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THE BLOCKCHAIN APPLICATION THE SUPPLY CHAINS

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ABSTRACT

La trasparenza è uno degli elementi che caratterizza ogni tipo di business. Sicuramente, con il processo della globalizzazione e l'internalizzazione della supply chain è diventato sempre più complesso per le aziende gestire i vari processi dal primo all'ultimo step. Le varie problematiche della supply chain non possono essere indirizzate dai sistemi tradizionali e per questo ci viene in aiuto la blockchain. La suddetta viene vista come una tecnologia che permette lo sviluppo di un database decentralizzato per la gestione delle informazioni e transazioni tra nodi nel network.

Questo lavoro viene strutturato in 4 capitoli:

- Nel primo capitolo si dà una definizione al concetto della blockchain e si ha uno studio dei suoi meccanismi per capirne meglio il funzionamento. Il capitolo si chiude con l'analisi dei vantaggi e disvantaggi;
- Nel secondo capitolo si approfondisce il concetto della supply chain differenziando le varie categorie, gli aspetti che lo definiscono e i limiti che lo caratterizzano;
- Nel terzo capitolo si vanno ad evidenziare i benefici, le soluzioni e le limitazioni dell'implementazione della blockchain nelle supply chain;

- Nell'ultimo capitolo si vanno ad analizzare le supply chain di 3 diverse industrie, soffermandosi sulle problematiche dovute ai sistemi tradizionali e ai cambiamenti che può apportare l'introduzione della blockchain in tali industrie.

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INTRODUCTION

This thesis is divided in four parts: initially introducing blockchain, after giving an introduction of supply chain and the finally implementing the blockchain in the supply chain, particularly in three different industries.

In chapter one is given a picture of the blockchain technology, expounding all the dynamics which characterize this technology.

The purpose of the blockchain in bitcoin was to solve the problem of double spending using a peer-to-peer network without the need of intermediaries or central authorities. In a nutshell, the blockchain is a decentralised, distributed and public ledger which is used for recording transactions while guaranteeing security, transparency and decentralization.

In the second section is described how the consensus algorithm is attained in a blockchain network. A consensus algorithm has the functions of ensuring that the block which is going to get added to the chain is the only one with the right answer. Between all the three mechanism, proof-of-work is the most famous one. Miners compete with each other solving an extremely difficult cryptographic puzzle and as a reward they receive a small number of tokens¹.

¹ In case of Bitcoin this token are called bitcoins and in Ethereum is called ether.

Continuing the third and the fourth section describe the possible advantages and disadvantages of the blockchain. Transparency, immutability and the removal of third parties is what makes make blockchain unique.

Transparency is one of the important elements of every business. However due to globalization and internalization of businesses has become more difficult for companies to deal with issues related to transparency paying other figures like intermediaries. Immutability is another issue concerning business is the manipulation, replacing and falsification of data.

Both these problems can address by blockchain. The transparency is achieved because every transaction is visible to all the participants of the network. Additionally, is impossible to alter data after it has been validated because the successive blocks in the chains will not accept the attempted alteration. Disadvantages in the blockchain involve: -the lack of privacy where the transaction in the case of cryptocurrencies can be tracked down to the public key of the node not providing very much privacy protection.

-security concerns about the complexity of the blockchain.

-no centralised control and the attack of 51% focus both on the issues of not having control over blockchain system.

The last section of this chapter introduces the Smart contract, an application of the blockchain technology. Due to the security of the blockchain, smart contracts are self-executed and self-enforcing contracts that can be used in different business,

(insurance, supply chains). These contracts can facilitate the exchange of goods and eliminate the roles intermediaries resulting in major efficiency, paper free, security and saving time and transparency.

In chapter 2 is given a general picture of the supply chain.

First section categorizes supply chain in three types considering their functions, based on the functional attributes: procurement type, product type, distribution type and sales type. Following in the second section, five attributes for having an effective supply chain are mentioned, such as leadership, innovation, punctuality, sustainable and planning. The last section of chapter two specifies the various limits of the supply chains giving a detailed description of the traditional systems resulting in minor transparency, elevated cost, limitations due to the insufficient resources.

In chapter 3 is given a report of the impact that blockchain can have in the supply chain, transforming how the services and products move across the supply chain.

The first section underlines the benefits of implementing blockchain: tracking of the product till the final consumer, minimising the losses by tracking the flow of products (in case of problems with product it can be easily and quickly identified), keeping an eye in the standard of the product and the most important value is level of trust which blockchain provides between participants in the supply chain.

Although implementing blockchain the supply chain has a its advantages, the technology still lacks maturity to support global implementation today due to being still in the early stage and having a lot of room for improvement.

In chapter 4 are taken in consideration three industries: food, pharmaceutical and fashion industry.

The first section highlights the problems in matter to with food security and contamination, which with the traditional supply chain it's impossible to address these concerns. Contrarily blockchain can address these concerns because it helps in providing critical product information such as, processing data, batch numbers, batch numbers and storage information.

The second and third section we are going to give a analyse of the actual problems due the traditional methods which operate the supply chains in these industries. Counterfeiting is the main problem, where is very difficult to check all the transactions between all the parties due to the complexity of these industries.

Additionally, the analyse with be focused in the possible solution that blockchain can offer, having a higher transparency in the supple chain, better distribution and inventory control.

CHAPTER 1 BLOCKCHAIN TECHNOLOGIES

“A blockchain is a new type of database that enables multiple parties to share the database and to be able to modify safely and securely even if they do not trust each other “

The blockchain was first mentioned in the original bitcoin white paper, although Satoshi never used the term blockchain or “block chain.” Satoshi used the term chain instead, in the same way, the term blockchain it is used today² (Satoshi, 2008, p. 3-7). Even though in the beginning blockchain is linked to bitcoin now they are two separate entities.

An essential aspect behind the blockchain technology is the cryptography.

Blockchain technology represents the next step in the peer-to-peer economy. By combining peer-to-peer networks, cryptographic algorithms³ (David), distributed

² Satoshi mentioned on the bitcoin white paper, on page 3, "As later blocks are chained after it, the work to change the block would include redoing all the blocks after it" and on page 7 "This prevents the sender from preparing a chain of blocks ahead of time by working on it continuously until he is lucky enough to get far enough ahead, then executing the transaction at that moment." See S. Nakamoto.

³ The peer-to-peer economy refers to decentralized individual action, specifically new and important cooperative and coordinate action carried out through radically distributed, the non-market mechanism that not depend on proprietary strategies.

data storage, and a decentralised consensus mechanism⁴, it provides a way for people to make and verify their transactions⁵ immediately.

Webopedia defines blockchain as *“a type of data structure that enables identifying and tracking transactions digitally and sharing this information across a distributed network of computers, creating, in a sense a distributed trust network. The distributed ledger technology offered by blockchain provides a transparent and secure means for tracking the ownership and transfer of assets⁶ (Webopedia, s.d.).”*

The difference between blockchain and other types of distributed databases that have a non-central database is that blockchain is designed to achieve agreement over autonomous participants who may have different motivations and interest.

Blockchain got introduced with Bitcoin (Satoshi, 2008), a cryptocurrency designed by Satoshi Nakamoto.

Nonetheless, blockchain supports a broader range of use cases because of its design.

A blockchain is essentially a database or digital public ledger that would record all the digital transactions that have been executed and shared between all the

⁴ Consensus mechanism, such as Proof of Work, is the most popular algorithm being used by currencies such as Bitcoin and Ethereum, each one with its own differences. Blockchains use consensus algorithms to elect a leader who will decide the contents of the next block. For an actor to be elected as a leader and choose the next block to be added to the blockchain they must find a solution to a mathematical problem.

⁵ With cryptocurrencies, for example, a transaction represents a transfer of the cryptocurrency between blockchain network users. For business-to-business scenarios, a transaction could be a way of recording activities occurring on digital or physical assets.

participants. Each blockchain is encrypted and organised into smaller datafile called blocks (Lambert).

1.1 HOW THE BLOCKCHAIN WORKS

Every block contains information about a certain number of transactions, a reference to the previous block in the blockchain, as well as an answer to a complex mathematical puzzle, which is used to validate the data associated with that block (David). The new block will be added to the end of the blockchain only after the majority of the participants on the network come to a consensus as the transaction being valid. As mentioned above the participants achieve consensus through the voting mechanism, which the most common is *Proof of Work* (8 Famous Blockchain Consensus Mechanisms and their Benefits, 2018). After a block, it is successfully united to the blockchains, it is permanent and unchangeable, and every participant on the network accesses the transactions. (as is illustrated in figure 1)

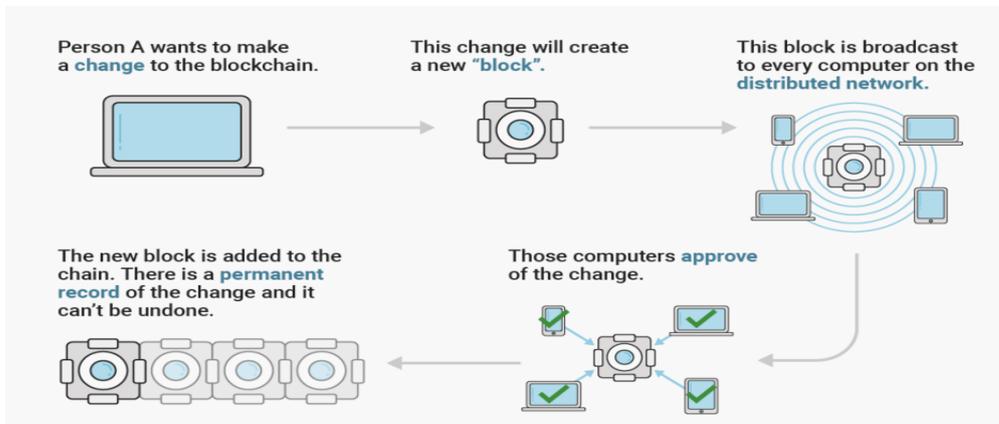


Figure 1 How blockchain works (Source Business Insider)

1.1.1 BLOCKCHAIN CRYPTOGRAPHY

Cryptography is the method of encrypting and decrypting information through a sophisticated mathematical algorithm. The information can be seen only by the intended recipient and nobody else. This method consists of taking unencrypted data and encrypting it using this mathematical algorithm called cypher. This process generates a ciphertext which is useless unless it is decrypted.

Blockchain technology utilises cryptography as a means of protecting the identities of users, ensuring transactions are done safely and securing all information and storages of value. Therefore, anyone using blockchain can have complete confidence that once something is recorded on a blockchain, it is done so legitimately and in a manner that preserves security (Lisk, Academy, s.d.).

The public cryptography allows data to be sent through a public key that can be shared with all participants on the network.

Instead of using a single key for encryption and decryption⁷ two keys are used, private key and public key (Sirt).

The process of encryption is done by a combination of the private key and public key of sender's while the process of decryption is done by a combination of sender's public key and recipient's private key. The sender will encrypt data that be only decrypted by the intended participant.

1.1.2 PEER-TO-PEER NETWORK

A peer-to-peer network is a group of computers, where each of them acts as a node for sharing files within the group. Instead of having a central server where all the files are stored, each computer is considered a server (Techopedia, s.d.).

Each peer is equal on the network and so-called nodes.

Regardless of being equal, they can have two different functions, mining and being a full node⁸.

⁸ The whole blockchain data is being stored in every single computer on the network. This means that all the data stored cannot be destroyed because to do so would mean to destroy every node on the network. Consequently, as long one single node exist all the network could be rebuilt.

Peer-to-peer network diverges completely from other today's centralised networks given that a server does not exist. This method of storing data is massive progress because it does not need a single party to control the data. Instead, the users are in control of their data. With the help of blockchain technology trust in third parties is not required given that all participants can rather deal with other nodes on the network within a protected and distributed and decentralised network.

Even though all the participants see the access of each node on the network, all information and their identity are concealed on the blockchain through a sophisticated algorithm.

1.1.3 NODES

A copy of the blockchain is stored on every node that exists on the network. A node can be any device, as long it has an IP address and connected to the network such a computer, a phone or even a printer. The primary function of a node is to support the network by saving a copy of the blockchain and processing the transaction (Lisk, Academy)⁹.

⁹ Processing these transactions can require large amounts of computing and processing power, meaning that the average computer's capabilities are inadequate. Generally, professional miners tend to invest in extremely powerful computing devices known as CPUs (central processing units) or GPUs (graphics processing units) in order to keep up with the demand for processing power that is required for them to validate transactions and as such earn the rewards that come with doing so.

1.1.4 HASHING

Hashing is the process of taking an input such as the block of transactions or a piece of information and converting into a complex cryptographic output through a mathematical algorithm (Lisk, Academy).

In the blockchain, each block contains within transactions, a hash, and the previous hash. The block zero of blockchain it has called “genesis block.”

The first block contains its transactions that, when united and approved, create a unique hash. The hash that is used in the next block is created after processing the previous hash and the new transactions as an input. Each block links back to the previous block through its hash, forming a chain back to block zero. This process is what makes the blockchain nature secure. If one of the participants wanted to alter the data stored in the tenth block of a blockchain, he would have to alter all the data stored in the succeeding blocks starting from the tenth block, making it almost impossible since it would require significant computing power.

1.1.5 CONSENSUS

Blockchain consensus protocols are what maintain all the nodes on a network synchronised with each other while providing an answer to the question: how do all the nodes make sure that all agree on what the truth is (Lisk, Academy)?

Given that everyone can add information onto a blockchain and consequently it is crucial to check and confirm and decide whenever to add that information.

These protocols are of the significant value of blockchain technology since they create an undisputable system of agreement between all nodes on the network while preventing manipulation of the system.

Exactly consensus means that all nodes agree on the same state of the blockchain.

These protocols have two essential functions, consents the blockchain to be updated while confirming that each block is correct and precludes single parties from running and changing the blockchain system.

1.1.5.1 PROOF-OF-WORK

Proof-of-Work¹⁰, or PoW, is the first consensus algorithm introduced by bitcoin.

The role of this algorithm is to confirm the new transactions and add blocks to the

¹⁰ The name of this consensus mechanism is called PoW because the probability to mine a block is increased if the amount of data within the transaction it's increased as well.

chain. Through this mechanism,¹¹ miners compete against each other to solve a mathematical puzzle and the first miner that manage to mine the next block attach the block to the chain and validate the transaction within it, and finally get the reward-related with the block (Lisk, Academy).

1.1.5.2 PROOF OF STAKE

Proof of stake or PoS is another consensus algorithm to validate blocks. Proof-of-Stake algorithms achieve consensus by requiring users to stake a number of their tokens to have a chance of being selected to validate blocks of transactions and get rewarded¹² for doing so¹³ (Virtualminingfarm)

In the PoS system, the miners are called forger. Unlike the PoW system where the miners have to solve a mathematical puzzle to validate transactions and add new blocks, in PoS system the one that adds the new block to the blockchain are chosen in a semi-random way, depending on their stake¹⁴ or sometimes how long they have been holding that particular stake. The main advantage of this system is the fact that

¹¹ The “proof of work” comes in the form of an answer to a mathematical problem, one that requires considerable work to arrive at, but is easily verified to be correct once the answer has been reached.

¹² In PoS system the chosen validator is rewarded by apart of the transaction fee.

¹⁴ Each participant must own a stake on the network. It means that participants must deposit a number of tokens into the system, locking it in and using it as warranty to guarantee for the block. The more a participant stakes, higher will be the probabilities of being selected as the validator of the transaction.

it needs less energy to run, which in case the PoW system is exceptionally high. Another advantage is the less of need to release new coins as a means of incentivising the miners to keep alive the network. This process maintains the price of a specific coin stable in an extended period.

1.1.5.3 DELEGATE PROOF OF STAKE

The delegate proof of stake or DPoS is a consensus logarithm system where a limited number of entities are chosen to validate the transaction and adding new blocks. This entity is chosen into power through the process of voting by the participants of the network. The number of votes that each participant can exert is proportional to the number of tokens they own (stake).

Delegates are incentivised to run and validate the transaction on the network with transaction fees and monthly rewards.

Among the consensus logarithm mentioned above, DPoS seem to be more democratic, and it is also more efficient, but it has required to sacrifice some decentralisation in exchange for higher performance and cost efficiency (Vitalik).

1.2 CATEGORIES OF BLOCKCHAIN

Many people have tried to classify blockchains, but there is no consensus on how to accurately distinguish different types of Blockchains (Types Of Blockchains & DltS).

There are three types of blockchain, distinguishing between public and private, or permissioned and permissionless.

1.2.1 PUBLIC BLOCKCHAINS

A Public Blockchain is a permissionless blockchain.

Anyone can join the blockchain network, meaning that they can read, write, or participate with a public blockchain (A Hybrid Blockchain For The Iot And Tokenized Hardware).

Public blockchains are decentralised, no one has control over the network, and they are secure in that the data cannot be changed once validated on the blockchain (Diary).

- Anyone can be part of the network downloading and running a public node, validating transactions and being part of the process for determining what block gets added to the chain

- Anyone can make transactions and to be added to the chain only if they are valid.
- Anyone can read the transactions in the public ledger.

1.2.1 PRIVATE BLOCKCHAINS

Private Blockchain is a permissioned blockchain. Permissioned networks place restrictions on who is allowed to participate in the network and what transactions (Bitcoin Is Example Of Which Type Of Blockchain).Example applications can be in database management, auditing, health care where the public readability may not be necessary.

Public and closed	Public and open
Voting	Currencies Betting
Private and closed	Private and open
Construction National Defences Military Tax returns	Supply chain Corporate earnings statement

Figure 2Types of blockchains (Source Blockchainhub.net)

1.2.2 CONSORTIUM BLOCKCHAINS

Consortium blockchains differ to their public counterpart in that they are permissioned; thus, not just anyone with an internet connection could gain access to a consortium blockchain (Mycryptopedia).

These types of blockchains are not entirely decentralised. The control is not given to a single node, but rather to a grouped of approved nodes.

Thus, consortium blockchains possess the security features that are inherent in public blockchains, while also allowing for a higher degree of control over the network (Mycryptopedia).

1.3 ADVANTAGES OF BLOCKCHAIN TECHNOLOGIES

1.3.1 TRANSPARENCY AND IMMUTABILITY

The property of transparency of the blockchain comes from the fact that the data or the transactions are visible to each node on the network, and once the transactions are validated, they cannot be altered or compromised (American Megatrends International Llc - Blockchain 101).

This level of transparency has never existed before, where with the actual record keeping system, a person or entity can alter the database or delete the data as they see fit (What Is Blockchain Technology). There have been many cases where frauds went undetected as the ledgers were not transparent.

The blockchain technologies provide transparency to all the participants on the network thanks to the consensus mechanism, which means that the majority of the nodes must approve transactions or changes to the blockchain avoiding transactions from being manipulated.

In private blockchains or consortium blockchains, only a few nodes have permission to access to individual records, depending on the rules set by the organisation that manages it, while in public blockchain everyone can check the transactions and verify the authenticity of the data.

1.3.2 REMOVAL OF A THIRD PARTY

Another advantage of the blockchain is the elimination of a third part where transactions are occurring directly between nodes (What Makes Bitcoin Valuable?). A majority of a transaction nowadays requires intermediaries or central authority to provide trust that assumes the role of the third party.

Blockchain technology creates a trusted, transparent environment making information publicly available through the entire network while assuring the integrity and immutability of data (Stefan Seebacher).

1.4 DISADVANTAGES OF BLOCKCHAIN TECHNOLOGIES

1.4.1 LACK OF PRIVACY

Decentralised blockchains lack privacy, which makes full acceptance difficult. Not only is the information not private, but it is also readily accessible at any given moment to anyone using the system (Fleming.).

If a person were to buy something using the bitcoins and make a payment, the vendor would see the transaction on the blockchain and from there would track the wallet from where the bitcoins were sent and being able to see all the bitcoins that person owns and all his past transaction. Given that the majority of blockchain networks are in countries such as Russia and China, this personal information might be used against people living there.

1.4.2 SECURITY CONCERNS

Blockchain systems use advanced encryption and decryption, which are more secure than bank passwords. To access a blockchain is needed both a public key and a private key, which represents both the strength and the weakness of blockchain technology since the hacker knows that without the keys they cannot access but on the other hand, with the right keys, they can easily access the data.

In the world of the blockchain, possession of keys and ownership of content are synonymous (5 Blockchain Security Risks and How To Reduce Them).

So basically, the hackers will not waste their time on guessing the keys but instead stealing them. If a hacker attacks the private key of a user, they can impersonate that user and extract all the money or other assets, and once the transactions are done, there is no way to reverse that process.

1.4.3 NO CENTRALISED CONTROL

The main idea of a blockchain system is designed to remove the need of a third party such as intermediaries and supposed to work agreeing to the rules imposed by consensus, where all the nodes can take part and ensure that the rules are followed. This nature of blockchains means that only if the majority of the peers agree they can decide the future direction of the network.

This makes decentralised networks risky for an organisation to use. A company may build a business or software around the network where they have no control over changes that could dramatically impact their software business.

1.4.4 ATTACK OF 51%

A 51% attack on a blockchain refers to a miner or a group of miners trying to control more than 50% of a network's mining power, computing power or hash rate. People in control of such mining power can block new transactions from taking place or being confirmed (51% Attack Explained: The Attack on A Blockchain).

For instance, one can spend ten bitcoins to buy a product. After the product is delivered, the user can reverse the transaction, obtaining the product and the ten bitcoin he spent.

1.5 SMART CONTRACTS

A smart contract is an automatable and enforceable agreement. Automatable by computer, although some parts may require human input and control (Arxiv, 15 Mar 2017).

Smart contracts help to make transactions or exchange properties, shares without the need of a layer or notary. Smart contracts not only define the rules and penalties around an agreement in the same way that a traditional contract does, but also automatically enforce those obligations (What Are Smart Contracts?).

In other words, smart contracts are self-executable lines of codes which are stored in a blockchain which contain predetermined rules. Only when the predetermined rules are met, the lines of codes execute and will give a specific output.

1.5.1 BENEFITS OF SMART CONTRACTS

Smart contracts share the same benefits as the blockchain. They are filled with rules and conditions which eliminate the chance of quarrels and issues between the participants. This quality of smart contracts ensures transparency during transactions. The speed of completing transactions with the help of smart contracts

is faster compared to traditional business, eliminating the intermediaries and the unnecessary steps along the way.

For a smart contract to be executed, all terms and conditions are needed to be met, therefore any condition that is left out, the contract might result in an error while executing.

The fact that smart contracts operate in a blockchain system they are immutable. This means that once a smart contract has been validated, it is impossible to alter it, which prevent third parties from changing the content of the contract.

Another essential aspect of smart contracts is the storage on the contract of all the details of the transactions where all the involved parties can access at any given time.

The properties of transparency and safety make smart contracts trustworthy, where any probability of manipulation and errors are deleted.

CHAPTER 2 SUPPLY CHAINS

Supply chain management is the broad range of activities required to plan, control and execute a product's flow, from acquiring raw materials and production through distribution to the final customer, in the most streamlined and cost-effective way possible (Rouse, p. 1).

The activities of supply chain consist of the transformation of raw materials and natural resources to manufacture products that are then supplied to the final customers. Therefore, the supply chain is the coordination of information, activities, individuals, and organisations that take part to transfer services or products from the suppliers to the customers.

Furthermore, supply chains include the businesses and the business activities required in the designing, making delivering and using a service or product (Hugos, 2018). This means that the majority of the businesses rely on the supply chains to give them what they require to grow and succeed in the competitive market.

In the literature, there are numerous definitions of supply chains by different scholars. For instance, Lu Dawei defines supply chain as collection inter-connected establishments that appraise to a continuous flow of converted inputs from their origin to the complete services or products needed by the end customers. For a supply chain to be created, some essential aspects have to be to present.

An essential aspect that ought to be present is that the organisations have a mutual obligation to add value to the flow of products over the supply chain.

On the other hand, a supply chain is defined as the set of businesses that are directly associated to the downstream and upstream flow of information, finances, services, and products to the consumers from the source of origin. This implies that through the supply chain, the services and products are conveyed to the final consumers. Similarly, the supply chain can also be termed as a group of organisations or entities that are involved in the downstream or upstream flow of information, finances, services, and products (Mentzer, 2001, p. 4). Consequently, supply chain works when there is a collaborative effort by different businesses to perform the role of procuring materials, transforming these materials to completed products, and then distribute the products to the final-consumers in the market (Hugos, 2018, p. 3-4). Supply chain ensures that the end consumers get the service that has been created. The supply chains utilise the flow of information to ensure that the end customers receive the appropriate products. The types of information flow that are vital in a supply chain include the design information flow, scheduling, and production information flows, forecasting information flow, and demand information flow (Lu, 2011, p. 8).

It should be noted that each supply chain has its distinctive forms of market demands as well as operational problems. However, despite this, all the businesses in the supply chain must make decisions independently and jointly concerning their

engagements in areas such as production, inventory, location, transportation, and information. For example, the companies are required to understand the products that the market requires, and the number of products required depending on the market before they embark in the production process (Hugos, 2018, p. 5). Similarly, companies in any supply chain should have an inventory on the number of products that should be stocked at every phase of the supply chain, and the quantity of inventory that ought to be detained as finished goods or as raw materials. In a supply chain companies that participate play various roles. Some companies add value, including raw material suppliers. Moreover, the manufacturers of products also add value to products through assembling, packaging, offering storage and transportation (Weaver, 2016).

Supply chains work by utilising specific drivers that facilitate particular competences. For instance, there is a production drive which the ability of a supply chain to produce as well as store goods. In most cases, factories and warehouses are the amenities of production. On the other hand, inventory drivers are spread all over the supply chain and the comprise of every activity that takes place in the production of goods from the raw materials to the finished products. Thus, in a supply chain, an inventory begins from the manufacturer, goes to the distributor, the retailer. Therefore, the companies that participate in a supply chain should make decisions on the establishment and holding of inventory.

They can do this by making three primary decisions:

1. Cycle inventory
2. Safety inventory
3. Seasonal inventory.

The location where the supply chain facilities are is also essential, that is why it is recommended that it should be close to the suppliers and customers (Hugos, 2018, p. 13).

For supply chains to be successful, there should be a supply chain management that will integrate vital business practices through the supply chain. Supply chain management was introduced in 1982 by Keith Oliver to manage the flow of services and products from the supplier to the end-consumer (Feller, 2006, p. 3).

Supply chain management is defined as the control of the system of inter-connected companies that take part in the delivery of services and products needed by the end-consumers in the supply chain (Harland, 1996). In other words, supply chain management is the process that monitors, controls, plans, and executes the activities in the supply chain with the intentions of generating net value and developing a competitive infrastructure. Through supply chain management, the production of products from raw materials is coordinated, the inventory created, and end products

are transported among the companies in the supply chain to ensure that the consumers receive their desired products.

2.1 CATEGORIES of SUPPLY CHAINS

Supply chains are available in both service and products industries, although the intricacy of the chain varies from one business to another. Besides, the types of supply chains are categorised depending on various attributes. For instance, a supply chain can be categorised based on functional attributes. Therefore, there are four categories of functional attributes that a business has.

1. Procurement type.
2. Product type.
3. Distribution type
4. Sales type

- 1- The first category is the procurement type, which is associated with a variety of products that are supposed to be procured. There are different types of products that are procured by companies ranging from unique products to

standard products that both required different production process as well as equipment. The source of raw materials also determines the procurement type to be adopted by a company. The source type comprises of multiple sourcing, double sourcing, and single sourcing. In multiple sourcing, the products to be procured are obtained from many suppliers, whereas in double sourcing has only two suppliers and single sourcing depend on only one supplier (Meyr, 2005, p. 66).

Nevertheless, the products to be procured in a supply chain can be obtained from many suppliers depending on the flexibility of these suppliers regards to the quantity to be supplied.

- 2- The second category of the functional attribute that determines the type of supply chain is the product type. The primary noticeable attributes of production type include repetition of operations and the company of the production process. Flow lines and process organisation represent the properties of the production process that are well acknowledged. A low line occurs when the resources used in the production of products are arranged adjacently and others conforming to the arrangement of the operations that are needed in the manufacture of the products. On the other hand, process organisation necessitates that all the assets can do a particular individual task are positioned in the same place or shop.

Additionally, in the repetition of operation, there are some characteristics associated with it: creating unique products, batch production, and mass production.

- 3- The second category of the functional attribute that determines the type of supply chain is the distribution type. Externally, the distribution type includes the deployment of transportation, the pattern of delivery, distribution configuration, and prospective loading restrictions. The distribution structure describes the linkage or network that exists between the consumers and the factory or warehouse. For example, when there is only one stage distribution configuration, it means that the factory and end consumers have direct links. Subsequently, the pattern of delivery can either be dynamic where the products are delivered to the consumers depending on the demand for transportation.

Nevertheless, in cyclic patterns, the transportation of products is done at fixed intervals of time. When it comes to the deployment of transportation, an individual can differentiate the vehicles deployed on different routes. Another requirement for a pattern of delivery is the loading restrictions that might develop an auxiliary requirement¹⁵.

¹⁵ Meyr, Herbert, and Hartmut Stadtler. "Types of supply chains." *Supply chain management and advanced planning*. Springer, Berlin, Heidelberg, 2005. p.68.

4- The fourth category of the functional attribute that determines the type of supply chain is the sales type. The sale of goods and services in the supply chains are significantly dependent on the relationship a company has with its end customers. The sales types are associated with the obtainability of future demands because the companies might be known or be predicted. The interval of the prediction horizon can help to describe the existence of reliable demand forecasts. The demand for particular goods affects their sale type; hence, their demand curve is vital. Also, the product life cycle of a product can affect the financial plans, production planning, and appropriate learning¹⁶. For example, the quantity of products types that the companies are offering to be sold and the degree of customisation will depend on the type of supply chain being used.

Apart from categorising the types of supply chain depending on various attributes, structural attributes can also be used. Supply chain's primary attributes are clustered into two groups: integration and coordination. Integration and coordination include attributes such as the type of information shared, the direction of coordination, and the legal position. When making decisions in an organisation about the supply

¹⁶ Meyr, Herbert, and Hartmut Stadtler. "Types of supply chains." *Supply chain management and advanced planning*. Springer, Berlin, Heidelberg, 2005. p.69.

chain, the balance of power plays a vital role. This is because a dominant participant in a supply chain may act as a central organisation.

Nevertheless, there can also be a polycentric supply chain where there are equal supply chains.

The supply chain represents a structure that designates the flow of materials to downstream from upstream businesses, which can be divergent, convergent, serial or a combination of the three. Some supply chains operate in a single country while others are in many countries across the globe, and this brings up the idea of the degree of globalisation (Meyr, 2005, p. 70).

The structure of supply chains can also be categorised into those that are focused on efficiency and those that focus on responsiveness.

The supply chain model that focuses on efficiency includes the 'efficient' supply chain model, the continuous flow mode, and the fact chain model. The efficient' supply chain model is appropriate for the businesses that operate the markets that are highly competitive and has numerous consumers and producers. In this type of businesses, the products are manufactured based on the sales for the production cycle period as well as in industries where the price determines the competition.

Contrarywise, the 'fast' supply chain model is appropriate for organisations that produce products that are trendy but have shorty lifecycles. In this type of supply chains, the end-customers are apprehensive of the speedy in which new products are manufactured depending on the fashion trends.

On the one hand, the ‘continuous-flow’ model is appropriate for the businesses that have high demand stability and those that are required to produce consistent information and product flow. On the other hand, the supply chains that focus on responsiveness include the custom-configured and agile supply chain models (Magaya, 2016).

2.2 ASPECT of SUPPLY CHAINS

Each business must choose an adequate supply chain strategy. In order for having an efficient strategy, companies have to consider particular attributes.

➤ Leadership.

Stable leadership helps to build strong roots for an effective supply chain. This creates a good foundation that enables the companies to collaborate with other participants in the supply chain. However, when companies keep on changing their top leaders, their foundation of the excellent supply chain is negatively affected.

Supply chain leaders must be able to understand and influence the “big picture” company goals and relay the importance of achieving these goals

to the supply chain team (Weaver, 2016). Also, a rewarding and incentivising process must be done to encourage the work of every single one in order to push the companies in the direction of progression.

➤ Innovation.

This aspect is fundamental for every supply chain, embracing the new technologies and innovation. Being open for changes ensures to stay competitive and being able to offer excellent services.

Some examples include the implementation of smart glasses in warehouses for optimised picking processes, the use of beacons on production floors to monitor manufacturing processes and the employment of geo-fencing for the optimisation of time slot management for truck deliveries (Weaver, 2016).

➤ Planning.

The planning process has shifted from Excel spreadsheets towards ERP systems and intelligent cloud-based adds resulting in better efficiency.

Coordination between all the key factors in the supply chain such as producers, suppliers and distributors are essential, which minimises cost and increase efficiencies. Besides, a supply chain is characterised by the production of products and the supply of these products to the consumers. This implies that products cannot be manufactured if there are no consumers, and this results in the model of demand and supply.

➤ Sustainable

Supply chain sustainability (SCS) is a holistic view of supply chain processes, logistics and technologies that address the environmental, social, economic and legal aspects of a supply chain's components (What Is Supply Chain Sustainability).

A supply chain should be sustainable, and it should not harm the environment. The packaging of products should also be environmentally friendly. Besides, emissions such as carbon dioxide should be minimised by using an enhanced transportation approach. Thus, the characteristic of an ethical supply chain should be the one that focuses on sustainability.

➤ Punctuality

Punctuality is another essential characteristic of a supply chain. In a supply chain, the end users expect to get particular products promptly. If a company fails to deliver its products on time, then the customers may be forced to look for an alternative which is likely to be a competitor.

Whenever a company fails to have its products delivered to time, then it should evaluate its supply chain to determine where the problem is. For example, the problem can be the supplier of the raw material or the distributor or supplier of the products.

2.3 LIMITS of THE SUPPLY CHAINS

Companies participating in the supply chain lack appropriate tools or approaches that can effectively, manage or evaluate the flow of goods and services from the source to the final customers. Since the supply chain included of all the participant, processes, companies, and individuals that play a role in the production, marketing, distributing, storing, and selling the products, an appropriate tool is required to manage this complex system. Nevertheless, these tools are expensive to purchase and manage to make it hard for small companies to acquire them. For that reason,

having an effective supply chain system required a lot of human resources, time, and money.

The second limit for supply chains is that if one participant stops its operations either temporarily or permanently, then the chain breaks, making it hard for the manufactures to produce products or make the delivery of the products to the final costumer difficult. Likewise, if the supplier of the raw materials fails to supply the materials or the manufacturer's machine breaks down, it will break down the supply chain hence affecting the entire chain (Mares, 2010, p. 195).

Another limit that exists in the supply chain is that various sections of the supply chain are found in diverse business functions; hence it makes it hard for the managers in the companies participating in the chain to work together. This is because of a lack of proper communication leading to potential problems.

The fourth limit for supply chains is the lack of enough training among the employees when it comes to integrating new and modern systems to the working supply chain. Most of the employees are familiar with the supply chain systems that they have been using, but when a company shifts to a new system due to technological advancements, the employees lack the skills needed.

Some companies in the supply chain may want to have an integrated supply chain, but that is faced with some limits, including excessive regulation. When the supply chain is integrated businesses will be required to manage each internal and external supply. However, there are some suppliers or distributors in the chain that would

not comply with the set regulations. Hence, if the company decides to integrate all the suppliers, then it will force them to follow the same standards (Mares, 2010, p. 196).

Also, since a supply chain is a complex system, some of the companies may lack a corporate understanding. This, in turn, affects the flow of the supply chain.

The continuous use of traditional planning systems is another limit for supply chains. This is because the use of traditional systems in a supply chain does not meet requirements in the modern business, including advanced analytics, agility, and adaptability (Brzoznowski, 2017). Today, companies are required to possess agility so that they can swiftly react to the market conditions that are changing fast and then as well as the deviations that might exist in the core business model.

For active supply chains companies are required to have new planning systems. However, the large enterprise planning systems that are required are tremendously sophisticated to set up and keep alive. As a result, it may take some companies many years to design and fully set up these systems. This is because since there are changes in the business that are taking place often, re-configuring of these systems are involved.

Also, the traditional planning systems that are currently being used by many companies fail to address adaptability, which is a vital requirement for business. Adaptability is essential because it enables the companies to precisely embody exceptional business processes that they can use in achieving competitive

advantage. Through adaptability, the companies can develop unique business processes that might help in the manufacturing of products or even an approach for they can use to smartly source materials. Therefore, the use of traditional planning systems does not allow adaptability, and this becomes a limit for the supply chain. On the other hand, traditional planning systems fail to address advanced analytics which is a requirement to control to data existing data in a measure of identifying opportunities to optimise and improve by utilising modern technologies and sophisticated systems (Brzoznowski, 2017).

Nonetheless, due to lack of resources, most of the business in the supply chain do not incorporate the necessary algorithmic technologies, and this makes it hard for these firms to scale the solutions or even maintain a long-term business solution. This, in turn, limits the supply chain when it comes to the adoption of newer technologies and systems.

Additionally, companies participating in the supply chain have an interconnected structure that limits the supply chain from introducing a centralised system that could help in controlling the third parties (Litke, 2019, p. 2).

CHAPTER 3. IMPLEMENTING BLOCKCHAIN IN SUPPLY CHAIN

The introduction of blockchains in supply chain has been of great importance because it transformed the way services and products move across the supply chain. Blockchain is a decentralised and distributed database that sustains a steadily progressing list of secure data records. When blockchain technology was applied in the cryptocurrency business, it offered an anonymous but secure method of transferring money between two companies and even people across different countries. For that reason, the use of blockchains in supply chains will revolutionise and transform the way companies will monitor the transparency of transactions in the chain (Montecchi, 2019, p. 2).

Companies that are currently using blockchain in supply chain have the benefits of acquiring real-time digital ledgers regarding the transactions that have been made by all other firms in the chain.

Integrating the blockchain into the supply chain is not as complicated as many people believe. Though companies intending to use the blockchain technology have to understand it is not a sheer software, but it is an integrative tool that synchronises the processes, data, and the entire system of the supply chain.

In general, blockchain has allowed businesses to find a solution to their existing fragmented infrastructure. Also, companies should worry about their current infrastructure when they want to implement blockchain. The good news is that blockchain can be integrated into the existing infrastructure, and it works as a layer supplementing the current enterprise resource planning (ERP) (Brody, 2017).

Unlike a traditional centralised database, blockchain is an asset database that is distributed across peer-to-peer networks of organisations. The implementation of blockchain in supply chains will allow businesses and organisations to do transactions with each other without having doubts on trust or without using third-party verification, which limits supply chains.

Moreover, blockchains will give companies in the supply chains, smart contracts: also referred to as self-executing digital contracts that will enable them to transact effectively (Wang, 2019, p. 221-236). The blockchains will allow the business in the supply chain to securely exchange data in a distributed way hence improving the sharing of information among the supply chain participants. This is likely to save the companies a lot of effort, money and time.

The traditional systems or technologies being used for supply chains today are not able to support the manufacture as well as supply cycles of goods. This is because the type of products that are being produced today have become fragmented henceforth requiring complex processes. However, the use of blockchain technology in the supply chain can solve this problem.

The use of blockchain in supply chain will transform the supply chain businesses and solve the limits that have been experienced by many companies (How Is Blockchain Disrupting The Supply Chain Industry). Blockchain can also automate documentation flow and enhance the information quality in a supply chain.

Subsequently, the blockchain allows companies to have the capabilities of recording the transactions through the supply chains in an unalterable way and also give the supply chain participant access to transactions history. Apart from being relevant to the companies, blockchain is also vital for the final-customers because it gives them an opportunity of tracing the source and well as tracking the consequent changes of products, and this, in turn, reduces the consumer's risks (Montecchi, 2019). In the current supply chains, the customers are unable to access information related to the products in the supply chain, and this has been associated with some risks which affect the purchase decisions that the customers make.

The use of blockchain can eradicate the traditional planning systems that are currently being used by many companies hence solving the limits of analytics, agility, and adaptability. This is because the blockchain technology will offer modern solutions to the companies participating in a supply chain. For instance, blockchain can help the suppliers and customers to establish background knowledge about the source of a product, following changes, and chain of custody by offering the infrastructure needed for building storing, and managing products.

Also, blockchain technology improves not only traceability but also transparency in the supply chain.

The blockchain can help companies to document the data that is collected when the products move across the supply chain from the production stage to consumption stage and store this information to provide a permanent history of these products. Also, the blockchain technology acts as an appropriate tool that can help companies in the supply chain to record all the assets as it goes along the supply chain and also be used to track orders, payments, receipts, and other vital documents. Apart from that, the blockchain technology can be used by firms in tracking digital assets including bar codes, serial numbers, licenses, copyrights, certifications, and warranties (Litke, 2019, p. 2).

On the other hand, blockchain can help companies to share information and data regarding the manufacturing processes, maintenance, delivery, and transportation of goods and products between the manufacturers, vendors, suppliers, and wholesalers. This solves the limit for a supply chain of introducing a centralised system because of having an interconnected structure.

The blockchain provides a flow of information regarding particular products and hence increases the trust between companies. For instance, if there is a problem in the production of certain products, the companies who are the manufacturers can send information instantly to the suppliers and transporters so that they can be aware and inform their customers regarding problems and give the right information.

Consequently, blockchains can help to solve the sophisticated measures and complexity of the supply chain. For example, the supply chains are affected by cost-reductions and globalisation that is currently taking place. Today, companies are trying to do everything so that they can deliver their products to consumers at cheaper costs. As a result, these companies are looking for practical solutions to minimise the costs of producing goods, including getting cheaper raw materials. This is where the blockchain technology comes in, which has been introduced to revolutionise supply chain management. This is because the digital ledgers used in blockchains bring together the partners in supply and enable them to share and access information about products flow on a real-time basis. Also, blockchain will allow the partners to add their data and be able to view information that has already been added by other companies. This will help all the partners to track their products (Gambhir, 2018).

Blockchain technology is vital in the supply chains because it enhances safety, trusty and makes the systems to be more reliable. Since in supply chains companies have to work with third parties, which in turn has many risks, the implementation of blockchain will remove the third parties from the chain. Hence the supply chain system will work without having intermediaries and most importantly, all the partners will be able to make decisions. Additionally, blockchain eliminates the necessity for reconciliation all the transactions are made with the suppliers and instead introduce smart contracts. The use of smart contracts by companies is likely

to end the costly procurement to-pay gaps. This is because the smart contracts provide a coded contract that is agreed between companies and then uploaded to the blockchain.

The good thing about using smart contracts is that it does not depend on any third-party authority. Instead, the technology manages the contracts automatically, and after all the participants have accomplished their roles, then the sections of the contract are implemented. Henceforth, blockchain offers appropriate visibility into procurement. For instance, firms can use smart contracts and creating terms such as paying the suppliers automatically upon receiving receipts to prove that delivery is made, and also to activate digital invoicing. This, in turn, will help the firms to minimise the requirements of working capital and make the financial operations easier (Brody, 2017). Also, the smart contracts will help the firms in a supply chain to have trustworthy transactions that are not only monitored but also validated over a digital network. The inbuilt system of blockchain ensures that a transaction is completed before another start and also allows transactions to take place if more than two participants have authorised them.

Blockchain also helps firms to do data analytics. For example, the technology can allow companies in the manufacturing industry to analyse the require materials they require in the production process and various locations where these materials are sourced from, as well as the actual demands of a particular product within a specified period.

3.1 BENEFITS OF USING BLOCKCHAIN IN SUPPLY CHAIN MANAGEMENT

There are several advantages of using blockchain in managing the supply chain.

- First, blockchain introduces operational efficiencies in a supply chain. It will allow the companies in the supply chain to track the journey of products starting with the acquisition of raw materials, production, transportation, and delivery to the consumers. Through the blockchains, the companies can be able to see delays as well as the obstacles that may be in the chain and turn, help them to respond effectively and swiftly.

Moreover, by knowing the source of the product, the conditions under which the goods are manufactured gives the participants in the supply chain confidence regarding the quality of the products and hence ensuring the products are not recalled once they reach to the consumers, knowing the origins of the products. Organisations can use blockchain technology in tracking the origin of products to make sure that it is being sourced ethically (Gambhir, 2018).

- Secondly, blockchain can help the organisation in the supply chain to minimise losses. This is because they will be tracking the flow of products, and if there is a problem, it could be quickly and easily identified so that the necessary steps can be taken to solve it. Also, by tracking the products through the blockchain technology, the partners that are causing delays in the product flow can be identified, warned or even replaced. Similarly, the blockchain can also give a picture of the problems that might occur in the supply chain and fix them where possible hence making the systems have a benefit of traceability (Golosova, 2018, p. 4).

- The third advantage of using blockchain in supply chain management is that it helps the companies to maintain the standard of the products. This is because it allows the organisations to track where the raw materials of a product are sources to ensure that quality materials are used in making products. Furthermore, the companies will be able to track the production process of the products and use sensors to trail the goods to ensure that all the steps are adhered to appropriately and to confirm that they need the standards set by that particular industry. By doing this, the firms can be able to maintain the standards of the goods that they are producing and supplying to the market (Wang, 2019, p. 221-236).

Besides, blockchain is beneficial for the supply chains because it enhances trust and security among the participants. This is because the blockchain technology records all the data regarding the production, supplying, and sale of products. The data recorded cannot be deleted or changed, and it is accessible to all the companies in the supply chain. The data in a blockchain cannot be altered or deleted because systems are decentralised; hence, decisions are not made by one person as it happens in a centralised system. Thus, this makes the blockchain technology to be indestructible and unalterable when used in supply chain management. In a supply chain, some of the companies transacting with each other do not know each other. This might bring trust issues because there are some companies they might not transact transparently. As a result, blockchain introduces trusty immutability and transparency in the supply chain (Golosova, 2018, p. 4).

In one hand, when using blockchain, companies in a supply chain can share costs by using costs and achieve the transactions agreed on.

On the other hand, the blockchain technology improves security in the supply chain. Security of the data is achieved because the managers that enter data into the information are given unique identity which is connected to their accounts. For that reason, it makes it hard for unauthorised individuals to access the system to enter, alter, and delete data. Similarly, the blockchain technology enhances the security of the supply chain through the

use of a dependable chain of the cryptographic hash which ensures that whenever a new block is generated, a hash value for that particular block is calculated. This makes it hard for any person to change the information stored in the hash value.

- Another advantage of the use of blockchain in supply chain management is that it introduces faster processing of information or data than the traditional supply chain systems. When transactions in blockchains are made, it only takes a short time to process the data, consequently making the systems more efficient and reliable. Apart from faster information processing, blockchain makes the procurement process to be simple increase its visibility and in turn, lead to more savings. Therefore, the digital ledger provided by blockchain will make it easier for companies to track and view data from all the firms in the chain. The digital ledger will also allow the organisations to view the purchase activity and the number of purchases that are being made

3.2 SOLUTIONS FOR SUPPLY CHAIN

The implementation of blockchain technology can bring promising results to supply chain management problems and limitations. In one hand this solves the problem of rigidity that may exist in a supply chain and in return give the companies enhanced flexibility to determine the price and markets risks through netting the worth of their investment in the chain (Biggs, 2017).

On the other hand, blockchain can provide solutions to the issues of security and trust that the current supply chains are facing. This ensures that the transactions made by the partners in a supply chain are secure and verifiable.

For instance, blockchain brings the companies in the supply chain together and creates a central trust by allowing these firms to track and record the transactions and assets between themselves (Cognizant, 2018). Besides, blockchain ensures that whenever a transaction has been made and verified, the data is stored in the network safety and hence, it cannot be tampered with by any of the partners. Most importantly, blockchain will help companies to transact without any fear of being defrauded. This is because the technology holds the place funds until all the organisations are in satisfaction with the transactions as well as the actions of the other participants.

Subsequently, the use of blockchain can offer solutions to the issues involving the clearing and settlement process in a supply chain. This can be done by using

disintermediation and decentralisation, which can, in turn, reduce the time consumed by the settlement cycles. Apart from that, the technology can help companies to minimise the costs associated with back-office activities. This is because blockchain can handle collateral management, compliance, and reporting, which is a supply chain management are done by back-office staff (Sadouskaya, 2017).

Also, the blockchain solves the issues of mediators and intermediary, which might be costly for businesses in the supply chain. Mediators or intermediaries are being used in the supply chain to do the receiving processing and storing of the transactions as a measure of bringing trust among companies that do not know each other well. However, with the blockchain, the mediators who are not necessary and technology allows the companies to do transactions without any trust issues.

3.3 LIMITATIONS OF USING BLOCKCHAIN

Contrarywise, despite the numerous benefits of the use of blockchains in supply chain, the technology also poses some challenges and limitations into the system. One of the biggest challenges of using blockchain is that it consumes much energy. In other words, maintaining a real-time ledger requires much energy as compared to the traditional systems used in the supply chain.

The latency issue is limitation that might affect the implementation of blockchain technology in the supply chains. The time that takes the requests to be processed should be instant. However, in a blockchain, the time that it takes to complete a transaction is approximately 10 minutes as shown from an example of Bitcoin transaction block. Thus, for a more significant transaction, the time might be more hence bringing latency issues (Koteska, 2017).

Currently, blockchain technology is facing scalability challenges because several big organisations are participating in new supply chains, having a massive flow of goods and sensitive information. However, blockchain, which provides a decentralised and network database for all the companies, might experience some failures. This was showed during the “Crypto kitties’ saga” where the Ethereum blockchain experienced network congestion. As a result, the congestion contributed to the transactions delays that took hours to be completed, and this led to the charging of high transaction fees. Therefore, the implementation of blockchain on large-scale to companies in the supply chain might be a challenge because the technology does not have a high transaction throughput. Nevertheless, researchers are doing everything possible to solve the scalability issues in the blockchain. For instance, one of the solutions that are being considered is implementing the accelerated chips to accelerate the speed in which the transactions and confirmations take (Bastin, 2018).

The issue of privacy is another challenge that the blockchain technology is facing. Seemingly, the network ledger showing the transactions that are used in the blockchain can be accessed by all the partners in the chain for transparency purposes. However, this contributes to a lack of privacy on some categories of transactions that might be confidential for a particular company. Conversely, some solutions have been suggested to help resolve the privacy issues on particular transactions. For instance, the Ring Signature has been suggested as an excellent privacy protocol whereby when a sender initiates a transaction, and it is joined with other partners' transactions to create a ring. This is a vital process because it masks the source of the transaction and guarantees that all contributions are almost identical from each other. Another possible solution to solve the privacy issue is the use of “Zero-knowledge proof technology” like the one used by Z-cash to enable anonymous transactions (Bastin, 2018). By using this technology, the transactions that are made in the supply chain are concealed in the sense that the sender, receiver, and amount of money is not revealed to other partners but to the companies that are doing that specific transaction.

Blockchain is also faced by another technical issue related to the consensus. There is no precise mechanism through which the companies in the supply chain can reach consensus to decide on how the subsequent block will be. The partners in the supply chain have to keep a universal agreement between nodes of the system regarding the submitted transactions data. However, the blockchain has not stipulated how the

companies can reach unanimity and the agreement tools that can be used. This can lead to selfish mining by some companies that come together and privately agree to mine the subsequent block without involving the rest of the organisations in the supply chain. By doing this, the companies that do selfish mining will end up creating their convention chain that might attack the network. This, in turn, negatively affects the trust that the blockchain technology attempts to improve among businesses in the supply chain.

Moreover, the consensus algorithms that are the critical foundation of the trust and node agreement has not been understood well by most of the companies in the supply chain (Litke, 2019, p. 13). For that reason, when companies want to implement the blockchain in their supply chain, they should be aware of the consensus instruments or tools to be used. This is because some consensus mechanisms are not appropriate for starters.

CHAPTER 4 BLOCKCHAIN APPLICATIONS

Blockchain is regarded as a next-generation information technology with many potential upsides in many fields beyond digital currencies (IET) (George F).

Blockchain allocates data storage across numerous points and ensures that each entry or transaction is being secured and locked. As a result, it makes it virtually impossible for people to modify or hack into the digital data ledger since that slight change shall impact everything in the entire system.

The four core challenges associated with the supply chain include:

- Data Visibility and Consolidation
- Process Optimization
- Demand Management
- Tracking, Transparency and Trust.

In data visibility and consolidation, there exist the challenge that comes with desperate record-keeping and reporting systems (Aitken, 2017). This challenge

leads to incomplete, scattered and unreliable information on approvals and certifications.

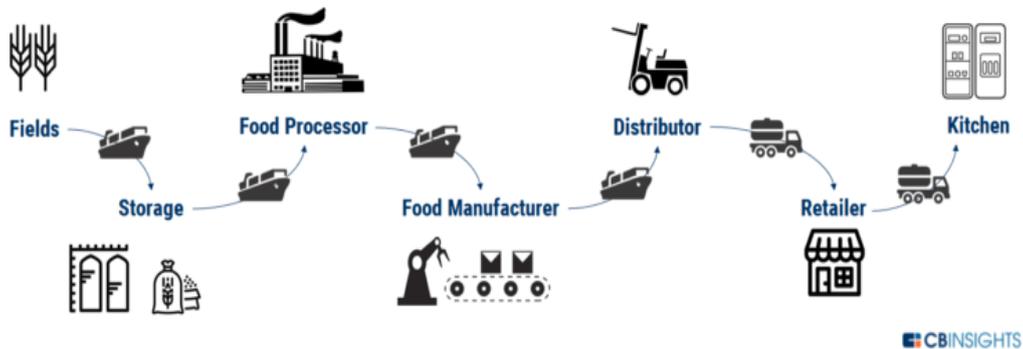
Besides, there exist the challenge of optimization, which leads to cargo losses and fraud. The high costs of administrative regulation and burdened paper-based processes have influenced the spread of information.

Also, there is the challenge of demand management, which affects the ability of companies to adapt to the changes in economic conditions (Armonk, 2017). This incomplete data has led to poor outcomes.

Lastly, there exist the challenge of tracking, transparency and trust, which has led to decreased ability to track flawed products. Further, this has challenged the ability to trace the origin of products. Generally, the challenge comes from the disputes which are associated with information gaps and trust in data.

4.1 FOOD INDUSTRY

The food industry is subject to encounters in matters to do with counterfeiting. It is for this reason that the technology is being integrated to transform the food industry by addressing these concerns. Currently, most of the food company are focusing on safety by ensuring that there is transparency in the supply chain system (Menon, 2018).



*Figure 3*the complexity of global supply chain (source CB insight)

The global supply chain is so intricate, bringing together different participants, farmers, shipping companies, stores. The blockchain would be relevant in addressing subjects of food security. The technology comes with extra layers of security, which improves transparency.

Farmers, manufacturers, retailers and suppliers are expected to input their information that verifies that the products are safe. This leads to the creation of a log that provides a piece of permanent evidence that can be tracked in case of a food security issue. Walmart believes that the customers are entitled to the transparent supply chain because it affects their purchase behaviour and preference (Business Wire). This approach will reduce the food safety gaps that come with the one-step-up and one-step-back model of food traceability. These outdated methods of data collection come with unverified methods that lead to food crimes. Through the food

chain system with transparency, companies will be able to reduce chances of food scandals since they will add on the insurance.

4.1.1 FOOD SECURITY AND CONTAMINATION

In the year 2017, there was an infection outbreak of multistate Salmonella in the US and over 220 people got infected (Sayer, 2017). The Salmonella outbreak was associated with Maradol papayas that are imported from Mexico.

In North America, the challenge of identifying and isolating the cause of the E. coli spinach outbreak in the year 2016 led to wastage in resources, time and energy. The entire ecosystem was challenged by creating public trust in the supply chain. It is, for this reason, most of the people stopped consuming spinach after it was associated with contamination.

In China, the cases of pork mislabelling also affected the consumption of meat products since the Chinese trust in meat products had eroded since 2011. The biggest challenge was identified to be the regulation of food in the different stages of the food chain.

In 2015, an international food and beverage firm had to cancel the market distribution of over 38,000 tonnes of noodles. The recall was done because due to the existence of some avoidable ingredients in their noodle's goods. The

company's brand experienced a drop from 80% to 60% in the market share. Besides, the firm spent over \$70 million in the recalls and sales losses of over \$277 million.

In 2013, in the UK, a food labelling scam outrage on horse meat was exposed. This scandal was whereby burgers and ready meals sold by prominent retailers and fast food joints were found to have high traces of horse meat rather than processed beef meat.

From these scenarios, one can argue that blockchain technology could have helped in tracing the entire process, initiate immediate corrective actions or prevent the occurrence of such scenarios.

4.1.2 IMPLEMENTING BLOCKCHAIN IN FOOD INDUSTRY

Traditional food safety strategies have failed to improve on the safety that comes with food products. The safety and management protocols have been challenged by the lack of transparent systems that can be used to prevent food crime and fraud (Burke, 2019, p. 133-143). This food safety gap will be addressed by blockchain technology, which has been identified to be drastic in improving the current systems by improving efficiency and transparency.

Traditional methods have identified false information on the origin of products because of the difficulty associated with tracing the country of origin.

Based on the current challenges in food security, there exist the need to integrate technology in supply chain management for purposes of improving the overall customer satisfaction and needs. Through the blockchain platform, the different companies will be able to collaborate for a common goal. Further, the platform will be of importance in automating the ability of the businesses to encode the rules and authority (Menon, 2018). Through IoT enabled management, companies will be able to quantify the risk, assess the supply chain impact, develop a mitigation strategy, make better choices and mitigate disasters.

Previous traditional methods have been associated with inconsistency when it comes to the flow of information across different organisations. Other than the inconsistency, the flow comes with cumbersome and complicated strategies that make the systems expensive. The approaches reduce the chance of getting the information required for assessment and dispute resolution. Blockchain is set to address this challenge because it comes with an end-to-end supply chain information, which helps in ensuring the flow of information from one source to another. This approach helps in ensuring fast and secure access to information. Most importantly, this approach comes with a single source of information. This single source of information comes with verifiable authenticity and immutability of digital documents.

Mostly, the blockchain helps in food security because it helps in providing critical product information, for instance expiration and origin dates, processing data, batch numbers, shipping details and storage information. All this information is digitalised and entered into the blockchain to trace, and tracing is usually done using smartphones which are used to read the QR code that comes with products (Loop, 2017). For instance, in the case of identifying a source of meat, information on the date of birth of animals, livestock harvest, usage of antibiotics vaccination and shipping can be easily traced. Through this technology, companies can integrate the supply chain transactions using a real-time technology which helps in identifying and auditing the source of food found in the chain.

Currently, most of the companies are thinking of using the technology to leverage the blockchain by making supply more efficient, robust and traceable (Boce, 2019). Some of the practical application of the technology include brands like Unilever, which has partnered with financial companies to assess how technology can be used for financial rewards and promoting sustainable practices for Malawian tea farmers.

4.1.2.1 FOOD TRACEABILITY

Food traceability has been identified to be one of the major concerns which affect the supply chain industry. Through blockchain, most of the companies will be able to create a competitive advantage. Through the blockchain enabled platform, these

challenges can be addressed using resource planning and point-of-sale systems which let the companies contact the suppliers.

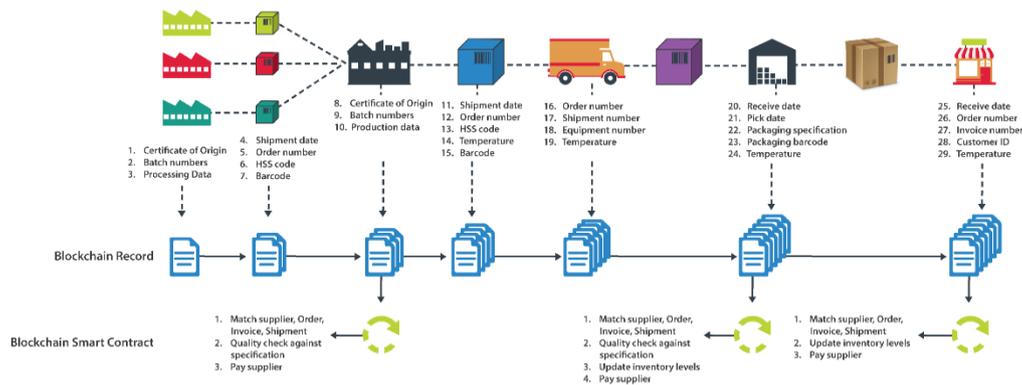


Figure 4 blockchain transaction in the supply chain (source Radarzero.com)

Through the blockchain technology is possible to improve the traceability and the quality of the products by providing consistent information about their origin.

Most of the customer who has lost trust in the current retailing industry can take advantage of the blockchain technology to regenerate their loyalty through the transparent record keeping system, which reduces the risks of fraud. Further, companies can take advantage of the technology to reduce their costs while at the same time, improve their profits.

This aspect will improve on the challenge that comes with the database system which is centralized. This traditional centralization has been associated with single

point breakdown which influences the traceability of a product along the supply chain. Blockchain will lead to an improved trust that comes with the provider. Other than improving traceability, the technology is also assumed to come with efficiency in the entire supply chain system. Broadly, the technology eases the process of identifying the potential source of food contamination during the supply chain cycle (Kaye, 2016). The aspects of transparency and traceability are based on the validation that comes with the authentication of the origin of food. This aspect helps in improving the credibility of a brand. Other than building the brand image, the two help in minimizing outbreaks of contamination. On a cost-benefit analysis, the technology can be used to minimize the expenses that come with food testing. Further, the costs associated with product recall will also be reduced. Through improved traceability, companies will be able to quickly track unsafe products and the destinations where they might be distributed. This aspect will help in saving lives and preventing illness.

4.1.2.2 INFORMED CLIENTS

After several concerns and scenarios on food safety, most of the customers have found it had to trust the integrity and quality that comes with the food product. Most of the customers want a system that will directly link them to the source of the produce. Through this technology, there will be informed choices and decisions

because the consumers will now expect to see the whole history that comes with their product. This aspect will allow the customers to align the products with their beliefs and values. Through this transparent system, the customers will be exposed to assurance that the product they are purchasing is in line with their ethics. This privilege makes the manufacturers and retailers demonstrate that they are producing the best quality of farm produce. This technology will push the retailers and manufacturers to ensure that their sourcing is ethical and caring for the environment. Broadly, this technology comes with an improved source of improved choice because it comes with the platform which collects the disparate parts of the food chain into a single shared ledger. This ledger can then be accessed by both the customers, retailers and manufacturers.

Fortunately, the technology comes with the ability of a company to hide information which affects their competitive advantage. Thus, only important information will be available to the market. Information that accounts on the information on where a product was grown will create satisfaction because the customers will know exactly what they are consuming and the source as well. Most importantly, this information will be important during importation and tracking of food from foreign countries. In the past, traditional methods have identified false information on the origin of products because of the difficulty associated with tracing the country of origin. Most of the food products that have labels that they are British have been found to be produced in other countries and only processed

in the UK. This fraud will be eliminated by blockchain which records all the transactions that come with a given item. The records on these products are stored in the form of digital certificates. The amount of fraud is reduced by the fact that information stored in blockchain comes with an open platform which ensures that information is accessed by all and none tampers. This reduces the instances of food fraud.

4.1.2.3 COMMODITY MANAGEMENT

Some of the challenges in food management are based on the problems that come with commodity management. Since agricultural products entail a number of commodities, it has become hard to track the supply chain or data management systems. Blockchain can address this challenge by commodity management services recorded onto a blockchain.

This technology provides a platform where they deal with documents like letters of credit, government certifications and contracts are automatically matched at any time. This aspect reduces the chances of duplication and manual checks because data is automatically matched in real time. Through technology, Castillo states that document processing will be reduced to one-fifth of the usual time. Thus, the overall transaction time will be halved and thus an improvement in commodity management.

Through the effective commodity management system, technology will help in reducing the waste of food products. Despite the fact that most of the waste has been associated with the consumer's end, the production and distribution are also subject to this waste (Castillo, 2016). Blockchain will help in reducing and preventing waste because it will come with easy procedures for investigating the illness associated with food waste. In attempts to regulate the freshness that comes with food products, the technology will help in temperature monitoring and supply chain optimization. A blockchain shared by the suppliers may, for example, come with temperature sensor data and product expiration date which can be used to better rotate the inventory. This better rotation of the inventory will help in isolating the expired foods and ultimately lead to an improvement in food safety. Though it might take time for companies to employ the technology, there is a greater value that is associated with the technology.

4.2 PHARMACEUTICAL INDUSTRY

Similar to food industry, for a long time now, various pharmaceutical companies around the globe have been trying to get rid of the counterfeit menace. Fake drugs negatively impact the pharmaceutical industry the same way in which pirated content plagues the entertainment sector.

4.2.1 COUNTERFEIT DRUGS

The pharmaceutical sector is one of the industries that require companies to obey strict policies and regulations.

Over the past years, counterfeiters have become more cunning, where they have come up with various means of manufacturing counterfeit drugs and medical commodities. Some position themselves in the supply chain and distribute synthetic raw materials, while others try to manufacture the drugs themselves. This has a negative consequence of providing the market with dangerous and unregulated medical products.

However, counterfeiters can avert working under the stipulated regulations and thus manufacture drugs without any safety measures (Finan, 2018) They produce the drugs cheaply using resources and labour from third-world countries, relabel the medicines using established brands and then sell them at premium prices.

Fake drugs are a threat to public health since they are ineffective in treating illnesses and cause harm. In some instances, they usually lead to fatalities. According to estimates by the World Health Organization (WHO), fake drugs cause over 1 million deaths each year. They also have affected the economy negatively because they hurt genuine revenues of authentic drug manufacturers, and this inhibits future innovation. Genuine drug producers spend much money on research and

development, but this will not be the case if they make persistent losses as a result of fake drugs.

4.2.2 RECALLS AND TRACEABILITY

The pharmaceutical supply chain is a sophisticated industry full of interlinked nodes all around the globe. Each pharmaceutical product is subjected to numerous transactions before reaching the final client. As a result, if there is an issue with a particular product or batch, it is considerably difficult to recall it.

As from 2017, it is a requirement for all prescription drug packages to contain a unique product identifier that ascertains the drug's expiration date, serial number, national drug code and lot number number (Morgan, 3 Pharmaceutical Supply Chain Challenges Blockchain Can Address, 2018). However, this particular system will take some years to become fully operational. Hence, at the moment, key players in this industry still need to cope with the numerous complex transactions, security issues and technology incompatibility. If pharmaceutical companies are to improve recall success and increase traceability, there is a dire need for a more cohesive and comprehensive solution.

4.2.3 LIMITS OF THE TRADITIONAL CHANNEL DISTRIBUTIONS

Distribution of pharmaceutical products is one of the significant challenges facing pharmaceutical companies around the globe. They usually depend on logistics companies to help them distribute their products to the final consumers. Unfortunately, transportation and storage of drugs are not inconsequential. All parties involved have to adhere to the stipulated guidelines to ensure correct air pressure, temperature, and humidity alongside other requirements. Products such as vaccines are sensitive to temperature and require to be observed throughout the supply chain. A slight temperature deviation from the recommended range can render the vaccines ineffective in the field. Due to the technological advances that have happened over the years, pharmaceutical companies have improved how they monitor their products. At the moment, a massive portion of companies in this sector is utilising IoT devices to monitor products in the supply chain. However, temperature deviation is still a critical issue, affecting close to 5 per cent of all medical shipping. One of the significant causes of temperature deviation is that there are some black boxes in the supply chain that cannot be monitored effectively. The impulsive nature of transportation can cause delays and increase the likelihood of product damage. On that note, the pharmaceutical supply chain needs a better way to monitor products to alleviate losses as a result of product deterioration.

4.2.4 ADVANTAGES OF THE BLOCCKAHN TECHNOLOGIES IN THE SUPPLY CHAIN

A blockchain application will ensure that pharmaceutical products are delivered to patients safely and effectively. Since blockchain ensures that companies have real-time data access, they can be able to expand their internal and external inventories by monitoring shipment of their product by utilising in-store and in-transit data.

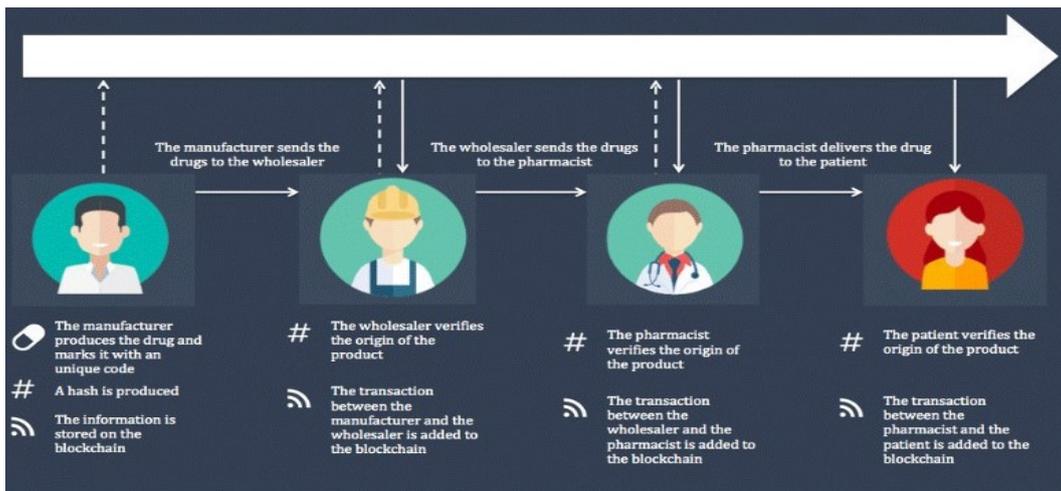


Figure 5 Blockchain for drug traceability. (source Domani Systems Inc.)

In figure above is shown how transaction is done by implementing blockchain in the pharmaceutical industry, starting from the producer to the final consumer.

Ultimately, this particular technology can help fill in the gaps currently existing in the pharmaceutical supply chain (Bhardwaj, 2018). At the moment, most people do not trust that all the drugs they use are safe and authentic. This is quite unfortunate since it is significant for pharmaceutical companies to offer a strong foundation for safe practices and trustworthy for all patients and society as a whole. These are aspects that can be attained with the use of blockchain since it can help companies to integrate these values by coming up with real-time and informative responses to issues hypothetically affecting patient health.

Another factor that blockchain can improve is recalled management. This technology can ensure that pharmaceutical companies have a better process of informing the masses of relevant crucial information such as errors or changes made to the product. This can help alleviate the number of fatalities experienced due to these errors (Hertz, 2017). It is estimated that close to 1 million individuals die annually as a result of medication errors. Blockchain will come in handy in solving this problem as it offers better tracking of products throughout the supply chain since companies can determine the exact location of their products. The batch reminders can be dispatched quickly and efficiently while upholding patient safety. Patient safety cannot be attained if pharmaceutical products spoil while on transit due to fluctuations and deviations in temperature from the recommended range. If patients consume damaged drugs due to inappropriate temperatures, they will be likely not to experience any positive changes or in other case, get sicker. This is

where blockchain can come in to sort this problem by ensuring cold-chain shipping as drugs can be shipped to various locations using IoT-enabled vehicles with temperature sensors. Also, it can be possible to store, and exchange information collected by temperature sensors situated on the blockchain. The immutable and transparent distributed ledger can save a substantial amount of time during an audit of temperature-sensitive medications and storage conditions.

It is important to note that blockchain transactions are accomplished in a transparent, decentralised and immutable manner. The transactions are immutable since it is impossible to overwrite data once it is written inside the blockchain (Rouquefort, 2018). The transactions are decentralized because control over the ledger is not the mandate of a single individual or party. Also, the transactions are transparent, given that fact that all participants can access similar data concurrently. These benefits are not available to companies at the moment since most of them use the cloud system, which is somewhat centralised, giving some few individuals or a single party full control. The disadvantages of this are that these few individuals under a cloud system do not indicate the validity and authenticity of the information they obtain or view. A blockchain application will prevent this from happening and increase integrity within the supply chain. This integrity will also ensure that companies can get rid of counterfeits within the supply chain (Zahreddine, 2018). . A blockchain application can ensure that pharmaceutical companies have a vivid visualisation of the path that their products follow right from production to the end-

consumer with the help of digitised transactions. Thus, it is easier to assess the most vulnerable points that counterfeits can capitalise on in the supply chain and reduce the likelihood of fraud cases and the loss of revenue associated with it.

4.3 THE FASHION INDUSTRY

The fashion sector is experiencing loss of revenue amounting to \$450 billion due to counterfeits according to estimates based on research conducted by the Organization for Economic Co-operation and Development (OECD). Added to the amount of counterfeited luxurious brands and pharmaceuticals, and it sums to a considerable figure or about \$1.8 trillion of fake products in the global market. As per 2016, 2.5 per cent of all fashion items around the world were counterfeits. Europe is the most affected, where 10 per cent of sales being made comprise of fake fashion products, Italy, Spain and the UK being the leading targets of counterfeit commodities.

4.3.1 COUNTERFEITING

Companies in the fashion industry are faced with the problem of product imitation. Counterfeiting in the fashion sector is an epidemic that affects not only regular brands but also established high-end luxury brands such as Louis Vuitton, Nike, and Adidas, to mention but a few. Counterfeiting in this particular industry is increasing rapidly at the moment due to the increased penetration of the internet; people are selling quickly more products online compared to offline. The likelihood of being detected and being caught by relevant authorities is very low online, and there is no real way in which clients can check if a product is authentic before purchase.

4.3.2 TRANSPARENCY IN THE SUPPLY CHAIN

At the moment, it is correct to claim that there is no transparency in the fashion industry (Radocchia, 2018). This is because of aspects such as the only way in which clients can determine where a piece of clothing was manufactured through a simple “made in” label. It is important to note that some corrupt companies can deceive consumers by manipulating this “made in” label to suit their needs.

This lack of transparency in this particular industry is something that is being exposed each day over the past few years, where one of the significant exposes took place in 2015, triggering the collapse of Rana Plaza, a Bangladesh garment factory

(Makulova, 2018). This particular plaza collapsed, killing over 1,000 people many of them being factory workers for leading international brands. This made many clients especially in developed nations to question the source of their fashion products most of them feeling like there was no transparency in the supply chain since the products made in the plaza did not have a “made in Bangladesh” label. That said, it is evident that most people do not have a clear idea of the true origins of their clothing or the stages a piece of fashion goes through before it reaches them. Some of those who are aware of this lack of transparency is spearheading a fashion revolution which demands to know where their clothes are made. One of the ways they are using to attain this is requesting brands to upload photos of their workers holding an image containing the hashtag “imadeyourclothes” to raise awareness of this issue.

4.3.3 ADVANTAGES OF THE BLOCCKAHN TECHNOLOGIES IN THE FASHION INDUSTRY

➤ ANTICIPATION OF COUNTERFEITS

By utilising blockchain, designers and producers in the fashion industry can protect their brands against counterfeiting. This is because this particular technology can ensure that each fashion item's possession and origin can be traced back to its source. Thus, various companies that are behind the counterfeit product in the market will not have an authentic chain of records. With the help of blockchain, brands can embrace supply chain tracking so that clients will have a clear picture of the whole product cycle (Makulova, 2018). As a result, counterfeits shall gradually cease to exist, since unethical firms behind the fakes will not be able to hack into the secure blockchain network or imitate the detailed and sophisticated manufacturing journey of an original product.

➤ TRANSPARENCY IN THE SUPPLY CHAIN

Blockchain technology is becoming more popular in the fashion industry due to its exceptional ability to develop a physical-digital link between commodities and their digital identities on a blockchain. A serial number or a cryptographic seal plays the role of a physical identifier, connecting back to the individual product's "digital

twin'. This particular link is the one that offers a great deal of transparency in the supply chain. For instance, each instance when a product shifts hands, that shift is recognised and recorded on the blockchain. Counterfeit fashion products will miss this crucial physical-digital link and will be detected. The chain of ownership on the blockchain offers a record of the last individual to possess the product, portraying where the counterfeit product gained access to the supply chain or where the original product was diverted out (Radocchia, 2018). More transparency in the supply chain will offer new incentives for firms so that they can transform how they conduct business or how they perceive themselves as an organisation.

Also, blockchain technology will allow producers to address any ethical issues surrounding the production of their fashion items as opposed to shying away from them. This will also act as a way of encouraging brands to be more considerate of their manufacturing practices (Diamond, 2018).

Thanks to the internet, the world is becoming aware of the inhumane working conditions that people are subjected to, especially in third world nations.

Apart from the dangerous and horrid conditions, these workers are subjected to, there are other controversies concerning pollution. Blockchain will help companies that are genuine and encourage work ethics to distance themselves from the rest. With blockchain technology, brands will be able to verify who is making their commodities, how much they are paid, the form of materials used, and where they were obtained from. Since people are becoming each day more aware of happenings

around the world, inclusive of the fashion industries, proving ethical practices is a adding value.

➤ INVENTORY CONTROL AND DISTRIBUTION

Blockchain applications have the potential to revolutionise the fashion industry, given the fact that it is based on a decentralised data system. This system can positively impact how players in this sector handle warehousing, inventory control and distribution. Currently, most manufacturers in this field are utilising centralised systems. However, they have limited abilities since they offer limited insight and visibility regarding where all products are situated at the moment. With blockchain, producers can change this, given that it is based on a distributed system, where each transaction can be monitored and tracked. This will help companies to avoid manipulation, leakage and omission of data without a particular transaction being tracked across the entire system. This will enhance safe and agile data collection, secure and transparent communication between the producer, supplier and retailer. On the same note, it will enhance quick data extraction for various commodity insights. Furthermore, customer responses can be sent back to brands so that they can make appropriate product adjustments according to the requests, such as design details, prints, and colour. All these will be automatically be sent to the producers when it is time to replenish and improve the stock.

CONCLUSIONS

The aim of this thesis was to analyse the impact that blockchain can have in the supply chain. Nowadays, companies who want to interact with different suppliers and consumers they have to take in consideration the limits of traditional systems. In the past the supply chains were local but now they have grown to be rather complex.

Blockchain was launched as support to bitcoin but as the analytical data shows, blockchain can be suitable for different industries but a deeper research must be done in order to have complete understanding on the possibilities this technology could give to supply chains.

Through our thesis we have underlined the importance that blockchain could have in our daily lives, such as trust and transparency between individuals and organisations.

Despite blockchain having an enormous optimistic impact in the supply chain some consideration must be done:

- Infrastructural issues, being the most challenging issue for the blockchain due to the impossibility of developing countries of implementing blockchain.

- Trad-off between transparency and confidentiality being a challenge between stakeholders trying to keep a balance between these two aspects
- Need for participation, the need to overcome the lack of participation where still some countries of company have doubts about the effectiveness of this technology.
- Confusion, currently most people are still not aware of the potential of the blockchain.

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