The Potential of Blockchain Technology for Safe Supply Chain Management: A comprehensive Study

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Abstract-Managing the flow of goods and services from point A to point B via a network of intermediaries is the job of supply chain management (SCM). Standard SCM is based on a top-down model, where decisions are made at headquarters and delegated to regional offices. Security, transactional transparency, traceability, stakeholder involvement, product counterfeiting, additional delays, fraud, and instabilities are some of the most pressing issues with current SCM systems. Blockchain (BC) has emerged as a transparent and efficient data management and trust-building tool. It can also help with payments and supply chain transaction authorization and verification without the need for a trusted third party. BC technology is an effective method for fixing current SCM problems. In light of the aforementioned, we present a survey on the use of BC in SCM.This paper reviews the existing research on BC features, applications, and business outcomes across a range of SCM. By reviewing and analysing 97 recent publications emphasising BC's applications in the supply chain, this Blockchain-centric study reveals the research state and outlines future research directions. Most of the push for BC in SCM comes from its ability to increase trust, transparency, traceability, information sharing, and protection against product counterfeiting. Furthermore, we analysed different SCM applications to determine if and how BC could be used to secure all transactions. The doors are now open for newcomers eager to get to work in this exciting field, as we have highlighted open issues and research challenges for adopting BC technology in SCM.

Keywords— Blockchain, security, supply chain management, traceability, transparency.

I. INTRODUCTION

Supply chain management (SCM) is the process by which items are transferred from manufacturer to end user. The manufacturing and distribution network consists of various participants in the supply chain, including manufacturers, wholesalers, retailers, and consumers. It includes everything from product development and sourcing to generation and coordination, as well as the necessary data structures.Chains of production and distribution have existed ever since the rst product or service was conceived and brought to market. However, SCM became more refined with industrialization and globalisation, allowing businesses to be more effective in their product development and distribution.With this newfound ability to predict failure, businesses can take preventative measures well in advance of any impending disaster. An accurate estimate is made that helps achieve both client needs and financial targets. Each link in the supply chain must be in agreement, nimble enough to adapt to changes in demand, and knowledgeable enough to handle issues like tracking, currency exchange, shipping mode, etc. When it comes to determining what should be a top priority for SCM, consumers are in the driver's seat because they have so many channels through which to make product purchases.

In light of this, we can state the following as one of the most pressing problems in modern SCM: 1) The supply chain is now centralised. However, managing a centralised supply chain can be difficult and expensive, and it lacks features necessary for analysing the market.2) Supply chain participants incur substantial extra costs due to the complexity of supply chains and value networks, and those costs are passed on to the customer. Most of the documents' data is kept on BC, which is an expensive process.(3) The current architecture of the supply chain does not provide enough visibility and tracking.4) The current supply chain creates problems for both stakeholders and consumers in terms of coordination, inventory management, reliance on human resources, order management, stock management, expiration date, etc. Hence, stakeholders are unable to assess demand, which prevents them from making informed decisions on how to best allocate resources.The centralization that defines traditional SCM is its defining characteristic.

Logistics, distribution, and procurement managers all work out of the same headquarters and warehouse and are responsible for monitoring their respective areas throughout the entire supply chain. There's a nearby database where they keep tabs on everything. The information on file may be deliberately misrepresented when it hinders the

company's progress. Consequently, there has been an increase in the cost of communicating between businesses as mistrust grows. Due to the presence of middlemen, the supply chain also lacks clear pricing information. Furthermore, the data across supply chain entities is incompatible, increasing the risk of data manipulation within the venture and delaying the product tracing process.

Today's supply chain lacks a secure method of storing customers' personal data. The information contained herein is vulnerable to cyber attacks and could expose sensitive public and private data. The fact that in present-day supply chain management, goods only move in one direction is also a major problem.

Therefore, in the case of a defective product, the onus of responsibility falls on the buyer. The only thing he could do was take the opportunity. Consequently, in conventional SCM, it is extremely difficult to facilitate the reverse ow of products and transactions for each individual customer. Today's SCM also faces the challenge of thwarting attacks on the supply chain. The objective of a supply chain attack is not the end user but rather a supplier or vendor. An assault against a trusted third-party provider of essential services or software to the SC. In a supply chain attack, the weaker links in the network are targeted in order to compromise the security of the more important trading partners.

II. RELATEDWORKS

In Table 1 we discuss some common supply chain attacks.Demand for SC's integrity, safety, and productivity has skyrocketed in recent years. Stakeholders have started to ask for more openness in the supply chain management process. Consumers want thorough descriptions of the items' histories. A tamper-proof tracking system is needed to solve this issue. BC technology has the potential to revolutionise the decentralisation of infrastructure and the creation of a trust layer for business logic. By encrypting data in reverse-chronological order, BC creates a system of records that cannot be altered. The BC system relies heavily on decentralisation, traceability, tamper-proofing, and cryptographic security. What's more, smart contracts can be drafted, allowing for secure business dealings to take place between parties who might not otherwise be able to trust one another. The term "smart contract" refers to a digital agreement or contract. One can programme a smart contract to perform an action automatically once a predetermined condition has been met.

Automatic payments, quality assurance, and the confidence of stakeholders are all possible thanks to BC. There are a number of benefits to implementing BC in supply chains, including real-time data handling with virtual environment monitoring and regulation, less paperwork, increased efficiency with faster response times, increased supply chain visibility, and reduced geographic limits [17]. Safeguarding against SCM attacks is another benefit.A number of sectors outside of nance, including the supplychain, are some of the most widely discussed uses of BC.The supply chain is a prime candidate for the application of BC technology.concerns. What could be the potential benefits of implementing BC technology in SCMhas been studied, and numerous reports have been compiled on the subject.so far been published that summarises the currentcircumstances, and suggest future directions for study. Having these as inspirationsThe facts are that we have looked at several supply chains in the potentialsurvey. In this section, we examine and contrast various state-of-the-art works.that centre on the synergy between BC and SCM. Table 1displays a comparison to previous polls and thea Survey is being Considered. Also, it emphasises their major goal,important results and restrictions, both of which provide valuable perspectiveindividuals interested in beginning research in this new field.

The emergence of SCM as a management strategy is a direct result of the growth of many sectors. Complexity in supply chains is inevitable given the number of parties involved and the number of transactions that must take place.During COVID-19, there are many disagreements in conventional supply chain networks due to issues like a lack of transparency and traceability, the introduction of counterfeit products like fake drugs, the difficulty in managing risks and disruptions, and the necessity of establishing trust and a good reputation. The need for a trustworthy, open, and trackable network has been met with the help of blockchain technology. Most supply chain networks employ an outdated tracking and tracing technology that has issues with centralised administration and data protection. The immutable and decentralised properties of BC, the underlying technology, have attracted a lot of attention from academics and businesses in recent years. Modern supply chain processes will be overhauled when BC is implemented, and third-party control will be eliminated. It allows for the elimination of many supply chain issues. Our curiosity with the supply chain applications of BC is driven by the technology's promise to improve transparency and security in the tracking of all sorts of transactions.Yet, using cutting-edge technology in any industry might give rise to unanticipated complications.BC technology's infancy in the supply chain industry makes it difficult to foresee its full potential.The economic and social conditions of SMEs would change as a result of the introduction of BC technology. In order to ease the minds of C-suite executives, it is important to assess how

scalable and cost-effective BC solutions are. This presents a significant difficulty, with many wondering what would become of the current operating system and how long it would take to develop a new BC-based system.

TABLE 1. Recent attacks on supply chain.

Company Name	Year	Description
Mimecast [139]	2021	Mimecast provides email security services that require clients to securely connect to Mimecast servers to utilize their Microsoft 365 accounts. The attackers discovered credentials that enabled them to breach the provider and access their certificates. Then they use the certificates to access customer data after the customer-validated and trusts the certificate .
SITA [140]	2021	SITA is a company that specializes in air and transportation information technology. Attackers had compromised SITA servers and stole passenger data from SITA's customers.
Kaseya [141]	2021	Kaseya is a software service supplier specializing in remote monitoring and management technologies. Attackers obtained access to Kaseya software by exploiting a software vulnerability. Attackers used this access to install ransomware on customers' infrastructure .
APPLE XCODE [142]	2021	Apple Xcode is a programming environment for creating OS X and iOS applications. A single malicious Xcode project was used to infect Xcode developers with a backdoor.
CLICKSTUDIOS [143]	2021	ClickStudios is a provider of business password management solutions. Their main product is a password management solution called Passwordstate. The 'upgrade director' online interface used by Passwordstate to update the program was hacked, leading users to download malware rather than the intended upgrades. The deployed virus was meant to steal data from the infected systems. [143].
BIGNOX [144]	2021	BigNox is a provider of emulation software. Their flagship product, NoxPlayer, is a well-known Android emulator for Windows and Mac computers. The infrastructure of NoxPlayer has been hacked. It might exploit the tool's update system to distribute malware instead of updates.
VERKADA [145]	2021	Verkada serves over 5,000 clients with cloud-based security surveillance solutions. Attackers hacked into the production server. This allowed attackers who gained the privileged credentials to access the security cameras installed on customers' premises .
SOLARWINDS [146]	2020	SolarWinds is a provider of management and monitoring software. SolarWinds' network management system (NMS) is called Orion. Orion had been jeopardized. Attackers got access to the SolarWinds network, which was then utilized to acquire and steal data.
ABLE [147]	2020	Able is a Mongolian company that provides software solutions to government bodies and enterprises in that region. The malware was introduced to the "Able Desktop" program by attackers. Then this program was utilized to steal data from the compromised devices of the consumers .
Ledger [148]	2020	Ledger is a company that manufactures hardware wallets. The attackers employed open-source intelligence tools to identify acceptable credentials for accessing Ledger records and stealing client data. Using such information, the attackers exploited users' faith in Ledger by sending phishing emails .

III. PROPOSED SYSTEM ARCHITECTURE

Supply chain management (SCM) is an integral part of every large organisation, since it coordinates the flow of goods and services among many different parties. In order to transform raw materials into finished goods and fulfil customer orders, a variety of different people, resources, behaviours, and organisations are involved in what are known as supply chains. The term "supply chain" refers to the web of organisations, people, and things involved in making and delivering a product or service from the manufacturer to the consumer through a predetermined flow of data, materials, and money. The process begins when suppliers provide materials to a factory and ends when customers get their purchased goods. Supply chain management is the process of planning, organising, and controlling the flow of goods and services to minimise costs, maximise efficiency, and meet or exceed customer requirements [19]. Supply chain management is used in many different industries, including the agribusiness and pharmaceutical sectors, the textile and automotive industries, the manufacturing sector, the high technology sector, the service sector, and so on. The many stages of a product's life cycle in a supply chain include receiving, processing, storing, manufacturing, shipping, and finally consumption. Current supply chain management has a number of flaws, including a lack of transparency (clarity), disruptions, extra delays, twisted data, and instability. Transparency and trust issues may arise from the current supply chain's reliance on a single point of data maintenance. Ledger data may be subtly falsified when it is not contributing to the development of the business. Very little is known regarding the origin, processing, or final destination of the product. Customers were often only privy to a subset of the data made public by major companies. Inadequate product expertise might make it difficult to confirm several of the product's features. Several of the substances the corporation claims to use in its products may be difficult for customers to verify. This has led to a rise in communication costs as well as a general increase in distrust amongst businesses.

Additionally, the corporation faces a significant risk of data manipulation, which makes information across supply chains unpredictable and therefore makes the product traceability process vulnerable to disruption. With a traditional supply chain, we risk additional problems including late deliveries, lost shipments, bribery, tampering, and fake or substandard goods.Hence, conventional supply chains have fallen short of satisfying consumers' preferences for affordable high-quality goods [20].Successful SCM aims to analyse and eliminate all waste, difficulties, and

complications throughout the internal supply chain in order to improve supply chain presentation, which includes external consequences such as customer attention and internal effciency. Commitment, confidence, collaborative decision-making, and the honest exchange of information are all necessary for the Blockchain to facilitate the integration of supply chain modules.

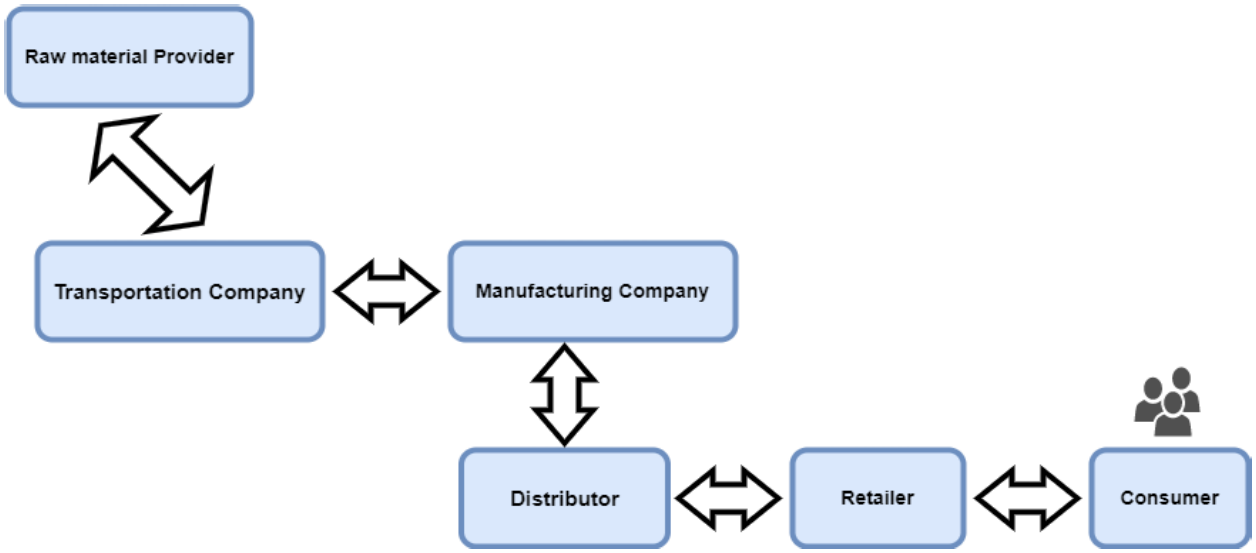

Fig.1 Flow of the traditional supply chain.

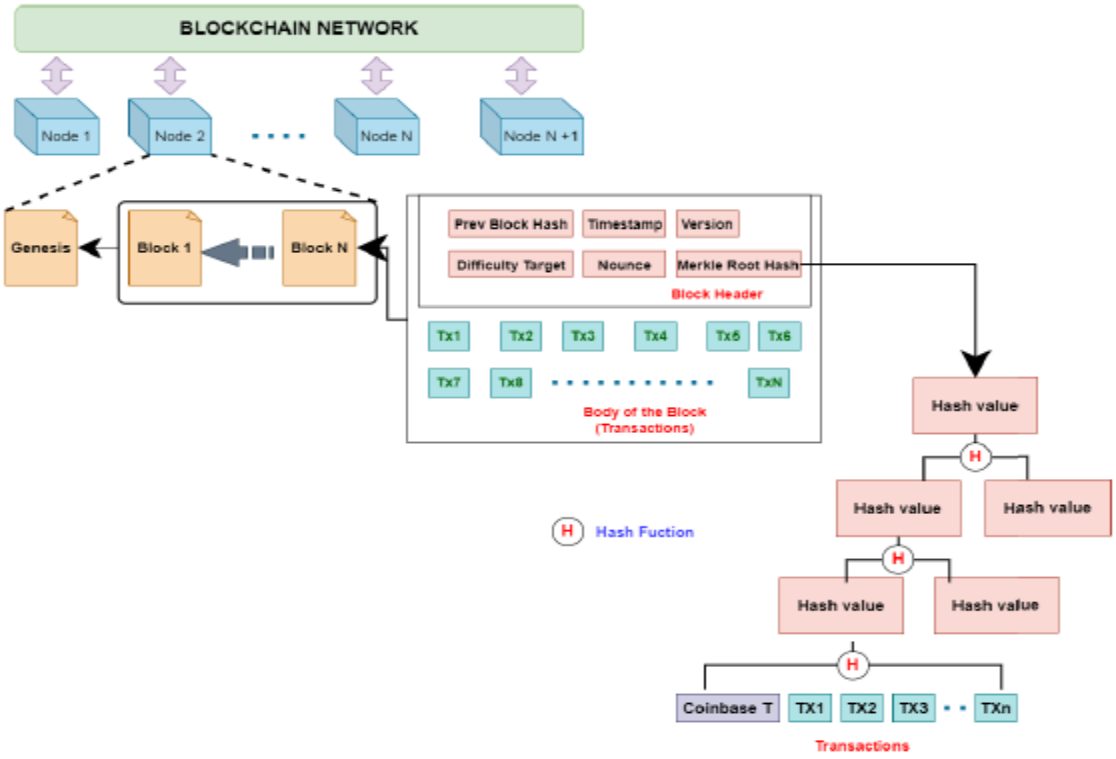

Fig.2Conceptual view of the Blockchain network to be used for supply chain.

A Blockchain is a distributed ledger or ledger-like database that stores information in a sequence of blocks. Each piece of fresh information is recorded in its own block and added to the growing list of blocks in the Blockchain. When a block is lled, it is connected to the prior lled block through a hash value, creating a chain of data known as a

"Blockchain." The first research on the concept of Blockchain was conducted in 1991 by tuart Haber and W. Scott Stornetta.To prevent tampering with time-stamped documents, they sought to develop a method. In 2008, an unidentified person or group using the name Satoshi Nakamoto created the Blockchain, a peer-to-peer network that effectively eliminated the possibility of double spending. A year later, a cryptocurrency called Bitcoin was developed using Blockchain as its decentralised ledger. The fundamental principle behind Blockchain (BC) technology is blocks. A hash value generated using the SHA256 hash technique is utilised as the block identifier. The hash of the parent block is stored in the most recent block's header eld. The form of a building block is affected by factors such as the BC's kind and design.The block header, which includes information about the previous block (its hash value, date, nonce, and Merkle root) and the content of the block (its transactions), might be required to meet certain standards. The term "nonce" refers to a one-time random number. When a hashed block is rehashed, this value is appended to it to ensure that it meets the difficulty level constraints.Merkle trees, named after its inventor Ralph Merkle, are a kind of binary tree that can store hash references. The Merkle tree stores the hash of each data block in its parent node and organises the blocks into pairs. All of the hashes of the parent nodes are stored again in pairs one level up the tree. By proceeding in this fashion, the topmost node of the Merkle tree will be reached. In this context, "Merkle Root" means the very top of the Merkle tree. A hash of all the transactions in a block is the Merkle root. This means that validating or verifying all transactions in a Merkle tree just requires inspecting the Merkle root, rather than each transaction separately.

A BC is a special kind of distributed ledger that leverages a novel technological approach to provide a cryptographically secure and immutable record of transactions. It is kept up via a distributed network where every data is verified using some kind of predetermined consensus procedure. Since it is a decentralised ledger, BC doesn't need a single authority figure to keep tabs on the network. In layman's terms, blockchain technology, or BC, is a chain of blocks that stores data in the form of transparent, chronologically recorded transactions that cannot be altered or tampered with. Using a consensus technique, the distributed nodes ensure the reliability of the transactions (user systems). Instead of having a central authority keep track of everything, the ledgers are dispersed among everyone involved. Once data has been stored on a BC, it is nearly impossible to modify it. A BC may be thought of as a limited database where information can only be accessed and modified by authorised users.

We present a taxonomy of possible approaches for incorporating BC into SCM here. It's no secret that the supply chain is one of the most talked-about uses for blockchain technology. Because of the high potential for BC implementation in supply chains [17], supply chains have a complex network structure of stakeholders, a need for information exchange between parties, the difficulty and risk of document transmission, and a lack of trust between parties. In a suspicious setting, BC ensures the safety of transactions via authentication and audit trails. There are a number of benefits to using BC in supply chains, including real-time data processing with virtual environment monitoring and regulation, fewer paperwork, greater efficiency with quicker reaction times, better supply chain visibility, and decreased geographic constraints [17]. Supply chain resilience, transparency, and product traceability might all be improved with the help of BC, since these goals have been proposed as potential applications of the technology [22, 68]. With BC, we were able to decrease the average time it took the system to complete a task by a significant margin, lighten our load, verify the origin of each order, and improve our visibility to all of the stakeholders in the supply chain. Hence, several facets of SCM, including supply chain management, manufacturing, logistics, and stock control, may be enhanced.

Each step in the production and distribution of a product is represented by a separate block in BC technology, and the blocks are then linked together to form the whole [24]. The immutability of the blocks ensures the integrity of the data and, in turn, the integrity of the products [25], [26], [27].In addition to the many obvious benefits already mentioned, [28] adds that it is immutable and very easy to access. Also, the quality of the goods may be closely monitored using BC. A participant in the supply chain, for instance, can analyse information about the route an item took and how long it stayed in a certain area to determine whether or not an item was misplaced. In the case of perishables like frozen foods, this is very essential. If consumers can be certain that the products they are purchasing are genuine and of high quality thanks to BC-based solutions, the brand's sales might increase. Block data was used by six of the Forbes "BC50" companies to develop business cases that directly relate to supply chain management. IBM, Nestlé, Walmart, and Amazon are just a few of the 50 organisations that have used BC technology for supply chain management-related traceability/provenance purposes.

The transaction cost is another key component of supply chain management. [105] research has used transaction cost theory to understand how BC may affect aspects of supply chain interactions including transaction costs and governance choices. According to the study's findings, BC technology has the potential to significantly reduce transaction costs and governance expenses in the supply chain, especially those associated with searching for and

acquiring relevant information.BC case examples at various stages of development for different causes to examine how they influence majorSCMgoals were discussed by Kshetri et al. [30]. The research found that BC affects many different metrics, including cost, value, speed, reliability, risk mitigation, sustainability, and flexibility.According to [31], implementing BC can help create digital solutions and boost the network's capacity to share real-time data about operations, giving it a significant competitive advantage. A shared, permanent ledger with hard-coded rules may reduce or do away with the requirement for internal systems and business processes to perform audits without the need for a third party, which is another significant benefit of BC technology [32]. Users may choose whether or not to reveal their identities. Hence, BC promotes confidence while also guaranteeing the safety of information exchange.A BC increases transparency and decreases the potential for fraud since all parties can view the data and no one party can alter it.BC has the potential to increase supply chain flexiblity. A flexible supply chain is one that can adapt to shifting demand and fluctuating costs. Using BC, sustainability indicators may be made more measurable and actionable. To put it another way, BC may put a stop to dishonest and unlawful practises in this way.

Cargo insurance, currency risk, responsibility for things lost during transit, and other problems in the supply chain and logistics industry may be amenable to BC technology. Using BC-based technologies might fully automate data accountability and supply monitoring during vaccine distribution [33].

IV. MAIN FINDINGS, CHALLENGES AND FUTURE RESEARCH DIRECTIONS

Many of the most significant benefits of BC for safe SCM are discussed below. BC has become the tool of the current day [63] because of its distinctive characteristics including real-time data interchange, transparency, dependability, traceability, immutability, and visibility. British Columbia's global supply chain market is expected to grow by 80.2% between 2015 and 2025, according Allied Market Research. Market Monitor predicts that by 2025, the worldwide market for BC-enabled supply chains would be worth $9.8 billion. It is projected that British Columbia would earn $424 million worldwide in the supply chain sector by the year 2023.For the next five to ten years, BC is predicted to become the de facto norm in SCM, making it one of the most successful BC implementations to date.Some of the difficulties in combining BC and SCM are discussed below. The incorporation of BC into supply chain procedures will not be as simple as hoped for, due to the many barriers and constraints that have already been identified. According to a survey done by ABI Research in 2017, 93% of decision-makers across 9 different industries said they knew little to nothing about BC, while 7% reported doing some basic study on the technology. The supply chain's negative perception of BC is the biggest barrier to its widespread adoption. There is a negative stigma attached to BC because of its frequent association with Bitcoin and other cryptocurrencies, and the general public's perception of cryptocurrency as a whole is negative. Thus, people are cautious to adopt it. A lot of companies don't understand what BC is or how it can help them.

Not all BC networks are compatible with one another, which is a second key problem. Interoperability in BC is having the ability to exchange information, conduct business, and carry out tasks on different BC systems. Due to the absence of a universal standard, companies are developing their own BCs and applications to run on top of them. Numerous BC systems, the vast majority of which are standalone, are now in use on thousands of projects. They use many different protocols, code languages, consensus procedures, and security mechanisms. Because there are so many separate networks, the BC industry is in disarray.The shortage of skilled programmers is a further pressing problem.As a result, businesses lack the ability to tap into the critical mass of BC expertise required to bridge the gap in BC adoption. There are significant legal and regulatory hurdles to implementing BC in global supply networks. Since that a BC ledger's participants may be located everywhere in the multiverse, it's hard to determine whether or not the BC would be subject to any particular legal system. Making decisions about which laws to apply and which courts have jurisdiction over certain matters may be difficult and even contradictory. Because of how BC works, there can be no one proprietor of a BC network. The complexity of BC technology makes it hard to determine who is at fault when anything goes wrong. There will be limited adoption of BC if it cannot meet regulatory requirements [5].

One typical way to compare the scalability of various BC models is by the number of transactions they can process per second (TPS). Transactions per second (TPS) is the maximum rate at which a single transaction may be processed in a certain time period. The scalability of BC models was affected by factors such as the architecture and conguration of the BC platform, the block size restriction, the consensus and transaction validation method, the varying needs for processing power, network bandwidth, the ledger system, and data storage, and so on [132]. The

BC framework requires a very large TPS in order to function properly.Nevertheless, current TPS of BC models is far from satisfying this need. For large-scale operations and corporations, finance departments need hundreds of TPS. In the present day, BC systems cannot reach this level of TPS [5]. One of the biggest obstacles to widespread use of SCM is the entry of erroneous or fraudulent data, which is not something that BC technology can address.

V. FUTURE SCOPE AND CONCLUSION

The purpose of this research is to get a better understanding of when and where BC technology may be used to resolve supply chain issues. Technology based on BC is used in supply chain management in many different industries. In this study, we investigate the current status of use of BC and Smart Contracts across a wide range of important industrial fields.The survey provides credible information on the current status of BC implementation across different supply chains. The study's findings and conclusions demonstrate the increased interest in studying supply networks in British Columbia.All things considered, most studies agreed on the potential benefits that BC may bring to the supply chain.Also, in order to uncover open research issues on realistically employing BC in the future, the challenges, opportunities, and prospective uses of BC in the supply chain are carefully studied. The benefits of BC technology might be jeopardised due to a lack of in-depth knowledge of the subject. We believe our research provides a solid grounding in BC's theoretical ideas for academics, engineers, teachers, and students of all stripes. It also pinpoints research priorities at the intersection of emerging technologies and BC.

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