concerned with research and development should be focused to enhance the technological support inside and mandating. Therefore organizations must utilize the inside and external available knowledge and information, while at the same time employing inside and outlying commercialization pathways because the businesses are attentive to developing their technological strength in terms of methods, tactics, and processes for developing products and services (Chesbrough, 2006a, 2006b). Therefore, soon the domain of open innovation becomes the central attention of practitioners, academia, and literature concerning managerial and innovation practices (Christensen et al., 2005).

Open innovation has jumped out of the growing world of “much bigger and much higher” prospects, which includes the domain of carry-outs conceptions, thoughts and philosophies around the allotment of knowledge and conceptions fundamentally executed by the info and communication technological domain (Pazaitis, 2020). The principal agenda and rationality are associated with the solution of problematic prospects, developing a previously unnoticed capability concerning massive scale arrangement, and synchronization of various participants (Benkler, 2017). Therefore, as a phenomenon, open innovation is associated with an extensive range of activities, which are extending from a planned central base and can control the procedures similar to joint and virtually available labor platform. Various strategies are built towards the concerns like workforce, capitalization, and uncertainty level can be described (Harhoff & Lakhani, 2016).

However, the fundamental prospects stay as focused: a standard aptitude for the purpose of implying knowledge in vibrant and ambiguous procedures and activities. This overall aptitude is progressively influencing the tactics businesses to adopt innovativeness, moving towards innovative corporate models, and possibly nature. Open innovation is commonly adapt as a deliberate preference for businesses to occupy marginal inputs (Brunswicker & Chesbrough, 2018).

Innovativeness considers the initial element of businesses which is associated with many crucial concerns of businesses. Now, the systems and the demand for innovation prospects are changing covering wider prospects than before and including many areas of organization and businesses. Innovativeness process shifts from a closed system to an open system of innovation (Chesbrough, 2003a, 2003b). The conception of open innovativeness was primarily explained by Chesbrough (2003a, 2003b) which is rapidly gaining the attention of experts and businesses as an innovative way of intellectual and rationality (Elmquist et al., 2009). In the application of the conception of open innovativeness, businesses joint with all concerned parties, for example, consumers, opponents, academia, and other distinct industries in the market for establishing the ground of open innovation (West & Gallagher, 2006). The primary philosophy of open innovativeness is associated with the plan of obtaining all the knowledge and information essential for fashioning innovativeness, which was not reachable within the organizations. Therefore, the organization is required to obtain the information and improve its knowledge capacity from other origins as well (Bigliardi et al., 2010).

Open innovation is described as "the utilization of knowledge and information available via inflows and outflow channels to accelerate core innovativeness and strengthen markets for marginal use of innovation" (Chesbrough, 2006a, 2006b). This standard of innovation includes research and development as an open arrangement. Which presumes that valued conceptions can develop from within the organization and externally available systems (Hauser et al., 2006). While experts asserted numerous originators of open innovation, which explain four bases of information for organizations, example, suppliers and consumers, academia, governmental institutions, and secluded research labs (Von Hippel, 1988).

For businesses, the creative way of facing competitively the challenges of the market and demand for change is to team up with other companies for the purpose of progression and to offer new products in the market (Huston & Sakkab, 2006). Predominantly, innovativeness is primarily attained by the networking system, which helps the business to acquire the knowledge and information important for fashioning innovation, by banding with the other bases like consumers, supplying channels and research bodies, etc. (Aylward & Glynn, 2006).

Therefore, in these rapidly varying scenarios and demands of market and change, many businesses establish incontrollable systems of supply chain gathering with the concerned stakeholders, for example, industrialists, distributing channels, supplying chain, and consumers. The contemporary supply chain systems comprise various establishments (Thomke & Von Hippel, 2002). Accordingly, open innovation contrivances are progressively gaining attention in the domain of supply chain management concerns (Chang & Makatsoris, 2001). As innovativeness is primarily driven by consumers, the business also establishes research and development prospects within the company, which provide direction for the latest technological interpretation for the challenges in the market (Angerhofer & Angelides, 2006).

Open innovation stratagems are usually depending on the supply chain concerned parties. Which establishes a wider domain of association amongst consumers, supplying bodies, distributing channels, and research (Azadegan & Dooley, 2010).

This association significantly works to identify new significant solutions to the challenges of the market. These open innovation prospects immensely affect all the associated parties concerning the supply chain in terms of better services to consumers, productivity, and sustainability (Elmquist et al., 2009).

The conception of the blockchain system is identifying attention-grabbing study areas for researchers due to its advanced characteristics which offer effective resolutions and answers for highlighted existing gaps concerning numerous industrial setups. However, the present literature on blockchain systems is limited in terms of addressing the concerns of applying blockchain systems related to the supply chain management domain (Tribis et al., 2018). Whereas, previous studies not covering the demand of blockchain in the domain of effective management of supply chain for the industrial sector, which should also highlight the potential mapping of studies in the domain (Maestrini et al., 2017; Khan et al., 2017).

The gap also determines the areas focused on by researchers in the domain of supply chain management concerns within the perspective of blockchain. Academia and business research and development prospects are also limited to food supply chain concerns and pharmaceutical supply chain concerns (Seebacher & Schüritz, 2017). If further narrowing down the focused areas of previous studies it's highlighted mostly the security apprehensions related to data and monetary distresses within the supply chain management system. However, academia focused on the improvement of supply chain systems. Therefore, asserted various explanations and resolutions for improving the supply management issues and blockchain systems. However, addressing the prospects of substantiation and appraisal in the domain of supply chain and blockchain is limited (Yli-Huumo et al., 2016).

1.2 Blockchain Architecture

The prompt growth of "blockchain" prospects is gaining attentiveness and has been adopted in several domains, for example, the banking sector, retailing, supply chain domain, medical care, and public organizations (Kosmarski, 2020). Blockchain brings the technological support to attain the solution for a transparent system on many levels for stakeholders as a whole arrangement. This networking arrangement offers a rationalized business system to acknowledge peer-to-peer interaction in supply chain administration (Cole et al., 2019). This progressive domain encourages a decentralized environment for connections for stakeholders of firms. Blockchain systems can offer safety, timeliness, and transparent approaches for all operators with the aim of clarity in probable applications during operational activities and supply chain management systems (Ganeriwalla et al., 2018). Certainly, experts asserted that blockchain proposes resolutions to the numerous challenging domain due to composite supply chain arrangement in the era when suppleness, speediness, and transparency is critical for businesses (Pilkington, 2016).

Blockchain technological prospects are concerned with the distribution-related database arrangement which contains proceedings of transactions and other relevant material, which are protected by cryptographically ascertain domain and administered by unanimity setup. This is the systemization associated with data configuration which unites data archives, known as blocks within a chain (Swan, 2015). Where chain is the automatically dispersed record to contain a listing of records that operators or accomplices retain through networking systems amongst the networks. Particularly, blockchain practices cryptograph technological aspects for the purpose of processing and validating the operations on record. The whole process ensures the benefit on a commercial level, which includes the participant as a collective domain including collective power. Therefore, the blockchain system provides resolution concerning revelation and liability among the participants and firms where the concern between the stakeholders holders are not certainly allied (Casey & Wong, 2017). Where at the same time this record can be beneficial for all the concerned parties and can be updated with time. This process also includes eliminating the vital for active and inaccuracy resolution procedures with the data of each participant (Kache & Seuring, 2017). The arrangement involves the practices that facilitate the participants networking with better and well-timed visibility of the transactions records within the network domain. This availability of big data can be advantageous for businesses and supply chain management systems, therefore gaining the attention of businesses and researchers. The records contains encrypting and encoding system in a blockchain domain to advance accuracy, proficiency, and confidence to share information and records (Misra, 2018).

The crucial characteristics of blockchain are concerned with four domains, firstly, blockchain arrangement is concerned with providing facilitation for distribution and synchronization among networks and linkages, which inspire firms for Records sharing that develops a multi-firms business networking, like supply chains or monetary corporations (Pilkington, 2016). Secondly, a blockchain system consists of smart agreements, which involve agreements among the parties before the head and put in the storage of the blockchain. These smart agreement arrangements in a computerized way are intended to have operations in a digital way and most importantly atomization of upcoming future payments among participants (Reyna et al., 2018). Where at the same time these smart agreements also outline the purposes and settings, for example, the authentication of possessions and resources within a collection of trades with non-financial foundations (Reyna et al., 2018). This atomization provides an assurance between the parties that within the network system every participant is in concert by guidelines. Thirdly, blockchain is established via P2P networking. However, the arrangement between the concerned participants is a must and also provides validation of transaction and remove the invalid or possibly deceitful transactions from the database. Fourthly, constancy of records confirm that all transactions are listed and not changed. That delivers the origin of resources in terms of history in relevance to the transactions (Cole et al., 2019).

2 Application of Blockchain in Supply Chain Management

The supply chain is an intricate arrangement, which is gaining fast progression in today's business world. This arrangement is the amalgamation of high-tech systems and networking technological prospects. Consequently, the supply chain domain has moved from the traditional outdated methods as a distinctive chain modeling to modern nonlinear networking chain modeling system (Akhtar et al., 2022a; Khan et al., 2017). This approach to supply chain effectiveness and efficacy is not only profitable for the profit maximization of businesses but also is constructive for the overall supply chain and related stakeholders (Meijer & Carlo, 2016). Because the threat concerning the supply chain can be a possible danger in the operational activities of the supply chain. The causes of every unspecified dynamics, due to the interrelationship of the business concerned processes and revenue between the supply chain businesses, can lead to the association amongst supply chain risk (Akhtar et al., 2022b; Fu & Zhu, 2019).

There are numerous firms that considered and applied blockchain technological support. This blockchain system application to the supply chain networking domain can transform the mode in which organizations are doing business.

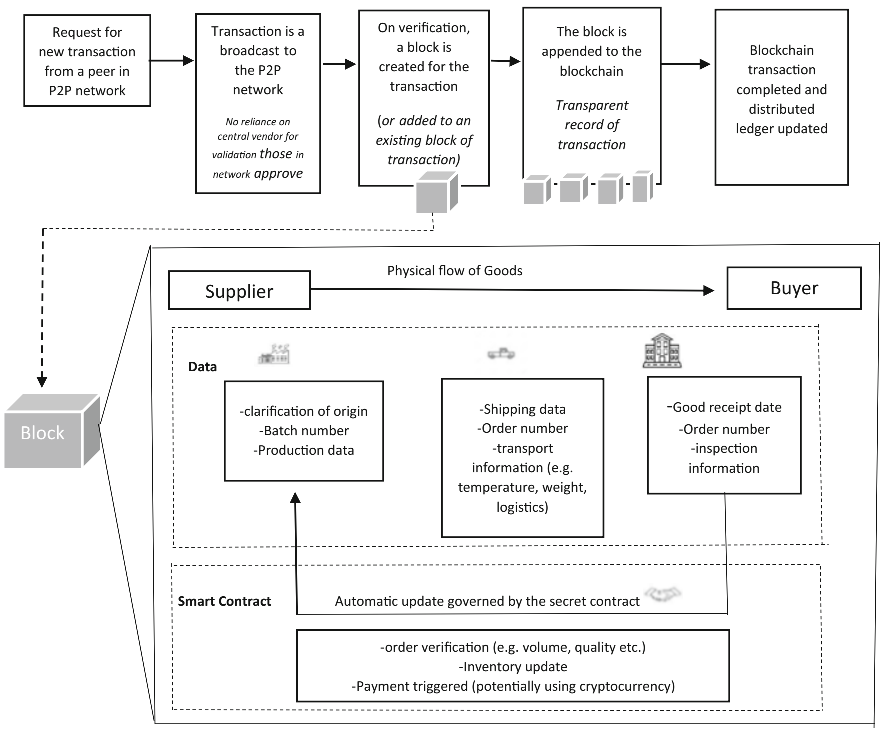

Fig. 1 The application of blockchain in supply chain management (IBM, 2018)

The above Fig. 1 illustrates the basic example of applying blockchain in the supply management system, which includes records or prompts for a smart agreement. The system comprises (a) the formation of the block from appealing a fresh transaction over the block attached to the chain. (b) Further detailing is exhibited with the help of purchaser supplier patterns of which statistics might be documented within the block at every phase and also how the smart agreement can complement the practice overall (IBM, 2018). This regionalized record is more like a representation of a stock archive, which performs as a private integrated basis of information on transactions. That also includes fashioning a vibrant assessment trial based on uniformity amongst the relevant dealers. For instance, industrialized processing, assembly, supply, and protection practices (Angrish et al., 2018). Furthermore, also assists in improving product protection and genuineness, cultivating better services, and lessening the estimation of preservation aspects (Li et al., 2018).

One of the important prospects while considering blockchain in applying to the system of the supply chain is to evaluate and confirm the appropriateness and suitability of the system under consideration. The following prospects are crucial, first, to confirm the involvement of several groups in the system. The operational aspects or transactional aspects are usually managed by the authorities (Lo et al., 2017). In this regard supply chain is a prominent example, as the supply chain is the incorporation of compound, dynamic, and multi-group engagements and activities along with governing and logistical constrictions covering multiple various jurisdictional restrictions (Carvalho & Cruz Machado, 2007). Such a multifaceted system of blockchain offers a collective and mutual structure or setup were ensuring the neutrality of power and stance which discourages the pressure of any group on dictating the projections on others. Therefore, a blockchain system provides perfect suitability in such set-ups and arrangements which includes several parties within the system, where possibly arbitrators are involved within the whole arrangement of the supply chain. Blockchain disturbs the storage of data systematized by a single group, whereas at the same time offers a better, quicker, and more economical system for all (Khan et al., 2020; Kim & Shin, 2019).

However, the system including a single group arrangement can select for the relatively inexpensive setup to gain the similar prospects proposed by the system of blockchain. Similarly, the arrangements which need a trustworthy authoritative body, where this authoritative body can be any system that is accredited for implementing several operational aspects or amending a plan, strategy, or structure for any operational activity within a system (Arun, 2017). Whereas, at the same time this authoritative body can also be the sole point of risk. This usually is the case when the trusted authoritative body faces complications and problems, all the users using the services from the body can be equally affected by the problems and challenges (Mesropyan, 2017). Blockchain is a system that works efficiently in all these circumstances deprived of a trusted authoritative body within a system. However, blockchain does not eliminate the trust element within a system, because all parties are always unprotected from uncertainty (Xue et al., 2020).

Parties within a supply management system are transposing and rearranging their trust in the blockchain system instead of relying on a singly trusted central body or authorities. The blockchain system is the structure that persuades "moral conduct" of the tolerance projections, which includes trusted arbitrators to perform as directive domain for protecting data within a blockchain system (Xue et al., 2020). Blockchain facilitates the parties in a supply chain arrangement for eliminating the aspect of trusting a self-contained particular body for the purpose of maintaining the record of transactional activities, which is described as a "disseminated trust"(Wang et al., 2021).

The other crucial element of the blockchain system is associated with the domain of applying a "smart contractual system", as the system operational domain is firmer to imply for the smart contractual system than the traditional isolated structure. The domain of these contracts contains encoding which controls the interfaces amongst the conjointly untrusting groups (Omohundro, 2014). Consequently, trust is based on the projection that this encoding arrangement cannot be modified with ease. When companies apply a blockchain management system in managing the supply chain, it ensures that not a singular body will control the system in any way, but every user can be eligible for controlling their records and resources, which inherently forms challenging prospects in terms of governing the system. Managing the progression of blockchain system fashions more towards delicacy rather than outmoded risk managing or conventional product managing system (Staples et al., 2017).

Blockchain technological proposes high security and indisputable accessibility concerning supply-chain records. The basic feature of decentralization of the system is the dominant focus where legitimacy and validation can be appraised. Within the system, no individual body has the proprietorship status of the supply chain management and data included (Kim & Laskowski, 2018). Therefore, businesses shifting towards blockchain prospects as an open innovation domain which significantly provides the superiority of the rapidity of the transactions and also can be the economical option in many cases. The transactions within the Overall supply chain management system can be traced and identification is possible after encoding of record, where it cannot be simply altered by any of the parties involved (Hackius & Petersen, 2017). Any transactional record is verifiable by unanimity and consent between the parties involved. Hence, when a record is encoded within the blockchain system, it cannot be reformed or erased by any of the individual parties. As the overall chain is encompassed by a blocking system. Therefore, amending a prevailing block would need the settlement and arrangement amongst all parties involved (Crosby et al., 2016). Similarly, within supply chain managing concerns and logistics, blockchain established singular, verifiable aspects of all activities within the arrangement, and ensures the concurrently of all the processes and activities amongst the parties and users involved within the arrangement (Xue et al., 2020; Khan & Ghouri, 2022).

There can be a significant association between the partners involved in the supply chain because trust between the parties can be established. Whereas, this trusting prospect can be the base for facilitating better attraction towards establishing objectives and tracking distresses (Sahay, 2003). Like, in the context of sustainable approaches and trust within supply chain affiliates and supportive dominance mechanisms for the purpose of forming significance (Cuevas et al., 2015). The blockchain systemization domain provides end-to-end encryption to deliver businesses assurance towards the overall supply chain (Glaser, 2017).

2.1 Application of Blockchain-Driven Supply Chain Management (BCSCM): An Inference on Open Innovation

At present, globalization and competitiveness in a local market enforced logistics to be inclined with innovativeness, the latest technological prospects, and the transformation of systems as per the demands of change defined by prioritization and objectives of the business. Where this transformational domain is also the determinant of competitiveness and density. This density continually administers the requisite for adaptation of systems, deciding on the technological support which can be beneficial on a mutual grounds for businesses and determine formatting prospects (Shcherbakov & Silkina, 2021). The phase of industry 4.0 demonstrates the need for digitalization and the supplementary aspects of combining firms and procedures as a networking domain (Lee et al., 2018). The expansion of inter-linked prospects of procurement and trade methods influences businesses, especially within industrialized segments to enlarge and advance the networking domain of communicating and elevating the supply chain practices business involved (Helo & Hao, 2019).

In the current scenario, the conception of open innovation highlights the prototypical modification in terms of tactics businesses are adapting to the innovativeness concerned actions. Open innovation is the distinction between outmoded tactics and activities within the domain of trade, supply chains, and R&D (Benkler, 2017; Khan et al., 2017). Within the context of open innovation, knowledge streams and market trails from inside and outside the origins and mix up in innovativeness-based business actions, activating greater inferences within the corresponding trade activities and arrangements. The limitations of businesses turn into lesser fixed and networking founded arrangements of businesses achieve distinction in effective stratagems (Chesbrough, 2003a, 2003b). The efforts of businesses related to innovation demand boundary-less practices by effectively employing inward-bound and outward-bound information for ensuring the effective implications of the innovation efforts (Chesbrough, 2006a, 2006b). Chesbrough (2006a, 2006b, 2003a, 2003b) asserted two alienated practices including (1) employing externally focused innovativeness within the organization, and (2) commercializing externally focused innovation efforts with internal innovativeness efforts.

Within the arrangement of open innovation businesses utilize both inside available facts and outside processed knowledge and information for the purpose of research and development progression, which has signed on the overall development of innovatively established produces processes, and services (Vanhaverbeke, 2006; West, 2006). For this purpose, the prototypical open innovation domain permits nurturing alliances with consumers, supplying bodies, and any other bases for value creation concerning the stakeholders of the company. The open innovativeness model is not only the combination of innovative mechanisms but defines universal innovativeness concerned managerial stratagems which determinedly lookout and act on a larger collection of foundations for innovativeness prospects via the variety of paths (Philips, 2009).

The primary need is concerned with the feasibility of information channels, for example, the locality and reputation of products, channels for money and reimbursement inflows and outflows, and records of manufacturing facilities and material availabilities within a supply chain arrangement. Technological support is reflected as the primary facet of these networking structures and innovativeness domain (Tijan et al., 2019).

Like these prospects are included in the supply chain to be sufficient for economic-based settings. Hence, supply chains are systematically shaped by arrangements of dealers and clients, where every client can immediately be a dealer/supplier, and inversely, the dealer can be the client. The basic conception of the supply chain, which was asserted by Oliver and Webber (1982), has gone through major modifications over the years. The contemporary domain of the supply chain is demonstrated as a multifaceted and multiphase arrangement. Which is the alliance of various vibrant and coherent arrangements of activities and systems for users on many levels (Oliver & Webber, 2012). The overall unification of networking construction and arrangement of the supply chain is molded to include the individual users (businesses or distinct individual entities) providing the products or services to one another, and also includes an accumulation of definite consumption charges for the goods (Hahn, 2020).

The supply chain management system of firms is comprised of contracted conditions to supply resources, elements, final goods and to ensure the distribution of final goods to particular markets. Overall, the arrangement shapes the networking structural design of the logistics. However, the concern associated with this simulated incorporation is crucial. Like, the simulated incorporated arrangement provides a solution to various matters concerning the alliances but also includes creating positive exposures and weaknesses based on integration (Scherbakov & Silkina, 2019). The following can be the main concerns associated with the simulated integration within the supply chain management system. (1) Improbability and vagueness associated with the situations of decision making (which are concerning with external setting); (2) improbability and vagueness associated with the user's activities, which are not controlled; (3) improbability and vagueness of the objectives of the users (Su et al., 2019).

However, the carefulness of the issues can increase or reduce with the transactional activities to innovative simulated integration, like the interface of users (and decisions) changes to the extent of the device-to-device collaboration and assimilation of info structures. Where also the effect of individual dynamics can be reduced but not fully vanished on many levels of the arrangement (Casino et al., 2019). When establishing shared undertakings, the major apprehension is associated with the fact that every individual user or party has their concern (s), their standards, and most importantly their stratagems for attaining the objectives planned. As the parties have their objectives to achieve, however, within the supply chain managing system these individual goals may not dispute the overall objectives and agendas of integration. This may prime to an establishment of a multi-criterion concern associated with interconnected standards (Rožman et al., 2019).

Blockchain technological domain has enclosed the effectiveness to amending the essential arrangements and foundations which shape the prospects of contemporary civilization, which includes the reimbursement structures, marketable settlements, and numerous executive arrangements which occupy the societal domain (Casino et al., 2019). The influence of scattered records and smart contractual undertakings to ensure the elimination of confrontation and drastically decrease the cost of trades, while at the same time providing better security arrangements of trade, certainty and most importantly ensuring transparent arrangements amongst the parties (Pazaitis et al., 2017). These aspects are concerned with the domain of businesses and industrialized segments, to facilitate them, especially regarding augmentation and mechanization of industrial setups and transactional activities (Rosa et al., 2017).

Certainly, blockchain is emerged as the utmost glorified, fiercely discussed, challenging, and still favorable technological support meanwhile in the origination of the internet. The broad and vigorous potentiality of blockchain is presently well as an indication of innovation and change (Tiwari et al., 2018). Consequently, the prominence and significance of blockchain are beginning to access businesses and processes globally, receiving substantial firms which are facilitating for enhancement of the competencies of the blockchain. In accumulation, to artificial intelligence (AI), blockchain has appeared as a prominent and stimulating high-tech progression and innovativeness (Ghouri et al., 2022; Ghouri et al., 2020; Teodorescu & Korchagina, 2021).

These features are principally significant for commercial and organizational activities, which permit the growth, development, and systematization of business and trading. Similarly, in supply chain managing concerns and logistics, establishing individual, validated activities nearly concurrently amongst all parties involved in trading activities is critical (De Filippi & Wright, 2018). Being the fragment of open innovation and technological prospects, blockchain establishes a larger extent of flexibility and distribution of authority which can establish favorable settings for open innovation. However, various affirmations are still assumed on expectations and activities which are disposed to the similar drawbacks of the current market systems and economic domain (Lansiti & Lakhani, 2017). The reasoning of dealings and connections exposes a faithfulness to unknowable and selective possession and controlling of capitals and supremacy domain which is included within the arrangement. At that point, accuracy and transparency can be the utmost authoritative and dominant prominences of the arrangement to regulate and force manufacturing and hinder undermining dynamics (Hackius & Petersen, 2017).

3 Conclusion

This chapter precisely addressed the domain of blockchain-driven supply chain management concerns and the overall purview of open innovation and its need for the industrial sector. Which focused on the importance of blockchain-driven supply chain from the open innovation perspectives on the major concerns like (1) supply chain tractability, (2) supply chain data security (3) overall supply chain financial prospects, (4) and evaluating the views on the application of blockchain in the dominion of supply chain and open innovation.

Overall this chapter highlighted the advantages offered by the application of blockchain systems within the domain of supply chain and concerns of open innovation. In the context of the supply chain, blockchain benefited the industries, especially on the concerns related to tracking ability with the trustworthy data and as well as an advanced level of consistency and trustworthiness amongst the connected parties with ingenuousness, transparent processes, reliance, eliminating chances of cheating and accessibility to end-to-end encryption facilitations (Xue et al., 2020). Which at the same time benefited the businesses by providing cost-effective operations. The advantages are not limited to business only in terms of tracking facilitation, monitoring, and appraising the overall supply chain management but at the same time also provide benefits to consumers from the prospects of product excellence and safety issues (Khan et al., 2022c).

However, further studies can also be done in the domain of evaluation and validation concerns by focusing on the practical examples of industries adopting blockchain-driven supply management systems. Assessing the impact of this application in the domain of open innovation for businesses and concerned stakeholders.

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Blockchain Supply Chain Management and Supply Chain Sustainability

Muhammad Rahies Khan, Mustafa Rehman Khan, and Kesavan Nallaluthan

1 Introduction

Supply chain management has been operated worldwide with great efficiency and smoothness till the last quarter of 2019. The last period of 2019 reported the immense disruption in the supply chains across the world due to the spread of the COVID-19 pandemic. This disruption has originated with the role of different new technologies and their role to optimize supply chain efficiency. These technologies include industry 4.0 like the Internet of things (IoT), robotics, artificial intelligence (AI), machine learning (ML), Big Data Predictive Analytics (BDPA), Blockchain technology, and many others (Ghouri et al., 2022; Ghouri et al., 2021; Khan & Manzoor, 2021; Khan et al., 2017).

One of the major blows caused to global supply chains by the COVID-19 pandemic was the dearth of visibility, traceability, and exchange of data. To promote visibility, traceability, and resilience in supply chains, blockchain technology was one of the prominent technologies that were incorporated by the firms through the utilization of distributed and decentralized ledgers (Prashar et al., 2020). These technologies accelerate the visibility and traceability of the goods and merchandise in the supply chains, hence promoting transparent and robust connectivity in the whole SCM process (Bai et al., 2022). Different businesses such as Ripple and Libra

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in financial services, IBM Food Trust and Bumble Bee Foods in food and agriculture, and ProCredEx and MediLedger in healthcare and pharmaceutical SCs have extensively incorporated blockchain technology in their SCs operations to optimize the visibility and traceability issues.

Previously, firms across the world and especially in developing and emerging economies are operating and performing business processes through traditional ways of manufacturing and consumption. The major objective of these firms is to gain efficiency and effective production. However, their production and consumption patterns are majorly contributing to environmental and social degradation through climatic changes and massively affecting human lives (Ali et al., 2021; Kusi-Sarpong et al., 2022; Mubarik et al., 2022; Kusi-Sarpong et al., 2022). Adoption of sustainable manufacturing and other business processes are considered to be the vital tool to address these pessimistic changes, however, achieving sustainable production is a highly sophisticated and challenging task for firms. Therefore, the emergence and adoption of industry 4.0 technologies have changed the way forward for firms to gain these challenging and sophisticated sustainability issues (Mohan & Katakojwala, 2021; Qader et al., 2022; Khan et al. 2022a, 2022b). Among industry 4.0 technologies, the use and implementation of blockchain technologies are prominent in the literature.

Hence, regarding the use and consequences of blockchain technology in supply chains, there exists a common consensus and agreement among businesses worldwide. Besides all the other benefits of this technology, blockchain is also evident in the previous literature to enhance supply chain sustainability, one of the largely discussed phenomena in the recent era (Akhtar et al., 2022a, 2022b; Jabbar et al., 2021). Some of the other digital solutions to sustainable performance in SCM were found to be unreliable due to data disintegration, inadequate reliability, and various distributed and implementation regulations. Therefore, blockchain technology has emerged as a leading tool as it provides reliable databases, traceability, visibility, and control mechanisms. Previous literature also indicated that blockchain technology has provided many significant influences in different fields during and after the disruption (Papadopoulos et al., 2020). Therefore, this chapter would be the first ever that addresses the nexus between blockchain-driven supply chain and supply chain sustainability. Further, this chapter concentrated on blockchain-driven supply chains and their exceptional role in supply chain sustainability i.e. economic sustainability (governance efficiency), environmental sustainability, and social sustainability (social equity).

Before exploring deeply, the blockchain-driven supply chains and their role in supply chain sustainability, this chapter is interested to address the following issues:

- Definitions of blockchain technology
- Emergence and growth of blockchain technology
- The present scenario in blockchain technology implementation in supply chains
- Blockchain-driven supply chain management
- Types of blockchain technology
- Definitions of supply chain sustainability

- Role of blockchain technology in achieving supply chain sustainability
- Barriers to blockchain technology implementation

1.1 Emergence and Growth of Blockchain Technology

The concept of blockchain started from the *cryptographical secured blocks* in 1991 by Haber and W. Scott Stornetta. Later on, in 1998 Nick Szabo started working on *"bit gold"* which was a decentralized digital currency. In 2000 Stefan Konst formulated a theory of cryptographically secured chains and also provided the way forward for their use and implementation. In 2008, a group of developers working under the project "*Pseudonym Satoshi Nakamoto"* published a paper on the model of blockchain and also uses the first-ever blockchain as a public ledger and recorded different transactions by using bitcoin. The breakthrough was witnessed in 2014 by separating blockchain technology from the currency and blockchain 2.0 was introduced when certain financial and other similar transactions were noted. However, the proper implementation of blockchain in business operations was recorded worldwide since 2017 (Bai et al., 2022; Kusi-Sarpong et al., 2022; Park & Li, 2021).

Since that, International Data Corporation (IDC) has reported that more than $ 4.1 billion has been spent till 2020 on the utilization and implementation of blockchain globally and this estimation and spending is 50% higher than that of 2019. Experts are in the expectation that the consumption and utilization of blockchain technology will rise to $ 17.9 billion by 2024 (Business Wire, 2020). This immense utilization and implementation of blockchain technology in the business operations and supply chains is witnessed due to the spread of the COVID-19 pandemic as this disruption has reported different weaknesses and failures in supply chains and other business operations. Since that organizations are immensely implementing this blockchain technology and digital ledger technology (DLT) in their business operations. These are one of the best alternatives to all the deficiencies highlighted in the supply chains (IDC, 2020). Till 2018, there were only 1000 blockchain-oriented startups are recognized globally. Some of them like Accenture, Deloitte, and PwC have shared their experience using these technologies and recommended their potential benefits in their studies. Blockchain technology has been widely used in the fields of finance, supply chains, and other economic and governance activities. China, one of the world's economic hubs has used this technology in more than 140 government services in Beijing city only (Kshetri, 2021).

1.2 Present Scenario of Blockchain Technology Implementation in Supply Chains

Blockchain technology from its inception in 2017 has started to play its deep-rooted role in international trade to facilitate the global supply chains and other business operations. In 2018, Maersk and IBM launched a jointly operated blockchain-based shipping solution named as TradeLens. The major role of this jointly developed venture was to promote harmony among the supply chain partners by sharing information, enhance combine global trade, and promoting the transparent transactions record of these partners (Rasiah et al., 2017; Mubarik & Naghavi, 2020). Till 2020, the TradeLens network has approximately 150 registered members. Among them, five of the top six ocean carriers are; (i) APM- Maersk (ii) Mediterranean Shipping Company (MSC), (iii) China Ocean Shipping Company (COSCO), (iv) Hapag- Lloyd, and (v) Ocean Network Express (ONE). Combinedly, they contributed about half of the world's cargo services capability. Since March 2020, this platform has crossed 15 million containers worldwide.

Similarly, there are several other initiatives in this line. In November 2020, nine ocean carriers have announced the formulation of a joint blockchain-driven platform named Global Shipping Business Network (GSBN). These include; (i) COSCO Shipping Lines (China), (ii) Compagnie Maritime d' Affetement and Compagnie General Maritime (CMA-CGM), (iii) Evergreen Marine (iv) Orient Overseas Container Line (OOCL) a Hong Kong-based company, (v) Yang Ming, (vi) DP World, (vii) Hutchison Ports, (viii) PSA International and (ix) Shanghai International Port and Cargo Smart. Among them, OOCL is the owner and founder of this blockchain-based joint platform GSBN. Additionally, some of the European-based organizations having operations in the developing world too like AB InBev, Accenture, APL, Kuehne plus N, agel, etc. also launched blockchain-based databases to promote transparent information and transfer of documents.

2 Definitions of Blockchain-Driven Supply Chains

> Technology used to store different databases and distribute the data among all the stakeholders including in the similar database and networks is called blockchain technology (Crosby et al., 2016).

> A digital, decentralized, and distributed ledger in which transactions are logged and added in chronological order to create permanent and tamper-proof records (Treiblmaier, 2018).

With this technology, stakeholders can access real-time information about all transactions. Previously, the said data was stored on a centralized hub system from where the data transactions information can be accessed by the stakeholders directly. In contrast with previously stored data, blockchain technology allows all the stakeholders to segregate the information on decentralized, secure, and smart databases. Hence, it allows the members to access the real-time transaction through a peer-to-peer network system sequentially. To enhance the security of the databases, signatures are used that are valuable to enhance the security and transparency of the systems. Therefore, this technique is useful to address operational issues and their solutions. Moreover, the transaction once recorded on the system with specific signatures or symbols, remain permanently on the database and cannot be changed. This characteristic is immutable in the system. In conclusion, it is said that this technology is used to store the data on different databases and can be distributed easily among the stakeholders having membership or partners in the supply chain network and this technology offers several benefits to the majority of the industries especially the supply chain networks where the role of SCs visibility, security and traceability is considered to be an essential element (Azmat et al., 2022; Piprani et al., 2022; Mubarik et al., 2022).

3 Types of Blockchain

Broadly speaking, there are three main types of blockchains which are as follows:

(i) Public blockchains or permissionless blockchains
(ii) Private blockchains or permissioned blockchains
(iii) Hybrid blockchains

3.1 Public Blockchains

This type of blockchain is an open-accessed database and did not require any permission to write or read any type of information on it. Therefore, it does not have any admin or controlling body, anyone can join, read and post their transactions on it. Some of the major examples of this type of blockchain are Bitcoin and Ethereum.

3.2 Private Blockchains

These blockchains as compared to public blockchains are restricted and are managed and controlled by somebody or authority. These are the major blockchains and are widely used and implemented in supply chains globally. These are the secured and reliable sources to communicate and post relevant information and transactions (Staples et al., 2017). A large number of companies had shifted their operations from public blockchains to private one due to the demand of supply chain partners and customer pressures as these are more secure, reliable, and transparent (Kapilkov, 2020).

3.3 Hybrid Blockchains

Hybrid blockchains are a combination of public and private blockchains. In the background, business transactions are carried out through the permissioned chains. Then these transactions are connected with the public chains by using an application programming interface (API) that allowed the customers and supply chain participants and partners to participate in business transactions and gain information about the products and services (Mearian, 2020).

Some of the famous hybrid blockchains are consortium blockchains. In hybrid blockchains, a group rather than individuals control the blockchains. In these blockchains, every node and connection has a different role and benefits. Some of them deal with the consensus procedure and others deal with the transaction process. Organizations operating in the same industry use to implement consortium blockchains as a priority blockchain. Organizations implement blockchains to promote their work efficiency, smooth segregation of information and resources, accountability, and enhance transparency (Blaha & Katafono, 2020). One of the widely used hybrid blockchains is R3 a multinational digital service provider to many industries and has more than 300 participants to date.

4 Blockchain-Driven Supply Chain Management

SCM is a process that deals with the transportation, sorting, and distribution of materials and information from point of origin to point of consumption and even the retrieval of an end-of-life product (Sarkis & Dou, 2017). However, the incorporation of blockchain technology in the entire SCs to handle the most imperative objectives of SCM like visibility, traceability, and security of the entire chain is called blockchain-driven supply chain management. The six major BCSCM attributes are decentralization, visibility, reliability with security, synchronized transactions mechanism, smart contracts, and cost efficiency (Kumar et al., 2020; Song et al., 2019).

4.1 Decentralization

Previously held databases implemented in supply chains and other fields were highly centralized. However, blockchain technology is a decentralized database that conducts valuable sustainable and transparent functions for the participants and helps to promote trust among them. Moreover, the old versions of databases were highly complicated and hectic and some of them required a third party to operate them for firms whereas blockchain is free of third-party involvement and performs the tasks faster in less expensive manners. Due to these and many other features, blockchain was similarly gaining attention and implementation from parties and companies who were in a state of denial and were unconvinced about its adoption (Hackett, 2017).

4.2 Traceability/Visibility

The real-time location identification of goods and merchandise through blockchain-driven technology is called traceability or visibility. Through the BCSCM this real-time and exact location identification of goods becomes easy and approachable. For example, detailed information about container freight management and documentation record of transactions performed can be stored and shared through blockchain.

Hence, all the information of transactions has been verified in real-time by the members with the association of the blockchain technology, therefore, improving the transparency (Pournader et al., 2020).

4.3 Reliability and Security

Blockchain technology is useful in the identification of counterfeiting products and helps to minimize the risk of unlicensed products distributed in the regional markets. The decentralized property of blockchain is useful in the identification and reduction of these products. Moreover, the majority of the industries like the food industry have incorporated this technology into their operations to enhance their supply chain efficiency and performance (Rogerson & Parry, 2020). Besides this blockchain technology can be used to trace and manage the inventory either in stocks or during logistics by keeping a record of all the transactions' historical data. This feature of blockchain technology in logistics and inventory management promotes customer trust and this leads to the visibility of shared information from the participants.

4.4 Synchronized Transactions

With the launch of blockchain technology, the entire process of SCs has been simplified. Previously, the formulation of contracts among the suppliers and the buyers are much more complicated and took financial and other monetary and technological resources. But the implementation of blockchain has made these hectic processes very simple. This technology also eliminates all the unnecessary, complicated, and resource burdens from the supplier-buyer contracts by removing the additional documentation. Hence, smart contracts originated in buyer-supplier relationships. Smart contracts are transaction protocols that are supported by the automatic accomplishment and control of all the documentation involved in the contracts. Through this process, all the parties involved in the contracts can easily check the digital documents through their signatures on the blockchain system (Pournader et al., 2020).

4.5 Smart Contracts

Computerized codes and scripts that contain contract terms and conditions and business regulations are smart contracts. These contracts are automated and execute and perform the agreement terms automatically. Smart contracts analyze the predefined terms and conditions that include business rules and consequences that are already agreed upon and accepted by all the partners and then perform the desired action according to the situations. These terms and conditions are already fed into the system and evaluated and approved by the partners (Luu et al., 2016).

Further, the computerized codes are self-regulated and executed, therefore, abolishing human interference in smart contracts. The issue of trust in existing contracts is eliminated by the smart contracts and partners can blindly trust the database. Terms and conditions of smart contracts are already written on the database through computerized programs and stored on the blockchain database. Therefore, smart contracts have eliminated the interference of humans in transactions and contract formulations. The interference and services of financial experts and legal teams have been reduced due to the implementation of smart contracts. This elimination has enhanced the efficiency of transactions and business operations. One of the widely used examples of a smart contract is automatic online payment. It is done when certain requirements and regulations are fulfilled (Giancaspro, 2017).

4.6 Cost Efficiency

SCs are a combination of various processes, steps, and procedures that are heavily concentrated with cost burdens that lead to increased total costs of production. However, recent literature suggested that business operations worldwide are competing based on their cost-efficient supply chains (Sarkis & Dou, 2017). This cost-based competition in SCs can be achieved through the incorporation of the latest technologies like blockchain as this technology helps to reduce inventory costs, logistic costs, and total production costs. Logistics is one of the most prominent and cost-oriented elements of SCs which encompasses all the steps from point of production to point of consumption. Hence, through blockchain technology, unnecessary losses and other irrelevant processes in logistics can be minimized to enhance profits. Besides this, the inventory and stocks are one of the backbones of any production concern, therefore the accurate forecast of inventory required as per demand is essential. Moreover, the function of just-in-time inventory can minimize unnecessary inventory and stocks. Unnecessary inventories can bring economic burdens and firms face failure in their competitions. All the cost-related optimization in the SCs can be achieved through the incorporation of blockchain technology only and where necessary with the combination of other industry 4.0 technologies. All the attributes of blockchain are therefore beneficial for the SCs operations and the blockchain-driven supply chains are essential to optimize the efficiency of business operations through the promotion of traceability and security measures (Benton et al., 2018) (Fig. 1).

5 Supply Chain Sustainability

The term sustainability was introduced by World Commission on Environment and Development in 1987. From its inception, sustainability has come out with approximately 300 definitions. The widest used and acceptable definition of sustainability is provided by United Nations in 2005. According to this definition *"sustainability*

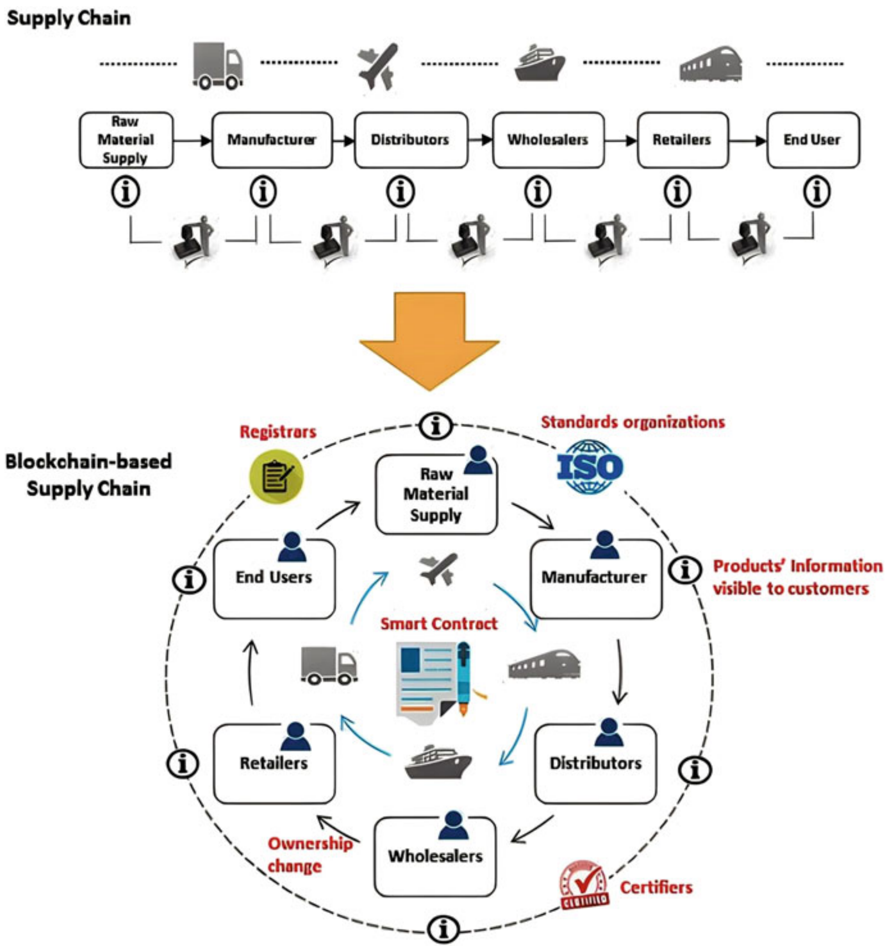

Fig. 1 Transformation of Supply Chains to Blockchain Based Supply Chains. Source: Saberi et al. (2019)

refers to the achievement of future goals without compromising the interest of future generations". Further, they divided sustainability into three pillars; economic sustainability, environmental sustainability, and social sustainability, and mainly known three pillars of sustainability.

Among them, the incorporation of environmental consciousness into the business operations of firms is called environmental sustainability and included the external influence or side effects of firms on the environment. The major environmental factors include the consumption of resources, energy sources, waste creation, and emission of gases through business operations. Similarly, social sustainability refers to the issues of workplace health and safety, workforce diversity, gender-discriminatory factors, equal employment opportunity, child labor, and other human rights factors. The economic or governance sustainability is the company's long-term success concerning profit and also includes the firm's internal affairs like communication among the workforce, workforce relationships, and organizational internal environment. The environmental, social, and economic sustainability are collectively addressed through ESG. This framework is widely used and incorporated by the majority of firms to highlight their commitment and engagement toward the sustainable performance of firms (Khan & Ghouri, 2022; Mahmood & Mubarik, 2020; Mubarik et al., 2021; Mubarik & Naghavi, 2020; Ahmed et al., 2021).

The incorporation of environmental, economic, and social sustainability issues in the supply chain networks comes under supply chain sustainability. Supply chains are the major contributors to the economic, social, and environmental performance of organizations. However, these factors also contribute to economic, environmental, and social burdens in terms of losses, waste creation, and pollution. To address these issues the term supply chain sustainability was introduced and various techniques are used to address them. One of the major practices to address these issues was introduced as green initiatives or green practices (Ghouri et al., 2020; Khan et al., 2020).

Unilever has incorporated blockchain technology in their supply chain operations to obtain sustainability as discussed in case study 1 below.

Case Study-1

SAP, Unilever pilot blockchain technology supporting deforestation-free palm oil

Raw materials like palm oil are often mixed with physically identical raw materials from verified sustainable and nonverified sources after the "first mile" of the supply chain, causing the origin information to be either hidden or lost.

In a successful proof of concept in Indonesia, Unilever applied GreenToken to source more than 188,000 tons of oil palm fruit. The solution enabled Golden Agri-Resources and other suppliers from whom Unilever sources to create tokens that mirror the material flow of the palm oil throughout the supply chain and capture the unique attributes linked to the oil's origin.

"With GreenToken, we want to bring the same traceability and supply chain transparency to bulk raw materials that you get from scanning a bar or QR code on any consumer product," said Nitin Jain, co-founder and general manager of the GreenToken by SAP solution, SAP. "Our solution allows companies to tell what percentage of palm oil products they purchased from a sustainable origin and track it to the end consumer product."

"Technology has played an important role in our efforts to enhance visibility and transparency in our own palm oil supply chains," said Anita Neville, chief sustainability and communications officer, Golden Agri-Resources. "Our

(continued)

participation in the GreenToken by SAP solution pilot with SAP and Unilever provided useful insights in how to successfully pass information between different actors in the supply chain."

The GreenToken solution helped Unilever track, verify and report in near real time the origins and journey that palm oil takes through its long and complex supply chain.

"Unilever is committed to achieving a deforestation-free supply chain by 2023, and blockchain technology has the potential to help companies, like ours, track their supply chains to ensure the commodities we source respect people and the planet," said Dave Ingram, chief procurement officer, Unilever. "We are encouraged by the promising results of our pilot with GreenToken by SAP, the latest building block in our tech-enabled approach to ensure a more traceable and transparent supply chain."

The work with GreenToken enhances Unilever's ongoing and industry-leading efforts to gain full visibility of its supply chain.

5.1 Blockchain-Driven Supply Chains and Environmental Sustainability

Environmental sustainability is associated with the interests and benefits of generations' equity received through the utilization of natural resources and environmental features. Environmental sustainability has been widely discussed in academia, industry, and government literature. From the supply chain perspective, environmental problems raise from both the early and later stages. The early stage includes the process of movement of raw material from point of origination to point of production however in the later stage, the segregation of the pollutants into the environment through the flow of economic activities to the natural environment. The first stage leads to the reduction of natural resources and their deterioration which leads to compromise of the interests of the future generations. In the second stage, air pollution, water scarcity, soil deterioration, the spread of diseases, and future generations' life standards are severely impacted. According to a recent the United States Environmental Protection Agency (US EPA) survey, manufacturing companies contributed 40–60% of carbon emissions into the atmosphere and non-manufacturing concerns contributed 80% of carbon footprints in the atmosphere.

To address the environmental sustainability in the SCs, incorporation, and adaptation of green initiatives to protect the natural resources and environment are essential techniques. Sarkis (2003) suggested a strategic decision model for the implementation of green supply chain management and also pointed out the challenging nature of business operations and their association with the natural environment. This dynamic nature of business operations needs real-time tracking, monitoring, and evaluation systems that could serve the members simultaneously in the SCs. Therefore, the incorporation of blockchain technology that serves to provide adequate features like traceability, reliability security, synchronized transaction procedures, and cost efficiency can serve as a better alternative measure to environmental issues as compared to the previously applied traditional methodologies to address the environmental problems. Particularly, blockchain technology is useful for many reasons but three of them are prominent:

(i) Environmental Emission Reduction and Monitoring
(ii) Resource Management
(iii) Waste management

(i) *Environmental emission reduction and monitoring*

This technology helps the supply chain partners to monitor and trace the amount and location of the pollutant emissions like carbon pollutants, wastewater, or any other toxic or hazardous substances at every step. Hence, helps to formulate remedial measures and environmental regulations. In addition to this, supply chain partners can also be able to verify the adherence of upstream SC partners to the environmental regulations and policies. Due to this monitoring and evaluation process, the emission of these pollutants can be minimized that ultimately leading to environmental performance.

(ii) *Resource management*

One of the other uses of blockchain technology is the monitoring and evaluation of the extraction of raw material. This monitoring reduces the unnecessary extraction and consumption of natural reservoirs which helps to reduce the chances of deforestation and salinization. Furthermore, this procedure also helps to promote the use of renewable energy sources and the reuse and recycling of the material used. So far, not a single study has been witnessed that is successful to show the sustainable resource-use percentage and the mechanism by which it can be measured.

(iii) *Waste management*

Thirdly, blockchain technology also helps businesses to monitor and track their industrial waste which also promotes the rate of recycling, reuse, or proper disposal of their wastes. For instance, IBM Food Trust has implemented this technology to record and monitor their food supply chains and the wastes created through the synthesis and distribution of food (Köhler & Pizzol, 2020). Through this technique, IBM Food Trust not only reduces the total costs but also enhances environmental protection. Further, energy efficiency and use of renewable energy resources in the SCs activities can also be addressed through blockchain technology but so far this area needs further elaboration and explanation from academicians and practitioners.

5.2 Blockchain Driven Supply Chains and Social Sustainability

Social sustainability deals with the impact of business operations on the workforce, customers, and society at large and also addresses the promotion of a healthy society. Social sustainability has been widely discussed and addressed in different seminars, conferences, and other platforms but in supply chain management this has not been addressed properly. However, little has been done at the economic and social interaction level where employees are involved. One of the major social sustainability concerns in the SCs is accountability and responsibility while purchasing, consuming, and distributing natural resources for possible manufacturing (Mani et al., 2016).

Blockchain-driven supply chains can be beneficial to social sustainability in the following ways:

(a) Blockchain technology can help to exploit child labor and unethical processes in supply chains as evident previously in the diamond industry.
(b) Blockchain technology helps supply chains to enhance the information security and immutability characteristic protecting all the participants from corruption and misconduct.
(c) Besides these, blockchain can also help buyers to procure goods from reliable suppliers as blockchain can keep the record of all suppliers on the database hence, avoid from a selection of unethical or fraudulent suppliers.
(d) In the sourcing industry, blockchain also promotes the transparent sourcing process as it prevents a selection of unethical and unfamiliar suppliers.

By summarizing the role of blockchain-driven SCs in social sustainability, it is evident that the immutability and transparent record of all parties in blockchain further appreciated the social sustainability dimensions and other social parameters. A transparent and balanced record of transactions on the database reduces the chances of corruption from all the participants in the SCs. Additionally, the traceability feature enhances the ethical sourcing process due to the product history on the database. Finally, the blockchain helps in protecting human rights violations and promotes a safe, healthy, and prosperous business environment in the supply chain network (Di Vaio & Varriale, 2020; Saberi et al., 2019).

5.3 Blockchain-Driven Supply Chains and Economic Sustainability

One of the challenging jobs for supply chains is to achieve economic sustainability without compromising environmental and social sustainability. Therefore, economic sustainability refers to the achievement of economic goals and growth without disturbing social and environmental performance and mostly it is also known as governance. To achieve economic sustainability, companies need to promote transparency, traceability, and accountability in their management structure so that firms can enhance their strong relationships with their external partners and gain the attention of valuable investors (Nayak & Dhaigude, 2019; Seuring & Müller, 2008). Economic sustainability promotes the achievement of the long-term goals for supply chains as it enhances the company's competitiveness, healthy and transparent corporate affairs, and enhance overall profits. Moreover, this also promotes social and environmental sustainability.

Despite achieving economic sustainability, it is important to address the following challenges:

(a) The propagation of irregular information among the supply chain partners can lead to altering the transparent structure in management and this scenario develops in global supply chains due to massive outsourcing.
(b) The absence of reliability is another substantial issue for the economic performance of supply chains as it leads to corruption and unethical deals due to a centralized transaction process.
(c) Traditional SCs can't achieve and monitor traceability and reliability along with the supply chain networks with minimum bare capital investment and managerial efforts. However, some of the SCs use voluntarily adopt environmental management systems like ISO 14000/14001 to address sustainability but it does not serve as a long-term measure against these challenges.

Following are the two main factors that motivate and promote economic sustainability:

(a) Corporate governance
(b) Corporate behavior

The former factors can be exploited from board policies, ownership, and the accountability of management and the latter can be explored from leadership style and ethics, organizational corruption and instability, anti-organizational practices, financial instability, and tax transparency. All these parameters are supported by Hastig and Sodhi (2020). They emphasize that organizational collaborative capabilities, technological acceptance, SCM practices, leadership role, governance, and traceability struggle collectively can promote SCM success achievement. Keeping these SCM issues into consideration, it is evident that the role of blockchain technology can enhance the economic sustainability of organizations. Following are the three main aspects of blockchain technology that can serve to enhance the SCM economic performance.

(a) The incorporation of blockchain technology enables the members of the network to immediately and simultaneously access reliable and accurate information thus promoting transparent and immediate transactions.
(b) Secondly, blockchain technology also provides sound solutions against irregular information through the introduction of smart contracts. These smart contracts a feature of blockchain technology can reduce the chances of corruption by

providing symmetrical information to all the participants and the deal is finalized only when all the members are agreeing to finalize it.

(c) Blockchain technology can store all the transactions processed in the past by suppliers and buyers. This historical information about suppliers like on-time deliveries, issuance of invoices, and payments can enhance the transparency and reliability of those suppliers and thus it helps to promote trust and collaboration among all the partners (Tan et al., 2020).

To recognize the sustainable contribution of companies worldwide, different rating agencies are working across the world and are known as ESG rating organizations. These ratings are based on the rate of carbon emission and the contribution to international trade in the global market. There are a lot of ESG rating agencies across the world that use different methodologies and parameters to assess the sustainable performance of companies. One of the well-known ESG rating agency is MSCI that issue the MSCI ESG rating to more than 8500 companies based on 37 ESG key factors within the three sustainability headings. Besides, the MSCI rating agency, Sustainalytics is another ESG rating agency that analyzes the risk of a company's business value due to three sustainability fronts. However, these rating agencies are not adequate and authentic and differentiate their parameters of measurement according to industry and social values. These ESG rating agencies are not completely successful to represent the sustainable performance of these companies (Escrig-Olmedo et al., 2019) and a further detailed list and explanation of these agencies are elaborated by Huber et al. (2017).

Case Study-2 Building on Success

The pilot project realised a substantial reduction in costs for the various partners involved in the purchase of a control valve. Processes became more streamlined through less time spent on administration, documentation and managing interfaces with other parties in the supply chain. "One-source of truth".

The initial results have been very positive, as Terry Booth, Project Engineering Manager at Worley said: "The pilot test has already realised cost benefits, improved workflow efficiency and increased transparency during workflow execution that will lead to a higher quality and safer product. We are excited to expand the project to bulk and multiple commodities and to be at the forefront of globalising the use of blockchain in our industry. The opportunities are endless!"

The pilot has shown that intercompany collaboration can address industry-wide issues. Jordan Zaiser, Director, Global Project Management at our equipment partner Flowserve, said, "The digital passport has brought together the full value chain to look at opportunities to create efficiencies to avoid the common problems that plague our industry. All the partners have worked well

(continued)

together to ensure that the outputs are beneficial for everyone without bias. Flowserve is excited about being part of the process to change the way we work, communicate and share information."

The decentralised digital passport complements the aims of the Joint Industry Programme (IOGP) for **Standardizing Procurement Specifications (JIP33)**. Participants in this programme, including us at Shell, are working to improve the specification, procurement and delivery of equipment for the energy industry by introducing standardised procurement specifications. JIP33 will help to reduce supply chain variation and increase efficiency, thereby providing significant value in scheduling and capital cost control.

Daniele Raini, Director of Global Operations Support at Bureau Veritas welcomes the opportunity to introduce a system that enhances quality assurance. "The digital passport has proven to be a powerful platform to enable all the stakeholders involved in purchasing, manufacturing, inspecting and delivering project equipment and materials to cooperate and to exchange data in a timely and transparent manner. Bureau Veritas is fully supportive of continuing the journey with Shell by complementing the solution with dedicated quality assurance and management frameworks so as to provide end-to-end trust in the data in the ecosystem and open the doors for wider adoption in the industry."

Future applications

The vision is to develop a streamlined, standardised, paperless and errorless equipment procurement process that can be adopted by the entire supply chain and that is accelerated by joint industry governance. The digital passport system has many potential applications beyond streamlining equipment audit trails. It could be used to track the carbon footprint of an item or to enable one-click, off-the-shelf procurement with a ready passport and automated milestone payments using smart contracts.

Gavin Langley Vice President Integrated Gas Projects at Shell believes that "The decentralised digital passport is the tip of the iceberg, and I see many uses and a lot of expansion potential for this technology. In the wake of the COVID-19 pandemic, there are clear benefits in using remote tools that are fully integrated into the blockchain for complete traceability and assurance without excessive travel. This is also a positive for the environment."

Dick Wynberg, Vice President Contracting and Procurement at Shell Projects and Technology added: "Some of the capability this concept has unlocked can be found beyond the technical tracing of bulks and components. The digital inspection processes during manufacturing, the factory acceptance tests, the certifications and supply chain logistics all the way to the Project site or Asset are mapped in real time, and everyone has access to (their respective parts) of the same data. Projecting this forward sees the potential on the Project-to-Asset transfer process in a data-centric way. The more we can

(continued)

leverage this process across bulks and more components, the more we can benefit from costs savings that benefit our bottom line. I believe that by adding this capability to our existing ARIBA/SAP process, this can have a significant impact on overall pricing".

Shell believes that a blockchain-based system has huge potential to change how businesses interact and to encourage new partnerships that will accelerate change. Widespread adoption of the decentralised digital passport could deliver industry-wide benefits, so, to achieve this, we are working with our partners to develop effective governance and encourage widespread adoption.

The digital passport ecosystem is learning, developing and growing. We look forward to the next phase of collaboration!

6 Barriers to Implementing Blockchain Technology in Sustainable Supply Chains

The application of blockchain technology to achieve sustainable supply chains has its benefits and advantages but there are certain internal and external barriers and challenges that inhibit the adequate incorporation of this technology. Before appropriate implementation and adoption of blockchain technology, business operations need to understand and identify these challenges and barriers. Various books, journals, and conferences have discussed these barriers previously. These identified barriers are the hindering factors in the implementation of blockchain technology in general and for achieving supply chain sustainability specifically. These barriers are classified into four major categories i.e., intra-organizational barriers, inter-organizational barriers, system-related barriers, and external barriers (Jabbar et al., 2021; Saberi et al., 2019).

6.1 Intra-Organizational Barriers

The formulation, adoption, and implementation of any activity in business started from the internal environment of the organization. Previous literature, especially in the supply chain context, revealed that the firm's management is the sole internal driver for the success or failure of any activity, and top management, middle management, and employees are the key factors in the successful implementation of policy, rule or practice (Sarkis & Dou, 2017). Nevertheless, some of the managerial capabilities are unsuccessful to execute and implement the long-term organizational goals and initiatives, thus failing to adopt the change, especially the technological change and sustainability objectives. Hence, the followings are the major intra-organizational barriers to the implementation of blockchain technology:

(i) Deficiencies of managerial commitment act as discouraging factors, especially in the implementation of sustainability objectives through the incorporation of green initiatives or other supply chain practices.
(ii) Similarly, the lack of interest, knowledge, and managerial commitment toward supply chains can also complicate the allocation of resources and restrict financial decisions (Fawcett et al., 2006).
(iii) Welcoming and adopting the technological change always requires high investment in the purchasing and installation of some hardware and software which is sometimes a difficult decision for the partners to execute.
(iv) Inadequate organizational policies to accept and implement blockchain technology may also challenge the incorporation of blockchain technology internally thus to accept the technology, organizations have to transform their existing organizational culture, norms, and values.
(v) Besides this, appointing new roles, responsibilities, and expertise to perform the newly established technology requires knowledge, expertise, and skills in blockchain technology. However, the existing expertise and skills are not adequate to handle this new situation confronting as a barrier.
(vi) The adoption of blockchain technology requires an alteration in the existing systems. The switching to a new organizational system or organizational structure may be confronted by hesitation and resistance from the management and employees. Previous literature has frequently evaluated the role of employees in the adoption and acceptance of new technology through the technology acceptance model (TAM) (Venkatesh et al., 2003; Wallace & Sheetz, 2014).
(vii) Organizations eager to implement supply chain sustainability practices along with the implementation of blockchain technology need to proactively implement sustainability practices into their organizational vision, mission statement, and even at all levels of organizations. To successfully incorporate supply chain sustainability through blockchain-based supply chains, the absence of standard methods, tools, indicators, and practices inhibit the successful incorporation of blockchain technology (Mangla et al., 2017).
(viii) Blockchain technology is in its initial stages hence, its implementation in developed countries is different compared to developing and emerging economies. The adoption of this technology and finding its role in sustainable performance is difficult to identify at different levels and different cultures.
(ix) Customers are the major contributors to the adoption of business policies, regulations, and practices. Hence, the role and awareness of customers to exert pressure for the implementation of these practices and technologies are essential and varied according to culture and economy. Customer awareness and knowledge also restrict organizations to implement blockchain technology to achieve supply chain sustainability (Mangla et al., 2017).
(x) Implementation of blockchain technology needs sound business models and fine practices. Formulating a sound business model and practices concerning sustainability is a challenging job for organizations globally and acts as a strong barrier to its implementation (Fig. 2).

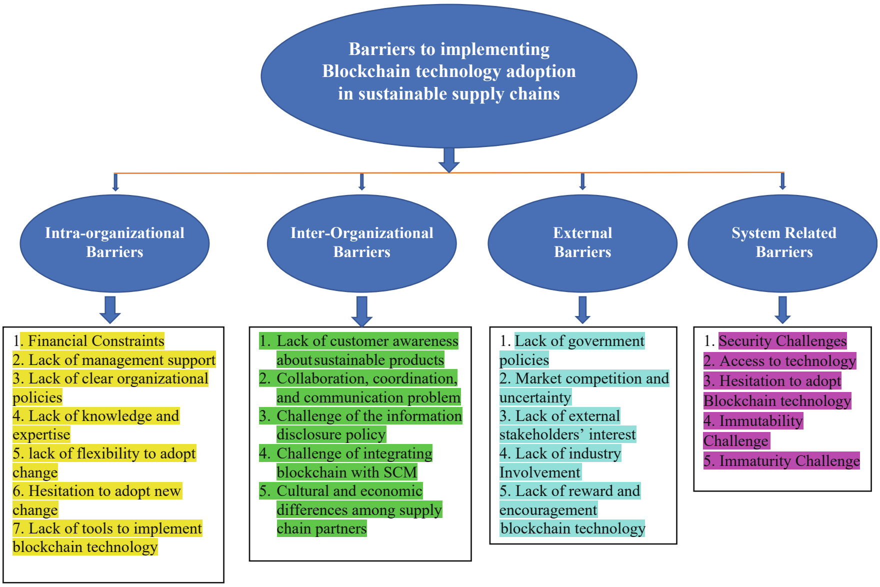

Fig. 2 Barriers to implementing Blockchain technology adoption in a sustainable supply chain

6.2 Inter-Organizational Barriers

Organizational external environmental interaction and relationships with its stakeholders are one of the most important perspectives in implementing and adopting the change, especially technological change. In the supply chain context, the relationships with supply chain partners are a critical element. The major role of supply chain management is to create strong and valuable relationships with their partners to produce value addition for the stakeholders (Lambert & Enz, 2017). It is a challenging task to do in supply chain management but becomes more challenging and critical in the case of sustainable performance and implementation of technological change in business operations. Similarly, the implementation of blockchain technology in achieving supply chain sustainability is more challenging for organizations as it deals with the sharing and transfer of valuable and secret business information. Hence, there are certain inter-organizational barriers to the implementation of blockchain technology to achieve supply chains sustainability which are as follows:

(i) One of the blockchain technology features is to secure shared information and limit it to reliable participants only. Some organizations consider business information as a competitive tool and are reluctant to share it with any partner but it is essential for blockchain technology to have such information for sustainability analysis. Hence, hesitation in sharing information from supply chain partners restricts the firms to implement and adopt this technology.

(ii) New development of policies and procedures relating to information sharing, especially in the hybrid blockchains may lead to a further deteriorating situation in blockchain technology implementation (Sayogo et al., 2015).
(iii) Blockchain technology is in its initial phase and rules, regulations, and policies about data sharing are premature and need further development. So, a lack of adequate information and data sharing rules, policies, and regulations can affect the trust among the supply chain partners and act as a significant barrier (Gorane & Kant, 2015).
(iv) Supply chain partners have different objectives, priorities, and narratives which can affect the communication and collaboration among them hence affecting the implementation of blockchain and sustainable performance measures. These communication barriers become more destructive when the supply chain partners are from different geographical areas and have different economic outlooks (Sajjad et al., 2015).
(v) Presently, the majority of organizations globally operate through conventional supply chain processes. Integration of recent technological designs, materials, and procedures is essential to improve old processes and sustainability at one end but it needs huge capital and investment that can affect the incorporation of these technologies.
(vi) More importantly, blockchain technology alone is not serving the supply chains and supply chain sustainability completely therefore, it needs to be integrated with other industry 4.0 technologies like Radio Frequency Identification (RFID), ArtificialIntelligence (AI), and Internet of Things (IoT), etc.

6.3 System Oriented Barriers

As discussed earlier, blockchain technology alone could not be able to serve the supply chain operations and supply chain sustainability issues thus the integration of other advanced technologies is critical to achieving the desired results. More importantly, the level of technological diffusion and adoption varies across cultures and economies hence making it difficult to adopt and implement by all supply chain partners. But the organizations need equal opportunities to access and share information about their business operations and especially product and services to attract customers (Ghouri et al., 2021; Gorane & Kant, 2015). Therefore, there are several technological and system-related barriers and challenges that restrict the implementation of blockchain technology among the supply chain partners which are as follows:

(i) Blockchain technology alone could not provide all information sharing and real-time information access features alone and it is one of the critical barriers for most financially weak clients.
(ii) Due to its immature nature and developmental stage, blockchain is unable to handle a large number of transactions and information sharing simultaneously.

(iii) Storing and handling large data in real-time is a nightmare for blockchain technology and is called a "*bloat problem*" in blockchain literature (Swan, 2015).
(iv) Supply chain management and especially sustainable practices need more storage to record the practices and processes which are beyond financial transactions. Blockchain doesn't have enough space to handle such a huge amount of data hence required an extension and integration of other advanced technologies like cloud computing etc.
(v) Although blockchain technology is a secure and reliable platform for information sharing and storage, however, some cyber-attacks have been reported in previous literature which made this technology doubtful among the supply chain partners (Lim et al., 2014; Vasek & Moore, 2015). However, some remedies have been suggested from time to time but they are not effectively and robustly addressed and evaluated in the literature.
(vi) Immutability of the information is one of the features of blockchain technology that can lead to falsification and adulteration of the information. The blockchain does not allow the participants to change that information without the consensus of all partners which is a hectic job (Tian, 2016).

6.4 External Barriers

External pressures and factors are very important to drive organizations to adopt adequate measures to achieve sustainable performance. External barriers in this discussion are those which are exerted by external stakeholders like governments, similar industries, NGOs, and institutions. However, these stakeholders are not direct beneficiaries of the supply chains but are essential drivers for the implementation of sustainable practices and advanced technology. These external pressures are also varied according to culture and economic outlook, therefore playing a crucial barrier in compelling the organizations to adopt these sustainable practices and advanced technologies (Mangla et al., 2018). These barriers are mentioned below:

(i) International agencies, governments, institutions, and other regulatory bodies did not clarify the authentic rules and policies regarding the use and implementation of bitcoin and other blockchain technologies in business operations and supply chain management which is hindering the broader implementation of blockchain technology.
(ii) Customers' tastes, preferences, and knowledge regarding sustainable products and services might affect the demand for sustainable products that influence the market competition. These factors restrict the implementation of sustainability practices and blockchain technology in business operations (Kaur et al., 2018).
(iii) As the implementation of blockchain technology and sustainable practices are capital intensive, governments and social organizations are not interested in subsidies them in the implementation of these processes and practices. The lack of interest from these actors and hence discourage the firms to have such practices and technologies in their operations.

The above-discussed barriers elaborate that, there is a need to further extend the research agenda to mitigate and address these barriers and provide adequate solutions so that organizations can promote their sustainable practices and enhance their technological implementation in achieving these sustainable performances.

7 Implications

This chapter has discussed blockchain-driven supply chains and supply chain sustainability and provided several practical implications. This chapter has discussed in brief the blockchain-driven supply chains and provided implications that how the managers of SCM concerns can achieve the implementation of BCSCM. Further, this chapter also provided the implications that managers could adequately address their environmental issues through incorporating environmental resource reduction, waste management, and resource management strategies. Moreover, the SCM social sustainability discussion has provided the managerial implications that through the traceability and visibility characteristics of blockchain stakeholders trust promotes transparency in transactions. From the economic sustainability perspective, this study provides implications to managers that how they can achieve the long-term goals for supply chains by integrating the BCSCM. This chapter also implicated that blockchain-driven SCM enhances the company's competitiveness, healthy and transparent corporate affairs, and enhance overall profits. Lastly, this chapter has discussed the barriers and drivers of blockchain-driven SCM and implicates that managers should consider these potential barriers and drivers while formulating the strategic level decisions for blockchain-driven SCMs.

8 Concluding Remarks

Blockchain technology is a significant technology in achieving supply chain sustainability. Increased attention and incorporation from global organizations witnessed a huge surge in reliability, security, and traceability in the supply chains. Recent application to address the COIVDI-19 pandemic disruption is the breakthrough in the emergence of this technology. More importantly, blockchain technology amalgamated with other industry 4.0 technologies was found the most successful strategy to address the supply chain disruption. Not only global and multinational companies have implemented this technology but also small firms took benefited from this technology. However, the role of supply chain partners is very important for its future growth. This chapter has discussed blockchain technology, its emergence, the present scenario, and its definitions. Further, types of blockchain technology and characteristics of blockchain-driven supply chains were discussed. The implementation of blockchain technology in supply chains to gain economic, environmental, and social sustainability in the supply chains along with its barriers in the implementation is also discussed.

This chapter has discussed the basics of blockchain-driven SCM and its role in achieving sustainable supply chain performance hence leaving other advanced issues for future research perspective. Future research can be done to evaluate the differential performance measures of BCSCM implementation. This chapter has discussed various barriers to the implementation of BCSCM. Future studies can be conducted to discuss and identify the strategies that could overcome these barriers. Finally, this chapter has discussed the broader terms of BCSCM and its role in SCM sustainability. Future research can be conducted based on case studies to evaluate the actual and find out the general results of BCSCM implementation in achieving sustainable SCM among various firms.

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Role of Blockchain Technology Adoption between Sustainability Related Supply Chain Risks and Triple Bottom Line Performance

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1 Introduction

Supply chain management plays an important role in the success of a company, but supply chains are facing hard-hitting challenges globally from various regulatory bodies and governments to implement green practices (Luthra et al., 2016). Due to climate change, pollution, waste, and an increase in socio-environmental problems, the concept of sustainability is gaining more popularity. According to Ahi and Searcy (2013), sustainable supply chains are "*the creation of coordinated supply chains through the voluntary integration of social, environmental, and economic considerations with key inter-organizational business systems designed to effectively and efficiently manage the capital, information, and material flows associated with the production, procurement, and distribution of services and products or in order to improve the resilience of the organization over the long and short-term and increase the profitability and competitiveness and meet stakeholder requirements*." On the other hand, firms are incorporating sustainability practices into their supply chains to make them greener and gain a competitive advantage (Suryanto et al., 2018). Adopting a sustainable supply chain requires firms to make green products that need green raw materials to initiate the process and a green buyer to finish the process (Zameer et al., 2020; Mahmood & Mubarik, 2020; Kusi-Sarpong et al., 2022). The process isn't as simple as the name looks, and many complexities make the firms more vulnerable. Therefore, green firms are more prone to SC risks related to sustainability (Gouda & Saranga, 2018).

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Sustainability-related SC risks are associated with sustainable operations and rigorous business decisions, which are different from traditional SC risks. For example, the raw materials required for green products are different, and it requires green suppliers which are less in quantity. Therefore, delivery delays are commonly observed (Rebs et al., 2019). On the other hand, the equipment used, the procedures, and the process followed to make a green product are different, making the firm more vulnerable to internal risks, such as human errors, machine breakdowns etc. (Syed et al., 2019; Mubarik et al., 2022; Qader et al., 2022; Khan et al., 2022b; Piprani et al., 2022; Mubarik et al., 2022). Similarly, green packaging, green designing, and green logistics are different from traditional practices. Technically, sustainability-related SC risks are divided into three types based on TBL: environmental, social, and economic risks. These risks are related to the ecosystem of sustainable practices. The environmental risks are related to not complying with practices for environmental sustainability. Social side risks are linked to TBL's social dimensions, such as guiding principles for customers, employees, SC partners, regulatory bodies, and societies (Khan et al., 2022a; Azmat et al., 2022; Ali et al., 2021). Economic risks represent the financial situations and issues related to the economic side of TBL. Therefore, the whole process, from raw material to delivery to the final consumer, is different, requiring careful consideration at each step (Bui et al., 2021). The green process becomes at stake if any of the information is not processed at the right time or there is a lap. Therefore, sustainable firms require to integrate with their supply chain partners and share information timely. The timely sharing of information and making the other partner assessable to this information transparently makes the sustainable supply chain processes smoother. The risks can be identified earlier, and their mitigation strategies can be developed accordingly (Mehrjerdi & Shafiee, 2021; Mubarik & Naghavi, 2020; Mubarik et al., 2021; Ahmed et al., 2021).

With the emergence of transformative innovation, the issue of transparency has been resolved, and firms are becoming more flexible. Technologies like blockchain, big data, cloud computing, internet of things, and machine learning have increased supply chain visibility, offering firms greater flexibility, agility, and resilience (Rasiah et al., 2017; Mubarik & Naghavi, 2021; Javaid et al., 2021). According to Crosby et al. (2016), "*blockchain technology is a database of general records or public/private ledgers that contain digital events and are shared among the agents involved in the blockchain*." On the other hand, Steiner and Baker (2015) claimed that "*BT differs from traditional information system design by integrating four key functions, i.e., decentralization, security, auditing, and smart implementation*." An important feature of BT is decentralization, which assesses any information integration, thus increasing the effectiveness of information. BT is used to share unique data and information with the supply chain partners (Agi & Jha, 2022).

Blockchain technology improves firms' information-sharing capabilities, offering them greater visibility and transparency and enhancing their triple-bottom-line performance (Yousefi & Tosarkani, 2022). According to Elkington (1998), the triple-bottom-line performance consists of three dimensions, economic, social, and environmental. Syed et al. (2019) explained TBL as the "*environmental, economic, and social sides of sustainability where the environmental side related to landfill deposits, non-renewable energy, reduction in energy and processes that emit carbon* *and are harmful to the natural environment. Economic or sometimes considered as organizational stability refers to when organizations act responsibly about environmental and social concerns keeping aligned with the financial viability. The social side of this concept is about the wellbeing of the society and deals with issues such as wages, ethical behaviour with employees, relationship with the labor, gender diversity, and equity.*"

Blockchain technology increases firms' SC visibility, enabling them to handle SC risks emerging in their supply chains and develop mitigation strategies accordingly (Sharma et al., 2021). Therefore, blockchain is a vital technology for sustainable firms as it can help reduce the impact of supply chain risks on economic, environmental, and social performance (Khan et al., 2021). The later sections in this chapter provide an overview of blockchain technology, traditional vs. sustainability-related supply chain risks, and triple-bottom-line performance. Finally, the chapter presents a framework for managing sustainability-related supply chain risks and enhancing triple-bottom-line performance.

2 Blockchain Technology

Blockchain technology is a database of general records or public/private ledgers that contain digital events shared among the agents involved in the blockchain (Crosby et al., 2016). BT differs from traditional information system design by integrating four key functions, i.e., decentralization, security, auditing, and smart implementation (Ghode et al., 2020). In the blockchain, agents create new transactions that are added to the blockchain. Afterward, these new transactions are broadcasted for auditing and verification. If most nodes in the chain accept these transactions according to the described rules, then new transactions are added as new blocks. For security, transaction records are stored on several distributed networks (Saberi et al., 2019). Smart contracts, an important feature of blockchain technology, offer the execution of stable transactions without the intervention of a third party. The main difference between internet design and current blockchain technology is that it is designed to share real-time information. In blockchains, the value of the transaction is recorded in a double-entry book that provides secure and verified information by providing records of audited transactions (Zhang et al., 2022). These transactions are presented through a verification process that complies with industry rules. When new entries are verified and entered into the blockchain, various copies are generated in a centralized way, creating a chain of trust (Mandolla et al., 2019).

Another important feature of BT is decentralization, which assesses any information integration, thus increasing the effectiveness of information. Deleting batch records is impractical, and verified records of each transaction can be accessed through a public or private account book distributed to participants (Crosby et al., 2016). A central database is most vulnerable to several attacks, e.g., corruption or hacks (Tian, 2016). Trust is an important result of decentralization through shared information in nodes of network participants (Nofer et al., 2017) because the information is easily assessed, viewed, and compared. Participants can look at the

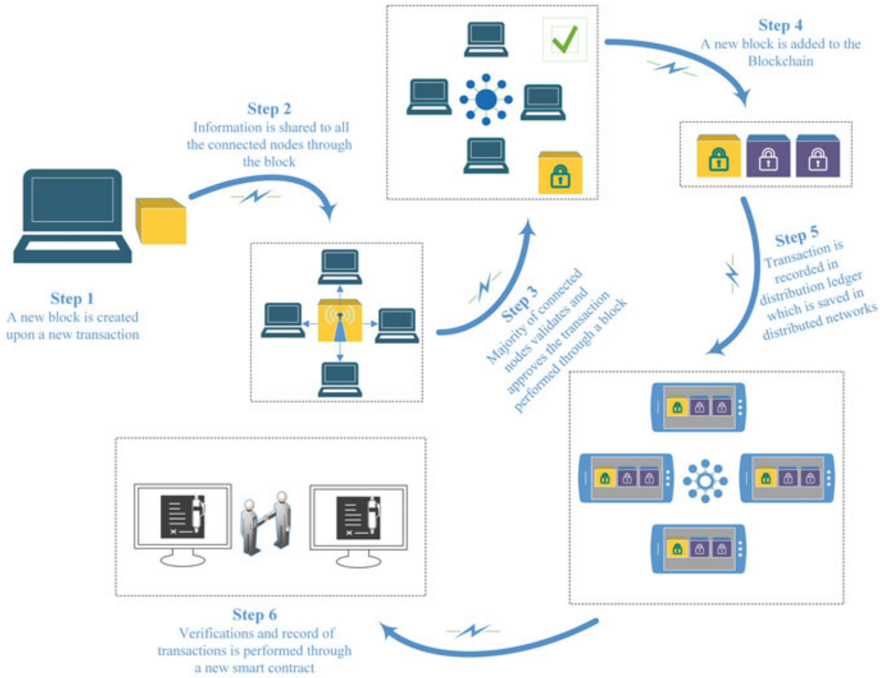

Fig. 1 Steps in Blockchain Transactions

account books (ledgers) and analyse the transactions. Therefore, blockchain technology provides transparency (Tian, 2016). Blockchains can be integrated and used to enforce agreed rules that either users or system administrators can't violate. They agree to use multiple segments on a unique platform that will require little trust among each other, e.g., supply chain fragmentation. It depends on how you apply BT because the design could be different for public and private networks (Prakash & Ambekar, 2020). BT fosters transparency, trust, and accountability through transactional applications, and smart contracts manage these applications. A smart contract is computer-operated software that stores information about policies, procedures, and rules for negotiations between different parties. The main feature of smart contracts is the automatic verification and execution of transactions according to the defined terms (Wang et al., 2019). A smart contract executes a code after receiving a message from a player in a network and updates the ledger if the contract's requirements are met (Karamitsos et al., 2018). Initially, BT evolved as a platform for managing digital currency, such as bitcoins and cryptocurrency (Sujatha et al., 2020). Later, BT implementation was broadened for developments in logistics management and supply chain management (Abeyratne & Monfared, 2016). Figure 1 represents the steps in blockchain transactions.

3 Blockchain Based Sustainable Supply Chain

Sustainable supply chain management (SSCM) simultaneously focuses on environmental, social, and economic aspects, which is known as a triple bottom line. Seuring and Müller briefly defined SSCM as "*the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development, i.e., economic, environmental and social, which are derived from customer and stakeholder requirements. In sustainable supply chains, environmental and social criteria need to be fulfilled by the members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria*" (Seuring & Müller, 2008, p. 1700). Due to the challenging environment, sustainable supply chains face several issues, such as poor coordination among SC partners, lack of transparency, visibility, and trust issues (Zhang & Song, 2022). Therefore, SSC requires transparent information and real-time visibility to avoid SC disruptions, which is possible through BT adoption.

BT adoption supports SSC in tracking the flow of transactions and information of their products and services, which helps TBL scrutinization. Blockchain technology can be adapted to SSC in four stages: registration, relevant standards, certification, and audition (Zhang & Song, 2022). Figure 2 represents the stages of adoption of BT to sustainable supply chains. Stage 1 suggests that the focal company must register its products, services, and supply chain partners into the blockchain network, providing unique identification to each partner entering the blockchain. Stage 2 requires a standard set of rules and regulations to govern the blockchain-based SSC. In stages 3 and 4 relevant certifications are required to initiate the smart contracts that offer transparency and traceability, thus enhancing the trust factor.

The adoption of blockchain can provide several benefits to sustainable supply chains. First, blockchain enhances SC visibility which means firms can monitor what's going on in their upstream, midstream, and downstream (Khan et al., 2021). It also tracks the product lifecycle record, enabling organizations to improve the design, processes, and functions (Agrawal et al., 2021). Second, it enhances traceability through smart contracts, enabling SC partners to check and verify the ledgers, thus improving SSC efficiency (Choi et al., 2019). Third, blockchain's decentralization attribute enhances SSC's efficiency by reducing the overall consumption of time. Thus, adopting BT provides multiple benefits and reduces various sustainable supply chain risks (Bumblauskas et al., 2020).

4 Traditional Supply Chain Risks Vs. Sustainability Related Supply Chain Risks

Supply chain risks (SCR) is a renowned phenomenon, but less attention is paid to sustainability-related supply chain risks (Rostamzadeh et al., 2018). The current literature on SCR management is not clear enough to deal with sustainability issues and risks associated with the supply chains of sustainable firms (Zhang & Song,

Fig. 2 Stages of BT adoption in sustainable supply chains

2022). Researchers have rarely noticed the relationship between supply chain risks and sustainable development (Hofmann et al., 2014; Gouda & Saranga, 2018). Sustainability-related supply chain risks are different from traditional supply chain risks. Christopher and Peck (2004) presented the first classification of SC risks, i.e., internal and external risks, which we now call traditional SC risks. SC risks were later categorized into internal, demand-driven, and supply-driven ones, commonly known as upstream, midstream, and downstream (Zhao et al., 2013). These risks classification was first brought into sustainable supply chains. Their impact on sustainable performance is measured by using different risk classifications and risk management techniques.

Previous literature suggests that external risks are the major sustainable SC risk, divided into sub-categories: sustainable supply side risks and sustainable demand side risks, also known as upstream and midstream risks (Rostamzadeh et al., 2018). Supply chain practitioners have seen many examples of how supply-side or demand-side risks effects firms' operations. This happens because of less coordination or no integration among various players in the supply chain (Junaid et al., 2022). Companies need to choose the right supplier while adhering to green practices. There are risks at various levels in the supply chain, from suppliers to production and marketing processes to the final customer. Competition between companies in current economic scenarios and sustainable practices requires firms to consider SSC risks to achieve their goals. Suppliers play an important role in a company's success but are considered one of the most important players in bringing uncertainty and risks (Syed et al., 2019). The key supply-side risks are green raw material quality issues, delivery delays, delivery failures, a smaller number of certified green suppliers, etc. (Rostamzadeh et al., 2018). Alternatively, the demand side is also associated with raising SSC risks. Previous researches advocate that demand-side risks harm sustainable operations, but their impact is low compared to the supply side (Grötsch et al., 2013). The main risks associated with downstream are market risks, insufficient inventory, forecasting errors, market/customer orientation, price uncertainty and incentives, customer need for green products, etc. (Xu et al., 2019).

Internal SCRs analysed and interpreted in previous literature generally fall into three main categories: operational, organizational, and industry-related risks (Ceryno et al., 2015). You can interpret these risks as midstream SC risks. Midstream risks are usually related to the focal firm and its functional divisions, which can be divided into strategic and operational risks. Strategic risks are related to company policies and decisions. For example, if SC executives follow green practices, and enforce employees to adhere strictly to green practices, then might be the new ways of doing business decrease productivity and performance due to increased costs, extra audits, compliance to regulations, and operational complexities (Burki et al., 2018; Zhang & Song, 2022). Alternatively, operational risks are associated with the day-to-day operations of an enterprise, such as machine breakdown, time management, IT problems, human errors, and changes in technology (Chopra & Sodhi, 2004). A few critical SSC risks internal to firms related in previous studies are due to mishandling green technology, machines and equipment's handling risk, green product design related risks, quality risks, production capacity risks etc. (Chopra & Sodhi, 2004; Wieland & Wallenburg, 2012; Nazam et al., 2015). Based on the above discussion, this study presents the classification of traditional SC risks related to sustainable supply chains in Table 1.

Lee and Vachon (2016) examined sustainable SC disruptions caused by environmental problems such as greenhouse gas emissions, energy consumption, natural disasters, waste of packaging, support for logistics, etc. These are linked to sustainability issues and are not represented by recent supply chain publications (Xu et al., 2019). To fully exploit SSC, it must be identified and respond to sustainable risks for the supply chain by formulating a common framework (Syed et al., 2019). At all levels of the supply chain, organizations face uncertainty, which can negatively impact institutional operations. Organizations can manage SC risks if they improve their risk identification and analysis capabilities.

Apart from the traditional SC risks discussed above, growing awareness is observed among sustainability-related SC risks. The risks are based on the triple bottom line concept and are considered environmental, social, and economic risks. These risks are related to the ecosystem of sustainable practices and look for the possible impact of not adhering to those practices (Giannakis & Papadopoulos, 2016). The environmental risks are related to not fulfilling the requirements and

Table 1 Traditional Supply Chain Risks

Risk Type	Risk	Source
Upstream risk	• Supplier quality problems • Supplier delivery failure • Insolvency of the supplier • Single sourcing • Increase in raw material price • Supplier communication failure • Upstream cargo damage	Christopher and Peck (2004); Wieland and Wallenburg (2012); Blome et al. (2013); Rostamzadeh et al. (2018); Syed et al. (2019); Xu et al. (2019); Junaid et al. (2020)
Midstream risk	• Green product risk • Competitor risk • Liability risk • Financial risk • R&D risk • Green technology risk • Machine breakdown	Christopher and Peck (2004); Wieland and Wallenburg (2012); Blome et al. (2013); Rostamzadeh et al. (2018); Syed et al. (2019); Xu et al. (2019); Junaid et al. (2020)
Downstream risk	• Demand fluctuations • Inventory shortage • Delivery chain disruptions • Forecasting error • Decline in market price • Troubling third-party logistics	Christopher and Peck (2004); Wieland and Wallenburg (2012); Blome et al. (2013); Rostamzadeh et al. (2018); Syed et al. (2019); Xu et al. (2019); Junaid et al. (2020)

fully adhering to the practices for environmental sustainability. Similarly, social side risks are linked to TBL's social dimensions, such as guiding principles for customers, employees, SC partners, regulatory bodies, and societies. Economic risks represent the financial situations and issues related to the economic side of TBL.

Sustainability-related SC risks were first presented by Un global compact and BSR (2010), and Giannakis and Papadopoulos (2016) noted them in their study as "*greenhouse gas emissions, natural disasters, accidents, energy consumption, packaging waste, environmental damages during logistics and transportation, litigation against companies to recoup financial damages caused by environmental accidents, non-compliance with laws, or unethical behaviour, social justice risks that arise*

Table 2 Sustainability-related SC risks

Risk Type	Risk Factor	Source
Environmental	• Frequent environmental accidents • No action for pollution • Non-compliance with local and international laws • Greenhouse gas emissions • Excessive energy consumption • Excessive or unnecessary packaging • Product wastage	BSR (2010); Hofmann et al. (2014); Giannakis and Papadopoulos (2016); Zhang and Song (2022)
Social	• Non-compliance with global social index • Non-compliance with global governance • Trust issues • Exploitative hiring policies • Regulations uncertainty • Discriminatory practices	BSR (2010); Hofmann et al. (2014); Giannakis and Papadopoulos (2016); Zhang and Song (2022)
Economic	• Increased cost • Economic instability • Fluctuations in forex rates • Requirements for extra audits • Bribery • False claims • Price fixing • Antitrust claims • Patent infringements • Tax evasion	BSR (2010); Hofmann et al. (2014); Giannakis and Papadopoulos (2016); Zhang and Song (2022)

from unfair employment and working practices, increase in commodities and energy prices as a result of fuel shortages" (Giannakis & Papadopoulos, 2016, p. 4). Recently, serious scandals related to the social side of sustainability were reported (BSR, 2007, 2010). Hofmann et al. (2014) noted these risks as child labour, malpractices, counterfeit products, mistreatment of employees, unfair wages, and inadequate health and safety environment. These risks may not directly trigger traditional SC risks but can adversely impact TBL performance. On the other hand, economic risks are those risks that cause damages to TBL's performance through economic malpractices such as tax evasion, bribery, patent infringement, false claims, forgery, fraud, etc. (Zhang & Song, 2022). Concerning the literature on sustainable supply chains, we have presented the classification of sustainability-related SC risks in Table 2. This might not be the all-inclusive list of sustainability-related SC risks. Still, we have tried to cover all the major areas so that organizations can keep an eye on these while developing risk management strategies.

5 Triple Bottom Line Performance

The Triple Bottom Line (TBL) concept, first proposed by Elkington (1994), has transformed how sustainable businesses measure their performance. TBL's performance framework encompasses social, environmental, and financial aspects to measure the performance of sustainable firms. According to Savitz (2013), "*TBL captures the essence of sustainability by measuring the impact of an organization's activities on the world . . . including both its profitability and shareholder values and its social, human and environmental capital*". The TBL concept suggests that organizations should be encouraged to focus on making financial profits and to engage in socially and environmentally sustainable practices and make positive monetary gains (Syed et al., 2019).

The theoretical underpinning of TBL suggests that an organization should measure its overall performance concerning its stakeholders (society, government, environment, etc.) instead of only focusing on the business or transactional parties (such as employees, suppliers, and customers) (Hubbard, 2009). Each component of TBL performance measurement represents a unique area of emphasis for organizations. The economic element relates to the organization's ability to generate monetary resources, while the environment refers to the sustainable conservation of waste and resources and their impact on the environment. The social element relates to the ability of the people to work together toward the implementation and adoption of sustainable causes, and it involves internal employees and external stakeholders (Hussain et al., 2018). In broader terms, social sustainability is concerned with organizations providing equal opportunities, implementing diversity, and ensuring the quality of life while delivering accountable governance (Elkington, 1998). The three diverse TBL components present an unsettling and challenging implementation dilemma since it implies that an organization's role and responsibilities are much broader and more demanding than simply producing, serving customers, and making a profit. Instead, they should focus equally on sustainable environmental and social factors.

With the growing awareness, organizations are moving their focus from the traditional economic perspective of business to the TBL model. It is observed that the adoption of TBL performance has a positive impact on the business, which could lead to competitive advantage and increased market share (Hourneaux Jr et al., 2018). Supply chains are also reacting to this trend and incorporating the TBL performance framework in developing sustainable supply chain management concepts and strategies with an increased focus on social and environmental issues (Bubicz et al., 2019; Zimon et al., 2019). Sustainability in the supply chain is the cumulative efforts of all partners, making the supply chain more vulnerable to sustainability-related SC risks. Literature confirms that SC risks negatively influence sustainability initiatives (Roehrich et al., 2014; Xu et al., 2019; Khan et al., 2021). However, there is a lack of research on sustainability-related risks (Zhang & Song, 2022), and further research is needed to overcome the TBL performance-related issues.

6 Proposed Framework and Relationships

6.1 Blockchain Technology and Triple Bottom Line Performance

The adoption of blockchain technology can provide real-time SC visibility, which can help minimize the negative impact of sustainability-related SC risks on TBL performance (Nayal et al., 2021). Blockchain technology has been implemented across industries recently and has presented potential benefits for predicting, controlling, and managing supply chain risks (Saberi et al., 2019). The unique characteristics of blockchain, which is real-time information sharing and higher visibility, offer great potential for minimizing the impact of supply chain risks on TBL (Rejeb et al., 2021). Adopting blockchain technology could lead to a complete overhaul of the design and function of supply chains which could provide an organization with a platform to improve TBL through reliability, traceability, and smart contracts for trustworthy relationships across the network (Saberi et al., 2019; Wang et al., 2019).

Apart from improving a firm's economic position, BT can potentially increase social performance. BT makes information available and allows modification in the information only by the authorized partners, which leads to assurance of human rights fewer corruption, similar wage rates, fair policies, etc., thus leading to an increase in social performance (Rejeb et al., 2021). BT also improves the firm environmental performance by tracking and handling substandard and non-sustainable products timely. BT can track Co2 emissions and greenhouse gas emissions (GHG) records, which allows firms and regulatory authorities to act accordingly. Adopting BT in SSCs reduces firm waste through BT-based e-chain (Saberi et al., 2019). Environmental-conscious customers are more willing to purchase sustainable products if the information is available to them regarding product sources, which is possible through BT (Kouhizadeh & Sarkis, 2018). For example, IKEA launched an office desk made of sustainable woodcut in an Indonesian forest. IKEA allows viewing the information from raw material procurement to delivery (Jiang et al., 2018). They provide information regarding what time the wood was cut, which tree it belongs to, what processes are done to manufacture the product, and all the other necessary information till it reaches the final customer. This looks quite complex, but BT made it possible (Rosencrance, 2017). BT helps reduce carbon and GHG emissions by applying low-carbon designs, manufacturing, and logistical facilities (Wong et al., 2020).

6.2 Blockchain and Sustainability Related Supply Chain Risks

Due to recent supply chain disruptions, sustainable firms have faced various sustainability-related risks (Montabon et al., 2016). These risks have impacted TBL's performance. Therefore, sustainable firms need a mechanism that provides them with real-timeme visibility (Khan et al., 2021). BT provides information and coordinates at every level of the supply chain, which increases supply chain coordination, integration and agility. When accurate information is available timely, firms can handle complexities and uncertainties, which increases the firm's performance (Wang et al., 2019). SC complexities are considered the major contributors to SC risks; therefore, reduction of complexities and access to verifiable information sharing reduces the probability of SC risks and increases firm's social, environmental, and economic performance (Kırılmaz & Erol, 2017). China's coal industry blockchain is a practical example of tracking the carbon assets of enterprises in accordance with China's carbon emission reduction policy in response to the Paris agreement (Al Sadawi et al., 2021). Blockchain-based supply chains assure the use of fair practices, e.g., BT offers transparency by making records available to buyers and sellers, in which details of products and process are provided through smart contracts (Truby et al., 2022).

Environmental uncertainties associated with natural disasters, pandemics, life cycle assessment, and greenhouse gas emissions challenge the traditional SC platforms (Lv et al., 2021). Firms cannot deal with these issues by having traditional network monitoring systems and coordination with SC partners. It doesn't offer real-time visibility to SC partners, leading to declining TBL performance (Nayal et al., 2021). Similarly, recent issues reported by the global social indexes, such as child labor, excessive work timings, unemployment, injuries and fatalities, toxins, and hazards, gender inequality, and human health issues, can't be handled through traditional means. Not having enough information regarding these issues could decrease a firm's social performance (Giannakis & Papadopoulos, 2016). BT offers social responsibility among supply chain partners to detect counterfeit producers, suppliers not complying with ISO standards, etc., through a centralized BT information system, in which only authorized partners can save the information or make a transaction. Issues with political stability, the rule of law, and quality regulations could decrease economic performance. BT adoption helps focal firms and SC partners connect with verified partners, making the transaction immutable, visible, and secure. This offers SC partners with real-time visibility, traceability, and transparency. BT enhances relationships with SC partners but also enhancess SC resilience, increasing TBL performance (Zhang & Song, 2022).

Due to recent trends and increased product complexities, SC risks related to firms' operations can arise anywhere in the supply chain, e.g., upstream, midstream, and downstream (Piya et al., 2017). These risks do not directly come under sustainability-related supply chain risks but could arise as a secondary risks because of the nature of their operations. Therefore, supply chains must reduce risks associated with products, technology, humans, machines, R&D, finance, competitors, suppliers, and consumers. The literature has observed that supply-side risks such as delivery delays, delivery failure, quality issues in raw materials, and price volatilities significantly impact TBL performance compared to the demand side and midstream risks (Syed et al., 2019). But due to recent economic downturns, sustainability firms have observed that finance and liability issues have increased, though they are covered through banks and other financial institutions. BT adoption can help firms remove banks and financial intuitions as a third parties to cover these risks. They can directly monitor the situation by establishing a private blockchain network. BT verifies and registers transactions permanently, reducing transactional risks (De Giovanni, 2022). Similarly, Blockchain helps in tracking the issues downstream, such as demand fluctuations, inventory shortages, forecasting errors, troubling third-party logistics, etc. adoption of BT can resolve these issues due to its salient features, BT onboards all the relevant parties in the supply chain, and shares the only information required for each party. This enhances trust among SC partners and increases SC transparency, visibility, flexibility, and resilience. Due to these salient features, we conclude that BT reduces the sustainability-related supply chain risks and enhances TBL's performance.

6.3 Sustainability Related Supply Chain Risks and Triple Bottom Line Performance

Due to the changing trends in the market and the adoption of sustainable business practices, different types of risks known as sustainability-related supply chain risks have emerged. These risks differ from operational risks such as upstream, midstream, and demand stream risks (Li & Leonas, 2019). These risks consider consequences on the natural environment, compliance with laws, governance issues, corporate reputation, social, and financial dimensions. Environmental risks are related to the shared ecosystem and requirements for its quality. Social risks refer to business partners, employees, government, and customers' responsibilities. Economic risks refer to the monetary risk due to counterfeit behaviour, irregularities, and the economic environment (Hofmann et al., 2014). According to Giannakis and Papadopoulos (2016), these three dimensions are classified into various risks types such as environmental accidents, pollution, noncompliance with sustainability law, greenhouse gas emissions, unfair wages, use of child labor, unethical treatment, health and safety issues, bribery, antitrust claims, tax evasions, counterfeit products, increasing costs, etc.

Based on the discussion in Sect. 6 of this chapter, this study developed a conceptual framework presented in Fig. 3.

7 Concluding Remarks

Drawing upon sustainable supply chain management literature, this chapter analyses the concepts of sustainability-related supply chain risks, blockchain technology adoption, and triple bottom line performance. The literature is distinct in terms of

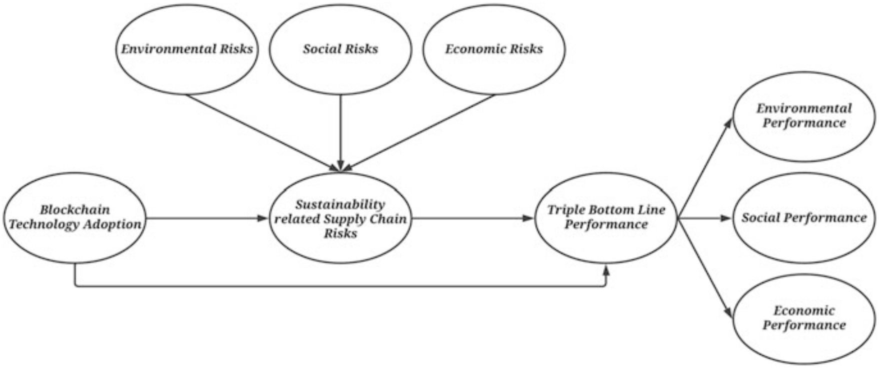

Fig. 3 Conceptual Framework

traditional supply chain risks and sustainability-related supply chain risks. Tradition SC risks may occur due to uncertainties, disruptions, or poor decision-making, which are purely related to the operational side. Alternatively, sustainability-related supply chain risks arise due to rigorous business decisions and practices (e.g., global sourcing, implementation of international standards, etc.). These decisions and practices trigger different reactions among stakeholders, leading to supply chain disruptions. Therefore, firms need a mechanism that provides them necessary information and data for informed decision-making (proactively). Blockchain Technology works through shared ledgers and smart contracts, which are only shared with the SC partners. Each SC member can write and edit his block, and the information published will be available to all the connected partners. This feature of blockchain has attracted supply chain practitioners, who started using BT to integrate SC partners and share the necessary information. Thus, BT provides firms with high-end real-time visibility, transparency, traceability, and flexibility, which makes firms ready for vulnerable events by appropriately using risk management practices. Having real-time visibility and traces of sustainability-related risks, firms can initiate their response by developing appropriate risk mitigation strategies. After initiating the response to SC risks, firms can monitor the situation through BT to ensure recovery from disruptions. Therefore, BT prepares firms to manage sustainability-related SC risks by initiating readiness, response, and recovery phases which are the key elements of SC resilience. Hence, this study concludes that BT adoption help firms in managing sustainability-related SC risks and TBL performance.

This study has several theoretical and practical implications. First, it provides the bifurcation of traditional and sustainability-related supply chain risks. Though the differentiation is presented in previous studies (Hofmann et al., 2014; Giannakis & Papadopoulos, 2016), it is limited to traditional risk management practices. Second, this study guides managers and practitioners about risk management using BT. Adopting BT among sustainable supply chains and taking SC partners on board will increase sustainable firms' potential to handle SC risks and enhance TBL performance. The issue is that industry and academia are unfamiliar with sustainability-related SC risk as it is still in its infancy (Zhang & Song, 2022). Third, this study addresses that BT adoption helps firms map their supply chains, improving SC integration. Mapping allows firms to track and trace all the processes and share real-time information with SC partners. This traceability option reduces the firm's cost of recalls (Khan et al., 2022c). The important thing is BT adoption is not a one-step cookbook and requires some prudent pace. Therefore, this study has presented the stages of BT adoption in sustainable supply chains, which could benefit supply chain professions. The proper implementation will give adequate results in managing sustainability-related SC risk and developing appropriate strategies to enhance TBL performance.

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Role of Intellectual Capital in Implementing Blockchain Technology-Driven Sustainable Supply Chain: A Proposed Framework

Sajid Nazir, Muhammad Junaid, Mahmood Ali, and Muhammad Saad

1 Introduction

Increased awareness against harmful business practices that impact the environment is observed globally. Globalization and extended supply chains have further contributed to greenhouse gas emissions and increased carbon footprint. The main affectees, such as consumers, and society are focusing on doing business with organizations that adopt green practices and conserve the environment. This has forced organizations to realign their business and operational strategies to image themselves as environmentally friendly in their production, processes, and systems (Vachon & Klassen, 2006). Porter and Kramer (2006) suggest that stakeholders expect organizations to extend their sustainability initiatives across their operations, including suppliers and transportation. According to a study, 68% of Global 250 firms generated an annual sustainability report in 2004, and 80% primarily focused on the supply chain challenges. As per a current study, 93% of the world's 250 largest firms report on sustainability (Park & Li, 2021). This growing interest in developing a sustainable supply chain capable of withstanding today's challenges has gained the attention of industry, academics, and practitioners (Fahimnia et al., 2015). It has resulted in increased development in supply chain sustainability (Dyllick & Hockerts, 2002; Mahmood and Mubarik, 2020; Kusi-Sarpong et al., 2022).

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_12

Researchers agree that the supply chain needs to be environmentally friendly while utilizing as few resources as possible (Carter & Jennings, 2002). The literature review identifies several areas of supply chain sustainability that have gained prominence. They include origins of raw materials (Lima et al., 2018; Machado et al., 2018), sustainability in upstream supply chains (Grimm et al., 2016; Wilhelm et al., 2016), green logistics strategies (Murphy & Poist, 2002), green purchasing (Min & Galle, 1997), increasing fuel efficiency and emissions reduction; transportation safety (Cantor et al., 2006) and adopting ethical practices in hiring (Lynagh et al., 1990) and suppliers selection (Mubarik et al., 2022; Qader et al., 2022; Khan, Mubarik et al., 2022b, 2022c).

Despite the calls for being more proactive in adopting sustainable practices, supply chain planners struggle to incorporate sustainability as geographically dispersed supply chains become more complex and extended (Bode & Wagner, 2015; Saberi et al., 2018). The goal of developing an ideal sustainable supply chain remains challenging despite efforts to restructure the supply chain (Hammami & Frein 2014). The supply chain professionals seek new tools and technologies to incorporate sustainable practices to ensure environmental standards are met along all the supply chain stages. Information technology seems promising for implementing sustainable practices and improving tracking and tracing capability in the supply chain (Fu et al., 2018). Advancements in information technology, such as Blockchain technology, can address the concern of enhancing accuracy and transparency in transporting goods across the global supply chain (Bumblauskas et al., 2020; Khan et al., 2022a; Azmat et al., 2022). There are many blockchain uses of applications; one of the foremost is supply chain sustainability (Saberi et al., 2018). It offers a set of tools that have the potential to develop a sustainable supply chain by providing traceability and verifiability between all members of the supply chain. Blockchain-driven supply chain influences the sustainability of a firm's production as it develops its capability to better monitor and evaluates business processes' sustainability (Mubarik et al., 2021a, 2021b). In the context of sustainability, it facilitates the participation of stakeholders in low-carbon energy initiatives, the implementation of environmental protection programs, and increases consumer access to clean energy (Ashley & Johnson, 2018). A gradual increase in blockchain adoption has been observed over the past few years despite new technology facing obstacles and barriers in widespread adoption. The most widely observed challenges emanate from behavioural, organizational, technological, or policy-oriented aspects that need continual changes (Crosby et al., 2016; Ali et al., 2021; Piprani et al., 2022; Mubarik et al., 2022). This makes implementation more challenging, considering blockchain is implemented across the supply chain with real-time information sharing.

Considering the challenges in implementing blockchain technology for sustainability, this research draws upon an intellectual-based view and develops new insights on the role of intellectual capital (IC) in incorporating blockchain into the supply chain. It is argued that the component of intellectual capital, human capital, structural capital, and relational capital are widely recognized in the extant literature (Hsu & Fang, 2009; Martín-de-Castro et al., 2011)—can play an instrumental role in improving a firm's abilities to develop the blockchain-driven sustainable supply chain. Each element of intellectual capital offers a unique characteristic that can facilitate the implementation of blockchain technology in developing a sustainable supply chain (Mubarik et al., 2021a, 2021b; Khan et al., 2021a, 2021b). Overall, IC has a multidimensional nature (Youndt et al., 2004) since it includes internal and external components (Bontis, 1998). Human and Structural capital represents the knowledge stored inside the firm, while Relational capital indicates the access to knowledge embedded in the external networks and inter-organizational relationships. Ahmed et al. (2019) argued that intellectual capital significantly increases an organization's commitment to the environment, community welfare, employee health, and safety. The elements of IC affect each other reciprocally (Bontis et al., 2000) in leveraging and supporting other components to improve an organization's performance (Youndt et al., 2004; Reed et al., 2006; Rasia et al., 2017; Mubarik and Naghavi 2020; Mubarik et al., 2021a, 2021b; Mubarik and Naghavi 2020; Ahmed et al., 2021). As Khan et al. (2021a, 2021b) suggest, firms with a high level of intellectual capital could have a comparatively higher level of sustainability in the production processes. Organizations could benefit by employing IC in adopting a blockchain-driven sustainable supply chain. This paper proposes a framework for implementing a blockchain-driven supply chain for sustainability by incorporating IC. A deductive approach has been employed. First, an extended literature review was carried out, including IC, BC, and SSC. Additionally, the relationships between IC & SSC, BC & SSC, and IC & BC are explained. Then a conceptual framework is proposed. It specifies the relevant variables and the working relationship between them. It is expected that the proposed framework would contribute toward a better understanding and propagation of knowledge in adopting blockchain in the supply chain for sustainability. Further then, a conclusion, managerial implications and future directions of this research have been discussed accordingly.

2 Intellectual Capital

The term "intellectual capital" can be defined as a knowledge-based resource available to companies that create high-value businesses and enables future growth (Ali et al., 2021). IC plays a significant role in improving the firm's performance (Mubarik et al., 2021a, 2021b) and it is considered as the most valuable asset of an organization (Cabrita et al., 2008). Organizations with a high IC value can effectively use their physical assets and achieve future benefits (Adegbayibi, 2021). Furthermore, in the knowledge economy, intellectual capital (IC) is typically known as the critical factor that affects organizational success (Xu et al., 2018). It consists of the collection of intangible assets in a form of human capital, relational capital, and structural capital that can be used to drive firm performance and generate value-added businesses, resulting in a long-term competitive advantage for a company (Saffitri & Maryanti, 2021). Since the IC is intangible in nature, therefore it cannot be measured in the company's budgetary document, however, it is essential for the formation of long-term value and sustainability (Jardon & Martínez-Cobas, 2019). Likewise, it allows organizations to improve their sustainable competitiveness and initiates the process of globalization, which encourages the exchange of information with overseas markets. Human Capital, Structural Capital, and Relational capital are the main components of IC (Mubarik et al., 2021a, 2021b; Fawzi Shubita, 2022). Human capital can be defined as the core of generating IC that leads to organizational learning, cognitive talents, absorptive abilities, problem-solving skills, and decision-making abilities. Structural capital is the second component of IC that defines intellectual property and intends to store and structurally handle employees' understanding, as well as to create mechanisms for knowledge acquisition and integration by building patterns of behaviour and interpretive systems. Thirdly, the relation capital encompasses the firm's relationships with its suppliers, customers, employees, and the company's processes and routines (Kusi-Sarpong et al., 2022).

3 Blockchain Technology

Blockchain technology is a potentially revolutionary innovation that incorporates elements of a decentralized 'trustless' database, which enables the disintermediation and decentralization of all digital events, worldwide transactions among participating agents, and processes between diverse blockchain parties (Crosby et al. 2016). Blockchains can be used to build a set of rules that no one, not users nor system operators, can break (Saberi et al., 2018). Blockchain is often known as a general-purpose technology that boosts productivity and transforms organizational business processes (Babich & Hilary, 2018). There are two primary types of blockchains: public (freely accessible) and private (permission-based) (Siba et al., 2017). To gain access, users must first sign up and then be approved by a network administrator via a predetermined approval process (Pilkington, 2016). It initiates with creating a new transaction by the blockchain user and is sent out to the network to be verified and audited by other users as well. Once this newly created transaction is authorized by the majority of the nodes it is recorded on the network as a new block and saved on multiple nodes in a decentralized manner for security purposes (Saberi et al., 2018). In the meantime, the smart contract, a key component of blockchain technology implemented in blockchain nodes enables transactions to be completed without the intervention of other parties (Kumar et al., 2019). As shown in the figure below the process flow of blockchain technology (Fig. 1).

BCT is created to store information as a value with a chain of verified, time-stamped transactions, making the information safe and auditable for all parties involved (Saberi et al., 2018). Previously, transaction data was consolidated and shared with relevant transaction participants. Blockchain technology, on the other hand, allows participants to share information through decentralization, security, and smart execution (Park & Li, 2021). Moreover, it consists of four additional characteristics such as decentralization (Di Vaio & Varriale, 2020), security (Park

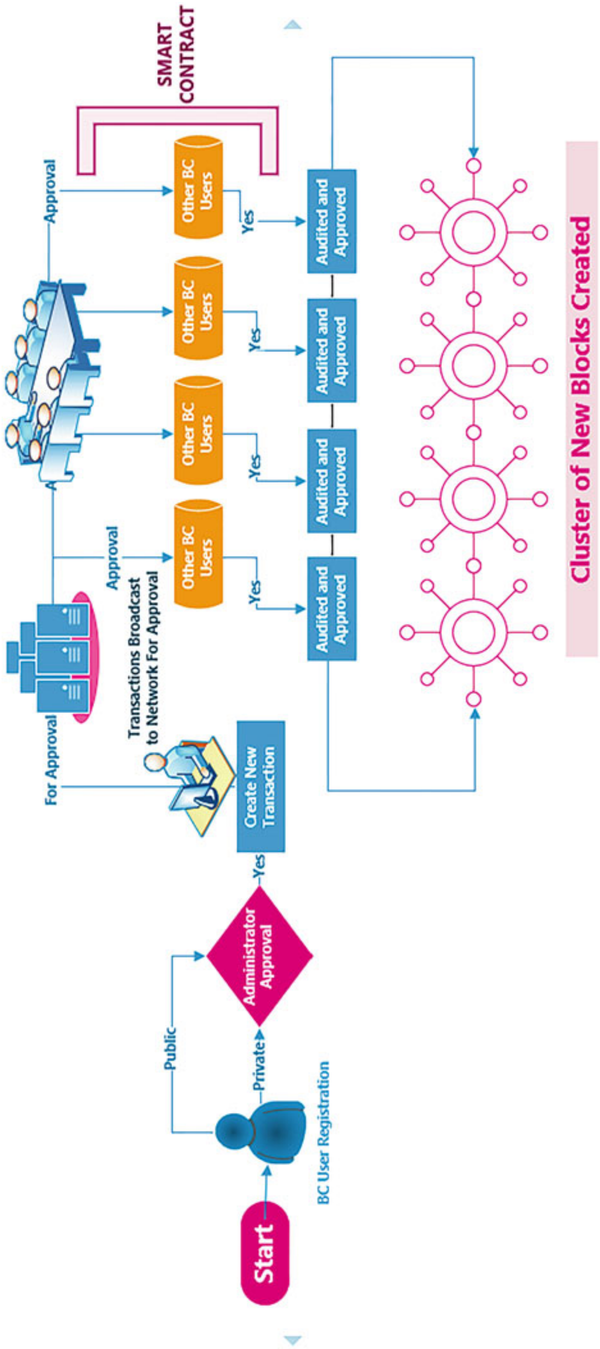

Fig. 1 Flow Diagram of Blockchain Processes

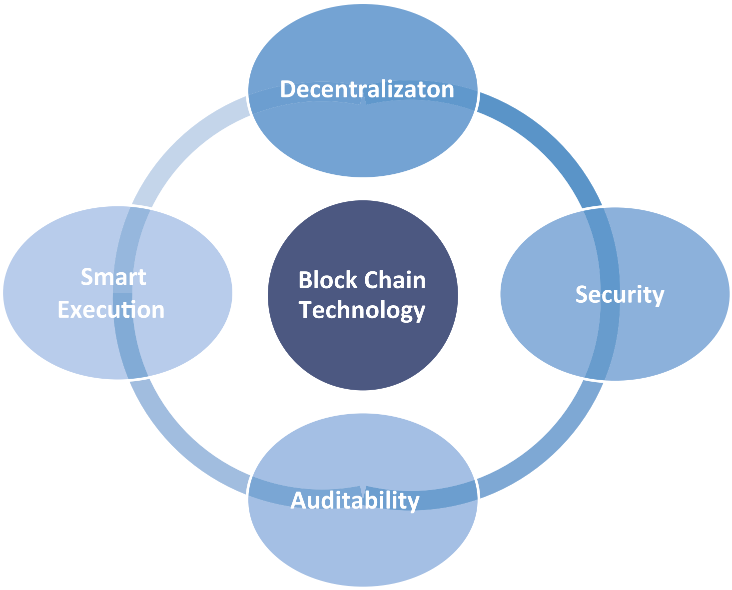

Fig. 2 Characteristics of Blockchain

& Li, 2021), auditability (Mangla et al., 2022), and smart execution as shown in the figure below (Fig. 2).

4 Sustainable Supply Chain

Due to the changing environment organizations are concerned about climate change, biodegradation, greenhouse gas emissions, and, other pollutants that contribute to environmental problems. Organizations are turning themselves greener, which means they are adopting sustainable practices. According to Syed et al., (2019) *"Sustainable supply chain and typical supply chain are not the same; they are different in terms of their goals, operations, processes, tools, procedures, etc."* A detailed definition of a sustainable supply chain was presented by Ahi and Searcy (2013), stating that *"the creation of coordinated supply chains through the voluntary integration of social, environmental, and economic considerations with key inter-organizational business systems designed to effectively and efficiently manage the capital, information, and material flows associated with the production, procurement, and distribution of services and products or to improve the resilience of the organization over the long and short-term and increase the profitability and competitiveness and meet stakeholder requirements"*.

A sustainable supply chain is associated with the term "sustainability" to define the triple bottom line (TBL), this idea describes the issues related to economic, social, and environmental factors (Junaid et al., 2022; Kumar et al., 2020). The idea of TBL, if linked properly with manufacturing activities, could be useful to accomplish organizational sustainability (Linton et al., 2007). With the advancement in sustainable supply chains, several authors have devolved sustainable supply chain (SSC) practices. These SSC practices have been employed by many different industries and received considerable attention from research scholars and practitioners (Ofori Antwi et al., 2022). The focus of earlier studies remained on the economic issues of SC integrating green/environmental issues which in turn become green supply chain management (Ahi & Searcy, 2013). A number of research scholars tried to find how green supply chain management can be utilized to safeguard the environment (Green et al., 2012; Lintukangas et al., 2013; Panpatil & Kant, 2022; Coetzee & Bean, 2016). For this purpose, researchers started to concentrate on green material design, green product design, green marketing, green manufacturing, green human resource, and so forth. With the passage of time, the demands of societies are growing to attract important SSCM practices to incorporate into SCM. The main pillars of SSCM are social, environmental, and economic. Such as Geissdoerfer et al., (2017) describe that number of organizations are choosing cleaner production practices and environmental management systems (EMS) to enhance SC performance. Xu et al., (2018) evaluate the risks to control SC for sustainability. Likewise, Raut et al., (2019) attempted to create a link between operational sustainability and big data analytics for sustainable business. Whereas Cole & Aitken (2020) demonstrated the role of intermediaries in accomplishing sustainability in SC. Huo et al., (2019) evaluated the effect of green processes on sustainability in terms of environmental, economic, and social performance. Synthesizing from the literature, the present study takes three SSCM practices namely, environmental management system, operations practice, and supply chain integration to represent SSCM.

5 IC and Sustainable Supply Chain

With the emergence of a concept known as a knowledge-based economy, intellectual capital has become the point of concern for sustainable operations, and competitive, green innovation. One element of IC is human capital which is also known as the backbone of the organization because of its knowledge, and consider as the most important resource of any organization. The people which are the mainstream for learning and development are the human capital for the organization, the culture and the technology are the structural capital, and how the organizations manage their relations with external sources comes under the relational capital (Xu and Wang, 2018). The combination of these three creates value for the organization and makes its operations more sustainable. The intellectual capital has merged with the green supply chain to create the maximum value out of the knowledge base (Caputo et al., 2016). Furthermore, intellectual capital provides the organization with an opportunity to transform its operations into economic, social, and environmental sustainability. According to Massaro et al. (2018), managerial practices of an organization enhance the firm's economic supply chain performance. Improvements in quality of life affect local human capital that supports company productivity, which increases social performance. Through education and training organizations can help their employees reduce waste which increases firms' environmental performance. Thus, intellectual capital has a vital role in managing sustainable supply chains, and it creates a positive impact on social, economic, and environmental performance.

6 Blockchain and Sustainable Supply Chain

The previous studies show that blockchain plays a vital role in supply chain operations and improves the overall ecosystem. Consequently, blockchain technology emerged earlier as a supporting technology to handle cryptocurrency transactions but later it was introduced to supply chains as an information-sharing technology (Guggenberger et al., 2020). Researchers have merged blockchain with the supply chain but they didn't reach a consensus about the definition of blockchain-related to the supply chain. For example, according to Al-Saqaf & Seidler (2017, p. 339) "blockchain is a distributed digital ledger or accounting book". On the other hand, Christidis & Devetsiokiotis (2016, p. 2293) called blockchain "a distributed data structure that is replicated and shared among the members of a network". These definitions provide the readers with an opportunity to get to know that it is a technology that can be used to share information among supply chain partners in its exact format. Therefore, it can be identified that blockchain shares information among supply chain partners by building the blocks in which the contract/information is written and stored (Saberi et al., 2018). Once the partner has an access to the block he can check the information shared by the other partner through the access code (Kumar et al., 2020). Blockchain allows organizations to develop collaborative frameworks to resolve the issues of information asymmetry, which increases the overall ecosystem. However, the transition from a traditional to a blockchain-based system requires careful consideration of costs, technology, drivers, and barriers, economic, environmental, and social benefits (Di Ciccio et al., 2019).

7 Intellectual Capital and Blockchain Technology: A Conceptual Framework

This chapter attempts to explain the adoption of IC for a technology-driven sustainable supply chain. The conceptual framework shows how the components of IC influence blockchain technology for developing a blockchain technology-driven sustainable supply chain. Modern supply chains have low visibility, accountability, and transparency due to its complex, multi-tiered, and universally dispersed supply chain network. Therefore, it's nearly impossible to analyze information and manage risk in this complex network because of globalization, various regulatory regulations, and diverse cultural & human behaviour in supply chain networks. As a result, supply chain participants and customers cannot confirm or validate the true value of a product because of the lack of transparency around its supply network. Consequently, ensuring reliability and consistency across the supply chain network requires efficient information systems that promote sustainability and enable visibility, accountability, and transparency. Blockchain technology could be the potential solution to all of these problems and concerns (Li and Lu, 2020). Technological innovations and applications based on the concept of blockchain enable transparency, accountability, process integrity, and visibility in the entire network (Ghalwash et al., 2022). This new technology is expected to have a big impact on business operations in several different industries, such as supply chain management (SCM), where it can give more visibility, accountability, and trust in inter-organizational collaboration (Ray et al., 2019). Blockchain technology, as a potentially revolutionary innovation that incorporates elements of a decentralized 'trust-less' database, enables disintermediation and decentralization of worldwide transactions and processes between diverse parties (Crosby et al. 2016). Blockchain is still in its early phases of development, posing several challenges in implementation, especially in the supply chain it requires diverse skills and characteristics encompassing structural changes, human resources, and collaboration among supply chain partners (Saberi et al., 2018). The intellectual capital offers a distinctive set of tools that could be useful in developing a blockchain-driven sustainable supply chain. The successful implementation of a blockchain-driven sustainable supply chain requires a well-integrated business process, strong relationships with its participant, and a strong sense of human capital, which is collectively known as IC (Secundo et al., 2020). Moreover, strong intellectual capital could make a substantial contribution to the adoption and implementation of blockchain-based supply chains, which can have a positive impact on sustainable business processes. Consequently, the relationship between IC and Blockchain technology has become a matter of discussion in academia and industry (Fig. 3).

7.1 Human Capital

Human Capital is employees' cumulative knowledge and skills through experience and education. It is the repository of the knowledge, skills, experience, and abilities of employee, which generates value through efficient and sustainable practices, and play an important role in incorporating new processes and technologies. Mubarik et al. (2021a, 2021b) define human capital as the knowledge, skills, multitasking ability, commitment, engagement, attitude, experience, intelligence, and creativity of employees of an organization. Eisenstat (1996) argued that the development of human capital contributes to increased sustainable practices and improved employees' green behaviour—on knowledge about sustainability (Rayner and Morgan, 2018).

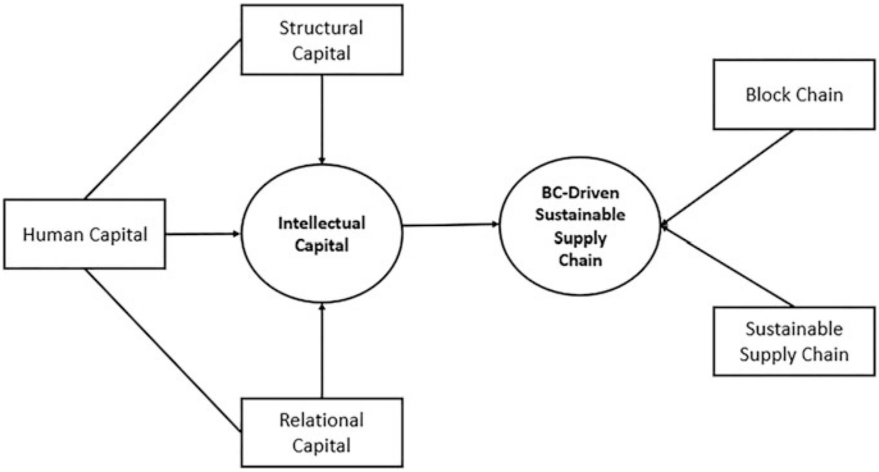

Fig. 3 Conceptual Framework

Prior research has shown the significant contribution of human capital in improving supply chain performance (Mahmood and Mubarik, 2020). A firm with a high level of human capital is better prepared to adapt to technological and environmental changes. Applying human capital of knowledge and experience, employees create and maintain collaboration with supply chain partners allowing information sharing, which is the core of blockchain technology. Essentially, human capital is a critical part of learning (Martin de Castro et al., 2011) and plays a critical role in organizations' efforts to develop a blockchain-driven sustainable supply chain. According to Teece (2007), human capabilities, skills, and knowledge assist in adapting to changing business environments and propagating innovation and collaboration with other entities. Human capital enables an organization to identify, acquire and utilize knowledge from external sources. The organization's capability to learn and incorporate new technology and practices reflects the importance of human capital in adopting blockchain in the supply chain.

Human capital plays a critical role in developing BSSC through creative and skilled employees eager to learn and adopt innovations from the external environment and incorporate them into their supply chain (Subramaniam and Youndt, 2005). Such capital of qualified employees can analyze, plan, and assimilate blockchain technology more easily than the organization with low or absence of human capital. Likewise, a robust human capital has shown a strong relationship with new patent applications, suggesting their ability to adopt new technologies.

7.2 Role of Relational Capital

Relational capital is defined as external relationships, associations, and connections of an organization with suppliers, customers, and the inter-relationships among employees (Mubarak). In a sustainable supply chain, relational capital reflects the relationship between internal and external partners in the supply chain uniformly working on a strategy to reduce waste and adopt green practices, thus forming an integrated sustainable supply chain. A robust relational capital is critical for a sustainable supply chain considering diverse entities perform a unique role in product flow under sustainable guidelines.

It is argued that organizations with a higher level of relational capital have better access to current information and market trends, allowing them to plan and formulate new strategies (such as implementing innovative technologies and sustainability) (Bontis, 1998; Matin de Castro, 2011). Relational capital promotes organizational learning and the adoption of new processes and practices. It also enables supply chain managers to implement sustainable practices and employ technologies, such as blockchain, which could assist in implementing them. Since the core of blockchain technology is shared centralized information, high relational capital facilitates required collaboration and learning among the supply chain partners. Relational capital develops a sense of trust among the supply chain participants, satisfying the core requirement of blockchain, i.e., trustworthiness and legitimacy of information (Saberi et al., 2018).

Further, the presence of strong relational capital in a blockchain-driven sustainable supply chain facilitates communication between blockchain entities that enable decision-making and establishing common values (Nooteboom, 2000) of the adopted strategy. The relational capital facilitates it by intensive communication within the blockchain to balance technical demands and coordinate interdependent tasks in product development, thereby reducing errors and maintaining a standard information ledger (Yan & Dooley, 2013). This enables inter-organizational learning, enabling more benefits from blockchain.

Relational capital supports blockchain technology-driven sustainable SC by transforming the relationship between parties in transactions, allowing integration and collaboration between the participants within a supply chain network. Cuevas-Rodríguez et al. (2014) reports that it is positively related to knowledge exchange and communication with external partners. External information and knowledge in the supply chain can be diffused efficiently within the organization through relational capital, which prepares the organization to implement new technologies and innovations.

7.3 Role of Structural Capital

Structural capital represents the organization's processes and systems structure through which it performs its business functions and accumulates knowledge in the organization, which then constitutes the company's internal knowledge [18]. It is also referred to as non-human knowledge embedded in organizational routines, databases, and processes (Ahmed et al., 2019). Such knowledge can facilitate the integration of external knowledge inside the organization (Cohen & Levinthal, 1990). Su et al. (2013, p. 179) suggest that a firm's knowledge resources are "one of the most important contributors to competitive advantage a firm can offer supply chain partners." This includes implementing sustainable practices as supported by (e.g. Khan et al., 2021a, 2021b; Mubarik et al., 2021a, 2021b), who argued that structural capital –organizational processes, routines, databases, and systems— play a critical role in augmenting sustainability in the organization. Research has shown that organizations with improved structures, processes, and routines can enhance an organization's ability to adopt new practices and technologies (such as blockchain) (Mubarik et al., 2021a, 2021b). Structural capital improves collaboration and communication between supply chain partners, thereby allowing an organization to continually review and implement 201 sustainable practices and tools needed to do so. Kang & Snell (2009) argue that organizations with standardized rules, procedures, and routines are better positioned to search and absorb external information and integrate novel ideas such as blockchain technology. Further, since all the supply chain members work in close collaboration, implementing new technology is less challenging.

Information technology, which forms a critical element of structural capital, according to Devaraj et al. (2007), works as a supportive platform or infrastructure for information and knowledge exchange and processing in the supply chain. Paulraj et al. (2008) confirm the role of information technology in promoting collaborative communication. A strong structural capital can help a firm assimilate and institutionalize such technological developments effectively and efficiently (Mahmood & Mubarik, 2020; Mubarik et al., 2021a, 2021b). The structural capital facilitates blockchain technology in transforming current logistics and supply chain business operations by fostering sustainability and streamlining organizational operations (Bai and Sarkis, 2020). The firm's information infrastructure sets the stage for establishing real-time connectivity with suppliers and customers and fosters an atmosphere of reliability and confidence in communication and knowledge sharing among the partners.

8 Concluding Remarks

In this perspective business resources such as (human, structural, and relational) commonly known as Intellectual Capital represents an essential role that improves efficiency all the way through the value chain. The study's findings demonstrate that the IC provides significant benefits to the company (Kusi-Sarpong et al., 2022). Firstly, it helps the organization in the adoption of blockchain technology. Secondly, it allows organizations to implement a blockchain technology-driven sustainable supply chain. The study also indicates the significance of the adoption of blockchain technology by a firm has positive outcomes for the business which further enables the BCT- driven sustainable supply chain. Blockchain's unique design also makes transactions faster and more efficient. Furthermore, a blockchain-based supply chain has a significant impact in improving a company's capability to manage and analyze the sustainability of its business processes.

The findings of this study have a number of significant implications for managers and policymakers such as firms can save money, boost output, and minimize environmental impact by managing and enhancing their supply chain's social, economic, and environmental performance. This could be possible through the adoption of digital technologies and modern business processes. Digital technologies have tremendous analytical capabilities that assist policymakers to prioritize sustainable development goals based in the context of blockchain technology. Overall, digital technologies have the potential to incorporate the right information and provide transparency in data sharing that plays a key role in developing a sustainable supply chain such as the quantity of material required for production, product traceability that enables recycling & remanufacturing, avoiding waste that further leads to minimizing the cost and increase productivity. The literature work suggests that the implementation of blockchain in the supply chain will have a substantial impact on its performance and will transform the participants' relationships (Kusi-Sarpong et al., 2022). In order to maximize the value that could be gained through using blockchain technology, businesses must rethink their internal structures and procedures to adopt new methods of technology and management (Saucedo-Martínez et al., 2017).

Studies have provided a clear understanding of the advent of blockchain technology, indicating its major characteristics, functions, and ramifications (Di Vaio & Varriale, 2020) yet, it's in the trial stage (Xue et al., 2020). Most reviewed literature focused on blockchain technology in Bitcoin and other cryptocurrencies. However, more research is needed to evaluate the application of blockchain technology for different business purposes. There is undoubtedly a large amount of work to be done in this area for future study directions. Multidisciplinary research efforts will be required to fully understand the effects of blockchain technology on the supply chain. Moreover, professional organizations must be involved and collaborate with academia for the deployment of BCT to set standards and give practical performance monitoring. Consequently, there is a significant need for an in-depth study of this technology and its application to move beyond conventional information systems and internet connectivity in supply chains. We also figured out how important blockchain technology is for making supply chains more sustainable. However, the environmental, economic, and social dimensions of sustainability, such as the United Nations' sustainable development goals (SDGs), can be used to examine the effectiveness of blockchain-enabled supply chains in the future. Some big organizations like Microsoft IBM, SAP, and Boeing have already started using blockchain technology for business purposes (Saberi et al., 2018). However, case studies and pilot programs must be evaluated to improve blockchain implementation. Future studies can also examine post-implementation success and failure factors.

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Blockchain Driven Supply Chain and Industry 4.0 Technologies

Syed Ahsan Ali Zaman, Hamza Muhammad Dawood, Syeda Nageen Zehra, and Syeda Zehra Saeed

1 Introduction

Since the 1970s, our society has rapidly adopted digital technologies like smart gadgets and robots, bringing us closer to a digitally transformed future (Kusi-Sarpong et al., 2022; Twi, 2019). The digital transformation uses digital technologies to establish or change existing business procedures, strategies, and consumer interactions to address the varying market and business demands. This reconceptualization of doing business in the digital world is known as digital transformation (Gupta, 2020; Vilkas et al., 2021). Industry 4.0 (I4.0), a component of digital transformation, is neither a recent breakthrough nor a new corporate structure. Our society's current trend is to exchange data and automate the creation and development of new technologies. Industry 4.0 digitally transforms workplaces into "smart" industries (Mubarak et al., 2021; Rossow, 2018). Blockchain is one of the most advanced and disruptive technologies that industry 4.0 has to offer, and it has the potential to have extensive applications in supply chains (Xue et al., 2020). The emergence of blockchain technology has significantly impacted the supply chain sector as a game-changing innovation. It has the potential to revolutionize

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_13

supply chain business practices, making it the most promising area of advanced research (Tiwari, 2021; Mubarik et al., 2022; Qader et al., 2022; Khan et al., 2022b, 2022c).

Literature on supply chain (e.g., Khan et al., 2022a; Azmat et al., 2022; Ali et al., 2021; Piprani et al., 2022; Mubarik et al., 2022) explains blockchain-driven supply chain management (Bscm) as a shared distributed ledger technology that can keep track of all shipments, locations, real-time process optimization, transparency and storage-related information. In addition to enhanced trust in the data in a decentralized network, blockchain provides access to "one source of reality" for data. However, it would not be possible to provide these services without merging blockchain with other I4.0 technologies, such as cognitive automation, the internet of things (IoT), smart devices, robotics, etc. (Rasiah et al., 2017; Weinberger, 2022; Mubarik & Naghavi, 2020, 2021; Mubarik et al., 2021a, 2021b; Ahmed et al., 2021). Regardless, other issues related to Bscm and I4.0 technologies must also be addressed, such as the threat posed by quantum computers to Bscm, fraudsters attacks, AI-based attacks etc. I4.0's promise is true, but only for businesses that are competent enough to accept it and have established a digital transformation roadmap (Card, 2021; Shah, 2022; Vilk, 2022; Mahmood & Mubarik, 2020; Kusi-Sarpong et al., 2022).

It is essential to conduct in-depth research into the benefits and drawbacks of Bscm and I4.0 technologies, particularly in light of their inherent potential and developing issues. This chapter describes the implementation of blockchain-driven supply chain management, with particular emphasis on its application within the framework of industry 4.0 technology. Since IoT devices are a critical component of I4.0, the idea of blockchain technology being used in industrial IoT is an intriguing notion that merits more exploration. When integrated with blockchain, the most sophisticated supply chain is integrated with blockchain, other industry 4.0 technologies such as machine learning (ML), autonomous mobile robots (AMRs), 3D printing, augmented and virtual reality, big data analytics, cloud computing, and so on management is obtained. Additional research is required to fully elaborate on the emergence of these combined technologies, which is the main takeaway from this chapter. Future researchers and enthusiasts interested in this field will benefit from this in-depth investigation of Bscm in other I4.0 technologies, its potential dangers, and possible solutions. This chapter is divided into sections: Sect. 3.2 describes the basic concept of industry 4.0. Section 3.3 discusses the role of I4.0 technologies in Bscm and their benefits and prospects. Section 3.4 discusses the challenges and threats of Bscm and I4.0 technologies. Section 3.5 discusses the future research direction. Lastly, Sect. 3.6 covers the chapter's conclusion. The graphical representation of the chapter's framework is shown below (Fig. 1).

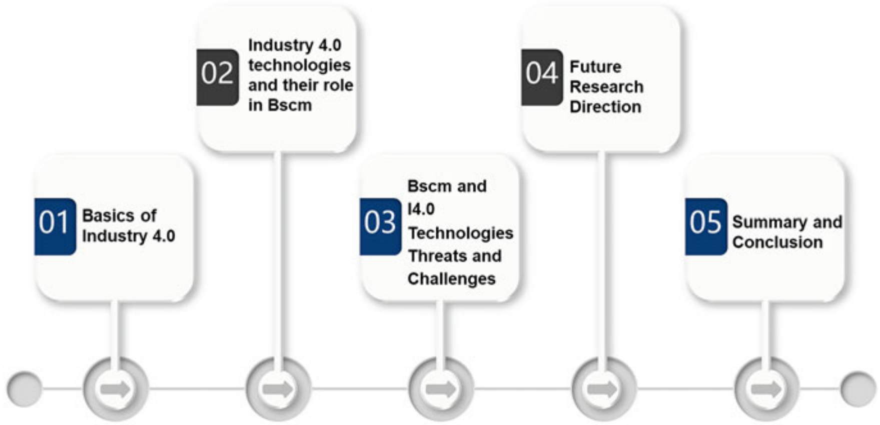

Fig. 1 A graphical framework of this chapter. (Source: Owned study)

2 Evolution of Industry 4.0

During the pandemic, we have witnessed how digital technologies have become an essential part of our lives. Examples include online shopping, teaching, virtual conferences, virtual trade exhibitions, and digital currencies such as PayTM, Google Pay, and PayPal (LaBerge, 2020). These technologies have already brought significant changes in industrial processes to the next level, i.e., Industry 4.0, which originated in 2011 from a German government project (Vogel-Heuser & Hess, 2016). The fourth industrial revolution was introduced by the executive chairman of the world economic forum Mr. Klaus Schwab in 2015. Talking about I4.0, he said,

> The fourth industrial revolution will affect the essence of our human experience.

There is a famous quote by André Kudelski, chairman and CEO, of the Kudelski Group, about this new digital world,

> Any skilled engineer can take control remotely of any connected 'thing.' Society has not yet realized the incredible scenarios this capability creates.

Gary Coleman, global industry and senior client advisor at Deloitte Consulting said,

> The fourth industrial revolution is still in its nascent state. But with the swift pace of change and disruption to business and society, the time to join in is now.

I4.0 interconnects factories, machines and systems to work together. For instance, if one machine is broken or malfunctioning, it might instruct other machines to take over without human interaction. This implies that machines are capable of cognition and communication. Similarly, if a factory is overloaded, it can link with other factories and alert them to start production. I4.0 offers remote access to production system machinery via smartphone applications. Equipment producers, for example, can remotely access their equipment for maintenance and software upgrades. System tracking is feasible due to Internet access and unique identity. Drones and remotely controllable robots make previously inaccessible remote areas easy to visit. I4.0 is a new phase of the industrial revolution that includes intelligent networking of machines and processes for industry using information and communication technologies (Alley, 2022; Morgan et al., 2021; Mubarik et al., 2021a, 2021b).

2.1 The Industrial Revolution

The industrial revolution began in the United Kingdom in the eighteenth century, when rural and handicraft economies rapidly transformed into industrial and machine-manufacturing-dominated sectors and eventually spread to many other countries. This economic shift impacted how labor was performed, how things were created and how people interacted with one another and the world. This radical transformation of the societal organization continues today and has had repercussions on global political, environmental, and cultural sectors (Rafferty, 2019) (Fig. 2).

Humanity has always needed technology. Each century's technology was not the same size and shape as today, but it was visually beautiful. The first industrial revolution began with the steam engine in 1784. Mechanization replaced agriculture as the economy's backbone. Coal extraction and the steam engine supplied a new energy source that sped up railroad manufacturing, boosting the economy (Mohajan, 2019).

A second industrial revolution started a hundred years after the previous one. Modern forms of electricity, natural gas, and petroleum emerged thanks to scientific discoveries in the nineteenth century. Through this upheaval, a massive engine was born. Steel production increased, chemicals were synthesized, and communications

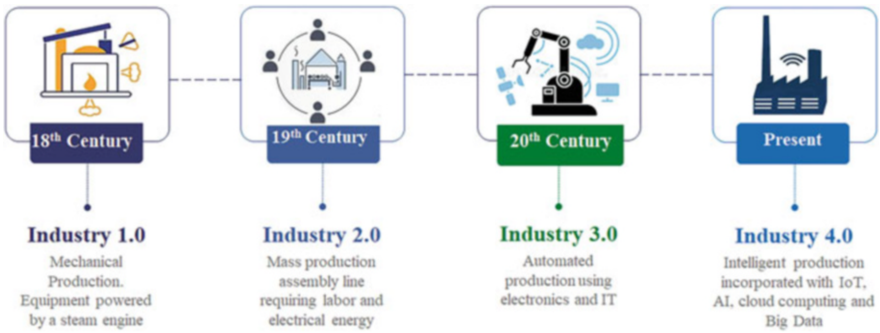

Fig. 2 The industrial revolutions from a historical perspective. (Source: Own work)

infrastructures were established during the second industrial revolution. The most significant industrial revolution occurred in the early twentieth century, thanks to the development of automobiles and airplanes (Niiler, 2019).

Another century has passed, and the third industrial revolution has begun. The third industrial revolution begins. In 1969, nuclear energy emerged as a previously unexplored source of energy. Electronics, telecommunications, automation, and computers powered the third revolution. New technologies enabled space exploration, research, and biotechnology during the third industrial revolution. Two essential inventions in the realm of industry, programmable logic controllers (PLCs) and robots, helped usher in an age of rising automation (The third industrial revolution, 2012).

The concept of cyber-physical systems characterizes the current fourth industrial revolution. It is a link between the natural world and the digital world. The internet was the catalyst for industry 4.0 at the turn of the third millennium. We can observe the transition from the first industrial revolution, founded on technological phenomena, to industry 4.0, which creates virtual reality worlds and enables us to defy the rules of physics. Programs and projects are being developed globally to assist people in everyday use of the wonders of the fourth industrial revolution (Team, 2019).

3 Industry 4.0 Technologies and Their Role in BSCM

A blockchain-driven supply chain management (Bscm) provides an adaptable solution to numerous challenges. Its adoption in financial transactions can help supply chain management procedures operate more smoothly (Khan et al., 2022d). There are various stages in a typical supply chain, such as production, financing, and sourcing, and one or more transactions can occur between these operations.

A blockchain-powered supply chain maintains transactions on secure blocks and across the ledger. These records are then disseminated over the blockchain network, making the data accessible and verifiable. Blockchain tracks and reflects real-time supply chain transactions. They turn everyone into a real-time transaction contributor (Kusi-Sarpong et al., 2022). Let us use the charcutier food business in France to demonstrate the importance of blockchain in supply chain management. Fresh product is used by enterprises in the food industry, such as restaurants, and these firms need to track the item from its origin to its final customer because it is consumable. Suppose the charcutier uses a more accessible Bscm approach. In that case, it will be better to monitor meat from China through its handling in France, when it is transported to the restaurant, and how it is sold to the consumer. Consequently, the overall process is improved, giving every member a higher degree of purity—the end customer a higher degree of satisfaction, the restaurant a more profitable operation, and the unprocessed meat handlers a lower risk of dispute (Khan et al., 2022d).

It is widely known that applying blockchain technology to our supply chain system can bring about significant improvements in transparency and traceability, optimum cybersecurity, greater cohesiveness, improved automation, and predictability. However, it is unclear if blockchain technology alone can provide all of these benefits or must be used in conjunction with other technologies. Ignoring I4.0 technologies makes the concept of Bscm impossible. Consequently, we must investigate the role of I4.0 technologies in Bscm. Following are the key technologies that are part of Industry 4.0.

3.1 Internet of Things (IoTs)

The term "internet of things" (IoTs) refers to a network of interconnected electronic devices that may gather information using sensors and relay that information to other devices in the network. In addition, the IoTs allow for less-manual connection and communication between various pieces of on-site machinery. Some examples of IoT devices are smart watches, smart eyewear, and smart water valves (Khodadadi et al., 2016). Recently, it has been common practice to talk about Bscm and the IoTs together. The Bscm IoT device's flexibility and ease of use have made it a frontrunner among exciting new logistics and supply chain innovations (Yuliya Melnik, 2022). For example, the following are the possible applications of Bscm and IoTs:

3.1.1 Product Sourcing

Companies should store IoT device transactional data on a blockchain, which can gather highly accurate data and can be used to validate the authenticity of transactional logs. A business can use this information to guarantee sustainable sourcing and improve financing. In addition, by leveraging Blockchain and IoT technologies, the parties and the customer can monitor a product's whole life cycle along the supply chain.

The data from IoT end devices are processed and transferred clearly. With decentralized ledger technology (DLT), blockchain protects the information's safety at every process stage (Nehra, 2022). It offers easy access to the data related to the product. IoT, for example, may be used to monitor and track unusual events, such as an increase in container temperature during a cold chain shipment. This issue may be documented on the blockchain so all parties can see the problem and access authenticated, verifiable facts from the blockchain ledger. Since implementing a blockchain-based system can be done in a decentralized step-by-step fashion, it does not require significant investments in information technology systems or costly third-party certification (Gaur, 2021; John Liu & Cannistraci, 2019) (Fig. 3).

3.1.2 Smart Contracts

Another area where the technologies of blockchain and the internet of things can be advantageous is reducing the amount of paperwork required. Multiple intermediaries are involved in transporting a container from one location to another. Smart contracts can be deployed to eliminate this problem by allowing partners to pre-program, conduct, and monitor agreements depending on the incidence of designated circumstances. Smart contracts adhere to rigorous restrictions and do not need

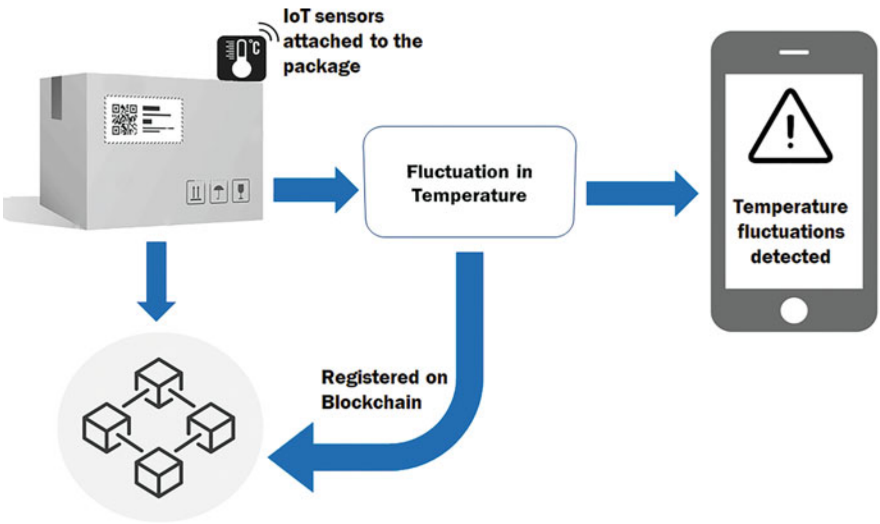

Fig. 3 The industrial revolutions from a historical perspective. (Source: Own work)

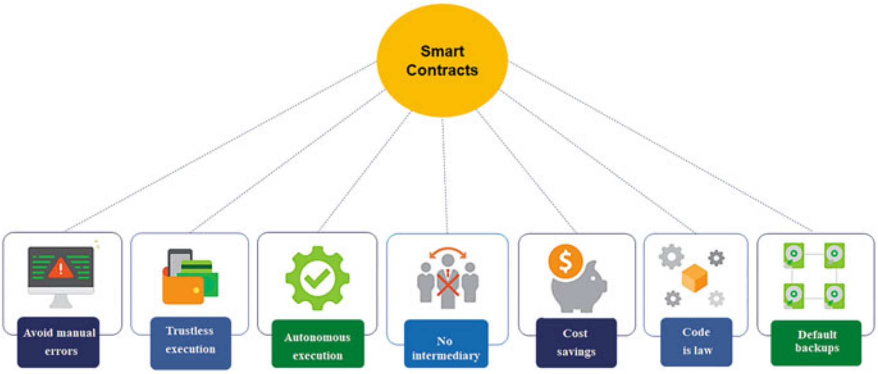

Fig. 4 A typical smart contract functionalities. (Source: Own work)

human involvement. For instance, a smart contract can be required for data processing by collecting temperature information from IoT sensors and producing a daily average or minimum and maximum temperatures (Fig. 4).

As long as most firms trade in traditional methods, documentation will be needed. Blockchain and IoT enable businesses to minimize labor expenses and ensure data security by reducing paperwork throughout the ecosystem. Even in cross-border operations, combining Blockchain and IoT ensures secure freight shipping. Trades may be made online using a system that connects all parties. Contracts are written in encrypted code, allowing money transactions between parties unfamiliar with one other to place without disagreement (Nehra, 2022; Verma, 2019).

3.1.3 Inventory Management

Most firms use enterprise resource planning (ERP) software to handle corporate supply chain inventory demands. Integrating IoT and ERP software can enhance corporate benefits by offering real-time information and offering existing ERPs real-time visibility into assistance and product inventories. Once this entire data set is recorded on the blockchain, manufacturers can access real-time inventory updates from businesses. As a result, real-time reservations based on specified circumstances can be made. Companies will obtain the delivery without lag, in this case, avoiding significant selling losses. As a result, these businesses' user experience will improve (Fig. 5).

RFID labels and sensors enable firms to monitor their inventory's status and location and track its whereabouts. In a word, the internet of things refers to developing a framework for an intelligent distribution center that allows a company to reduce its losses. It also guarantees that the product is stored safely and efficiently detects goods out of access. It also helps businesses improve warehouse management, leading to cheaper labor charges and higher competence due to fewer mistakes (Matellio, 2022).

3.2 Artificial Intelligence (AI)

AI is a computer program that enables a machine to simulate human behavior like learning, planning, reasoning, knowledge sharing, problem-solving etc. one of the most common applications of AI for manufacturing is machine learning. Machine learning (ML) allows the machine to automatically learn from past data to give accurate output and alert to any abnormality in the output. Machine learning creates waves in recognizing patterns and insights from existing data using descriptive and predictive approaches. Using Blockchain and AI technologies in supply chain management will further disrupt them. Both can improve transactional security by speeding up data interpretation and processing (Deshpande, 2012).

Moreover, distributed blockchains are an excellent and established source for machine learning, requiring extensive data sets to generate accurate predictions. AI and blockchain are revolutionizing supply chains beyond businesses and providing

Fig. 5 ERP software provides real-time visibility into goods and service inventories. (Source: Own work)

great possibilities by automating previously manual processes, making data more reliable and transparent, and bringing intelligence and automation to transactions. A company, for instance, can measure CO_2 emissions data at the production or component level, bringing precision and insight to carbon-neutral measures (IBM, 2019).

3.3 Advanced Robotics

Robots are programmable machines that usually carry out a series of actions autonomously. Robotics is a branch of technology that deals with physical robots. In advanced robotics, robots can interact with one another, work safely side-by-side with humans, and learn from them. In the future, we can say that there will be increased human-robot collaboration and much work will be replaced by robots (Singh & Banga, 2022).

The epidemic has created numerous new challenges for businesses and exacerbated others, like a shortage of warehouse staff. Due to the e-commerce growth, warehouses can be stressful, hazardous, and poorly compensated places of employment. New automated technologies, such as autonomous mobile robots, are being implemented (AMRs). AMRs work with warehouse staff to move goods and choose, collect, and replenish supplies. On the other hand, automated storage and retrieval systems (ASRS) deposit and retrieve cargo from specific locations (SupplyChain, 2022). According to a paper published in IEEE transactions on robotics by researchers from MIT and the polytechnic university of Madrid, adopting blockchain technology as a transmission media for a workforce of robots could offer safety and prevent deceit. The study might have uses in places where multi-robot networks of autonomous vehicles distribute things and transport humans (Zewe, 2021) (Fig. 6).

In the field of swarm robotics, the integration of Blockchain with AI is believed to be advantageous. The field comprises many physical robots performing activities or

Fig. 6 Illustrates a typical working mechanism of autonomous mobile robots (AMRs). (Source: Own work)

processes as a "swarm." Each robot in this field is equipped with AI to communicate with the external environment according to predetermined principles. When these robots are networked together, the stability and flexibility of their group behavior and communicative potential are greatly enhanced (Afanasyev et al., 2019). Blockchain ensures data security via distributed networks by employing modern encrypted algorithms, including cryptographic electronic signatures and cryptographically secured public-key authentication. The accessibility to the information is governed by the encryption password given to the robot. Blockchain provides an optimal security solution for automation, which has evolved as a leading technology, just as industrial intelligence robots have become a leading technology (Ghanchi, 2019).

3.4 Additive Manufacturing

3D printing or additive manufacturing (AM) is ideal for distributed business. Transporting electronic documents beyond borders or around the globe does not provide the same difficulties as transporting physical products. With the correct substance and expertise, 3D printing technology can create shapes without a mold, cutting blade, or another workpiece. Production can be transferred between printers situated everywhere flexibly. From the design phase of AM to final production on the shop floor, AM files can be transmitted with a single click. AM's digital nature enables the construction of digital supply networks and supply chains, making it simpler to interchange and transport components and goods (Stuart Trouton, 2016).

In addition, every step of the design process for each AM component can be accounted for and documented. Distributed production aspires to achieve this, but doing so successfully is challenging. Providing a 3D printable file to remote manufacturers or end users poses dangers, including the likelihood that the file may be distorted or altered, that more prints will be created than are permitted, and that intellectual property will be lost (Klöckner et al., 2020). As a method for protecting the digital thread of 3D printing processes, blockchain has garnered increasing interest from industry and government agencies. The University of Exeter law school, coordinated by Dr. James Griffin, has a patented watermarking technique for 3D printing (Everett, 2022); Dr. Griffin said,

> Blockchain is an easy way for copyright data to be stored, and a means by which licensing of 3D printed content could be standardized.

According to Col. James Allen Regenor, U.S. air force (retired) and founder of VeriTX Corp.,

> Production became centralized because of cost and control, but blockchain can be the key to making trusted distributed manufacturing a reality.

The combination of 3D printing and blockchain technology opens the door for everything that can be printed to be considered a token, either fungible or non-fungible, that can be traded. Example: a factory acquires the capability to 3D print 1000 units but only produces 900, leaving 100 units unused. Beyond just 3D printing, tokenization of machine use could enable businesses to market and trade available machine time (Hendrixson, 2022).

3.5 Cloud Computing

Cloud computing allows users to access data from any location by storing it on a remote server. Examples: Google's Gmail, Microsoft's OneDrive, etc. Cloud computing, in a nutshell, is a method of storing, managing, and processing data that uses remote servers and makes this data available through the internet on demand. Purchasing space for data storage on the cloud allows businesses to avoid investing in costly and space-consuming on-premises servers (Alouffi et al., 2021).

The cloud may be used to automate tasks for workers, and smart contracts on the blockchain can automate processes with several participants. However, only 35% of respondents claim they use smart contracts on the blockchain to ease existing activities, indicating that blockchain is still behind the curve. To facilitate better supply chain transactions between different companies, Coca-Cola built an Ethereum-based corporate blockchain platform. This was achieved by streamlining coordination between several franchise bottling facilities (Chmielewski et al., 2021). IBM's vice president of blockchain for corporate, Jerry Cuomo, anticipates that the demand for computing capacity will expand rapidly as business operations are completed at an unprecedented rate. According to Gartner, the inefficiencies of sending all of this information to a centralized cloud or data center in order to be processed increase in direct proportion to the volume and velocity of the data (Mrvosevic, 2019) (Fig. 7).

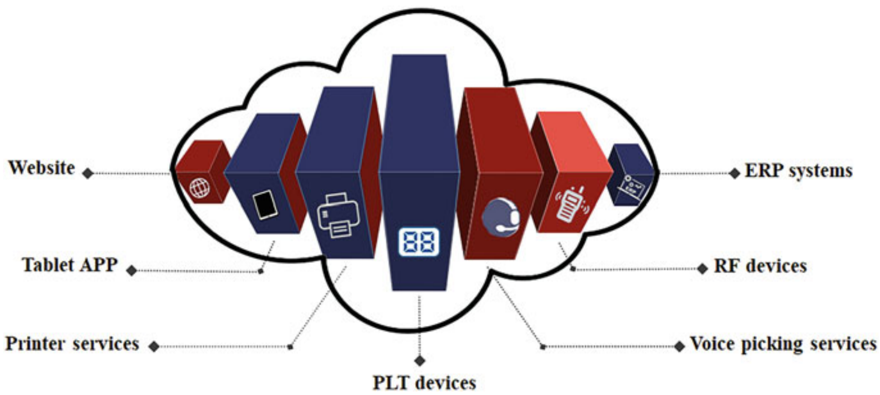

Fig. 7 Cloud services providing interconnected I4.0 devices in SCM. (Source: Owned Study)

Decentralization of cloud-computing services can close security gaps. Moreover, there is no better way to accomplish this than integrating blockchain into cloud computing technology. In recent years, there has been a growing interest in blockchain solutions, which are now utilized in virtually every area, including supply chain, healthcare, banking, and more. The primary reason for this remains the security of blockchains. Owing to blockchain's consensus mechanism makes any transaction data saved using blockchain technology difficult to erase or alter. Many blockchain nodes make it challenging for an intruder to alter the data. Utilizing blockchain technology in cloud computing has many advantages. Utilizing blockchain technology in cloud computing has many advantages. A few of the more significant advantages are listed below:

1. Decentralization
2. Enhanced data security
3. Quick disaster recovery
4. Geo-independence

Blockchain-based cloud computing is the pinnacle of efficiency and safety. Because of this, the technology is a great choice for bolstering cloud safety. When it comes to blockchain, cloud computing is just getting started. On the other hand, many new businesses have entered this emerging blockchain cloud computing sector to improve data safety and streamline information exchange. In short, blockchain in cloud computing is anticipated to alter how businesses function fundamentally (Sharma, 2021).

3.6 Big Data Analytics

We know that all IoT devices are linked and constantly transfer big data. Big data refers to the large amount of data received from numerous linked devices. This vast volume of data must be evaluated to extract meaningful information, including photos, audio, video, or text. In a nutshell, it is a data storage method that examines a vast volume of data from numerous sources and systematically extracts valuable information.

Big data analysis utilizes blockchain technology, which provides a new data layer. Most crucially, this data layer satisfies the two primary requirements of the analysis of big data, which are as follows:

1. Due to the design of the blockchain network, the big data it generates is completely trustworthy and cannot be altered in any way.
2. Big data based on blockchains is helpful because it is organized, there is a lot of it, and complete. This makes it an ideal source for conducting additional research.

The ledger information may apply to various businesses, including energy commerce, real estate, etc. This fact has resulted in various big data analytics improvements. For example, financial organizations may use blockchain technology to evaluate every transaction in real-time, allowing them to avoid fraud. In other words, rather than reviewing previously committed fraud records, banks may now identify potentially fraudulent or risky transactions in real-time, removing the need to examine previously committed fraud. Big data is expected to generate an additional $203 billion in revenue by 2020, making it an incredibly profitable sector. To elaborate even further, the information recorded in the blockchain ledger may account for up to 20% of the total value of the big data market by the year 2030 and produce annual revenue of up to one hundred billion dollars (Fedak, 2018).

3.7 Augmented Reality (AR) and Virtual Reality (VR)

AR is a technology that adds a layer of digital information to the natural environment in front of users to produce an augmented version. In brief, digital data is placed on top of an existing natural environment. Augmented reality is used in many devices, including smartphones, tablet PCs, smart glasses, and other intelligent gadgets. VR, on the other hand, uses computer technology to create a 3D virtual world. With virtual reality apps, one may travel to locations he has never been before, such as walking on the surface of Mars or standing on the summit of Mount Everest. Virtual reality, augmented reality, and digital twins are just some technologies that present significant prospects for automating industrial facilities, warehouses, and other areas of the supply chain (Schmidt, 2022) (Fig. 8).

Customers have grown accustomed to anticipating improvements in delivery speed, service quality, and experience personalization, necessitating further supporting technology. According to Forbes, augmented and virtual reality are assisting the supply chain and logistics industry in combating the different difficulties it is now facing. As previously said, this is a cost-effective solution that can contribute to developing "rapid and error-free" shipping lifecycles. The

Fig. 8 AR visual selection in logistics and supply chain management. (Source: Own work)

following examples illustrate how augmented, and virtual reality might help enhance supply chains:

- Information about “manufacturing facilities, distribution hubs, and warehouses” is updated in real-time.
- Provides the most efficient transportation routes to ensure on-time delivery of products.
- Provides comprehensive information regarding the entirety of the package as well as the contents, hence lowering the likelihood of any damage occurring.
- Increases safety by equipping drivers with “facial recognition technology” to verify customers more accurately.

Since the 2018 bitcoin market meltdown, organizations have rebounded and are more robust than before. Naturally, many people have begun to look at how blockchain technology and the benefits of virtual reality may be merged (Saunders, 2019).

> Augmented reality (AR) and virtual reality (VR) are ‘revolutionary’ emerging platforms that are changing the game for supply chains.

It was observed that these cutting-edge technologies complement each other rather well.

1. As a first step, it allows for the safe distribution of VR content that has previously been stored centrally. To put it succinctly, blockchain allows for the creation of a fully working virtual world that is populated by the creations of the platform’s users and operates according to the rules devised by the users themselves, without the need for any intervention from the platform’s designers. Users can create a self-sustaining environment and freely roam it without fear of repercussions.
2. Blockchain technology will be used to provide copyright protection even in a decentralized system. The blockchain will keep track of who, if anyone, attempts to claim authorship of someone else’s creative work without that person’s permission. Copyright protection can be liberated from the red tape that now stymies it, and with the correct safeguards in place, VR platforms can work together to establish a thriving ecosystem.
3. Combining the virtual reality industry with the lucrative bitcoin business makes it much simpler to spread awareness about VR. People’s interest in virtual worlds is likely to skyrocket once they understand that, in addition to spending their spare time there, they can generate a respectable income by participating in them (Lim, 2021).

4 Bscm and I4.0 Technologies: Threats and Challenges

Blockchain is one of the ground-breaking technologies that has taken the world by storm in recent years. Integration with I4.0 technologies is becoming increasingly important in the digital supply chain. These technologies include smart contract technology, record-keeping, real-time commodity monitoring and tracing, etc. The decentralized nature of blockchain, its consensus system of checks and balances, and the cryptographic foundation used to encrypt data safely and veritably all contribute to the widely held belief that blockchain provides an extraordinarily high level of security. As a result, it has become a distinct financial asset class for individuals and influential organizations (Bodkhe et al., 2020). However, the Bscm and I4.0 technologies still face the threats and challenges described below.

4.1 The Quantum Computer

According to reports, quantum computing would threaten the blockchain by upsetting its cryptographic underpinning, communication protocols, and ledger immutability. Since quantum computers are available through the cloud and are purposely constructed by state actors to break current cryptography, it is only a matter before blockchain and cryptocurrency challenges are deployed. In every essential way, a quantum computer differs from the classically-operated machines with which we are all familiar. By using entanglement and superposition at the subatomic level, quantum computers can carry out computations that are vastly more powerful than those that can be performed by conventional computers (Bolfing, 2020; Luckow et al., 2021). Because of the substantial wealth connected to blockchain technology, these cascading effects can bring the entire economy to a grinding halt. It is of the utmost importance to safeguard this value by resolving the issues of communication between wallets and nodes and the fundamental infrastructure and fortifying the underlying algorithms that run the blockchain itself (Vilk, 2022).

Let us look at the relationship between blockchain and the two well-known quantum computing techniques that Grover and Shor developed. Users can identify values among billions of unstructured data points all at once with the help of Grover’s technique, which optimizes search capabilities through quantum characteristics and a quantum computer. In contrast, Shor’s algorithm can solve the problem, summarised as follows: “given an integer, determine its prime factors.” Cryptographic hashing and information stored are more at risk from Grover’s attack, while the transmission link between the wallet and the blockchain networks is more at risk from Shor’s attack. The traditional computers still in use today cannot reverse-engineer cryptographic hashing because the processing power required is too expensive in terms of both times and the resources required. Using linear processes on traditional computers takes too much time, even considering GPU farms (Jaffali & Holweck, 2019).

Fraudsters Attacks BSCM utilizes consensus, decentralization, and cryptography to protect the integrity of transactions. However, many blockchain security vulnerabilities related to Blockchain and I4.0 tech have occurred due to the inadequate application of the technology.

Percentage of Attack A 51% attack happens when a single person or organization (malicious hackers) gains control of the entire system by collecting more than half of the hash rate, which can be fatal. Intruders can alter the ordering of transactions and block their confirmation. They can even undo successful transactions, leading to double expenditure.

Phishing Attack In a phishing attack, the hacker's goal is to obtain the user's password. They can send emails that appear valid to the holder of the wallet key. The user must submit their login credentials via a phishing link. Getting a user's login information and other sensitive data could hinder the consumer and the blockchain network.

Routing Attack Users in a blockchain are typically uninformed of a routing attack because data transfer and processes continue as usual. Without the user's knowledge, there is a possibility that these attacks will commonly expose personal information or steal confidential information (Shah, 2022).

AI-Based Attacks Cyberattacks have been based on artificial intelligence (AI) since 2007, but their significance as a danger to the Internet of Things (IoT) is only increasing. Hackers may soon be able to develop AI-powered tools for their attacks that are faster, more scalable, and more successful than those developed by humans. The IoT ecosystem is in danger because of this issue. While the techniques and components of classic IoT risks posed by cybercriminals will remain the same, the scale, automation, and personalization of AI-powered cyberattacks will make them incredibly tough to combat (Card, 2021).

5 Concluding Remarks

This chapter examines the fundamentals of industry 4.0, its history, and the use of blockchain technology in blockchain-driven supply chain management. We illustrated how I4.0 technologies, including IoT, robotics, AI, big data cloud computing, additive manufacturing, and AR/VR, may advance the Bscm. We also discuss the limitations of blockchain and I4.0 technologies in implementation and adaptation. Nonetheless, these technologies can provide other solutions to supply chain management problems, enabling an extensive array of applications. Reducing quantum computer threats, fraudsters, and AI-based attacks are emphasized. Future studies into the fields and applications described in this chapter will elevate Bscm and I4.0 technologies in the global business sector.

There is no denying that the Bscm and I4.0 technologies have a significant opportunity for the industries of the next generation. However, it is equally valid that the degree of this possibility is currently unclear to us. Consequently, it is evident that specific problems exist inside the process and that additional research is required to determine how to eliminate them. For instance, a 51% assault can be mitigated by enhancing mining pool management, increasing the hash rate, and avoiding proof-of-work (PoW) agreement protocols. In addition, the phishing attacks could be prevented by installing a browser add-on that notifies you of hazardous websites, prevents phishing, installing malware monitoring and antivirus software to secure your device, providing the following to the client if an email requests login data, reviewing the URL before clicking, instead of clicking on links, type in the address, when utilizing a digital wallet or conducting any sensitive financial operations, you should avoid unsecured wi-fi networks, update system and software. Lastly, AI-based attacks can be prevented by integrating a more robust blockchain algorithm with the machine and deep learning algorithms. Preventive ideas mentioned above are still ongoing research and could need more insights.

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Blockchain Driven Supply Chain Management and Supply Chain Resilience: Role of Intellectual Capital

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1 Introduction

Today's extended supply chains are increasingly vulnerable and suspectable to the impact of changes and unforeseen events. The uncertainty associated with supply chain events is recognized as one of the significant challenges in managing and controlling the supply chain (Ali et al., 2021; Qader et al., 2022; Azmat et al., 2022). Globalization and the increasing number of entities involved in the supply chain have made the supply chain vulnerable while there is renewed focus on increasing efficiency (Kamalahmadi & Parast, 2016; Papadopoulos et al., 2017; Stecke & Kumar, 2009). Weather, port congestion, strikes, fuel cost, shortage of raw materials, and transportation are among the factors causing disruption. This impacts the stability and security of businesses and the well-being of society and consumers. The impacts of supply chain disruption could be so far and wide that supply chain planners are continually pursuing strategies to develop a supply chain capable of overcoming the disruption and operating under extremely turbulent and disruptive situations (Mubarik et al., 2022; Khan et al., 2022b, 2022c). In this context, an organization's supply chain resilience (SCR) is an important strategic weapon for economic and financial survival (Melnyk et al., 2014; Pettit et al., 2019). Supply chain resilience mitigates the negative impacts of unforeseen events by developing and incorporating strategies to overcome the contingencies and return to a normal or improved state (Shekarian & Mellat-Parast, 2020; Mahmood & Mubarik, 2020; Kusi-Sarpong et al., 2022).

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Glickman and White (2006) suggest that disruptions and disturbances are inevitable in the contemporary supply chain. In these circumstances, the supply chain planners and managers have a dual role to play. While they should be focused on the adverse events (whether they will occur or not), they should also work towards developing a supply chain that is more capable of responding to the challenges using the tools and technology available. A new development in digital technology that has the potential to play a critical role in developing such a supply chain through transparent, secure, and efficient collaboration is blockchain technology (BCT) (Leible et al., 2019; Khan et al., 2022a). Kuhi et al. (2018) suggest that digitization has the potential to improve supply chains, and by incorporating blockchain technology, a more proactive and resilient supply chain could develop which is secure and transparent with data integrity (Manupati et al., 2020; Saberi et al., 2019; Piprani et al., 2022; Mubarik et al., 2022).

Blockchain technology has opened new opportunities to develop innovative frameworks and business models (Schmidt & Wagner, 2019) while demonstrating significant improvements in resource management, traceability, and security (Aranda et al., 2019). Further, it offers the potential to transform supply chain operations, such as procurement, distribution, order fulfillment, etc., with integrated, sustainable, and streamlined business practices (Bai & Sarkis, 2020). Despite these potential benefits, blockchain can pose several implementation challenges, such as a lack of organizational readiness or technical expertise, IT infrastructure, user resistance to new technology, and limited financial resources for investment in blockchain technology. As such, there is an urgent need to develop managerial strategies to help firms overcome those challenges while fully exploiting the benefits of blockchain technology. Considering the challenges in implementing blockchain due to its holistic nature, intellectual capital offers the right set of diverse tools to assist in implementing blockchain technology. Intellectual capital represents the knowledge, processes, and relationships that can be transformed into organizational performance. It is defined as the sum of intangible knowledge resources within the organization and is considered a vital source of supply chain competence and organizational performance (Subramaniam & Youndt, 2005; Bontis et al., 2018; Mubarik & Naghavi, 2020; Mubarik et al., 2021a, 2021b). The three main dimensions of intellectual capital. Human capital refers to the information, expertise, and capabilities an individual possesses to use in day-to-day operations (Qin & Kong, 2021). Structural capital refers to the organization's procedures, routines, and non-human knowledge embedded in the operations and data basis of the organization (Ahmed et al., 2019). Relational capital is the third component of intellectual capital and refers to the relationship and association between the firm and its stakeholders, such as its suppliers, employees, consumers, and other partners (Mahmood & Mubarik, 2020; Mubarik & Naghavi, 2020; Ahmed et al., 2021). Considering the aforementioned benefits of intellectual capital, it is proposed that it is a critical link between developing a resilient supply chain and implementing blockchain technology. Although blockchain technology application in the supply chain is covered in literature, there is a lack of studies that focus exclusively on the strategies for implementing blockchain. Against this backdrop, this study examines the potentially facilitating role of intellectual capital in developing a blockchain-driven resilient supply chain. It is proposed that the holistic nature of intellectual capital offers a unique set of tools and techniques that could form a core for developing a robust, resilient supply chain. Thus, this research will provide an understanding of how intellectual capital facilitates the implementation of blockchain technology to build a resilient supply chain by proposing a conceptual framework. The role of each element of intellectual capital in developing a resilient supply chain is discussed in detail. The framework will provide supply chain planners and managers guidance on utilizing the full potential of intellectual capital and developing a resilient supply chain.

The remainder of this book chapter is organized as follows: In the next sections provide a review of literature in the area of intellectual capital, blockchain technology, blockchain-based supply chain, and supply chain resilience. The next section proposes a framework for developing a blockchain-driven supply chain by incorporating intellectual capital. In the last section, a brief overview is presented, and some concluding thoughts on future research direction are discussed.

2 Literature Review

2.1 Intellectual Capital

The term "Intellectual Capital" was first introduced by Galbraith in 1969 (Itami & Roehl, 1991) by describing it as transformable organizational knowledge (Stewart, 1997; Harris, 2000). However, the IC didn't become widely used until Stewart's (1997) groundbreaking article appeared in Fortune magazine. He defined IC as employees' knowledge, competence, and abilities to boost a company's competitiveness. However, more recent academics see IC from a broader standpoint (Bontis, 1998a, 1998b; Youndt et al., 2004; Khalique et al., 2015; Mubarik et al., 2016a, 2016b, 2019; Rasiah et al., 2017) by recognizing the three main aspects of IC. Intellectual capital is considered as a driver of both financial and nonfinancial performance. It positively affects innovation (Lee et al., 2011; Menor et al., 2007; Subramaniam & Youndt, 2005) and firm performance (Hsu & Wang, 2012; Youndt et al., 2004). Furthermore, it is widely accepted that an organization's IC is the primary factor in creating value and improving its performance (Mubarik et al., 2021a, 2021b; Cabrita et al., 2013). It broadly encompasses the organization's relationships with its employees, suppliers, and customers, as well as its procedures and operations, and also the workforce's knowledge, expertise, and technical competencies (Mubarik et al., 2021a, 2021b). Intellectual Capital comprises three constructs: human capital, structural capital, and relational capital (Mubarik et al., 2019; Ahmed et al., 2019; Subramaniam & Youndt, 2005).

Human capital refers to a firm's potential to extract the best solutions from the skills and knowledge of its employees (Bontis, 1998a, 1998b). It is the knowledge, skills, and abilities individuals possess and apply in daily activities (Subramaniam & Youndt, 2005). The presence of human capital facilitates blockchain implementation by making the best use of individuals' skills and potential and learning new technology. The second component of intellectual capital, structural capital, arises from processes and organizational values indicating the knowledge embedded in databases, routines, patents, manuals, structures, and procedures (Youndt et al., 2004). A robust structural capital benefits the adoption of blockchain technology by providing a solid foundation of established processes and procedures. The last component, relational capital, is related to the "knowledge embedded within, available through, and utilized by the interactions among individuals and their networks of interrelationships" (Subramaniam & Youndt, 2005, p. 451) in the organization. It makes a critical contribution toward blockchain implementation since to core of this technology is integrating different entities in the supply chain and utilizing the knowledge and wisdom gained through it effectively connect the entities and communicate between them. Overall, human capital, structural capital, and relational capital complement each other in developing an ideal environment to implement new technologies and a higher level of firm performance (Inkinen, 2015).

2.2 Block Chain Technology

The concept of Blockchain technology (BCT) was first introduced in 2008 for digital currency, also known as Bitcoin (Batwa & Norrman, 2020; Nakamoto, 2008), and later in 2013, it gained the significant interest of academic researchers and industrial experts due to its unique features (Iansiti & Lakhani, 2017). It operates as a network of nodes, ensuring each node has a decentralized copy of the ledger in its database. On each transaction, a new block is created and to the chain; after that, each node confirms the block to ensure that it has not been altered. As soon as the block has been verified, it is added to the blockchain. Consequently, all nodes in this network reach a consensus, which indicates that they agree on which block is valid and which is not (Batwa & Norrman, 2020; Yli-Huumo et al., 2016; Iansiti & Lakhani, 2017). Moreover, according to Crosby et al. (2016), blockchain technology offers a shared and consensus-based distributed ledger, which stores information in blocks on each participant's node (Yli-Huumo et al., 2016). The development of blockchain technology has resulted in increased flexibility across time and space and has both positive and negative impacts on the global business community (Aste et al., 2017; Giungato et al., 2017; Kewell et al., 2017). In particular, disruptive technological advancements have significantly transformed the entire end-to-end production and business models in key sectors.

2.3 Blockchain-Based-Supply Chain

It is an undeniable fact that the increasing use of modern technologies such as the Internet of Things (IoT), Big Data Analytics, and Artificial Intelligence (AI) has a significant impact on the supply chain (Saberi et al., 2018). Blockchain technology can improve collaboration among SCM members, which indirectly impacts supply chain costs and efficiencies (Aste et al., 2017). Moreover, it has the potential to increase consumers' trust in businesses as it allows them to track the items throughout their entire journey (Di Vaio & Varriale, 2020). Extensive research demonstrates the benefits of blockchain in logistics and supply chain, such as increased cybersecurity, accountability, transparency, and fraud prevention (Schuetz & Venkatesh, 2020; Morkunas et al., 2019; Queiroz & Fosso Wamba, 2019; Wang et al., 2019; Chen, 2018; Kshetri, 2018; Kamble et al., 2018; Ying et al., 2018). Blockchain technology has the ability to redefine, rethink, and restructure the relationships among all supply chain participants (Queiroz & Fosso Wamba, 2019). Furthermore, using blockchain technology in SCM improves operations management's security, openness, traceability, and efficiency (Kshetri, 2018). A supply chain is full of activities and procedures that can be significantly transformed by blockchain technology (Kshetri, 2018) such as, blockchain technology offers improved and real-time tracking of materials and goods from their origins through the entire SCM operations. Furthermore, in the supply chain, blockchain technology enables all participants to determine who is executing which actions by specifying and demonstrating who performed them (Di Vaio & Varriale, 2020). Due to this technological advancement, supply chain operations management is dramatically transforming (Di Vaio & Varriale, 2020).

2.4 Supply Chain Resilience

Supply chain resilience can be defined as the ability of an organization or cluster of business enterprises to sustain, adapt, and grow in the context of unprecedented change (Fiksel et al., 2015). Conventionally, the technique of supply risk management was utilized to prevent supply chain disturbances. However, such conventional risk management and assessment systems remained inadequate for accommodating unforeseen events (Pettit, 2008). But, this gap is filled by supply chain resilience, which lifted the idea of supply chain risk management to a different level (Mubarik et al., 2021a, 2021b). Consequently, supply chain resilience refers to an organization's capacity to continue operations despite challenging, turbulent, and disruptive circumstances. According to Barroso et al. (2011), these situations refer to when the normal working conditions are inadequate, and employees must work under very different circumstances than usual, which makes it more difficult for them to work efficiently. However, a firm's performance can be improved by increasing its supply resilience. An organization's supply chain resilience is defined by Ponomarov and Holcomb (2009) as the supply chain's ability to adapt, plan, and respond to obstructions in a cost-effective and timely manner, and to be able to move toward post-obstruction operations in a cost-effective manner. In recent years, severe earthquakes, political instability, fuel crises, epidemics, wars, and terrorism have severely disrupted businesses' ability to produce and deliver their products (Hosseini et al., 2019). Such events have enhanced academic and practitioners' attention to the need to build more resilient supply networks to mitigate disruptions. For instance, according to a recent survey conducted by the World Economic Forum (2013), over 80% of businesses are concerned about the resilience of their supply networks.

Consequently, having a resilient supply chain can be crucial for both short-term survival and long-term competitiveness (Tukamuhabwa et al., 2015). Nevertheless, resilience is much more than just recovery; it also incorporates a level of adaptability and flexibility. In addition, it consists of a unique and sustainable source of competitive advantage (Gunasekaran et al., 2015; Hamel & Valikangas, 2003), such as supply chain preparedness, agility, and recovery (Mubarik et al., 2021a, 2021b). A company should combine these three dimensions to deal with and recover from supply chain disruptions effectively.

Supply chain preparedness refers to the degree to which a supply chain is prepared to deal with disruptions (Mubarik et al., 2021a, 2021b) and how advanced supply chain technologies can reduce the impact of disruptions. Better preparation enhances the ability to respond efficiently (Jahre et al., 2016; Scholten et al., 2014; Van Wassenhove, 2006), even though there are serious tradeoffs between cost-effectiveness and flexibility (Jahre & Fabbe-Costes, 2015; Day, 2013). The second dimension is agility in the supply chain refers to the capacity of SC businesses to respond quickly, efficiently, and cost-effectively to unforeseen events (Wieland & Wallenburg, 2013). SC networks with greater agility can respond more efficiently to complex situations (Dubey et al., 2018). Furthermore, supply chain agility improves SC resilience and positively impacts the consumer value provided by SC (Hosseini et al., 2019; Wieland & Wallenburg, 2013). Third, recovery is the capacity of a supply chain to bounce back from disturbances in the shortest possible time possible. Supply networks typically face numerous obstacles when developing plans to recover from the repercussions of disruptions (DuHadway et al., 2017; Son & Orchard, 2013). Recovery strategies in the supply chain are essential to effectively managing supply chain disasters and resilience. Research shows that 80% of enterprises that didn't plan for supply chain interruption during significant epidemics closed within 2 years (Cerullo & Cerullo, 2004). Formulating recovery plans to restore, and normalize or improve operational levels after catastrophic occurrences is necessary for survival and speedy recovery (Paul et al., 2021).

3 Developing a Block Chain Driven Resilient Supply Chain Framework

Derived from the discussion in previous sections, this study proposes a framework for developing a blockchain-driven resilient supply chain using intellectual capital. As discussed, implementing blockchain technology encompasses several entities and unique roles while requiring established processes and procedures in the organizational supply chain. Keeping in perspective the unique and diverse activities performed by several entities in blockchain, it is proposed that a comprehensive tool such as intellectual capital has the potential to facilitate the implementation of blockchain in the supply chain. Each element of intellectual capital brings together

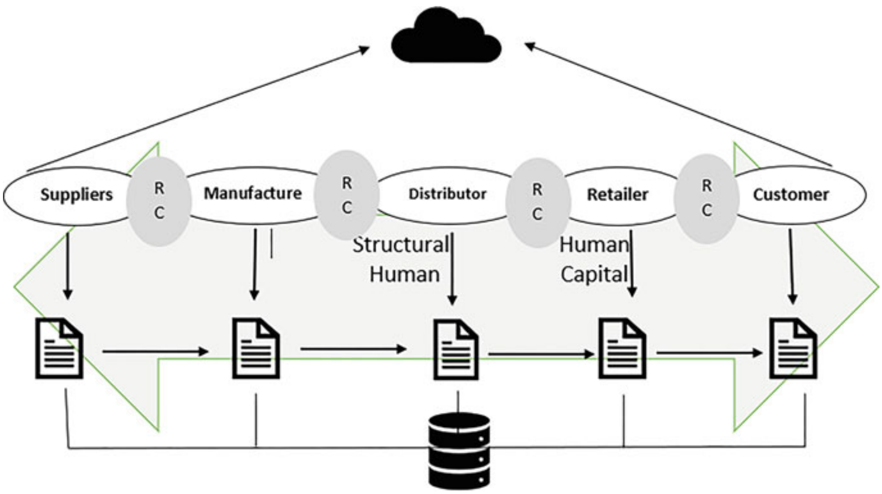

Fig. 1 Conceptual framework blockchain-driven supply chain resilience

a unique attribute that complements blockchain implementation and application in the supply chain (Fig. 1).

3.1 Role of IC in Developing a Blockchain-Driven Resilient Supply Chain (BCDRSC)

Intellectual capital consists of human, relational, and structural capital which is considered as the driving force for sustainable production in firms (Al-Omoush et al., 2022). Intellectual capital puts a great amount of effort into building a sustainable supply chain through a knowledge-based economy. The sustainable supply chains then require collaboration with SC partners. Therefore, it is necessary to create information-sharing platforms for smooth sustainable production and operations. Intellectual capital allows organizations to implement the concept of digitization in sustainable supply chains which consists of various transformative technologies such as blockchain, big data, cloud, computing, internet of things, etc. (Gashenko et al., 2020). According to Kusi-Sarpong et al. (2022), intellectual capital and all of its dimensions are increasing the blockchain-based supply chain management due along with supply chain mapping. It allows organizations to map their sustainable supply chains from upstream to downstream. Furthermore, the implementation of blockchain technology improves firms' transparency and provides greater visibility thus increasing firms' performance (Benzidia et al., 2021). Also, the dimensions of intellectual capital enable blockchain adoption in the supply chain which emerges a new concept of the blockchain-driven supply chain.

3.1.1 Effect of Human Capital

Intellectual capital (IC) is the accumulated knowledge and skills of an organization's employees that can be used to improve its competitive advantage. This type of asset is commonly referred to as IC. It can be used to drive a firm's profits and expand its customer base. Aside from being able to improve a firm's operational efficiency, IC also contributes to a firm's bottom line. So, in this context, human capital is the sum of various skills and knowledge that an individual can use to improve their performance. It can also mediate the exchange of knowledge among colleagues, which is considered a vital asset for organizations to gain a competitive advantage. Because of its value, it can be used to enhance their knowledge base. HC has been studied to determine its impact on investors' decision-making process (Lim et al., 2010). HC is a type of intangible asset that is acquired through working experience (Kučarčíková & Mičiak, 2018). It allows entrepreneurs to gain a deeper understanding of themselves and their potential. Through this experience, they can improve their entrepreneurial judgment and forecasting ability. In light of previous literature, HC has been integrated with the latest technologies, such as blockchain, cyber security, the internet of things, and cloud computing which is an integral part of industry 4.0 (Flores et al., 2020). Human capital Not only helps the organization to implement the latest technologies, but it also improves the performance of supply chain management. High levels of HC benefit manufacturing organizations by allowing them to improve their processes and gain a deeper understanding of their suppliers' technological innovations. This can also help them develop effective strategies and improve customer relationships.

3.1.2 Effect of Relational Capital

Relational Capital (RC) is a type of intellectual capital that focuses on the intangible value that an organization has gained through its relationships with other businesses and external parties (Hussinki et al., 2019). It also includes various elements such as customer potential and corporate reputation. This intellectual capital is used to evaluate a firm's relationships with its customers and partners (Mehralian et al., 2018). The ability to focus on the needs of customers is a key component of competitive performance in high-tech and knowledge-based telecommunication markets. Organizations must develop the necessary relational capabilities to meet their customers' needs. Relational capital also refers to the organization's internal and external relations that allow it to connect its various intellectual resources with its external shareholders (Abd-Elrahman & Kamal, 2020). This allows it to create value by developing and managing effective customer relationships. This concept is commonly used to describe the various relationships that an organization has with its customers. It can also describe the multiple interactions it has with its partners and suppliers (Abd-Elrahman & Kamal, 2020). The RC is widely acknowledged both at the institutional and individual levels. The literature shows that its role in transforming knowledge into innovations is significant. Zhang and Lv (2015) suggest that the influence of external relations on technological innovation is positive. It is consistent with the idea that external relationships can help bring new ideas and insights into the organization. According to the definition of relational capital, it can be incurred that it can help to develop better strategies pertaining to the implementation of the latest technologies in the organization, which ultimately leads to efficient supply chain management.

3.1.3 Effect of Structural Capital

One of the main elements of IC is structural capital (SC). It is a collection of resources and capabilities an organization has that enable it to function (Yusoff et al., 2019). It includes various procedures and techniques designed to support its employees' work. Even after people resign from the company, SC remains within the firm (Chowdhury et al., 2019). The increasing interest in structural capital has led to the development of new research programs that focus on designing and implementing capital structures geared toward improving an organization's performance (Jia et al., 2020). The objective of these programs is to help organizations compete in the market. Structural capital is an organization's structure that supports the development of its human capital (AlQershi et al., 2021). It includes various processes and procedures, information resources, and intellectual property rights. According to (Bontis et al., 2015), the structures and processes necessary for an organization to be productive are those designed to support its employees. These include the development of strategies, procedures, and databases. He also states that any company whose value exceeds its financial value can benefit from structural capital. Strong structural capital can also help an organization develop a supportive culture that encourages employees to try new things and improve their skills. It can additionally help an organization develop its marketing relationship. A comprehensive assessment of structural capital is also important in order to create a framework for effective communication between various stakeholder groups (Gogan et al., 2015). According to structural capital, knowledge always remains within the firm; this knowledge can benefit the remaining staff of the organization even though the amount of resourceful human capital leaves for the other firm. In this vein, structural relations can bridge the gap between implementing blockchain technologies under the umbrella of supply chain management.

4 Concluding Remarks

The study examined the influence of IC on implementing a blockchain-driven resilient supply chain. Several studies have examined the impact of blockchain technology in improving the supply chain's operational effectiveness, including its resilience toward uncertainty. However, there is a lack of information on to build such a supply chain. What tools, techniques, and strategies are available that can assist supply chain managers in achieving resilience using blockchain technology? To overcome these challenges and guide supply chain planners, this paper presents a conceptual framework for developing a blockchain-driven resilient supply chain, demonstrating the facilitating role of intellectual capital in incorporating blockchain in a supply chain to develop resiliency. Intellectual capital presents a diverse set of critical elements, human, structural, and social capital, effective in implementing new tools and strategies. Based on a rigorous literature review, the model proposed in this study will assist supply chain planners in implementing blockchain in their supply chain. This would facilitate implementing and monitoring resilience strategies in the supply chain.

The findings provide managerial implications for practitioners and supply chain managers, which should aid in planning and developing a resilient supply chain. First, supply chain planners working on improving and developing a resilient supply chain now could benefit from the development of Blockchain technology. This new technology enables real-time tracking, information sharing and updates forming the core requirements for resiliency. Second, this study suggests that since the implementation of any new technology across the wide and dispersed supply chain could be challenging, this study argues that intellectual capital could have a critical role in implementing and adopting blockchain technology. The element of intellectual capital covers a wide spectrum such as human, structural and relational aspects that facilitate incorporating a blockchain-driven supply chain. Lastly, it proposes a framework for implementing a blockchain-driven resilient supply chain. The framework provides a guideline for establishing resilience in a supply chain by directing as it guides the manager in implementing intellectual capital resources and blockchain in the supply chain. It demonstrates the role of each intellectual capital element in facilitating the implementation of blockchain, which in turn guides managers to plan resources accordingly. The framework provides a holistic picture of developing a resilient supply chain to the decision-makers, enabling them to improve planning and foresee the issues and challenges.

Future work should focus more on each element of intellectual capital and further explore its role in implementing blockchain technology. The new developments in the blockchain technology should be further investigated, and their role in developing a resilient supply chain should be explored. Another important future research could be collecting and quantifying the data derived from intellectual capital elements and measuring how it improves blockchain technology's role and supply chain resilience.

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Implications of the Blockchain-Driven Supply Chains for Marketers: A Review and Guiding Insights

Adeel Khalid, Munazza Saeed, Muhammad Usman, and Majid Khan

1 Introduction

In today's digital era, information and communication technologies have played a key role to bring a revolution in the traditional business processes and models (Akhtar et al., 2020; Ismagilova et al., 2019). Digital advancements and cutting-edge technologies have the potential to transform and disrupt inefficient models (Ahmed et al., 2021; Kusi-Sarpong et al., 2022). The most prominent technology is blockchain (Khan et al., 2022a, 2022b, 2022c; Xue et al., 2020) and it is changing the trade and market dynamics. The adoption of disruptive blockchain technology facilitates the sharing of knowledge and information among network members (Wagner & Buko, 2005). Blockchain technology helps in saving costs and improving efficiency (Al-Saqaf & Seidler, 2017). Importantly, all business transactions in blockchain technology are transparent, efficient, safe, and traceable (Mahmood & Mubarik, 2020; Kusi-Sarpong et al., 2022; Xue et al., 2020).

Before suggestions on the adoption of disruptive blockchain technology that positively impacts business models, the key issues and challenges faced by the traditional supply chain need to be understood. Contemporary supply chains depend on centralized, sometimes distinct and independent management information systems (Ivanov et al., 2019). Organizations in the supply chain need an enhanced level of trust for depending on one sole firm or agent for keeping their invaluable and sensitive information (Abeyratne & Monfared, 2016; Mubarik et al., 2022). As such, a single-point failure is a key drawback of consolidated information systems that

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_15

make the entire system at risk of cyberattacks and other corrupt practices (Dong et al., 2017). Moreover, in the traditional supply chain system, supply chain entities are facing emergent pressure to consider and authenticate supply chain sustainability (Seuring & Müller, 2008; Qader et al., 2022; Khan et al., 2022b, 2022c). A key issue for sustainability in supply chains is the support and confirmation that all business activities within the supply chain networks should comply with sustainability standards and certifications (Grimm et al., 2016). Importantly, current supply chains are innately complicated containing multi-echelon, geographically disconnected systems vying to deliver customers (Johnson, 2006; Lambert & Enz, 2017; Mubarik & Naghavi, 2020). It seems impossible to assess information and control risk in complex supply chain networks due to globalization, distinct regulatory policies, and diverse cultural and individual actions (Sarpong, 2014). Fraud, larceny, insecure, and inefficient supply chains create trust issues, and thus better information processing and verifiability are required (Lambert & Enz, 2017; Ali et al., 2021; Khan et al., 2022a; Azmat et al., 2022).

These types of issues in the supply chain raise questions on whether information systems in modern supply chain networks can provide information, which is secured, certain, and robust enough to be trusted for the timely provision of goods and services. These complex issues can be addressed by improving the transparency, security, and durability of supply chain networks (Ivanov et al., 2019; Piprani et al., 2022; Mubarik et al., 2022). Blockchain technology may provide solutions to address these problems. Additionally, the idea of blockchain technology to improve an organization's process is technologically and economically feasible (Abeyratne & Monfared, 2016), as blockchain technology is a decentralized database that permits global-scale transactions and processes among supply chain network entities (Crosby et al., 2016). Additionally, the blockchain traceability mechanism has the potential to mitigate counterfeiting and product fraud (Mackey & Nayyar, 2017) and transparency in processes further improves customers' trust and confidence and enables them to conduct business transactions with minimum risks (Tsanos & Zografos, 2016; Rasiah et al., 2017; Mubarik & Naghavi, 2020; Mubarik et al., 2021). Given such benefits of the blockchain-driven supply chain, blockchain technology has become popular over the past few years in various domains such as airlines, financial service providers, and retailing (Casino et al., 2019; Kokina et al., 2017).

Existing literature on supply chain has provided important insights into how blockchain-driven supply chains can address the issues in the traditional supply chains and reduce customers' perceived risk and customer trust. Likewise, the contemporary marketing literature on the potential benefits of blockchain technology adoption for organizations' marketing activities remains scarce (Hughes et al., 2019; Morkunas et al., 2019). As such, there is no comprehensive framework is available to inform organizations as to how their marketing functions can benefit from the blockchain-driven supply chain. In this chapter, we seek to address this critical gap by shedding light on how the blockchain-driven supply chain can improve the trading processes and highlights its key implications for marketers.

2 Key Facets of Blockchain Technology

Blockchain technology is a distributed database of transaction records like public/private conventional ledgers containing information on all digital affairs that have occurred and shared among network members (Crosby et al., 2016). The disruptive technology of blockchain is different from traditional management information systems in that it incorporates security, decentralization, and smart implementation (Saberi et al., 2019). It is important to note that there is no need for a third party in the blockchain contrary to the centralized network (Min, 2019). The smart contract is the key facet of the blockchain system that permits the performance of valid and reliable transactions without engaging third parties (Saberi et al., 2019). Therefore, transactions are approved rapidly, and invalid business activities are not accepted.

There is a series of steps involved in creating a new transaction in the system in the blockchain. A broker generates a new transaction and then this transaction is disseminated to the network for validation and verification (Abeyratne & Monfared, 2016). Additionally, the new transaction is included in the network as a new block after being approved by most of the nodes in the network according to pre-defined and authorized rules (Min, 2019). This new transaction is recorded and stored in various appropriate nodes for security. Importantly, when the new transaction record is validated and included in the blockchain, various copies are generated in a decentralized way to develop a trusting chain (Crosby et al., 2016).

In blockchain technology, information validity is increased since there is always a check on any misleading information and information systems are decentralized (Saberi et al., 2019). Additionally, valid records of transactions are available to the engaging and active members through conventional public or private ledgers (Crosby et al., 2016). Information can be easily accessed and compared because trustworthiness is not required of any participants in the supply chain network (Nofer et al., 2017). On the contrary, traditional centralized systems are vulnerable to corruption and hacking and have trust issues (Min, 2019). The disruptive technology of blockchain works on the principle of an agreed-upon set of rules that no participating agents or system operators can change or break. The design of blockchain could be different and available in public or private networks and ledgers (Ølnes et al., 2017). Maintaining network rules and diverse entities make this advanced system more valuable and unique (Nofer et al., 2017).

Public and private are two main types of blockchain networks. In a closed or private blockchain, known entities work together in a supply chain network to manufacture and offer products (Saberi et al., 2019), and thus there is no anonymity. In this situation, certification is offered to the system entities to support this private supply chain network (Ølnes et al., 2017). On the other hand, in public or an open blockchain, cryptographic techniques are used to allow clients to enter the network and register their transactions that enhance the trust level among several agents (Saberi et al., 2019).

3 Blockchain-Driven Supply Chain

Modern technologies mostly linked with industry are inducing important disruptions and driving the supply chain management domain to form new business strategy models (Ølnes et al., 2017). Blockchain is one of the most significant and common among these technologies. Blockchain was first used in the bitcoin setting (Crosby et al., 2016). It functions in a distributed data design that relies on a peer group network transaction (Marsal-Llacuna, 2018). Thus, all the transaction records are deemed virtually fixed (Grewal et al., 2018).

The application of blockchain is becoming popular in the supply chain domain. This technology has been used in several domains since its initiation, such as supply chain transparency (Saberi et al., 2019) and distributed billing (Abeyratne & Monfared, 2016). Blockchain technology records transactions of all entities which can improve data transparency and transmission efficiency, assure data security, and avert tampering (Mackey & Nayyar, 2017). Blockchain records are maintained and updated by distributed actors instead of the traditional central method (Crosby et al., 2016). The traditional central mechanism leads to various problems such as time delay and disconnections and thus a lack of trust among involved agents. However, the decentralized feature of blockchain technology addresses this issue by not only eradicating the intermediary costs but also mitigating the delays caused by an intermediary (Kusi-Sarpong et al., 2022), thereby leading to enhanced trust among agents.

Blockchain technology influences product management and supply chain networks, and financial transactions among various network entities (Zhang et al., 2020). The key benefit of a blockchain-driven supply chain is the elimination of financial intermediaries, such as stock exchanges, payment networks, and money transfer facilities (Tapscott & Tapscott, 2017). This makes the entire trading process accurate and efficient. There are four main entities (registrars, standards organizations, certifiers, and actors) involved in blockchain-driven supply chains (Saberi et al., 2019). The role of the registrars is to offer distinctive identities to the network players. Similarly, standard organizations explain blockchain rules and technological requirements (Crosby et al., 2016), and certifiers issue certifications to network players for their participation. Finally, actors involve customers, retailers, and manufacturers that should be approved by an approved certifier to keep the network members in trust (Saberi et al., 2019).

Smart contracts play a key role in restructuring business frameworks (Xue et al., 2020). Smart contracts are defined as written guidelines stored in the blockchain that assist in explaining the network players interplay (Xue et al., 2020). They impact data sharing among network entities (Crosby et al., 2016). For example, standard organizations and certifiers electronically validate network players' products and profiles. Products and network players have their separate electronic profiles within the supply chain network that exhibit information, such as location, certifications, description, and linkages with products (Lu & Xu, 2017). Each actor of the blockchain network can see relevant and important information about a specific product and its status (Lu & Xu, 2017). Importantly, smart contracts make sure that adequate capital is available for projects and timely payments are made to network players (Tapscott & Tapscott, 2017).

It is important to understand the trade mechanism in blockchain technology. The trade between two parties, such as producers and supermarkets, starts with trade conditions (Saberi et al., 2019). Once the trade conditions are met for both entities, a contract is written, coded, and stored in the blockchain system (Crosby et al., 2016). A contract is activated when most requirements of negotiations are fulfilled. Subsequently, products and money are transferred in line with the contract. This entire process does not involve an intermediary. Thus, it not only improves the transaction speed but also reduces the cost associated with transactions and enhances the trust level of participating entities, since all actors have a copy of the ledger (Al-Saqaf & Seidler, 2017).

4 Applications of Blockchain-Driven Supply and Blockchain Technology in Marketing

In recent years, blockchain technology has been used in a variety of different organizations, ranging from banks to online companies for value creation (Mačiulienė & Skaržauskienė, 2021); healthcare (Tandon et al., 2020); social media (Rathnakar, 2019); circular economy (Kouhizadeh et al., 2020) and insurance companies (Kar & Navin, 2021). However, the literature examining the role and applications of blockchain technology in marketing is limited. Blockchain technology is commonly used to make digital payments. Digital currency (cryptocurrency) is used to carry out transactions in Business to Business (B2B) and Business to Customers (B2C) jointly with smart contracts to improve the security and speed of transactions (Saberi et al., 2019). Additionally, smart contracts can assist participating members in efficiently finding suppliers and retailers and reducing fraud and security risks that ultimately enhance customer trust and brand loyalty (Jain et al., 2021).

Blockchain-driven supply chain eliminates intermediaries that decrease financial and operating expenses that eventually increase the profit margin of each transaction (Gupta, 2017). Additionally, the traceability mechanism has the potential to mitigate counterfeiting and product fraud (Mackey & Nayyar, 2017) and transparency in processes enhances customers' trust and facilitates the conduction of business transactions with minimum risks (Tsanos & Zografos, 2016). The blockchain-driven supply chain not only can reshape business models and facilitate trade activities by reducing costs and enhancing security, privacy, and trust among network members but also reduce their perceptions of risk while conducting business transactions.

A blockchain is an important tool that can assist marketers in several ways. Nowadays, marketers pay huge money to third parties to access consumer data (Jain et al., 2021). However, blockchain technology could provide an opportunity to use micropayments to encourage consumers to share their individual or personal data directly, without involving intermediaries and thus without risks (Saberi et al., 2019). For instance, grocery store owners can pay $1 for installing the app and an additional amount if they permit location tracking on their phones. The retailer can offer consumers some money or any other incentive every time they log in through the app and spend some time on it. This method can improve customers' data security, reduce fraud and mitigate incomplete and inaccurate information from customers (Harvey et al., 2018). Similarly, marketers can facilitate smart contracts that consumers can initiate when they sign up for electronic newsletters (Harvey et al., 2018). Micropayments are transferred directly to consumers' wallets every time they deal with commercial emails.

Most online users hate watching pop-up advertisements (Raza et al., 2022) and they consider online advertisements disturbing (Saberi et al., 2019). Thus, they use ad blockers to address this issue and it costs billions of dollars to publishers. Blockchain-driven supply chains potentially provide marketers with opportunities to regain some of that income with a different business model (Treiblmaier, 2021). For instance, traders can transfer incentives directly to consumers for their attention, thereby eliminating Google-Facebook intervention. In short, with the help of blockchain technology, organizations can ignore social media groups by engaging with consumers and transferring the reward of advertisement exposure directly to them (Harvey et al., 2018). Additionally, this technology can authenticate ad delivery and users' engagement; averting online content and advertisements that develop animosity and discourage users from buying (Jain et al., 2021). Similarly, it stops advertisements that are no more appealing to the audience.

In blockchain technology, micropayments help businesses in eradicating the modern idea of mass phishing spam that mitigates the benefits of marketing for all the entities involved (Jain et al., 2021). The blockchain-driven supply chain could make it hard for bots to create and run online social media accounts and hinder flood users with deceptive messages to rob online advertising money from large companies (Harvey et al., 2018). Online validity and legality are well integrated into blockchain technology (Treiblmaier, 2021). Thus, making it easier for organizations to evaluate marketing effectiveness and justify marketing expenses.

Additionally, customers' loyalty projects and schemes can be restructured and transformed by using tokens and technology (Utz et al., 2022). Tokenization plays a key role by combining all loyalty programs into a single platform that contains not only transactions but also the overall interaction of a consumer with brands or agents (Harvey et al., 2018). Additionally, tokenization can enhance the overall experience in loyalty schemes, where overall engagement of users with the company and brand (e.g., reviews and purchases) is considered in a way that is transparent and easy to evaluate (Saberi et al., 2019). Recently, several airline companies have transformed their loyalty and benefit schemes by using blockchain technology, which has improved the overall customer experience. Blockchain-related transformations should have a primacy not only for marketers but also for all other decision-makers in society at large, as blockchain technology provides an opportunity for societies to be more credible and empowered, increasing visibility, linking entities, and offers benefits to people for their contributions to transactions. Figure 1 summarizes the key implications of blockchain technology for marketers.

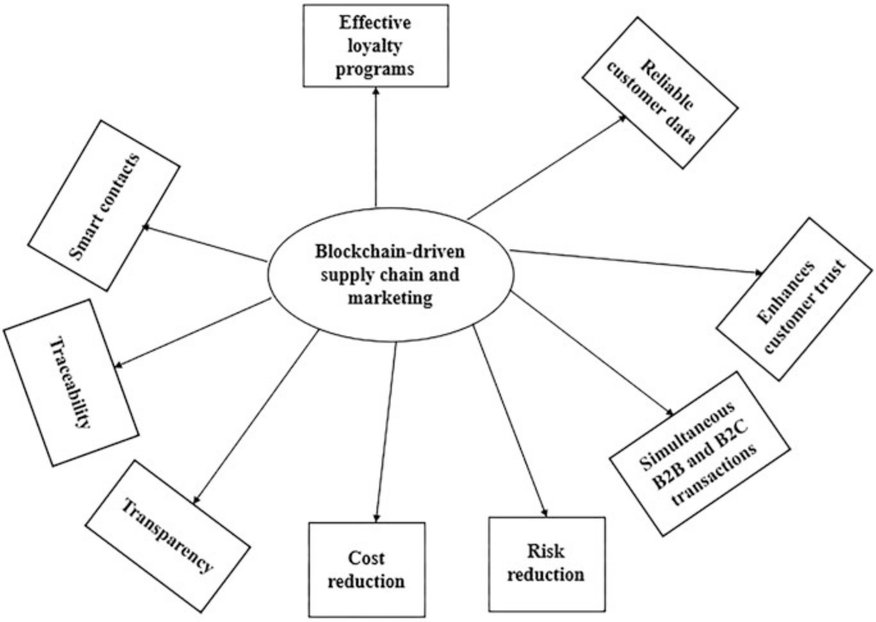

Fig. 1 Usage of blockchain technology in marketing

5 Conclusion

We conclude that blockchain offers solutions to several contemporary problems pertaining to supply chain and marketing. This chapter discusses that incorporating blockchain technology could help organizations save costs and make business processes more efficient. Transparent and traceable features of blockchain enhance trust among network members that encourage them to share their personal information without any risks. Moreover, organizations have better control over trade activities, as blockchain technology helps firms understand and serve customers' needs in a better way.

Blockchain-driven supply chain helps marketers target and deliver products and services to their customers more effectively. Additionally, it protects customers' privacy and improves transparency in online payment processes, helps marketers in mitigating advertisement fraud, and assists them in transferring rewards directly to individuals. Finally, a blockchain-driven supply chain enables marketers to restructure, transform and integrate all loyalty programs in one platform, leading to enhancing customer trust level and brand loyalty.

Nevertheless, although blockchain technology offers various benefits, there are some significant limitations. For example, the transaction cost is increasing in blockchain networks, since the amount of information that needs to be validated in every transaction is continuously rising. Thus, transactions cost in blockchain network in particular bitcoin network has become significant. Additionally, information that users enter blockchain database need to be of good quality. For instance, if they enter misleading information about the source of a product, this becomes difficult to change that information and will be carried across all transactions, thereby misleading registered and available users in the network. Blockchain networks are also not perfect. Different groups of users could attack and take control of the computing power of the blockchain networks and stop new transactions from being verified.

6 Limitations and Future Research Directions

One core limitation of this work is that it focuses on the holistic view of the blockchain-driven supply chain in the marketing domain without specifically identifying and highlighting how marketing activities vary in public versus private blockchain platforms. Moreover, although we provide a framework that integrates different benefits of using the blockchain-driven supply chains for marketers there is no empirical evidence to support our proposed framework. Future studies could test using primary data.

Furthermore, future studies could examine the role of virtual reality in digital marketing. Further studies could investigate the readiness of organizations and consumers to adopt such a disruptive technology. Another important area for future investigation is how blockchain facets influence consumers' perceptions and experiences with contemporary brands. Additionally, how blockchain apps help organizations enhance customer experience and how organizations could use blockchain-enabled storytelling to encourage customers' engagement with brands when their motivation is low can be important research areas. Researchers could also investigate which consumer markets generate more revenue using blockchain apps. Finally, future research could examine how blockchain technology can improve organizations' financial performance.

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Blockchain Based Digital Economy and Industry 4.0

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1 Introduction

The world is transforming in parallel with technological advancements (Rasiah et al., 2017). In addition to being versatile, this transformation process shows what we are capable of doing with the technology we have. Thus, we have a new world before us, and we need new definitions of this new world. We will witness those gigantic central structures operating in the field of finance, economics, management and education in the world are gradually turning into a decentralized structure in this transformation process. Digitization, which is spreading rapidly in almost every sector of the economy, including logistics, is a process that reduces costs in the market while improving optimization processes and reducing costs (Kusi-Sarpong et al., 2022). Therefore, in this study, information economy, digitalization, blockchain technology, decentralized finance and metaverse, which are the leading elements of the digital economy, will be mentioned and the relationship of these elements with industry 4.0 will be mentioned. While considering each element, their contribution to the economy will also be taken into account. With this study, it is also aimed to contribute to the literature by summarizing the technologies developing on the way from the information economy to digitalization in production and their cost-reducing and performance-enhancing effects in the processes from resource allocation to production and distribution.

Therefore, the main purpose of this study is to examine the digital economy and digital industry equipped with blockchain-based technologies together with the supply chain and to reveal their interactions with each other. Hyperconnectivity between mobile devices, the internet of things, and the internet of things are key

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M. S. Mubarik, M. Shahbaz (eds.), *Blockchain Driven Supply Chain Management*, Management for Professionals, https://doi.org/10.1007/978-981-99-0699-4_16

components of the digital economy. The digital economy can be examined in two ways as information economy and e-economy. In the foundations of the digital economy, there are elements such as the internet, electronic communication, digital automation, digital payments, social media and finally the metaverse. The digital economy is an economic activity resulting from billions of online connections between people, businesses, devices and processes. The digital economy develops the digital finance structure along with it. Blockchain is a candidate to be the backbone of the digitalization of production and economy, as it can provide a decentralized and reliable infrastructure at this point (Gumah & Jamaludin, 2006; Mahmood & Mubarik, 2020).

There have been talks for the last decade about a new system that would allow many transactions, from financial transactions to ownership of movable and immovable property, from voter registration to copyright approval, without relying on a central authority, without intermediaries, and free of charge. The blockchain system, which is frequently mentioned today, is actually a system based on trust. Many scientists and experts believe blockchain technology will be the next great revolution after the invention of writing and money. Blockchains are databases without a central storage center, which are constantly updated with data entries from a variety of sources (Catalini, 2017).

Blockchain technologies are a revolutionary formation at every stage of digitalization. Blockchain technologies have also begun to penetrate into the digitalization processes of production, which is called Industry 4.0. We see cost-reducing and time-saving effects in the procurement, production, marketing and logistics stages, where blockchain technologies are starting to come into play. So, what does Industry 4.0 or digitalization in production mean? In order to understand this, we need to examine the development stages of production in the historical process. People used muscle power in production until the eighteenth century. With the invention of steam-powered machines towards the end of the eighteenth century, industry 1.0 was realized. This period is called the "Industrial Revolution". With the use of electricity in production at the end of the nineteenth century, when we came to 1903, the automobile industry leader Henry Ford brought the mass production line to production. Thus, industry 2.0 began. In the 1970s, production based on mechanical and electronic technology began to be replaced by programmable machines with the introduction of computers. We call this new production, which emerged with the combination of electronics and information technologies, Industry 3.0. Industry 4.0 was heard for the first time at the Hannover fair in Germany in 2011, as a new industrial strategy plan where digitalization in production started. With Industry 4.0, it is aimed to establish smart factories where only robots and machines work, where people are minimal or absent. With this technology, it is also aimed to minimize human errors with the development of artificial intelligence. On the basis of this technological revolution, it is thought that large-scale productions with 3D printers will be reduced to homes. The basics necessary for smart factories to operate are briefly as follows: particularly focused on are big data, smart robot automation, internet of things, internet of services, augmented reality, cyber security, end-to-end software integrations, simulations, 3D printing and cloud systems. With the Internet of Things all kinds of devices, including refrigerators, vacuum cleaners, washing machines, that have taken their place in our lives, are in communication with other devices by accessing the internet and provide a source for a common data pool. In short, the aim of Industry 4.0 is to take over the production of robots that can communicate with each other, perceive the environment with their sensors, and realize the needs by making data analysis. Thus, to develop a higher quality, cheaper and more economical production model (Vinitha et al., 2020).

2 Knowledge Economy and Digital Transformation

It may be possible to understand the processes of the transition from the knowledge-based economy to the digital economy by defining Industry 4.0, which covers the production processes where knowledge-based technologies have begun to dominate. In a changing world, it has become an inevitable phenomenon that production systems will be replaced by new and effective ones after they become effective in certain processes. We see that each new production process is transforming the previous model by blending it in, and social and social life simultaneously participates in this process of change. An important factor that has come to the fore with digitalization is that the production and economy models, which used to be dominated by money, that is, capital, are now being replaced by models based on data. With the beginning of digitalization to replace the old cumbersome production systems, money-based economic systems are replaced by information and data-based digital systems. In these new digital production and economy models, huge production centers, cumbersome production tools and most importantly the human factor are replaced by more compact, more efficient, faster and more efficient systems where information flows more and faster. We know that the cumbersome production systems, economic and financial structures of the past were basically money-based structures. Here money represents capital. This system has now begun to leave its place to the digital economy, where data is expressed in numbers and has become the main production tool. Due to the problems arising from the system's own dynamics, the money economy and centralized large-scale production models have started to give way to the information economy and digital currencies, which are the new production system based on information and human capital in digital environments (Unger, 2022).

The new form of the system, which is expected to transform, will be adopted not only in developed countries, but also in all parts of the world, albeit not simultaneously. We can say that we are in the last period of the money economy and the transition to the information economy started with the production of the first microchips in the 1950s. In fact, knowledge has been the most basic factor of production in all economic production systems ranging from the agricultural economy to the industrial economy, then to the mass production economy in the mid-1900s with industry, and to the knowledge economy largely based on technology and human capital as of the mid-1900s and early 2000s. For example, in agricultural production systems, how to farm and how to harvest was also based on knowledge. Knowledge, which is not limited to production systems, has been a driving force for development in all life. When information is digitized and with the help of the internet, it has begun to transform into economic activities more easily. In this way, it has gained an undeniable place in economic growth and development. The point reached in information and technological infrastructure facilitates the rapid globalization of economic activities.

Therefore, the knowledge economy is seen as the last stage in the structuring of the global economic system. It should be noted here that in historical processes where production systems change, one system does not completely eliminate the other, it only transforms the old system by blending it into the new. For example, agriculture did not come to an end just because the industrial revolution took place, and the knowledge economy will not end the industry. People will always need physical products, where it will be the form of production that changes and the form of resources used (Roberts, 2009).

2.1 Knowledge Economy

It is possible to see the advanced production systems of that period at every stage of economic history. To understand the functioning of the economy, it is necessary to examine the most advanced production practices. Because it is the production systems that fully reveal the powers of humanity. The most advanced production system during the industrial revolution was mechanized production, which turned into industrial mass production. In our time, it is the knowledge economy (Clarke, 2001).

Before we produce a definition for the knowledge economy, we can say what it is not, knowledge economy does not mean that everything is necessarily technology-based. That is, the knowledge economy is not just a structure with a very high-tech working class. In a sense, we can say that the knowledge economy is the infusion of technology into everything we do and all kinds of work right now. It is present in every part of the production system, not only as an advanced producer, but also as intellectually intensive services and even precision or scientific agriculture. This means we are no longer employable if we don't have technology skills. The knowledge economy is about many other things besides technology. This actually has to do with the education levels and skill levels required for any job (Ruggles & Holtshouse, 1999).

The knowledge economy has important differences from the money economy. One of the most important features of the knowledge economy is that it combines large-scale production with the de-standardization of products and services. Another feature is that it seems to loosen and even reverse the law of diminishing returns, which is one of the cornerstones of the economic system we live in. Namely, in the knowledge economy, there is the potential for continuous innovation. Continuous innovation has the potential to loosen or reverse this most universal constraint in the economic system. The concept of scarcity is fundamental in the money economy. However, the concept of abundance is fundamental in the knowledge economy. In a money economy, most resources are depleted when used, while in a knowledge economy, information multiplies as it is used and shared. Virtual markets and virtual organizations take the place of many markets in the money economy. Efficiency and productivity are higher in knowledge-intensive productions. Costs incurred in physical environments are reduced and price advantages arise. In the new system, human capital and competencies will be the most important inputs of production. In the money economy, the centralized and large-scale standardized molds can be produced in smaller and distributed centers and personalized molds in the information economy (Powell & Snellman, 2004).

Another feature of the knowledge economy is that it more closely combines the activity of producing with the activity of imagination or discovery. The best firms become like the best schools and have the potential to radically change the relationship between man and machine. There is a big difference between understanding the term knowledge economy and understanding the meaning of knowledge economy. The knowledge economy requires raising the level of discretionary initiatives and trust allowed and demanded by all participants in the production process. The knowledge economy is a new forerunner of revolutionary potential. However, it is not pervasive throughout the economy, we are just at the beginning of the change. This is one of the causes of economic stagnation and inequality. Artificial intelligence, which we can call the leader of modern technology, is the locomotive of the new industrial revolution. We can say that the real basis of the economic recession we are in is that most of the workers and firms are far from working at peak efficiency (Unger, 2019).

In the current system, economy is a system of allocating scarce resources. In the free-market system based on money, production is now largely directed by people's brains. Whether you are producing something or providing a service, the quality of what is achieved now more than ever depends on the quality of the mental input that goes into the production stages. Many factories, which are part of the knowledge economy, make us understand that production cannot be continued with the old methods and must become smarter and leaner. In the knowledge economy, smart mindset and technology-oriented solutions are used. Therefore, the knowledge economy needs skilled workforce at all levels, not only those with doctoral education, but also those who work at the doctoral level, employees with a 4-year university degree, partners, workers, and qualified high school graduates. In our age, companies have to compete not only with companies in the country, but also with other companies and states in the world. In such an environment, while the knowledge economy surrounds us as a change coming from the foundation of the world, it becomes necessary to fulfill the requirements of the knowledge economy in order to survive and make competition sustainable (Brinkley, 2006; Ali et al., 2021; Piprani et al., 2022).

At the core of the knowledge economy is a starting point about the flexibility and adaptability of the workforce, because many of the high-demand jobs today didn't exist two decades ago, so investing in education would be an important step towards achieving that flexibility if we started investing in education as soon as possible. Private sector companies should cooperate with universities on the issues that industries need, and while universities renew themselves with programs to meet the demands, they should be units where knowledge itself is produced, as well as educating knowledgeable and flexible staff for the economy. Technology is hidden inside the product, as technology develops, it emerges as higher quality and differentiated products. The demand for knowledge workers is high in the markets where knowledge economies are moving forward. The supply of programs to train these workers is too small to compare with this demand. In this process, flexible and well-educated individuals are needed. Companies should train workers to be versatile and knowledgeable about every stage of production. For this purpose, joint studies should be carried out with schools and universities that train technical staff (Stiglitz, 1999).

The deepening and dissemination of the knowledge economy depends primarily on a new kind of education, an analytical and dialectical form of education available to the entire population. Secondly, it depends on the accumulation of social capital, the dense network of cooperation, and the increase in our ability to cooperate. Another way of spreading and deepening the knowledge economy is the legal and institutional reorganization of the market economy. One of the ways to make all parts of the economy capable of producing in technologies that lead the knowledge economy in the forms of production stuck in the old technology is to ensure that more people have access to productive resources and opportunities. All educational institutions should be able to respond to this situation that the system has transformed. Of course, this is not a problem that can be solved overnight. It will take time, so act as early as possible. The decentralized market economy, in which different ownership and contracting regimes will experimentally coexist, can no longer adhere to the old version of itself. The new system, which emerged under the name of knowledge economy, should be deepened and expanded in order to increase the productivity of every unit in the economy in the ways suggested above (Unger, 2019).

2.2 Digital Transformation in Economy

Digital transformation is an inevitable phenomenon in all business activities, from small to large, and in all social environments. The world is becoming increasingly digital, penetrating almost every aspect of life, from the way of doing business to the production stages, from marketing to consumption habits. In the digitalizing world, competitive environments are also being moved to different platforms. In order to be competitive in different environments, it is not too late to adapt to digitalization. The backbone of the digital economy is the internet (web 3), the internet of things, augmented reality, cyber security, end-to-end software integrations, simulations, 3D printing, cloud systems and hyperconnectivity deployed between mobile devices. Many of these technologies are not new (Udaltsova, 2020).

At this point, it is important to understand what digital transformation actually is. Beyond understanding, what steps should be taken in order to progress in this regard? Before talking about the digitizing economy, it is necessary to mention the difference between digital transformation and digitalization. The digital transformation process started with Industry 4.0. Digitization can be defined as the adaptation of the activities of the community, including the companies, individuals and states that make up the economy, to digital systems. We can give virtual reality applications as an example of digitalization. For example, it can be applied when buying clothes in a store. You can decide by viewing the models in the store as if they were on you. This is digitalization. Digital transformation on the other hand, in its simplest form, is the collection of information about the tastes and preferences of customers with the software used by this store in addition to this application, and the adaptation of this collected information to the design and production processes (Gutbrod, 2020).

3 Block Chain Technology and Its Effects on Transforming the Economy

According to some analysts, the blockchain revolution is an information processing and storage revolution that will happen once in thousands of years in human history. To understand the blockchain, let's remember what the current system is. Currently used information processing and storage systems work centrally. Blockchain, on the other hand, is the first of the technology to store data in a distributed manner. Digitization has also made the supply chain very complex. In order to simplify this complexity and make it more efficient, some companies have implemented blockchain technology.

The company that implements blockchain technology sees who/by whom the product is purchased and where it is at every stage. In this way, transparency occurs and customer satisfaction increases (Mentsiev et al., 2019). There are also technologies such as Tangle, Avalanche, Hashgraph that developed after blockchain. It is very difficult to shut down the blockchain system. For this, it is necessary to be able to shut down 51% of the computers included in the block. This is very difficult in the current situation.

As can be seen in Table 1, although blockchain is still very new and infantile, it has visible effects on cost, consumer and income effects in the sectors where it has started to be implemented. For example, it can be said that it is very useful in all three categories in areas such as healthcare, agriculture, financial services, property sector, public sector and utilities.

In fact, blockchain offers its most basic feature with its decentralization feature. Data is recorded in distributed ledgers with an immutable cryptography. These ledgers are transparent, open to all users on the network. It provides an indispensable and reliable environment for information exchange. In addition, blockchain technology has an infrastructure that can be adapted to every system. Blockchain is not mature yet. Even at this basic initial level, it is in a position to add value and transform many sectors. For example, it can be used to streamline supply chains, so you don't have to waste time and money on middlemen and administrative paperwork. On the other hand, it avoids collaborative and administrative barriers,

Table 1 Level of blockchain impact on sectors

Sector	Revenue	Cost	Consumer
Manufacturing	N/A	2	N/A
Technology, Media, Telecommunications	4	2	2
Financial Services	3	4	2
Arts and Recreation	3	1	3
Helathcare	4	3	4
Utilities	3	4	3
Transport and Logistics	1	3	2
Mining	N/A	2	1
Agricultural	3	4	4
Property	4	4	2
Public Sector	4	4	3
Retail	2	2	4
Insurance	2	4	3
Automative	4	2	2

Source: https://www.weforum.org/agenda/2018/12/the-business-value-of-the-blockchain
Note: The table is created by authors. Level of impact by blockchain: 1-limited, 2-low, 3-medium, 4-High

leading to innovative business strategies. While creating new service areas for consumers with these new business models, it also plays an active role in ensuring consumer confidence and comfort.

Blockchain has the potential to eliminate many problems experienced in the past, especially in the field of patient information and follow-up. By using synchronized records and smart maintenance devices in the network, these barriers can be eliminated. It is a technology that can bring regulations in the agricultural sector. It can organize all the links from the producer to the end consumer, and can be used to create the agricultural supply chain by evaluating the resources and needs together with the demand. In this way, intermediaries can be reduced and small producers and farmers can be included in the system. In addition to these, a supply chain can be created in the automotive industry in a way that can benefit from economies of scale. In the logistics sector, it can be ensured that it is more effective and efficient by regulating issues such as vehicle organization and transportation planning (Al-Jaroodi & Mohamed, 2019).

Blockchain has the potential to increase productivity and save time, even in daily business and large productions. One of the most important advantages of blockchain is resource saving. Let’s take a bank for example. Banks usually have large buildings in a central location. There are hundreds or thousands of employees working in these buildings and their branches. If the system runs on the blockchain, none of this is needed. There is no need for approvals given at the headquarters for decisions, in short, there is no need for approval mechanisms and personnel to give approvals. In this way, a great saving is achieved from those buildings, from the resources given to those buildings, from the expenses and trainings made to the personnel working in those buildings. The value of all banks in the world is approximately $9 trillion. With the revolution that blockchain will bring to the banking sector, this cost will decrease considerably. The innovations that blockchain can bring to the banking industry can be summarized as follows: Serving the unbanked, interbank transactions, smart contract enforcement, crypto banking, remittance, record sharing and storage, regulatory reporting, loan syndication, increasing transparency, trade finance, data security, KYC/AML and regulatory technology[1]. The revolutionary impact of blockchain technology in areas such as finance and marketing manifests itself in two main areas, decentralized finance (DE-FI) and the metaverse.

3.1 Decentralized Finance (DE-FI)

Blockchain has led to the emergence of decentralized finance, thanks to the decentralization and cost advantages it promises in many areas of the economy. It offers more reliable, innovative and transparent transactions with decentralized finance decentralized platforms (Chen & Bellavitis, 2019).

As a new field, decentralized finance seems to change the structure of global finance. Zetzsche, D. A. et al. indicate that DeFi, puts in the context of the conventional financial economy, link with DeFi in order to open banking system, and also result in numerous policy deliberations. In this framework, decentralization harms traditional means of accountability and also corrodes the productivity of orthodox fiscal directive and enactment. At once, it stands set forth that share of the monetary services value, benefit from chain stay decentralized, there will reconcentrate in a miscellaneous slice of the value chain. DeFi regulation should focus on the value chain to ensure effective oversight and risk control. Instead of abandoning the necessity to regulate, DeFi needs arrangement in order for achieving its essential goal of decentralization. In addition to this, DeFi possibly does present a prospect for the growth of a completely fresh route for developing the concept on regulation termed as “embedded regulation”. Monitoring methods possibly will be constructed onto the project of DeFi. Consequently, this in theory decentralizes not only finance but also its instruction within the milieu of decisive appearance of RegTech (Zetzsche et al., 2020).

Popescu, A. D. state that Blockchain Technology could advance the important and essential services in terms of orthodox finance and it is capable of turning out to be the basis of decentralized business models, authorize entrepreneurs and trendsetters equipped with necessary means. Through an untrustworthy and circulated set-up, blockchain technology stands adjusting transactional expenses and permits the increase of decentralized, inventive, interoperable, borderless and clear applications which ease open access and encourage illegal developments. DeFi means “Decentralized Finance” and is defined as the ecosystem consist of financial applications that are being advanced on blockchain and circulated register schemes. The Decentralized Finance initiative advances this condition to (Popescu, 2020).

[1] https://www.disruptordaily.com/blockchain-use-cases-banking/

Momtaz (2022) investigates the problematic of how efficient is Decentralized Finance. By taking into account this question, we will try to examine the productivity and the part of mediation in a huge DeFi section, specifically, the marketplace for Initial Coin Offerings. Precisely, we will attempt to develop a research-associated theoretical design of DeFi, wherein search frictions somewhat counterbalance the competence outcomes derived from condensed transaction expenses because of blockchain technology and clever agreements. The strength of search, for instance, the procedure of recognizing respected projects, stands snowballing in market hardness. Blockchain technology rises market hardness via lesser access blockades. Lower-end participants, yet, upsurge collective exploration concentration that lacks of research capabilities (Momtaz, 2022).

Ramos and Zanko state that they have released their primary study text outlining the DeFi. When it is focused on presenting this flourishing business of the cryptocurrency market, along certain events seem to stand trend-setting for the next terms, with imperative notions mandatory to comprehend further studies regarding this market. The most significant notion to revive stands the Total Value Locked, a metrical employed for quantifying the relevancy of the market as a whole and of specific stands, despite the kind of service that they present (Ramos & Zanko, 2020).

Charoenwong et al. indicate that Decentralized Finance objects to practise progressions in both calculation and cryptoanalysis to challenge normal economic difficulties. Consequently, it remains essential to function in the juncture of restraints obligated by both the computer science and economic fields. Considering this context, the authors will attempt to discover an introductory question at the connection of those fields and help from a conservative model representing a great class of present decentralized accord set of rules that an encouraging riskless rate stands implausible. It displays that producing decentralized, fixed-monetary-policy, riskless assets are not simply an engineering question. These consequences put on to decentralized, permissionless coins individually. This embraces such Layer tokens as Bitcoin and Ethereum (Charoenwong et al., 2022).

3.2 Metaverse

Gadekallu et al. (2022) deliberate that, due to Facebook's name change as Metaverse since Oct. 2021, the metaverse has been a fresh standard of social webs and three-dimensional (3D) simulated worlds. The metaverse intends to present 3D immersive and modified practices to users via leveraging numerous relevant technologies. Aside great care and reimbursements, an important issue in terms of metaverse stands how the users' digital data and content are protected by this application. Thus, blockchain remains a hopeful answer because of its separate structures of decentralization, immutableness, and openness. For understanding blockchain's position in the metaverse, the authors will present a preliminary to blockchain and the metaverse and highlight the motivations behind the use of blockchain for the metaverse (Gadekallu et al., 2022).

Huynh-The et al. (2022) indicate that with the enormous progress of Internet since the 1990s, many pioneering know-hows have been formed to provide users remarkable practices with further virtual exchanges in cyberworld. In this framework, metaverse, a term coined from meta and universe, has been introduced as a shared virtual world, run by various developing know-hows explicitly fifth-generation links and beyond, virtual reality, and artificial intelligence (AI). In this survey, the authors will try to benefit from the exploration of AI's role in the underpinning and advancement of metaverse (Huynh-The et al., 2022).

Kim and Kim (2021) state that business shareholders have closely revealed enormous attention to how to intensify business worth by mixing real world businesses with a growing metaverse concept. Exactly, a diverse relative case method has been pursued to scrutinize three metaverse application cases from 2000 to 2020. When the outcomes are measured, it is discovered that diverse metaverse structures have been benefited for leveraging outmoded simulation games, societal groups, and simulated communication actions to shape working designs. The practise of metaverse structures stand probably to be supportive in acquiring competitive rewards. To realize the usefulness of metaverse over digital transformation, this study will perform a qualitative study based on a metaverse context from 2006 Metaverse Roadmap and reference theories over business designs (Kim & Kim, 2021).

Ağırman and Barakalı (2022) indicate that, this stands not a new conceptualization for the ones who are closely following innovations within the context of technological fields: Metaverse. However, it is too early to talk about the applicability of Metaverse in many areas. No one can make a clear prediction about how successful Metaverse will be for its use in any field. However, it is known that large technology companies have invested huge amounts of time, resources and money for the use and development of Metaverse. If this anticipated development in the Metaverse is realized, the finance and financial services industry will be able to use this potential new market as a field where they can develop their own products and services. In the virtual world of Metaverse, the investments of giant technology organizations are in the game completely changed its principles. Requiring rapid transformation and creative editing in each of the cycles, banks and other traditional monetary-based structures remain competitive. It will be the fastest alternative way to own an important asset. Digital for personal and business interactions, including financial transactions. Its importance as a platform is expected to increase. This brand-new phenomenon stands as immersive as thinkable. To make it realistic, the capability for the management of finances and operations will remain noteworthy. Pandemic, people more than ever before, it encourages you to interact and pay digitally. Conclusion as a result, fintech adoption has exploded worldwide. Conceptualization of Metaverse concept under two main headings as finance and financial services. In this research, a framework of which is tried to be established, the financial sector is the most open to innovation. The innovations that it brought and will bring to the payment systems, which is one of the dimensions, were examined. Metaverse plays an important role in the industry and has much greater potential is seen. Simultaneous with crypto platforms, unlimited growth potential the metaverse is also evolving. Cryptocurrency and NFTs are fueling this growth and hold a significant place for unlocking the full potential of know-how. With this meta database to execute lending, payments, real estate investment and more various innovations are needed. Metaverse is taking firm steps forward to become one of the main elements of our lives (Ağırman & Barakalı, 2022).

4 Industry 4.0

Starting production with information-based and digital technologies requires the transformation of traditional elements such as production, advertising, marketing and distribution, which have been customary for about 250 years. The shift of economic competition to the digital environment will be a natural consequence of this. Economic competition in digital environments, and especially digital currency competition, is vastly different from traditional currency competition. At this point, the internet, with the opportunities it offers us, facilitates the creation of both individual, economic, commercial and social relations on a new platform, that is, on a digital platform. Since this network can be established much faster and more widely than before, it provides the opportunity to reach all parts of the world in a very short time. For example, Facebook has a social network with connections to three billion people. Once the network is established, information can spread between them cheaply and almost instantly. Thus, technology forms the basis of establishing economic and social relations and making transactions between them much more fluent, easier and in a short time than before. In addition, the possibility of unfair attitudes and behaviors that hinder competition in the money economy weakens in digital environments. With the digitalization of money, there is also competition for new currencies created in digital environments. Each digital currency will not differ from the features of the platform on which it was created (Brunnermeier et al., 2019).

It is expected that the structure of the production inputs will change to a great extent with the developments in the field of nano technology. In addition, at the level reached in the field of artificial intelligence, machines seem to be candidates to disable the human factor in production and in many parts of the economy, with their equipment that can collect, use and analyze information about almost everything in the digital environment and even make decisions at the last stage. As can be seen in Fig. 1, we can understand that the world is going digital in production. In the figure, we see that globally, robot installations increased by approximately 13% to 435,000 in 2021.

In addition, the percentage values of robot usage in the service sector in 2019 are given in Fig. 2. The rapidly expanding use of robots, especially in industries that are traditionally labor-dependent and sensitive to minimum wages, is fast becoming a necessary de facto proposition for robotics companies. These industries include cleaning services, transportation and logistics, medical robotics, hospitality and agriculture. At the cleaning industry especially during and after pandemic demand for professional cleaning robots grew by 92% to 34,400 units sold. On the other

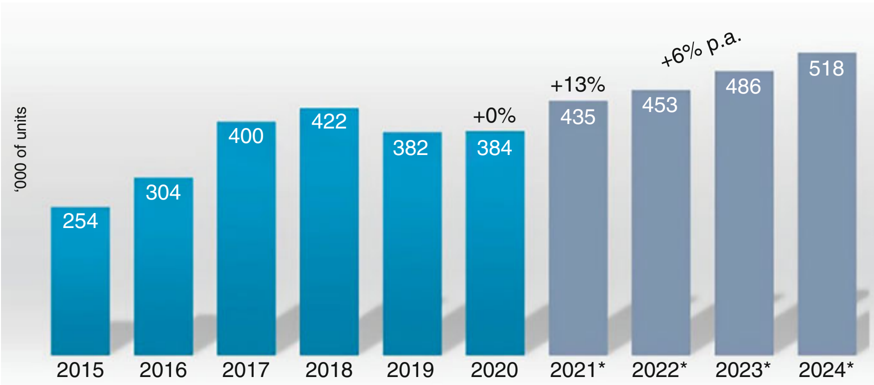

Fig. 1 Industrial robot installations (2015–2020 and forecast 2021–2024). Source: World Robotics 2021, https://ifr.org/ifr-press-releases/news/robot-sales-rise-again

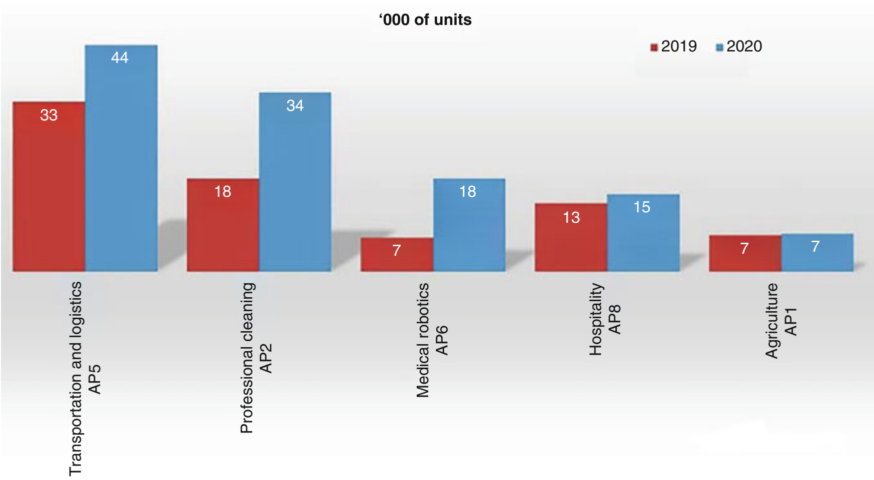

Fig. 2 Robotics use at service sector (2019–2020). Source: World Robotics 2021, https://www.theindustrialautomation.com/2021-the-year-of-service-robots-for-ifr/

hand, robots started to be used in social services with the effect of the global epidemic. For example, communication robots started to be used for nursing home residents to stay in touch with their families and friends.

It is clear that the workforce that is expected to be in demand the most in the information economy, besides robots, will be for people who are expert workforce, computer and internet literate, equipped with the ability to process data, develop algorithms and simulation models, and innovate on production processes and systems. Therefore, knowledge is the catalyst and connective tissue in modern economies (Ruggles & Holtshouse, 1999). The world is in the first transitional stage of an economy based solely on knowledge (data). For example, global internet protocol (IP) traffic as a proxy for data streams has grown from about 100 gigabytes per second in 1992 to over 45,000 gigabytes per second in 2017. It is expected to reach 150,700 gigabytes per second by 2022. The growth of digital platforms is directly linked to their capacity to collect and analyze digital data, but their interests and behaviors largely depend on how they monetize that data to generate revenue (UNCTAD, 2019).

5 Discussion and Conclusion

The world is changing rapidly. As a result of technological developments, our environments have changed significantly in the last few decades. We can see that leaders in different countries approach things differently when we look at changes around the world from a worldwide political perspective. Blockchain technology is at the heart of this change. This is a revolution. Despite its early stage, blockchain is undoubtedly the foundation for next-generation technologies. A better understanding of blockchain capabilities and knowledge is definitely something we need to look into further. The creation of these value relationships with stakeholders around the world is particularly beneficial.

Benefits of blockchain can be listed in short as the real time previewing and reviewing, transparent factoring, no intermediates, no double spending, smart contract execution, proof of ownership and regulations. The support developments required for the success of the blockchain, the basic technology of the future, can be listed as infrastructure, digital platforms, talented and skilled personnel, education, e-commerce, investment, quality data and convergence. Blockchain technology will make complex supply chain processes more transparent and traceable. A blockchain recordkeeping system assigns unique identifiers to assets such as inventory units, orders, loans and bills of lading. As the transaction proceeds, the blockchain records each step as a transfer of tokens from one participant to another.

In conclusion, blockchain technology is first and foremost used in the financial sector, but its immutable nature makes it applicable to other ecosystems including supply chains, identification, qualification, health records, insurance, etc. As technology advances blend with Industry 4.0, blockchain applications are rapidly shaping the future. Those industries that cannot adapt to this rapid change and are not prepared for it will not be able to exist in the future.

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