



Application of Blockchain in Supply Chain Management

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Abstract

The blockchain technology has been applied in various fields like financial, inter-organizational and so on in recent days. Supply chain management is an important technology which is used commonly by all the products across the globe over a decade. There are some bottlenecks for the supply chain, such as lack of communication between the participants in the supply chain network, which sometimes causes major problems and losses for the enterprises. The methodology behind supply chain has improved over time which made it easy for the users but applying blockchain technology in supply chain management would be a real game changer, which brings many potential benefits for the supply chain like traceability, transparency, protection from frauds and much more. The paper gives brief explanation of supply chain and its current problems, and also explains how the implementation of blockchain technology can resolve those. This paper primarily focuses on the applications of blockchain technology in the supply chain management and also covers the technical and non-technical challenges of applying it. There are many industries which recognized the benefits of blockchain enabled supply chain to enhance their business profits, these businesses and their strategies towards the implementation of blockchain technology in their conventional supply chain has been explained in the paper.

Contents

1	Introduction	1
1.1	Structure	2
2	What is Blockchain?	3
2.1	Categorizations:	4
2.1.1	Permissionless	4
2.1.2	Permissioned	4
3	How does Blockchain work?	5
4	Supply Chain System	6
5	Background	7
5.1	Why does Supply chain need Blockchain?	8
6	Connecting Supply Chain Management and Blockchain Technology	11
6.1	Supply Chain Visibility	12
6.2	Supply chain Integrity	12
6.3	Supply chain orchestration	12
6.4	Supply chain virtualization	13
6.5	Supply chain finance	13
7	Challenges of applying blockchain in supply chain	13
7.1	Non technical challenges	14
7.2	Technical Challenges	15
7.2.1	Scalability	15
7.2.2	Interoperability	16
8	Industries which use Blockchain in Supply chain	17
8.1	Supply chain of Jewelry	18
8.2	Tea Industry	18
8.3	Food Industry	19
8.4	Beer and Beverages	20
8.5	Automotive Supply Chain	20
9	Conclusion	21

List of Figures

1	Working of blockchain	6
2	Traditional Supply Chain system	7
3	Characteristics and implementation areas of blockchain in logistics and supply chain	14
4	Summary of interoperability solutions.	17

1 Introduction

The concept of blockchain is not very old, it just has a history of 10 years when a cryptographically secured chains of block was described [6]. It was first created by some unknown people under the pseudonym Satoshi Nakamoto. Initially blockchain was mounted with currency, like bitcoins, but later, in 2014, it was separated from currency and explored other transactions including financial, inter-organizational and so on. Though bitcoin is the largest blockchain transaction, today, Ethereum and ripple also has taken place in the blockchain family.

The application of block-chain is not limited, it has been used today in several different ways; starting from bitcoin, now it is used in securing medical data, real-time IoT operating systems, personal identity security and so on. However, this paper explains the applications of blockchain which can be implemented in the supply chain system. Supply chain is used widely across the globe in various industries ranging from small businesses to multi national companies, it went through huge transformation over time as well, but yet there are a few drawbacks and challenges which have not solved yet in the supply chain, for example the transparency issues, fraudulent activities at some points of transitions and so on. Implementing blockchain technology in supply chain networks will eliminate most of the fore-mentioned issues. Blockchain has caught global attention through financial world where it was used in bitcoin and other cryptocurrency networks. But it also has great applications in supply chain management system. It can promise product traceability, improve the co-operation between the partners, assisting finance to be more transparent and thereby more secure and much more[5].

Supply chain has started over a century ago. The development of mass production along assembly lines in the late 1920s created the groundwork for supply chain management. The idea of creating consistent items on a wide scale with enhanced efficiency was first successfully adopted by Ford, and it transformed trade and supply chains forever. A supply chain is basically a network that connects a business and its suppliers in order to manufacture and distribute a certain product or service. All of the functions that begin with receiving an order and end with meeting the customer's request are included in the elements of a supply chain. Product creation, marketing, operations, distribution networks, financing, and customer support are among these functions. The management of the supply chain is a critical component of the business process. There are numerous connections in this chain that necessitate

skill and knowledge. When supply chain management is done correctly, it can reduce a company's overall expenses while also increasing profits. If one link fails, it can have a negative impact on the rest of the chain, which can be costly.

Though supply chain is familiar of everyone, blockchain is still a mystery for many reasons, primarily because it's still emerging and showing its strength in various fields. Blockchain has currently few applications in supply chain network, but here we are exploring for the most relevant ones including security, transparency and much more. Since supply chain is crucial for every business, unfortunately it lacks some properties like transparency and security which will improve its functionality; using blockchain in supply chain is considerable in this case. Similarly, there are many other benefits by applying the concept of block chain in supply chain such as quicker product delivery, proper coordination among the partners, easier financial handling and so on.

The main goal of this research paper is to identify the potential applications or properties which blockchain can provide to supply chain to boost its existing properties, thereby making the supply chain management easier to control. There are research papers similar to this, however, they merely explain the blockchain and its application [9], where this paper has explained both blockchain and supply chain along with the applications and challenges of implementing it. Furthermore, the paper has listed the real life examples of different industries which uses blockchain enabled supply chain.

1.1 Structure

This paper overall shows the wide applications of block chain technology in the supply chain management system. The paper first explains what a blockchain(section 3) and how does it work (section 4), it also addresses what is supply chain system in section 5. Later, in section 6 it discusses the background of the paper that is why does we need to connect both and how can we do it (section 7). The technical and non-technical challenges of applying blockchain is explained then in section 8, finally, the real industrial examples of blockchain enables supply chain is listed in section 9. The paper is concluded in section 10, followed by the references.

2 What is Blockchain?

Blockchains are decentralized digital ledgers that are tamper evident and resistant to manipulation (i.e., they don't have a single repository) and often operate without a central authority (i.e., a bank, enterprise, or government). They allow a group of users to record transactions in a shared ledger within that group, with the effect that no transaction can be amended once it has been published, as long as the blockchain network is up and running[16]. Around 2008, the blockchain concept was combined with a variety of other technologies and computer principles to create today's cryptocurrencies: i.e., instead of an authority or a central repository, the electronic cash is able to protect using some advanced cryptographic mechanisms.

It is often easy to explain blockchain in terms of bitcoin as it is the first electronic cash or blockchain element. The basic idea is to exchange or transfer the digital information which basically represents the electronic cash, within a distributed system[28]. The users have the eligibility to validate the transaction by signing it digitally and thereby transfer their rights to that particular information to other different users in the network, the bitcoin blockchain enables to record all the transactions publicly so that everyone in the network can confirm or validate the transaction hence no fake transactions are possible[31]. The blockchain is managed and maintained solely by a group of participants in the network, however cryptographic methods are used to protect it from fraudulent activities such as alteration attempts on the "blocks".

However, the participants in the blockchain network have to build trust in the environment where they should not be identified easily. The trust which used to provide by third party intermediaries before is eliminated, instead, it is provided by four key characteristics of blockchain technology such as: -

- Ledger – to provide the entire transaction history, blockchain technology used an append only ledger
- Secure – the cryptographically secure blockchains ensure that the data inside the ledger is attestable and it is not altered in unauthorized way.
- Shared – the ledger can be viewed by multiple participants in the network, this ensures the transparency among the node participants.
- Distributed - The blockchain is a publicly accessible distributed ledger. This allows the number of nodes in a blockchain network to be scaled up to make it

more resilient to attacks by bad actors. A malicious actor's ability to influence the blockchain's consensus method is reduced by increasing the number of nodes.

2.1 Categorizations:

There are two types of permission models that determine who is allowed to operate a blockchain network. It is permissionless if one can add a new block. It's permissioned if just specified people can post blocks. A permissioned blockchain network is like a regulated business intranet, whereas a permissionless blockchain network is like the internet. A consortium is a group of firms and people who cooperate together to utilise permissioned blockchain platform.

2.1.1 Permissionless

Permissionless blockchains are decentralized blockchain platforms which enables anyone to create blocks without the need for approval from anyone else. Permissionless blockchain solutions are generally available for free download as open source software[10]. Anyone can read the blockchain and execute transactions on it since anyone has the ability to publish blocks (by including those transactions within published blocks). In a permissionless blockchain network, every blockchain system user has chance to view and write to the network[8]. Malevolent individuals may attempt to destabilize the system by publishing blocks on public blockchain networks that are open to anyone.. To overcome this, permissionless blockchain networks usually has a multiparty agreement or 'consensus' model, in which users are compelled to invest or maintain resources during the blocks are published[10]. This makes it more difficult for rogue people to wreak havoc with the system.

2.1.2 Permissioned

Permissioned blockchain networks are systems in which users must be authorized by a third party before publishing blocks (be it centralized or decentralized)[22]. Because the blockchain is maintained by only authorized users, it is possible to regulate read access and who can issue transactions. Anyone can read the blockchain in a permissioned blockchain network, or only authorized users can read it. They could also allow anyone to submit transactions for inclusion on the blockchain, or they

could restrict access to only those who have been approved. Permissioned blockchain networks can be built and maintained using open source or closed source software.

Permissioned blockchain networks can offer the same amount of digital asset tracing as permissionless blockchain networks, and also the same decentralised, reliable, and independent data storage. They also use consensus models for posting blocks, albeit these methods may not always require resource expenditure or maintenance . This is because verifying one's identity is essential to enter the permissioned blockchain network; those who administer the blockchain have a feeling of integrity in one another because they were all given permission to post blocks, and that permission can be changed at any time if they misbehave. Consensus models are frequently faster and less computationally demanding in permissioned blockchain networks[22].

3 How does Blockchain work?

Blockchain, example bitcoin, uses cryptographic proof which replaces the third party interference when two participants carryout a transaction. Where all the transactions are secured by digital signatures, the money cannot be sent unless the signature is verified and confirmed[4]. All the transactions are sent to every node in the blockchain, which is stored in the public ledger after the verification. Each and every transaction has to be verified before storing in the public ledge. For verification two things are mainly checked: -

- Whether the spender owns the cryptocurrency
- Whether the spender has enough cryptocurrency in his account

The Bitcoin system organizes transactions by dividing them into blocks and then connecting them using Blockchain technology. The transactions in a single block are considered to have happened at the same time. These blocks are linked in a sequential, linear fashion (like a chain), with each block containing the hash of the previous block[31].

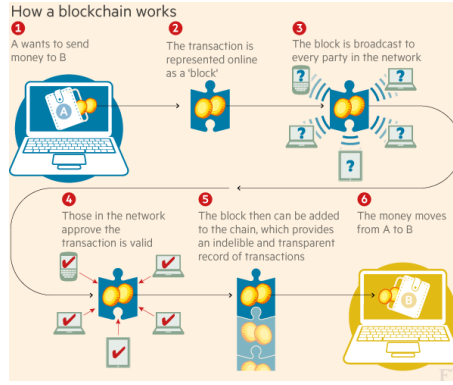


Figure 1: Working of blockchain
[21]

4 Supply Chain System

The blockchain technology has been explained clearly in the previous section, now before identifying the applications it is better to have a clear understanding about supply chain management. There are several definitions and implications for the term supply chain management. A supply chain is a collection of businesses that work together to create, engineer, market, manufacture, and deliver goods and services to end customers[17]. For the better working of a business a strong and balanced supply chain is necessary. While focusing on their core capabilities, companies are successfully integrating their internal business processes and information flows. By optimizing their core competencies, companies are seeking to improve their competitive position as part of a larger supply chain. This forces the company's management to learn more about their clients' requirements.

The Council of Supply Chain Management Professionals defines supply chain management as "the organising, execution, and control of basic activities that generate and bring value for the end consumer, as well as the coordination and collaboration of relating enterprise applications within and across companies."[15] Whereas integration describes the "technical" execution of systems and processes to ensure that material, economic, and data flows are associated along the SC, cooperation addresses the "managerial" and "organizational" obstacles of placing together a system of mostly individual firms.

Supply chain can be explained clearly in terms of five interconnected business systems:

- Engineering Systems - In order to supply the things that customers desire, both

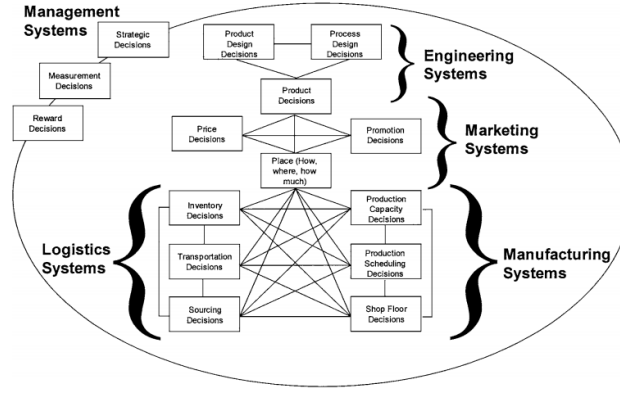


Figure 2: Traditional Supply Chain system
[15]

the product and its manufacturing and distribution procedures must be properly created and engineered.

- Marketing System - It's crucial to understand the product market, as well as to identify and cultivate product desires. In addition to creating requirements for the firm's products in the minds of customers, the marketing function also creates expectations for a dependable delivery system and excellent customer service.
- Manufacturing system - Manufacturing processes must be coordinated and maintained in order to develop goods that are both reliable and cost effective.
- Logistics systems - Raw materials and components must be delivered to supply chain partners on time and at a reasonable cost, and finished items must be delivered to customers on time and at a reasonable cost.
- Management Systems - Management planning, control, and reward systems must be followed when developing and implementing the activities.

5 Background

As discussed in the previous section, supply chain management is the planning and execution of all linked operations that contribute to the deployment of a final product. It is made up of a network of individuals or businesses that stretches from raw material suppliers to product manufacturers and eventually to distributors. A well-run supply chain ensures maximum output while reducing fraud and administrative costs[3]. As you might expect, putting this into practice in the real world is challenging. Although

AI and Machine Learning have been used to automate processes, blockchain has the potential to be a game-changer in this area. As a result, one of the real-world problems that blockchain has solved is this.

5.1 Why does Supply chain need Blockchain?

As supply chain and blockchain have been explained in the previous sections, now it is time to check the need of blockchain technology in the supply chain management system. One of the most significant benefits of blockchain in Supply Chain Management is interoperability.[27]. Most of the problems supply chain currently encounter is due to the lack of communication and data sharing between the stakeholders, blockchain's interoperability features enables the everyone in the chain to communicate and view the data.[32] Data sharing transparency guarantees that everyone is on the same page, from manufacturers to retailers, distributors, and even contractors[26]. As a result, there are fewer conflicts and operational delays. Furthermore, because all products can be traced in real time, the chances of misplacing or stranded items in the supply chain are reduced. As if that weren't enough, blockchain enables incredible scalability, allowing enormous datasets to be accessed from multiple locations around the world. This means that a firm, no matter how big or spread out, will be able to easily manage its supply chain using blockchain.

Furthermore, blockchain's usage in the supply chain networks has the capability to increase transparency and traceability while lowering administrative expenses[24]. Besides recording cost, time, position, quality, accreditation, and other vital data, a blockchain supply chain can assist individuals effectively regulate the supply chain[11]. The accessibility of this data in blockchain can help improve resource supply chain traceability, reduce fraudulent and gray market failures, increase transparency and conformance over external provider product manufacturing, and potentially boost an organization's reputation as a liable production pioneer. Blockchain-driven supply chain advancements have allowed to generate substantial economic value by increasing supply chain transparency, reducing risk, and enhancing efficiency and overall supply chain management.

Large, complicated datasets are usual among supply chain professionals. It may cause massive delays and bottlenecks, particularly among lower-tier suppliers[14]. Smart contracts are a good example. They are mainly pieces of code which stay within a single block in a blockchain and automate processes when particular conditions are

met. This establishes the ground rules for a transaction and guarantees that any obligations are met[18]. When utilized in supply chain management, blockchain could allow businesses to create tamper-proof smart contracts that execute multiparty agreements automatically.

In most firms, access to information is crucial, but in supply chain management, information flow is critical. Segregated data not only increases inefficiencies, but it also puts the organization at risk, especially as supply chains become more important. Blockchain technologies can help the right individuals obtain access to mission-critical data and improve information flow both within and across businesses.

The main benefits of applying blockchain in supply chain are: -

- Increase the traceability of the material supply chain to ensure compliance with company regulations.
- Losses from gray market/counterfeit trades are decreased.
- Increase transparency and compliance in outsourced contract production.
- Reduce the amount of time and money you spend on administration and paperwork.
- To strengthen the company's reputation, make the materials utilized in products transparent.
- Increase the legitimacy of the information presented and the public's trust in it.
- Reduce the likelihood of a public relations disaster as a result of supply chain problems.
- Include stakeholders for better transparency.

Organizations can digitize physical assets and create a decentralized, immutable record of all transactions, allowing them to track assets from manufacturing to distribution and end-user use, providing for more transparent and accurate end-to-end supply chain tracking. This increased transparency in the supply chain benefits both businesses and customers.

Blockchain can help prevent theft in high-value goods like diamonds and medicines by boosting supply chain visibility[14]. By eliminating or reducing the effect of fake

products, blockchain might help companies understand how components and completed products are transported through every subcontractor, reducing revenue losses from fraudulent and gray market transactions and boosting final consumer trust.

Organizations may also have better supervision on external product manufacturing. With blockchain, all participants in a supply chain can view the same information, possibly minimizing communication and information transfer concerns[23]. Instead of reviewing data, considerable time can be spent delivering products and services performance, decreasing prices, or doing both.

Blockchain can improve administrative operations and lower costs by enabling an effective audit of supply chain data. Processes that currently take weeks to complete, such as manual compliance or credit checks, can be sped up by employing a distributed ledger that holds all necessary data[25].

Information is recorded into a protected and visible database utilizing blockchain technology at every stage of the supply chain process, which none of the individuals involved may alter without it being instantly visible to others[19]. In the event that something unexpected happens during the shipment, the chain of custody can be utilized to determine when and where the problem happened. More visibility in the manufacturing of retail products and the supply of goods like coal, oil, and gold is made possible by precise monitoring. This not only adds another degree of accountability, but it also reduces the likelihood of criminal activity.

Because it promises immutability, transparency, security, and fault tolerance, blockchain is a promising solution, at particularly for trust and traceability issues[19]. Organizations are already using this technology to enhance the process in practice, with some displaying promising outcomes.

Demand management is an important part of supply chain because of its collaboration and integration capabilities. Demand management includes methods for controlling supply and demand as well as a coordinated approach to supply chain demand planning[12]. Demand and supply in the supply chain are adjusted through demand management to maximize overall revenues. Demand management is defined in the context of supply chain management as the readiness of supply chain participants for incoming supply chain changes by effective coordination to anticipate anticipated future need, jointly impacting demand, and relatively increasing their supply.

The smart contract is a feature of the Ethereum Blockchain that enables businesses

to handle large quantities of transactions automatically and with total confidence for both direct and indirect stakeholders[20]. Despite the standard 30-day credit contract limit, certain Fortune 100 businesses' supply networks may have sales outstanding for up to 60 days. Keeping track of overdue invoices is challenging in these circumstances. Thanks to blockchain-powered smart contracts, this procedure may now be automated with programmable clauses. The contract is automatically activated to run when a set of conditions is met, shortening the sales cycle.

As a result of many successful ventures, other industry players have been encouraged to utilize Blockchain-based solutions. According to a team of innovation analysts at Innovator's Guide who conducted a comprehensive analysis on the potential of Blockchain in the supply chain industry, there are over 800 companies working in the subject worldwide.

6 Connecting Supply Chain Management and Blockchain Technology

The blockchain technology and supply chain systems have been explained well in the previous sections; It is also discussed the gaps of supply chain. The properties which blockchain can offer supply chain networks has been discussed earlier. The four key features of blockchain technology that can increase SC member integration and coordination are (1) automation , (2) validation, (3) transparency, and (4) tokenization[2].Transparency refers to the blockchain's public ledger of information, which is assembled from a variety of sources and participants. Information validation is possible due to the immutability of information and consensus-based authentication[7]. The capacity to implement smart contracts based on verified data on the blockchain is referred to as automation. The production of tokens that reflect a specific claim on any valued item, as well as their interchange (tokenization) between blockchain stakeholders, is possible due to blockchain technology. There are four key elements of blockchain technology which allow the production of connected use case groups in supply chain management that depend on one another; those are:

6.1 Supply Chain Visibility

A lack of end-to-end transparency is one of the primary cause of supply chain inadequacies, which also contributes to the so-called bullwhip effect. Blockchain technology enables a vast number of supply chain participants to communicate real-time information about a material's status and condition. Any measurable aspect, such as temperature variation in a cold chain or the provision of technical equipment in a supply chain, can be tracked using sensor technology and the Internet of Things. This enhances accuracy of data, allowing for more cooperative design and execution, as well as the implementation of reactive and proactive risk management strategies.

6.2 Supply chain Integrity

Blockchain technology allows users to track assets back to their source through a shared ledger of visible and immutable data. Provenance information is used to validate the validity of assets, which includes both things and technical equipment. This could aid in the enforcement of responsible sourcing as well as the detection and prevention of product counterfeiting and other types of fraud. One of the uses could be tracing asset ownership after a sale for warranty purposes. Furthermore, implementation of blockchain technology simplifies international trade paperwork by ensuring the validity of freight documents, such as those used in customs clearance.

6.3 Supply chain orchestration

Supply chains that function highly automated based on pre-specified norms may be envisioned if transparency and validation were combined with automation via smart contracts. Speed and coordination are improved because information and matching options or measures are disseminated across the supply chain. When a machine malfunctions, it may request maintenance, submit a supplier order for a replacement part, and notify downstream partners of potential delays. Another advantage of automation is that contracts are ex-post enforceable, which means that contractual parties cannot refuse to perform their obligations.

6.4 Supply chain virtualization

Virtualization is a well-known IT infrastructure management method that involves creating a logical representation of physical hardware in software in order to enhance the use and flexibility of IT assets. Because there is an alternative to shifting SC asset acquisition/sale onto the blockchain, tokenization of physical SC assets, such as technical equipment and inventory, is an analogous notion. Outside of ordinary (bilateral) contractual engagements, tokens reflecting claims on capacities or ordering alternatives could be created and circulated. Excess capacities could be monetized in the same way that virtualization of IT hardware allows for more efficient use of SC assets. Virtualization would also improve contract flexibility and facilitate risk reallocation in supply chains in general.

While the above use cases are largely concerned with the management of physical assets and material flows, cross-cutting applications that enable the administration of related financial claims and financial flows are put together in a separate use case cluster.

6.5 Supply chain finance

Financial supply chain management applications are a suitable fit for blockchain technology given their strong ties to cryptocurrencies and the critical importance of financial mediators in international commerce. As a result, blockchain technology can be used to handle multi-party and multi-tier financial transactions in supply chains that emerge from blockchain members' collective value creation. Second, transparent and validated information, automated transactions, and tokenized financial claims find things simpler for blockchain members to invest working capital, lowering financing costs. Supply chain assets could be collateralized for this objective by generating comparative financial claims.

7 Challenges of applying blockchain in supply chain

Although the blockchain enabled supply chain technology is innovative in and of itself, there are significant limitations and challenges in putting it into practice. Some

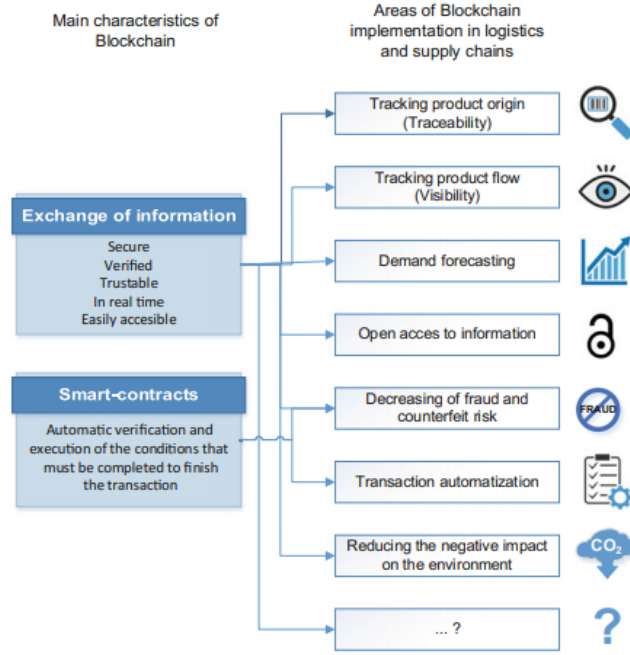


Figure 3: Characteristics and implementation areas of blockchain in logistics and supply chain

[7]

comprehensive assessment of the non-technical and technical barriers to Blockchain implementation in the supply chain is presented in this paper.

7.1 Non technical challenges

Despite the lack of manufacturing procedures and guidelines, many corporate leaders who recognize the potential of Blockchain are hesitant to spend time and capital in it[30]. To also be successful, everybody in a conventional management of the supply chain must believe in the benefits which blockchain offers; relevant players should be on board and see the value of deploying Blockchain. As a consequence, gaining market acceptance is a huge challenge.

The bulk of enterprise resource planning (ERP) platforms don't really accept blockchain. As a consequence, the corporation should either contract software development or develop in-house for its particular supply chain. Since an enterprise should engage the assistance of a third party who should be trustworthy with the organization's assets, data leakage, along with other risks, could be a significant problem. In the latter instance, the threat of privacy is minimal, but long-term

investments are needed. Current staff should be trained, or qualified professionals should be recruited. Because the creation involves a broad range of software capabilities, and also a comprehension of the fundamental supply chain structure and business and financial challenges, that might be tough.

The issue of data accuracy is at the crossroads of technological and non-technical challenges. Because Blockchain technology is immutable and transparent, data entered into a Blockchain must be correct; the user cannot easily alter or modify the record.

The use of Blockchain technology may be more destructive to the user than advantageous if a supply chain partner's information is recorded in an inaccurate system. The immutability of the Blockchain does not guarantee the data quality.

7.2 Technical Challenges

Fetching and committing entries on Blockchain is substantially slower than on a regular database. It also needs a substantial increase in computational capacity, with scalability posing a considerable barrier. Any systems that interact with the Blockchain must be able to communicate with one another. The payment period must be brief and flexible enough to take payments in any currency.

7.2.1 Scalability

Scalability refers to a system's ability to respond and function after increasing the size of the input to fulfill user demand. To address scalability issues, Soohyeong Kim divides scalability solutions into on-chain, off-chain, side-chain, child-chain, and inter-chain approaches. The number of transactions, block interval time, data storage, and data transfer are all factors that Junfeng Xie considers when categorizing scalability options. Scalability solutions are divided into four categories here. Scalability on the blockchain, Scalability off the blockchain, Consensus techniques for scalability, Distributed acyclic networks provide scalability. Figure 6 shows the different types of scalability solutions available, as well as examples of specific solutions within each category.

On-chain solutions necessitate a structural or fundamental change to the Blockchain protocol, as well as alterations to its underlying concepts. This is referred to as a hard fork or controversial hard fork when there is a split in the community, since there are

factions that favor or reject the proposed adjustment[13]. Sharding and SEGWIT are two popular options. Litecoin, DASH, and Bitcoin Cash are just a few instances of hard fork solutions.

Because it uses extra protocols constructed on top of the core Blockchain, the off-chain technique is known to as a second layer scaling option. In this technique, transactions are offloaded from the main Blockchain and carried out privately among the interacting partners. Reduced MainNet congestion, increased throughput, decreased transaction fees, and space savings are just a few of the advantages. Off-chain options include RAIDEN, Trinity Network, Plasma Cash, and Lightning Network.

In Consensus Mechanism based Scalability, the functioning of the consensus algorithm is optimized to aid in addressing scalability difficulties.

Distributed Acyclic Graph-Based Scalability is not the same as Blockchain. The blockchain is another widely used distributed ledger technology. There is no need to follow a set of rules because transactions run asynchronously and independently of one another. The system uses a topological ordering data structure to keep track of transactions.

7.2.2 Interoperability

While Blockchain adoption is increasing, the separation of Blockchains into their own "silos" due to a lack of interoperability standards is preventing wider acceptance. Collaboration and cross-chain contact between public, private, and consortium Blockchains could pave the path for a hyper-connected society.

Blockchain platforms must speak the same language, sharing identical capabilities and feature sets in terms of consensus models, transactions, and contract functionality. Notary Schemes, SideChain Relays, and Hash Locking are the three types of proposed solutions for Blockchain interoperability[29].

- A notary, an intermediary trustworthy person, witnesses and validates the status of the interacting Blockchains to make operations easier. Liquid's Federated Pegged Sidechain is a significant solution in this category.
- The relay mechanism is used in several interoperability solutions. Cosmos, Polkadot, and ChainLink are just a few examples.

- Why Hash Locking is the most practical way to Blockchain interoperability, despite its limitations. The Interledger Protocol (ILP) and the ARK Core Series are its principal solutions.

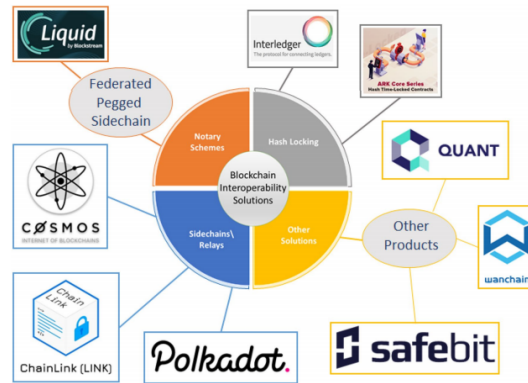


Figure 4: Summary of interoperability solutions.

8 Industries which use Blockchain in Supply chain

As we saw in the previous sections, blockchain can bring many advantages in the supply chain which many industries have realized and began to implement in their business. Previously, it was quite easy to manage supply chain as the trade was local, but later when it become global, supply chain management became more complex, which required efficient and reliable strategies for managing the supply chains. When the application of blockchain was expanded out from just bitcoin and cryptocurrencies, various other industries started using blockchain for efficient supply chains, which brought efficiency and transparency throughout the chain[1].

Some top companies who use blockchain in supply chain has been discussed here,

- In jewelry supply chain
- Tea Industry
- Food Supply Chains
- Beer and beverage
- Automotive Supply Chain

8.1 Supply chain of Jewelry

A few years ago, tech-savvy players in the jewellery business, especially in the gold and diamond industries, began experimenting with blockchain-based supply chain solutions. At the moment, there are minimum of two or three sites which have been established well. De Beers

Due to the tangled origins of diamonds and, to a lesser extent, gold, organizations like De Beers have turned into blockchain technology to ensure that the jewels are not generated from the any emergency funding or compelled labor. Company's Tracer can track diamonds from mine to store and provide provenance information. Throughout its infancy, the system has shown to be a success.

As a result, preparations are being made to split it out as an global organization which open to any company that wants to trace the location of diamonds across the supply chain.

Berkshire Hathaway

A system similar to Tracer is used by Berkshire-Hathaway, an American business. This multinational corporation's holdings include jewelry retail chains and precious metals businesses. TrustChain Jewelry is a blockchain-based jewelry project that focuses on gold and gemstones. Its purpose is to assuage the concerns of the 70To improve supply chain transparency, a few start-up businesses in the jewellery sector are currently embracing blockchain technology or plan to do so in the future. There does not appear to be a problem that blockchain can fix in the sector.Entrepreneurs believe that using blockchain to establish ethical sourcing and refining will help them avoid the problem.

8.2 Tea Industry

Unilever has several tea plantations across Africa which use blockchain technology to enhance the sustainable feature and fight deception. It's not like the company's monitoring and mapping of tea all over the supply chain is a novel concept. This is something Unilever has been doing for a long time. On the other side, blockchain technology is enhancing the activity's pace and efficiency.

Trado, a blockchain solution developed by Unilever, Sainsbury's, and the Institute for Sustainability Leadership at the University of Cambridge, is the result of a cooperation

between the three firms (CISL). The participants, which included growers who were paid to input data into the system, hailed it as a victory, stating that it improved transparency in the tea supply chain and reduced the cost of funding sustainability benefits.

8.3 Food Industry

Walmart executives believe that blockchain technology can help avert or at least mitigate the effects of food spoilage disasters like the e-coli tainted lettuce and melamine-adulterated milk crises that shook the US and China just several years back. Because all produce movements are immutably documented on a distributed network, tracking tainted food or goods back to their source can take hours instead of days or weeks.

Using Walmart's blockchain technology, customers will be able to identify items in-store and get easy access to information on them, revealing their vendors and the shipping processes involved in their trips through source to local shop. Thanks to agreements with Nestle, Dole, and Unilever, as well as technology behemoth IBM, Walmart has cemented its place in the blockchain earlier start ring of honor. The Food Trust Blockchain, a decentralized blockchain platform capable of collecting information linked to over a million individual commodities, is the product of the agreement. Other examples of food supply chain includes: -

- GS1 has initiated a project to address interoperability challenges in food-industry blockchains in accountant with FoodLogiQ, SAP, IBM Food Trust, and ripe.io.
- Kvary Arctic, a major salmon producer, has joined Food Trust to make it easier to track the provenance of arctic salmon and the food they eat.
- The Sea Food Association in Norwegian has used a blockchain technology for their users, which provides the storage of information regarding catches related to:
 - Make a note of the time and place.
 - Storage temperature
 - Getting through customs
 - Information about the type of fish feed used

8.4 Beer and Beverages

Anheuser-Busch Inbev is the world's biggest manufacturer. This behemoth corporation is employing blockchain technology to help poor peasants in Africa become more economically self-sufficient by linking farmers straight to its supply chain without using costly mediators. Farm owners may assess creditworthiness, activate banking, and develop their fields into commercially successful enterprises using the blockchain's irrevocable data.

Alpha Acid, a regional brewer in the San Francisco Bay area, recently partnered with Oracle to develop a blockchain-based system that will automate and speed up supply chain processes in the United States. Alpha Acid now has an end-to-end comprehensive overview of its own supply chain as a result of the cooperation. It enables digital signatures at every step of the brewing process, from hop harvest to fermentation processes, brewing, and aging. In the brewing supply chain, this amount of transparency is priceless. The accuracy of beer products is dependent on having a consistent formula and using naturally volatile ingredients such as yeast, hops, and barley.

Sensor data is sent to Alpha Acid's blockchain system from the brewing company fermenting containers, as well as the industry's yeast, hop, and grain suppliers. With most of this information, potential issues with a completed volume of beer may be quickly identified, allowing the issue to be isolated and rectified. Even before introduction of blockchain, it would not have been possible to quickly identify the tainted batch, necessitating a much wider product recall.

8.5 Automotive Supply Chain

Vehicle manufacturers have a history of being early users of digitally transformed supply chain technologies, hence blockchain adoption by this industry is not a surprise. Renault, Ford, General Motors, BMW, and, finally, Tesla, are developing or implementing blockchain based methods.

The blockchain, as per Ford, has the potential to ensure the legal acquisition of cobalt, an element that is rapidly utilized in electric vehicle batteries. Ford, like many of the other corporations, has collaborated with IBM to develop a ledger for end-to-end supply-chain openness. The prototype program analyzes cobalt sources and documents

every supply-chain activities, from mine packing to processing, shipping, and delivery to automakers.

Meanwhile, BMW has begun testing its PartChain platform, which will first be used to follow the supply chain activities of automobile headlamps, such as all parts and components, with the goal of expanding the range that included providers of a variety of other automobile components in the future.

The goal of a blockchain relationship between Tesla and port and shipping corporations is to improve supply chain performance and accuracy. For imports to its Shanghai facility, which is recognized for its own focus on clean energy and electric vehicles, the innovative automaker has put a blockchain application to the test. According to a study by Business Blockchain HQ, Tesla successfully implemented the technology in collaboration with COSCO Freight and Shanghai International Port Group to streamline the incoming supply chain to its manufacturing facilities. Some benefits are:

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- Processes for picking up freight more quickly
- The time it takes to unload cargo at Shanghai port has been reduced.
- The time it takes for a product to be delivered from the factory is shorter.
- The efficiency of the supply chain has improved.

All of these advantages arise from the blockchain solution's capacity to permit quicker financial statements and transactions, allowing goods to ship by the supply chain faster than traditional handoffs used to allow.

9 Conclusion

In conclusion, implementing blockchain in supply chain can increase the potential of supply chain by increasing the transparency which makes the participation of all the members in the supply chain as nodes, thereby make it very hard to alter the transactions. Along with that, the time consumption for manual paper works can be eliminated and implement a clear and strong methodology to run the business which helps in the overall progress in productivity and reputation of the business. The business transparency, prevention of fraudulent activities, proper tracking of

commodities from the production stage till it reaches the end customer, demand management, smart contract feature and many other features can be promised by blockchain enabled supply chain. It is clear from the success stories of businesses which implemented blockchain based supply chain that despite of the minor disadvantages, implementing supply chain in block chain can be very advantageous for the business. Future works can be done to mitigate the challenges of applying blockchain based supply chain management.

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