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Comparison of Blockchain technology in various segments of supply chain management using meta-synthesis

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ABSTRACT:
Blockchain technology promises to disrupt existing business processes by replacing existing centralized systems. Blockchain technology has gotten plenty of attention in the past few years. The interest in the new technology has reached logistics and supply chain management. When blockchain technology is implemented successfully it can bring benefits such as cost savings, better visibility, and better efficiency. Businesses could greatly benefit from these matters and get competitive advantage if they succeed to implement blockchain technology successfully before their competitors. There are various blockchain platforms available and new platforms are created continuously. These platforms can differ greatly from each other in terms of performance, scalability, and privacy. When considering implementing blockchain technology to supply chains it is key to choose a platform which has the best match to the particular use case. There is earlier research done about different blockchain platforms in different applications, but it is hard to get a bigger picture difference of blockchain platforms in supply chain applications from single studies. This research combines earlier research of the topic using qualitative meta-synthesis. The aim of the study is to find out the differences between Hyperledger Fabric, Ethereum, Corda, Multichain, and Bitcoin platforms. Study found big differences in the suitability to supply chain applications between the platforms. It is key to understand comprehensively the needs for the platform before any decisions between platforms are made, because choosing between these platforms is a tradeoff. The result of the study was that Hyperledger Fabric shoved the best results in most use cases. The biggest challenge in this thesis was to find relevant information because the technology is relatively new.

Keywords: Blockchain, Supply chain, Platforms, Comparison

Tiivistelmä:
Blockchain teknologialla on mahdollisuus häiritä olevia liiketoimintaprosesseja korvaamalla nykyiset keskitetyt järjestelmät. Lohkoketju teknologia on saanut yhä enemmissä määrin huomiota viime vuosina. Kiinnostus uutta teknologiaa kohtaan on saavuttanut logistiikan ja toimitusketjun hallinnan. Jos lohkoketju teknologia pystytään implementoimaan onnistuneesti, se voi tuoda etuja, kuten kustannussäästöjä ja parempaa tehokkuutta. Tämä voisi suuresti hyödyttää yrityksiä, jos ne onnistuvat ottamaan lohkoketju teknologian käyttöön onnistuneesti ennen kilpailijoitaan. Jo nykyisin saatavilla on erilaisia lohkoketju alustoja ja uusia alustoja luodaan jatkuvasti. Nämä alustat voivat erota suuresti toisistaan muun muassa suorituskyvyn, skaalautuvuuden ja yksityisyyden suhteen. Kun harkitaan lohkoketju teknologian käyttöönottoa toimitusketjuissa, on tärkeää valita alusta, joka sopii parhaiten omaan käyttötarkoitukseen. Eri sovelluksissa eri lohkoketju alustoista on tehty aiemminkin tutkimuksia, mutta yksittäisistä tutkimuksista on vaikea saada suurempaa kuvaa lohkoketju alustojen eroista toimitusketju sovelluksissa. Tämän tutkimuksen tarkoituksena on tutkia metasynteesi tutkimusmenetelmää hyödyntäen Hyperledger Fabric-, Ethereum-, Corda-, Multichain- ja Bitcoin- alustojen eroavaisuuksia. Tutkimuksessa havaittiin suuria eroja alustojen välillä soveltuvuudessa toimitusketju sovelluksiin. On tärkeää ymmärtää kokonaisvaltaisesti omat tarpeet alustalle ennen päätöksiä alustojen välillä, sillä valinta on kompromissi alustojen eroavaisuuksista johtuen. Tutkimuksen tuloksena havaittiin, että Hyperledger Fabric saavutti parhaat tulokset

useimmissa käyttötapauksissa. Suurin haaste tässä opinnäytetyössä oli olennaisen tiedon löytäminen, koska tekniikka on suhteellisen uutta.

Avainsanat: Blockchain, Platform, Supply chain, Toimitusketju, Lohkoketju, Alusta, Vertailu

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1. Introduction

Blockchain technology offers permanent recordkeeping of transactions which are grouped into Blockchain technology offers permanent recordkeeping of transactions which are grouped into blocks that can't be altered (Ramamurthy, 2016). The purpose of a supply chain is to enable a group of firms to design, engineer, manufacture, and distribute products and services to the end-customers (Muckstad et al. 2001, p.427-228).

Supply chains could benefit greatly from blockchain technology. Consumers are demanding more transparency and supply chains are getting more complex causing growing interest in the new technology. In supply chains blockchain technology can be used to get better traceability and transparency of material through the supply chain. (Lapper, et al. 2017, p.3)

Blockchains' permanent and altering resistant nature can be a better alternative to traditional tracking and inspection systems which can cause inaccuracies in supply chains (Ramamurthy, 2016). Blockchain technology is still facing challenges in supply chains considering cost, security, implications, and difficulties with linking blockchain to supply chain. There are also challenges to convince all the parties in the supply chain to adopt blockchain. (Lapper, et al. 2017, p.3)

The blockchain technology started when Satoshi Nakamoto introduced the Bitcoin blockchain (Nakamoto, 2008). (Nakamoto, 2008). There are many different blockchain platforms available. This thesis examines the pros and cons of five different blockchain platforms Hyperledger Fabric, Ethereum, Multichain, Corda, and Bitcoin. Many blockchain platforms had to be excluded so that the thesis would not become too extensive. The platform for this thesis was chosen because they are well recognized and constantly coming up in studies handling the matter. When deciding which platform to choose, it is important to know the differences in performance, scalability, and the best

use cases of different blockchain platforms. Choosing between platforms is a trade-off so the choice must be made carefully (Polge et al, 2020, p.231).

1.1 Research Methodology

This thesis uses qualitative meta-synthesis to compare major blockchain platforms in supply chain applications to find out the scalability, suitability, and maturity of these platforms. A comparison is much needed because of the many available blockchain platforms and differences between them. Qualitative meta-synthesis is the right method for this study because meta-synthesis brings together findings systematically and formally from qualitative studies. Meta-synthesis interpretatively integrates qualitative findings. Meta-synthesis is much more than the sum of its parts in the sense that it offers a new interpretation of the findings, whose result it is. (Sandelowski & Barroso 2007. p.17-18)

1.2 Research objectives

The objectives of this research are the following: literature review of blockchains and supply chains, data collection from articles handling blockchain platforms Ethereum, Corda, Multichain, Hyperledger, and Bitcoin for the meta-summary, analyzing the results of meta-summary, presenting the results of the study.

1.3 Structure of the thesis

The structure of the thesis: First is the abstract and introduction to the study. This is followed by literature review of blockchain technology and supply chain. Followed by introduction to the meta-synthesis research method. After this is the actual research

including abstracted findings. This is followed by a findings section, conclusion, references.

1.4 Research questions

The research questions for this thesis are: 1. How do blockchain platforms Bitcoin, Corda, Multichain, Ethereum, and Hyperledger compare with each other? What is the suitability of these platforms for supply chain use?

1.5 Background

The background for this thesis was the increasing interest in blockchain supply chain integration. When the number of single studies done regarding the use of blockchain platforms in supply chains are growing, a qualitative meta-synthesis about the topic was needed. Combining a wide range of qualitative research to find out common themes and to compare diverse groups on this topic provides insights which would not come up in a single qualitative study.

1.6 Criteria for selected material in literature review

The articles and books used in this thesis are gathered from the Tritonia Finna web applications. The search engine in Tritonia Finna finds articles in numerous databases, such as Scopus, Web of Science, Abi/Inform Collection etc. (www.tritonia.finna.fi, 2022)

2. Literature review

Literature review section will go through the basics of blockchain technology, the use cases of blockchain technology and the basics of supply chains and supply chain management.

2.1 Blockchain basics

There are a lot of excitements around the word blockchain. It might be one of the most important technical innovations since the beginning of the internet. Blockchains are mentioned in various contexts, whether people are talking about money transfers between banks, electronic ledgers, or supply chain management. The meaning of the blockchain can be quite hard to grasp. Perhaps the versatility of the world blockchain makes it more difficult to comprehend. If blockchain can be simultaneously many different things, it can be hard to understand what it actually is. (Johansson et al, 2019, p. 26-27)

In fact, there is no exact universal definition of blockchain, but rather several definitions which are depending on the situations and applications. In principle, blockchain are a new technology. It can be explained as a developed technological version of a ledger used once in villages and towns for recording everything important, such things as purchases, sales, marriages, births, deaths, etc. Instead of someone recording the events in a ledger using a pen, blockchains use cryptography and distributed system architecture to achieve a better result. Due to blockchains it is possible to create a transparent, safe, and unchangeable source of truth which is designed to withstand attacks and manipulation. In simple terms blockchain is a trustworthy digital ledger where transactions are recorded in chronological order. (Johansson et al, 2019, p. 26-27)

Blockchains are precisely what the name suggests, it is a ledger of transactions (blocks) that form a systematic and linear chain of transactions that are ever made. The blocks in the chain are anonymized and highly encrypted but the transaction headers are public. The headers are not owned or intermediated by any entity or person. The headers are available to all those who like to inspect the transactions, they only need to know the *hash,* also known as the wallet information, details. When a transaction happens in the blockchain, a new block is solved by a miner. Miners are individuals in the blockchain network that verify all the transactions. (Hughes et al, 2019 p.274-275)

Record keeping is something so basic that we do not think about it, although record keeping is happening everywhere around us. Blockchain technology has an opportunity to change these record keeping habits. This is a big part of the reason why blockchains are held to be so disruptive in the future. (Hernandez K, 2017, p.1)

In 20 years blockchain technology can shake and disrupt society more severely than the internet disrupted media and communication. This will be possible because of the huge potential that blockchains could replace financial institutions offering cheap banking for everyone globally, it could prevent corruption and provide ways to track aid. Only time will tell what is going to happen with blockchains, but it is widely agreed that blockchains will play an important role in the society of the future. (Hernandez K, 2017, p.1)

The key point that makes blockchain technology so hyped and different from other new technologies is the point that blockchains have big potential to supplement or to completely replace existing practices and software technologies. The last time humankind saw this magnitude of a catalytic technology dates to the arrival of the World Wide Web. (Mougayar, 2016, p. 25-26)

2.1 History of blockchain technology

Last decade has been an interesting time for the progress of decentralized technologies. Before the invention of blockchain coders, cryptographers and mathematicians worked

hard for advanced and increasingly specific protocols to get better authenticity and privacy guarantees out of numerous systems such as voting, electronic cash, or file transfer systems. Although all the effort, progress was very slow for over 30 years. The innovation of the blockchain or, more precisely, the invention of public economic consensus seemed to be the last missing piece that gave the industry a giant leap forward. (Mougar, 2016, p.16)

The concept of the public economic consensus was born in 2008 when Satoshi Nakamoto published a white paper considering benefits of an electronic cash system called Bitcoin which were later released as open-source software in 2009. The year 2008 was critical in the history of global capitalism because of the financial crisis which happened in the same year. The financial crisis gave one more reason for the rise of the distributed digital currencies. The year 2008 will remain in the history books for a year when several institutions collapsed and when Satoshi Nakamoto published his article about Bitcoin. (Johansson et al, 2019, p. 23-24)

It has been said that the financial crisis would not happen if blockchain technology had been widely in use. Blockchain technology has a good potential to save us from a similar financial crisis that we had in 2008. The account books of big banks have become so complex that even totally honest accounting is nothing more than a set of educated guesses as to how much the bank has actual wealth on markets. In a sense it can be said that the current financial accounting system has reached the limits of its scalability. It is practically impossible to know for sure if a bank has made a profit or a loss in the previous quarter. This ended a credit bubble in 2008, which gave the extra momentum for the development and adaptation of blockchain technologies. (Johansson et al, 2019, p. 23-24)

In the beginning of blockchain technology the early adopters, or the blockchain “scene”, which then was realistically just “bitcoin scene” was heavily crypto -anarchist in spirit. The early adopters were mainly idealistic revolutionaries excited about fighting the

authorities such as banks, companies, and governments. But then something happened and institutional adaptation of the technology became rapid. Nowadays the most interesting announcements considering blockchain technology come from big corporations such as Microsoft, IBM or by banks. So, what happened and how the blockchain environment changed so quickly? The crypto anarchists did not understand how technologically progressive, flexible, and idealistic banks and companies can be. The people in corporations have similar concerns and values as regular people. The blockchain technology has a lot to give for corporations and institutions because they do not completely trust one another either. And a centralized institution in one industry can be concerned about centralization in other industries. The switch in the blockchain scene from crypto anarchists to institutions, corporations and banks has for its part accelerated the adaptation of blockchain technology. (Mougar, 2016, p.17)

2.1.1 Nakamoto's paper

When talking about the history of blockchains you cannot ignore the work of a pseudonym that called himself Satoshi Nakamoto who invented the cryptocurrency Bitcoin. The story of Bitcoin began when Satoshi Nakamoto made an announcement on The Cryptography Mailing list where Satoshi said, "I've been working on a new electronic cash system that's fully peer-to-peer, with no trusted third party." From this sentence started a project which would later spark debate around the world while questioning our current thinking and social system. In the year 2008 Satoshi published the famous whitepaper called "Bitcoin: A Peer-to-Peer Electronic Cash System" where Satoshi introduced a system which would allow electronic cash transactions without a trusted third party. (Johansson et al, 2019, p. 87-88)

Bitcoin was the first blockchain, which has since grown to a system worth over 200 billion US dollars and triggered a global development of blockchain technology. So, who is or was the inventor of this system? Short answer is that nobody knows, or at least very few know. There has been a lot of research trying to find who he was but without

a result. Now it is widely accepted that Satoshi Nakamoto is a pseudonym and there are one- or several-person hiding behind the name who wish to remain anonymous. Whoever Satoshi Nakamoto was, he has succeeded respectably, keeping himself hidden from the public. (Johansson et al, 2019, p.88)

Regardless of who Nakamoto was, he created a system that enables payments to be sent directly with no intermediary to hold the two parties accountable. In Nakamoto's system the token that transfers value is known as Bitcoin. In this system cheating has been made impossible, Bitcoins cannot be spent twice. The verification of transactions is not done by an intermediary. In Bitcoin the network itself assures and verifies the transactions. (Laurence, 2019, p.46)

Nakamoto had seen a big hole in the concept of digital trust, blockchain was his answer to closing this hole. Nakamoto's Blockchain finally solves the Byzantine general's problem, which have been said to be the ultimate human problem, especially in the online world: How can you rely on the information you are given and the parties giving you that information, when malicious third parties and self-interest can betray you? Many believe that in the future societies can operate entirely online because it reframes trust by recording information that cannot be removed in a public space, that can always be read making dishonesty very difficult. (Laurence, 2019, p.46)

2.1.2 Underlying technology

When talking about the history of blockchain it is important to mention that blockchains are a mic of many old technologies that people have used for thousands of years. For instance, payment and cryptography are combined into cryptocurrency. Secure communication when a third party is watching is called Cryptography. People have used tokens that represent a certain value for payments for a very long time, but when combined it generates cryptocurrencies that are entirely new things. A cryptocurrency

becomes a new separate technology which allows you to move money online with the capability to trade value securely via a token. (Laurence, 2019, p.46)

Blockchain technology uses hashing. Hashing means transforming data of any size into short and fixed length values. Hashing on the other hand features another older technology which is called Markle trees, these take several hashes and extract them to one hash, while still able to prove all the data that washes hashed. Blockchains can be defined as ledgers that people have also used thousands of years as financial accounts. But when ledgers are facilitated and merged online in a distributed database, they come with a new innovative technology called blockchain. (Laurence, 2019, p.47)

Bitcoin's purpose at the beginning was mainly to send cryptocurrency. But it did not take very long before the creators (Satoshi Nakamoto) realized that the system had much bigger potential. Because of the underlying potential bitcoin creators created the blockchain to be able to record token movement data. Since then, Bitcoin has become the world's oldest and largest blockchain. (Laurence, 2019, p.47)

2.2 The structure of blockchains

There is no structure that could apply to each blockchain because every blockchain has a slightly different structure. Nevertheless, the most used template for later blockchains was Bitcoin and as a result it is the most suitable Blockchain to study. The information on Bitcoin is structured in a way that every full node includes all the information in the network. Nodes are the computers that run the Bitcoin network. (Laurence, 2019, p.10 –– 11)

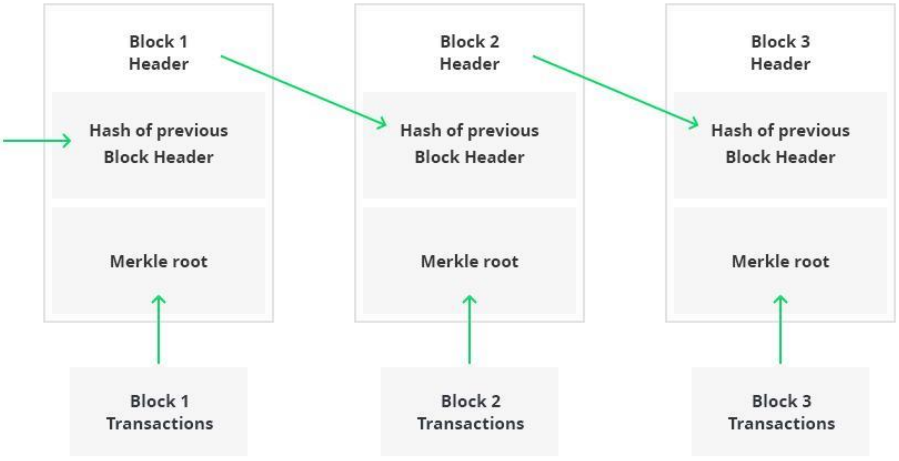


Figure 1. Blockchain structure (Lastovetska A. 2021)

From a data point of view this structure is very compelling because it leads to good data persistence. It means that although some nodes would become compromised the data would still stay totally intact. The drawback is that this system is very memory intensive. Because every node must keep a full track of all the transactions that have happened in the blockchain since the first transaction, and all the transactions that will happen in the future. This requires that the data markings to the blockchain must be as small as possible. Otherwise, the nodes of the blockchain would quickly become overloaded with information. (Laurence, 2019, p.10–11)

The structure of blockchains cause the data size to be much smaller than in other distributed networks such as Napster or Pirate Bay that are online indexes of data. It is possible to share large files because specific nodes share individual files in the network. This system has plenty of drawbacks compared to blockchain systems, it can be hard to get the data that you need because it is not available on all the network participants. Also, you cannot be sure the data that you received is somehow corrupted or intact. The data can contain files or information that you really do not want, such as malware, spyware, or a virus. (Laurence, 2019, p.10–11)

2.2.1 Structure of a block

As the name suggests, a block is a key concept of the blockchain. One can think that blocks are files where data is recorded. In Bitcoins case the files consist of transaction data. All the information that has not yet been recorded to earlier blocks is saved to the block. Therefore, the block is like a single page in a ledger, and when the block is full it gives room to the next block. Like when a page comes full in a ledger you just turn the page. (Johansson et al, 2019, p. 66-67)

The block is made of a header which contains metadata, after the header comes the list of all the transactions in the block. On average a block contains about 500 transactions. Average transaction is about 250 bytes in size. The block header on the other hand is only about 80 bytes. So, the complete block is 1000 times larger in size than the block header. The header keeps inside three different sets of block metadata. The first set contains a reference to the previous block hash, with this reference the block connects itself to the blockchain. The second set contains the timestamp, difficulty and nonce related to the mining competition. The third set contains the Merkle tree root. This is a structure of data which is used to summarize the transactions efficiently. (Antonopoulos, 2015, P. 160)

To make things clear the block is a list of transactions over a given time recorded into a ledger. Every blockchain has different triggering events for block, periods, and sizes, (in the bitcoin block is about 500 transactions like mentioned above). Transactions can be thought of as simply the recording of information (data), which usually is movement of cryptocurrency or token. (Laurence, 2019, p.11)

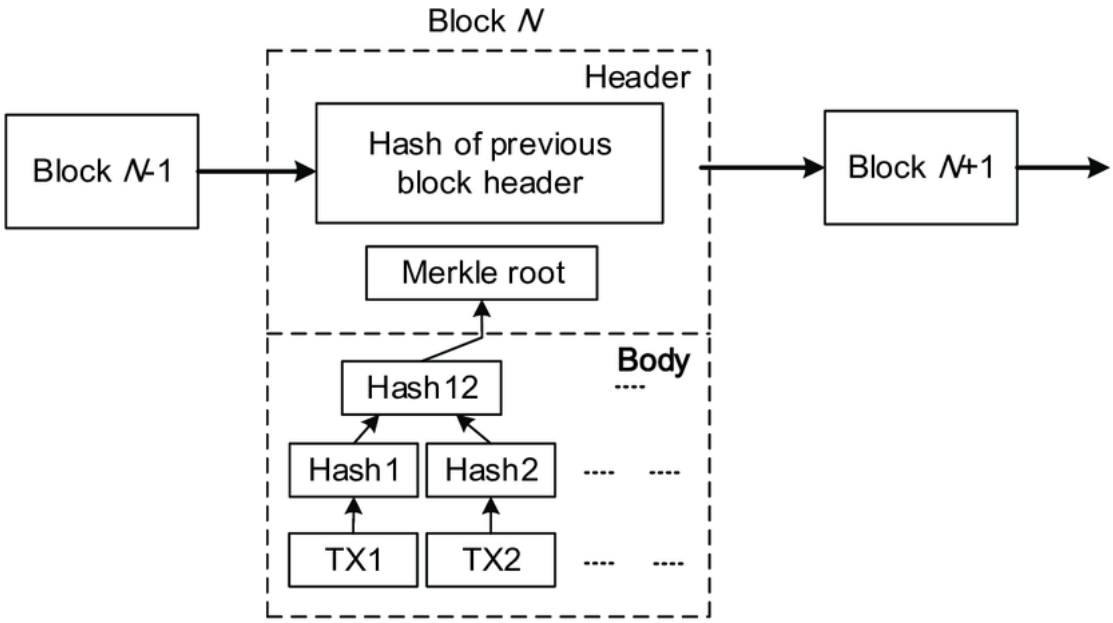


Figure 2. Structure of a block (Wang et al. 2017)

When transactions are recorded to the block, all the data is encrypted. As mentioned above every block contains a reference to the previous block (block header) and when new blocks are born, they form an unbroken chain of blocks, where each block refers itself to the previous block. This self-repeating process ensures that the chain cannot be broken and the immunity of the older blocks all the way to the genesis block. The first block of the blockchain is called the genesis block. (Johansson et al, 2019, p.67)

The consensus mechanisms in blockchains plays an important role maintaining legitimation and security of the information recorded in the blocks. Proof-of-Work (PoW) is the most known consensus mechanism. Bitcoin uses PoW and it also has the highest market value. The main idea in PoW is that the miners must use a lot of computing power to do the hashing operation. (Cao et al, 2019, p.480) Because blockchains don't have any central party for transaction validation blockchains need a way to achieve security and consensus (Frankenfield J. 2021).

Another popular consensus method is Proof-of-Stake (PoS), it was created to be an alternative to PoW. PoS reduces the needed amount of computational power, by

validating the transactions with randomly selected miners. In PoS the blocks are verified only by the coin owners. (Frankenfield J. 2021). Supply chains would benefit more from PoS because it is much more scalable than PoW. PoS has much higher transaction throughput. (EdChain, 2018).

2.2.2 Structure of the chain

The chain of the blockchain is called “hash”. A hash links blocks together by mathematically chaining them to another. Hash creates the blockchains mathematical trust which is the magic that attaches blockchains together. The blockchains hash is formed from the data of the previous block. The hash is like a fingerprint of the previous block data, this locks blocks in time and order. Hashing is an old innovation although blockchains are a relatively new thing, the history of hashing started over 30 years ago. (Laurence, 2019, p.11)

Blockchain technology is created around hashing because it enables a one-way function that is impossible to decrypt. A hashing function produces a mathematical algorithm that records data of any size to a string of bits of a fixed size. The bit string is in most cases 32 characters in length, the string represents the hashed data. The hash is easier to comprehend if you think of it as a digital data fingerprint which is used to lock the data in its place in the blockchains. (Laurence, 2019, p.11)

It is important to notice that block hash is not included in the block’s data, neither when the block is moved on the network, nor when a node stores the block as a part of the blockchain. The hash is instead computed by nodes as the block is received from the network. To enable indexing and quicker retrieval of blocks the block hash is stored in a separate database as a part of the block metadata. (Antonopoulos, 2015, P. 161)

There is also a second way to identify blocks in addition to hash, this is called block height. The first block of the chain is the block zero (genesis block), the first block's block

height is therefore 0. So, you can identify blocks by referencing the block height or referencing the block hash. Each block is one position higher in the chain than the other. In bitcoins case the block height is now over 640000. So, there have been 640000 blocks stacked up after the first block that was created in January 2009. (Antonopoulos, 2015, P. 160)

2.2.3 Structure of the network

How the blockchain network works. The example is from the most known blockchain platform Bitcoin.

1. The new transactions are sent to all nodes.
2. Each node of the network collects the new transactions into a block.
3. Nodes work on finding a Proof of Work for its block.
4. When a Proof of Work is found by a node, it sends the block to all nodes.
5. If the transactions in the block are valid the other nodes accept it.
6. The nodes show their acceptance of the block by using the hash of the new block to create the next block in the chain. (Nakamoto S. 2008, p.3)

The blockchain network composition consists of full nodes. They are responsible for securing the network by running the blockchains algorithm. Each node holds a full record of all the transactions in the blockchain. The node can be operated by anyone over the world who has a computer. But being a full node is very expensive, difficult, and time-consuming so nobody does it for free. Biggest expenses are hardware and electricity costs. So, people want a reward in return for their costs, the reward is usually token or cryptocurrency for example, Bitcoin or Ethereum. The blockchain algorithms reward nodes for their computing time. (Laurence, 2019, p.12)

2.2.4 Consensus algorithm

The underlying network produces an honest system that will self-correct without a third party controlling the transactions. Blockchain technology accomplishes this by a consensus algorithm which works in the shoes of the third party enforcing everyone to follow the rules. In blockchain the consensus is the process where commonly mistrusting parties develop an agreement. These are the so-called “full nodes” in the blockchain network. The full nodes work tasks consist of the validation of the transactions that are coming into the blockchain network to be saved as a part of the ledger. Every blockchain has its own rules and algorithms considering the forming of the consensus agreement on the entries being added to the network. There are many kinds of blockchains, others are for storing data or trading value, and others are for contracts and securing systems. Due to the different variations of blockchains with different kinds of entries, several models for creating consensus are needed. (Laurence, 2019, p.13-14)

Let us take for example the cryptocurrency Bitcoin, which is for trading its token (Bitcoin) through the network between members. Bitcoin must have a high security level because of the token's high market value, Bitcoin has high requirements considering consistency, scalability, threat model, performance, and failure model. The Bitcoin network must operate with the assumption that an evil attacker might want to fiddle the trade history and steal tokens. Bitcoins answer to this is called proof of work, which is a consensus model. This model solves the famous Byzantine general’s problem. The problem was how you can know if the information that you are looking for has not been corrupted internally or externally. This is a huge problem also outside the Bitcoin world, because data reliability is so important in computer science and data manipulation is almost always possible. (Laurence, 2019, p.13-14)

Usually, blockchains run under the assumption that someday an outside or inside party will attack the network. Blockchains have different expected threat and thrust levels to the nodes that operate the network. The degree of thrust will determine the consensus algorithms used by the network. Cryptocurrencies like Bitcoin and Ethereum have no

trust in the network, so they use the proof of work algorithm which is useful in high threat networks. But the proof of work algorithm is very slow and requires a lot of computing power which is not ideal in many situations. (Laurence, 2019, p.14-15)

A lighter consensus algorithm is suited better for blockchains that are used between known parities. With known party blockchain systems it makes sense to favor faster consensus algorithms because of the higher trust in the network. For example, when known parties have a blockchain system to record financial transactions the proof of work is way too slow and costly to operate. This kind of known party networks need instant finality for each transaction, and they do not need cryptocurrency or a token to stimulate the processing of transactions. (Laurence, 2019, p.14-15)

2.3 Mining and consensus

Because Bitcoin is a key thing in the blockchain field it is key to know how the Bitcoin mining process works. New bitcoin is added to the cryptocurrency supply by “mining”. It also protects the blockchain network from double spending and fraudulent transactions. Miners give their processing power to the network and in exchange miners are rewarded with the opportunity to receive bitcoin. The transactions are recorded to the blockchain after miners have validated them. (Antonopoulos, 2015, P. 173)

A new block is created or rather “mined” every 10 minutes. The new block contains all the transactions that have occurred after the earlier block, this adds the transactions of the new block to the blockchain. All the transactions that become part of the new block added to the blockchain are now confirmed, now the new owners of bitcoins can spend the coins that they received in the confirmed transactions. (Antonopoulos, 2015, P. 173)

2.3.1 Miner rewards

The miners are rewarded in two ways. Miners can get new bitcoins when a new block is created, and they get the transaction fees from the transactions included in the new block. To get the rewards miners must solve the earlier mentioned hash algorithm (a very difficult mathematical problem that needs a lot of computing effort). The proof of work is the solution to this hash algorithm. The solution is included in the new block as a proof that the miner used significant computing effort. The competition between the miners for solving the cryptographic proof of work algorithm to earn cryptocurrency and the right to record the transactions to the blockchain is the very core for bitcoin's security model. (Antonopoulos, 2015, P. 173)

The history behind the name "mining" comes from the fact that it has the same features as real mining of precious metals. Just like in real mining the mined thing is slowly diminishing. Bitcoins coin supply is created by mining, similarly like central banks are printing new money. The difference between the two is that there is a limited amount of bitcoin that can be mined. On the other hand, central banks have no limits on how much they can print new money. The amount of new bitcoin created in each block decreases about every four years. More precisely the amount is decreased every 210 000 blocks. The bitcoin mining started in January 2009 with 50 bitcoins in every block and halved in November 2012 to 25 bitcoins per block. According to the mining rewards decreasing exponentially the last bitcoin will be mined around the year 2140. Then all the bitcoins (21 million) have been mined and now new bitcoins will be issued. (Antonopoulos, 2015, P. 173-174)

Every bitcoin transaction includes a small transaction fee, which is created from the surplus of coins between the transaction input and output. The winning bitcoin miner gets to keep this surplus on the transactions included in the block. But the bitcoin fees make only a small portion of miner's income, only about 0,5%. The 99,5% is coming from the mined bitcoins. But this will change in the future because the number of new bitcoins from a block will decrease. And when the number of transactions per block

increases the fees will play a bigger role in the miner's income in the future. If you are a miner after the year 2140 all your rewards are coming from transaction fees because all the new bitcoins have been issued already. (Antonopoulos, 2015, P. 174)

2.3.2 Purpose of mining

It can be slightly misleading when talking about "mining" because it focuses the attention to the reward of mining. But the primary purpose of the mining process is not the reward or the creation of new coins. The rewards are just the motivator to keep the miners mining. The actual goal of this mining process is to keep the decentralized consensus -network running where transactions are cleared and validated. The consensus is achieved in the network without a third party by the miners who are tirelessly validating the transactions in the network. Mining is the key thing that makes bitcoin so revolutionary and ground-breaking, it enables a completely third-party free peer to peer digital cash by creating a decentralized security mechanism. The rewards that a miner gets is just a scheme which aligns the acts of miners with the network security. (Antonopoulos, 2015, P. 174)

2.3.3 Consensus mechanisms for supply chain use

When adopting blockchain to supply chain it is important to make the decision which consensus mechanism is used. For example, the Proof-of-Work consensus mechanism requires a lot of computing power, this will increase the costs to the supply chain. (Litke et al, 2018, p.13) The Proof-of-Work consensus mechanisms can be suitable for public ledgers where anyone can enter the network. Supply chains could benefit more from a permissioned blockchain where nodes must be approved before joining the network, in this case Proof-of-Work is unnecessary and expensive because all the participants of the network are authorized. (Azzi et al, 2019, p.584) For supply chain use there are also other options available. For example, if an organization uses Hyperledger Fabric the

platform's architecture lets the user organization choose a service whose consensus mechanism fits the best in their use case. (Rilee K, 2018)

2.4 Blockchain applications

There is no shortage of possible blockchain uses and applications, opportunities can be found everywhere. There are constantly arising promises that blockchain technology could for example remove unnecessary third parties, speed processes in organizations, prevent theft, protect the business dealing of companies, better manage the assets etc. There are numerous possibilities, the problem is to figure out where and how to use and take advantage of these possibilities that blockchain technology has to offer. (Hughes et al, 2019 p.276)

2.4.1 Interest for the new technology

The spread of blockchain adaptation is evident in many business communities, especially among intrapreneurs and start-ups where there is plenty of interest in launching new disruptive technologies like blockchain. Entrepreneurs keep a close eye on blockchain technology, because of its potential in numerous fields. For example, blockchains offer a platform for development of new cryptographically secure and decentralized software applications. Blockchains can be developed by everyone because they use software that is open source. This will help the blockchain ecosystem itself because open software encourages people to develop the system incrementally and further make the system better and more robust. In blockchain the lack of third parties combined with new technologies such as artificial intelligence and Internet of things are now driving innovation in numerous fields and at same time lowering costs and taking down barriers to entry. (Hughes et al, 2019 p.276-277)

2.4.2 Supply chain applications

Although most supply chains operate well without blockchain technology, at least in most cases the new technology has still riced quite a lot of hype in the supply chain and IT worlds. There are already many very promising pilots considering blockchain technology in supply chains. For example, Walmart has tested a blockchain application focusing on the tracing of Chinese pork from China to the United States. This helps Walmart to get more accurate and efficient record keeping and authenticate transactions. Maersk and IBM are also working on a pilot project where cross-party, cross-border transactions which use blockchain technology in improving process efficiency. A company called BHP is establishing an application where blockchain technology replaces spreadsheets for tracking samples externally and internally from a wide range of providers. (Alicke et al 2017)

The blockchain technology hasn't yet been widely adopted in supply chain applications. This raises a question: can blockchain technology be successfully adapted in supply chains? Most of today's supply chains can already transport data between supply chain parties in real time. To evaluate the value of the blockchain technology for supply chains we must look at the areas in supply chains where blockchain implementation could add benefits. (Alicke et al 2017)

Blockchain technology could for example replace slow manual processes. In many supply chains there are still a lot of lower tiers that are slow and rely entirely on paper. Another area where blockchain technology could add value for supply chains is in strengthening traceability. Better traceability could offer improved product information to customers, and it would help companies to meet the increasing regulation considering product traceability. Better traceability of the blockchain technology could also add value by lowering the costs of quality issues such as recalls and reputational damage. (Alicke et al 2017)

Supply chain management is a 16 trillion-dollar industry with its problems, like frauds, errors, and costs. Blockchains could be a huge disrupter for the sector, especially when combined with IoT. The key here is that when blockchain and IoT technology is combined many of the problems in supply chains can be reduced or eliminated. This is achieved by giving each supply chain stakeholder a private key with which they can write confirmations to the blockchain about the movement of the product through the supply chain. This gives a higher certainty of how and where the product has been handled. This also gives the supply chain parties to see better where possible mishandling might have happened. Thanks to these new technologies there have been born new companies which use blockchain and IoT technologies to offer tracking, transparency, and provenance services. (Hughes et al, 2019 p.278)

	Technology	**Trust**	**Trade**	**Traceability/Transparency**
Supply chain management	Addressing IoT connectivity and security issues. (Counterfeit drugs elimination)	Decentralising supply chain data with blockchain and cloud technology. Offering proof of identity for supply chain transactions. (IBM and Securekey blockhain)	P2P energy trade across supply chain partners and increasing energy consumption efficiency. Using cryptocurrencies to facilitate financial transactions and supply chain finance	Sustainable and ethical supply chain operations. Inventory traceability and safety (IBM and Walmart food tracking blockchain).
Transport and logistics	Better synchronisation across logistics and transport entities (Instant payments). Controlling the characteristics of the environment during transport using smart contracts and IoT e.g., vaccine cold chain.	Increased trust between shipping intermediaries by secure data sharing.	One Belt One Road (OBOR) project applying an immutable distributed ledger technology for streamlining logistics and transport operations	Insuring cargo across the transportation network. (Insurwave by EY and Microsoft)

Table 1. Blockchain applications in the supply chain. (Pournader et al, 2019, p.2074)

Companies have slowly begun to understand that blockchains can give them competitive advantage with customers with concerns about the origin of the products. Blockchains can also protect companies and customers from counterfeit frauds. This is done by registering the initial purchase into the blockchain where the authenticity of the product will be permanently stored, and the movement and ownership of the product monitored and managed by smart contracts. (Hughes et al, 2019 p.278)

2.5 Challenges in adoption

Observers and academics agree that blockchains have huge potential, but the scope of blockchain technology's usefulness is still a subject to debate. The development of blockchain technology is compared to the Word Wide Web's Road to maturity through the recent decades. It is also widely seen that blockchain is going through a three decade-long and three phase road to maturity. The first phase is cryptocurrencies, second is smart contracts and the last phase is broader adaptation of society. Each of these phases faces their own business and technical challenges before larger adoption. For example, the cryptocurrency phase is not yet matured, and we are currently seeing huge fluctuation in valuation because people are trying to make short-term profits rather than using them as a currency. (Hughes et al, 2019 p.278-279)

We are gradually entering the phase of smart contracts where blockchain technology is being used as a platform for decentralized contacts. Though, smart contracts are still mostly used to create new cryptocurrencies. The adaptation of blockchain technology is held back by organizational acceptance and regulation, their culture and the opinions towards blockchain need to change before the blockchain technology can be used in new applications more broadly. This stage is still quite far in the future, because of the societal and technical barriers that blockchain technology still faces. (Hughes et al, 2019 p.278-279)

Although we are going through the first phase of the blockchains (cryptocurrencies), the second and third phases are the most promising for disrupting the old ways of doing. The first obstacle in the way of blockchain adaption is the technical challenges. There are numerous challenges that require a lot of research from various parties such as start-ups, developers, software engineers, venture capitalists etc. The technical challenges consider for example, scalability, secure transactions, and ability to exchange information between blockchains. (Hughes et al, 2019 p.279)

2.5.1 Regulatory challenges

There are a lot of regulatory and legal issues that blockchains face before wider adaptation is possible. These are caused by the fact that although blockchain technology is rapidly evolving and going forward, the legislation and regulation are changing very slowly. The laws concerning blockchain technology can also differ greatly between countries. For example, in the United Kingdom the legislation on blockchains is neutral. They consider the future usage of blockchains acceptable if the risks are kept in mind and reduced. The United States on other hand have quite the opposite stance for blockchains, and there the regulation is much stricter. (Hughes et al, 2019 p.279)

2.5.2 Future challenges

One thing is clear, blockchains are still in the very early phases of their journey. Many of the promises can be still considered as speculation or hype. How much of the ongoing debate is speculation over whether cryptocurrencies could become, or at least complement existing currencies. Blockchains have a long way to go before it is widely applied as a societal product, though there are already business areas where adaptation of blockchain technology has made huge progress. It seems likely that similarly in the early phases of the internet that the success and development of the technology will be in the hands of business communities that disrupt the way through old ways of doing things. But the success of the blockchain technology is dependent on the heavy work that the blockchain community is doing to develop infrastructure and tools that the technology needs for it to be successful. (Hughes et al, 2019 p.280)

Challenges in blockchain technology adoption			
Interorganizational challenges	**System related challenges**	**External Challenges**	**Intraorganizational challenges**
Lack of customer awareness	Challenges in security	Lack of governmental policies	Financial constraints
Challenges in collaboration, coordination, and communication in the supply chain	Access to technology	Uncertainty and market competition	Lack of management support and commitment
Challenges in information disclosure policies between supply chain partners	Hesitation in adopting the technology	Lack of involvement from the external stakeholders	Lack of organizational policies for the new technology
Challenges in integration of blockchain and sustainable practices	Immutability challenge of the technology	Lack of industry involvement	Lack of expertise and knowledge
Cultural differences between supply chain partners	Immaturity of the technology	Lack of rewards and encouragement programs	Difficulties in changing the culture
			Hesitation when converting to new system
			Lack of tools for blockchain implementation

Table 2. Challenges in blockchain adoption (Saberi et al, 2018, p.2124)

2.6 Blockchain types

One of the most important things to notice is that there are different types of blockchains: public, private, hybrid and federated -blockchains. Each of these different blockchain technologies has developed to serve their own purpose and to solve a problem or a set of different problems. First when Satoshi Nakamoto introduced the blockchain technology the only blockchain type was public because bitcoin used it in its cryptocurrency use case. (Anwar H, 2020)

Satoshi's bitcoin created the decentralized ledger technology concept. This technology solved many problems considering drawbacks of centralization, but on the other hand itself caused a lot of problems when people tried to apply this technology to other

situations. The biggest drawback is the proof of work algorithm that needs huge amounts of processing power which consumes a lot of energy. This was not a problem in the start but as the difficulty of the proof of work algorithm rises the energy needed to solve these hard-mathematical tasks increased also. This made the blockchain adaptation in the private sector quite hard because the private sector is dealing with huge numbers of transactions daily. The public blockchain technology just was not suitable for the private sector. (Anwar H, 2020)

There are also other reasons why in many cases organizations cannot use public blockchains. First, companies have critical data that they cannot make public, this data makes their business successful. This problem has been solved by introducing private blockchains where organizations can choose the participants. In this way organizations can benefit from all the advantages that blockchain technology offers without having to give their data public and at the same time avoid data being passed to competitors. (Anwar H, 2020) But this requires that the competitor would be aware of the company identity in the blockchain network, which in practice would be very difficult to find out. (Johansson et al, 2019, p. 77)

There are also a lot of similarities between public and private blockchains. They both are based on a distributed peer to peer network, where every party maintains their own copy of the distributed ledger where data can only be added. Both use the consensus protocol. They both offer certain guarantees considering the persistence of the data even in situations when some of the parties are untrustworthy. (Johansson et al, 2019, p.75)

Blockchain types	
Public Blockchain	Anyone can join and do transactions in a public blockchain because it is a permission-less technology.
Private Blockchain	Private blockchains are permissioned and they are under control of the parties using it.
Hybrid Blockchain	Organizations can manage the blockchain rules. They are secure, although they are connected in a public network.
Consortium Blockchain	Type of a hybrid blockchain. Multiple organizations participate in a semi-closed chain, instead of just one organization.

Table 3. Blockchain types (Fields N. 2021)

2.6.1 Public blockchains

Anyone can join and do transactions in a public blockchain because it is a permission-less technology. Anyone with an internet connection can access a public blockchain. Transactions in the blockchain are done by consensus methods (proof of work). (Anwar H, 2020) Public blockchains typically have an incentive mechanism to increase the number of participants in the network. (Johansson et al, 2019, p.75)

A public blockchain needs to have a certain number of peers participating in transaction solving, otherwise the blockchain will not work. The biggest advantages in public blockchains are that everyone can access a public blockchain. Public blockchain technology brings thrust among the user community. Everyone benefits from the work towards a better network due to incentive mechanisms. Blockchain can work without third parties. The public blockchain technology is very secure if there are enough nodes in the system. Public blockchains also bring transparency to the network because the data is public. (Anwar H, 2020)

The biggest drawbacks of public blockchains: The transactions are very slow compared to other technologies currently in use. It can take anywhere from a couple of minutes to even hours before a transaction is completed. This is because of the computing power demanding proof of work consensus algorithms. For instance, VISA can do 24 000

transactions every second, while bitcoin is capable of only seven transactions per second. (Anwar H, 2020)

Another big problem is the scalability of public blockchains. They don't scale very well because when the number of nodes increases the network becomes slower and clumsier. There have been attempts to improve the situation by lightning the network by taking transactions off-chain, but this only helps up to a certain limit and the problem is still present. Last drawback of public blockchain is the high energy consumption of the network caused by the consensus proof of work consensus method. There are some efforts to reduce the energy needs of a public network by introducing new less energy demanding consensus methods such as Proof-of-Stake algorithm. (Anwar H, 2020)

2.6.2 Private Blockchains

As the name suggests, private blockchain is the opposite of public blockchains. This is the best network for companies that want to benefit from blockchain technology. Private blockchains are permissioned and they are under control of the parties using it. Differences to the public blockchain is the way that it is accessed, and it is not a truly decentralized system because only one authority takes care of the network. (Anwar H, 2020)

The biggest advantages of private blockchains are that they are fast because there are less participants in the network compared to public blockchain. Fewer participants lead to fast transactions since consensus can be reached much quicker. Private blockchains are also scalable, unlike public blockchains. This is due to the low number of nodes needed to validate transactions in the network. (Anwar H, 2020)

The biggest disadvantages on the other hand are that private blockchains are not decentralized by nature. This is bad because it is against the basic values and philosophy of the distributed ledger technology. Trust is also harder to get in private blockchains because of the very centralized nodes. The few numbers of nodes also lead to lower

security. Fewer corrupted nodes are needed to influence the consensus method. (Anwar H, 2020)

2.6.3 Consortium Blockchain

Consortium blockchain has features from both public and private blockchains. This blockchain comes handy when organizations need both private and public blockchain features. In this blockchain some aspects of the systems are public, while certain aspects are kept private. Although this system's consensus is formed among predetermined nodes the system is still decentralized in nature. This is achieved by giving the management of the system to several organizations. In consortium blockchain there are so called validator nodes which can both initiate or receive transactions and validate transactions. This blockchain type gives the benefits of private blockchain with more decentralized nature. (Anwar H, 2020)

The advantages are that it offers much better control and customization. They are more efficient, secure, and scalable than public blockchains. They work well in situations where governance structures are well defined. Obvious disadvantages of consortium blockchains are that there are still chances that the network could be compromised because of the relatively low number of nodes and system member integrity. System is less transparent than the public. Compared to other types of blockchains the system is less anonymous. (Anwar H, 2020)

2.6.4 Hybrid blockchain

The last blockchain type is hybrid blockchain. This sounds a lot like consortium blockchain, but they are two different things. This is for organizations that do not want to establish public or private blockchain but want the absolute best of private and public blockchain worlds. Hybrid blockchains work in closed systems without the need of

publishing everything. Organizations can manage the blockchain rules. They are secure, although they are connected in a public network. The disadvantages of this system are that it is not completely transparent and it lacks incentives for nodes to participate in the network. (Anwar H, 2020)

3. Supply chains

Supply chains can be defined in various ways, one way is to think of them as groups of companies working together to satisfy the end customer by sourcing, producing, and delivering goods and services. A typical supply chain involves four different types of parties. There is a central company that makes products or services to customers. Second type is the whole range of different suppliers which make the components and raw materials. There are also the distributors who deliver the goods to consumers. As well as the modes of transport which are responsible for the movement of the products between the links of the supply chain. (Sadler, 2007, p.1-2)

It is easy to think that the supply chain consists only of the visible movement of products and materials between companies along the supply chain before they reach the end of the chain, which is the end customer. But the supply chain also includes other factors, such as information exchange, management, and supply chain leadership, which companies must take into account, if they are aiming to be competitive. (Sadler, 2007, p.1-2)

3.1 Supply chain segments

One of the key factors of business is the process that creates products or services that fulfills the requirements of the customer within agreed schedule. This series of events can be explained as a process, flow or as a chain where different events and functions follow each other. Supply chain contains all the steps that are needed for producing the product from the raw material suppliers all the way to the end customer. These functions are for example procurement, manufacturing, transportation, importation, forwarding, storage, communication, and money transactions. These have traditionally been under the responsibility of several persons or departments, which has caused interruptions in the flow of information, overlapping functions and ineffectiveness. Now the organization of these functions has started to develop from a more holistic

perspective, this is called SCM – Supply Chain Management, to which we will return later in this thesis. (Viitala & Jylhä, 2013, p.156-157)

3.1.1 Process stages

In a supply chain there can be a numerous group of various operators at different stages of the process. These processes and stages make up the supply chain, which includes everything from the transportation and storage of the raw materials, production planning and manufacturing, inventory accounting at the time of production, inventory management, logistics, relations with suppliers, and to the delivery of the finished products to the end customer. Supply chain includes all the activities towards suppliers, retailers, as well as towards end customers. The supply chain also includes possible return flow from the customers, such as recycling, warranty, and scrapping services. (Viitala & Jylhä, 2013, p.156-157)

In a controlled supply chain, every party is closely following the markets and trying to respond as quickly as possible to all the returning feedback. Everyone should also aim to continuously improve their competitiveness. Companies have begun to unite different functions under one supply chain to improve seamlessness, customer orientation, and to get better cooperation between different parties. This would not be possible without various information systems that have been created to facilitate the interaction of these functions. Nowadays the flow of goods, information, and money are coordinated by integrated planning systems such as Enterprise Resource Planning (ERP), Supply Chain Management (SCM), and Customer Relationship Management (CRM). (Viitala & Jylhä, 2013, p.156-157)

Companies tend increasingly to outsource the phases of the supply chain that are not worth doing or which they cannot do by themselves. In this outsourcing development the supply chain coordination and continuous improvement have become more important than ever. In this case the supply chain can include various groups of different

actors that participate in the handling of product- and information flow. Products are flowing through suppliers' manufacturing and sales all the way up to the end customer, but the information about the needs of the customer are going in the opposite direction from customer all the way to the supplier of raw materials. The principle of how these flows are started and regulated can be done in two ways, either with a pull or push model, to which we will return later in the thesis. (Viitala & Jylhä, 2013, p.156-157)

The key basic principles to remember are that supply chain is the information directed flow of products or services from sources to customers controlled by various partner firms. In supply chains communication is both electronic and person to person communication through all the processes for providing maximal value to customers. The supply chain efficiency can be improved if all the parties work for the same goal by improving their flow, processes, design, and provisions. The system wide perspective helps firms to take tradeoffs between variable costs such as transport, production, inventory, and purchasing and between resource costs such as labor, equipment, and information systems. (Sadler, 2007, p.7-8)

3.1.2 Value

Value can be sustainably produced for all parties of the chain if all parties work coordinated for the same goal. The maximization of the overall value created is the ultimate purpose of the supply chain. The generated value is the difference between the efforts that the supply chain uses trying to fill the customer needs and what the end customer is willing to pay for the final product or service. The supply chain network is defined by the total sum of supply chains across all the different products and services that are supplied to the end customer through a focal company. (Sadler, 2007, p.7-8)

You can analyze the supply chain by several different methods. These various perspectives help to comprehend how the supply chain works and are there any possible

places for improvement. There are many useful methods to analyze the same issue, so it is important which approach is best for each situation. (Stanton, 2018, p. 34)

It is maybe easier to describe the supply chain as three rivers that flow from customer back to the source of the raw materials. These three flows, or rivers are information, money, and materials. The information river flows in both ways, downstream and upstream while the customer makes orders, and all the suppliers give information on the products and delivery times. Money on the other hand flows only upstream beginning form the customer through every supplier that is providing goods and services along the path. The third river materials flow only downstream in the supply chain. It starts from the raw materials and follows the river gaining value, until the finished product ends up to the end customer. It is key to be able to manage these flows effectively. (Stanton, 2018, p. 34-35)

It is key to make the right decisions considering how long you can wait between sending the finished product and receiving the payment from the customer. It is also important to know exactly when and what information you must send each way of the supply chain for the chain to be able to operate correctly and efficiently. Every euro that flows through the supply chain rivers comes from the end customer and before moving upstream. The organizations in the same supply chain must cooperate to catch that euro. But the supply chain organizations are also competing fiercely how much they can keep off the euro as their own profit. (Stanton, 2018, p. 34-35)

3.1.3 Supply chain integration

It is important to integrate three supply chain functions, which are logistics, purchasing, and operations. These are critical supply chain functions and bad decisions in one of these affect the other two, which means that success of one of these functions needs also good coordination of the other two. The operations, purchasing, and logistics can have different and conflicting goals, which usually leads to bad total performance in the

company. Organizations must make sure that the goals of these three functions are aligned to meet the organizations top level objectives. It could help everyone's department to see the big picture if everyone focused for example on the return of investment and not to the traditional supply chain metrics such as transport costs and capacity utilization. (Stanton, 2018, p. 35-36)

3.2 How blockchain can be used to promote supply chain management

Blockchain can promote supply chain management by offering tamperproof transaction records. Blockchains data structure enables organizations to make tamper-proof digital ledger of transactions and share them to other participants. The technology enables authentication and traceability of the products in real time upstream the supply chain. (Helo P, 2019, p.244) This also strengthens the chain stakeholder's confidence downstream in the product security which grows the trust among suppliers (Kshetri N, 2018, p.80).

Supply chain management can benefit from information synchronization and sharing that blockchain technology enables. This reduces the risk of the bullwhip effect. Blockchain improves the information sharing in the supply chain which reduces the capacity risk. (Nakasumi, 2017) Blockchain achieves this by using a peer-to-peer network. Each node in the network is in consensus of the current state of the distributed ledger which guarantees the information consistency. (Helo P, 2019, p.244)

Blockchain technology enables smart contract execution. Smart contract is a computer protocol which controls the user's digital assets. Smart contracts can execute contracts automatically. (Lin I, 2017, p.655) Smart contracts can simplify the supply chain management process. It also reduces the third party costs and dramatically guarantees the transaction reliability and security. (Chen G, 2018, p.6)

Supply chain indicators	Blockchain concepts		
	Tamper-proof transaction records	Information synchronization and sharing	Execution of smart contracts
Improve quality	X	X	X
Cost reduction	X	X	X
Quicker delivery		X	
Risk reduction	X		X
Increased trust	X		X

Table 4. Blockchain enabled benefits for supply chain management (Helo P, 2019, p.244)

3.3 Supply Chain Logistics

The economy would not work without logistics. Effective and working logistics are the lifeline to modern organizations. The purpose of logistics is to deliver the raw materials, semi-finished products, and finished products to agreed location in agreed time with the agreed quantity and quality. The delivery must happen at an agreed service level and at the same time minimizing the impact to the environment. To fully understand the logistics, you must have a correct overall picture of the whole business environment. It is not enough if we look at one area without considering the whole field of activity. For example, actions in purchasing have effects in manufacturing, inventories, and delivery. Logistics must be an overall process aimed at improving the whole supply chain's competitiveness. (Ritvanen, 2011, p. 19-20)

Logistics and supply chain management are often looked to be synonyms for each other. But logistics are rather acting as a driver for supply chain management. The concept of logistics as a management term can be dated back to the 1950’s. Before the term logistics was associated with warfare and military operations. Later people began to draw attention to the overall costs and reducing them, together with storage and transportation development. The concept of modern logistics together with supply chain management got its final form mainly after the 2000s. (Ritvanen, 2011, p. 19-20)

A good definition for logistics is the management of products, services, information, or money in an organization to meet customer needs. (Ritvanen, 2011, p. 19-20) The term logistics has several different definitions, another definition is process where resources are acquired, stored, and transported to the end destination. (Kenton, 2020)

3.4 Supply Chain Management

The phrase supply chain comes out everywhere: in news, company reports, and in conversations. But this has not always been the case, supply chain management is a comparatively new concept which dates to the 1980s. The concept has gradually become general business language from being only a distant academic concept. Despite the ongoing attention around supply chains, the concept is not actually that new. People have always been buying materials from suppliers and selling things to customers. But the concept of supply chain "management" is quite a new concept which started to form in the 80s, approximately at the same time as the computers started to make their way to the business field. (Stanton, 2018, p. 20)

Supply chain management can be defined as the coordination and planning considering all the processes, people, and technology that are producing value for a company. Efficient supply chain management requires that you can coordinate the things happening in your firm with the factors that are occurring outside your firm. It is useful to visualize your company as a one link in a lengthy chain which only purpose is to supply value to customer. The crucial supply chain management task such as managing logistics, manufacturing scheduling, and price negotiations greatly affect the balance sheet of a company. These tasks are so interdependent that it is quite terrible idea to make decisions considering them separately. Everything can have effects on everything. (Stanton, 2018, p. 21)

The importance of supply chain management grows, and it becomes harder to keep the supply chain functions aligned when the company grows, because then the supply chains also get longer, and the phase of the company functions becomes faster. Unfortunately, a big part of the old metrics and strategies that were widely trusted by the management of the companies can cause totally wrong behaviors and do more damage than good for the company. An example of this situation could be when a sales department has done a big deal with the customer by themselves it can cause losses to the company because other departments were not ready for a sudden large order. It increases the costs of manufacturing, logistics, and procurement functions. It's very important that all these functions are closely connected and doing cooperation that the business would not hunt deals that are not profitable. (Stanton, 2018, p. 21)

In other hand if the company has good supply chain management it can benefit from these sudden cash-generating chances which their competitors could not profitably exploit. This can be done for example, by using lean manufacturing tools and principles. With a lean company can be more responsive despite smaller inventories. This can bring a lot of benefits. For example, when being responsive to customers, it can cause better customer relationships and increased sales. Better collaboration with suppliers can help to get needed materials quicker and more cost effectively. Nowadays usually over 70 percent of costs and 100 percent of profits are reliant on the management of supply chains. So, the business can't run successfully if the supply chain functions are not aligned. This is the most important factor behind the excitement around supply chain management. (Stanton, 2018, p. 21-22)

People try often to explain supply chain management by describing what they do. It would be much better to talk what supply chain management creates. There are ten principles for describing supply chain management. First principle is customer focus. The first step in supply chain management is to know who your customers are and what makes them to buy the product or service that you are selling. When a customer buys your product, your company are filling a need or solving a problem that the customer

has. It is very important that the supply chain managers have a good understanding of the need or problem that the customers have, so that they can answer to that need or problem quicker, better, and cheaper than the competitors. (Stanton, 2018, p. 25-26)

3.4.1 System thinking

System thinking is the second supply chain management principle. Supply chain managers must have a good understanding of the whole system, they need to know technologies, processes and people work in sync so that your company is able to provide the products and services, when needed and with correct quality and quantity. System thinking requires a good understanding of how different actions in the supply chain cause effects in other parts of the supply chain. Supply chains are so complex systems that even a small change can make the whole chain perform in totally unpredictable ways. The small change can also make a big effect in other parts of the supply chain. (Stanton, 2018, p. 26)

In third place comes the bimodal innovation principle. Supply chains are in a hurry to keep up with the quickly changing business environment. The best practices for keeping up with the trends is to invest in continuous improvement and innovation to keep up with the competitors. In this task Lean, Six Sigma, and Theory of Constraints can provide help. But continuous improvement is not automatically sufficient because of the new technologies that can disturb industries. This effect is called “disruptive innovation”. When customers accept a new method or way that answers to their needs this new solution becomes the dominant paradigm. So, you must constantly try to invent new ways to make your product, for example, cheaper, faster, and better but at the same time you have to think and sort out what the next dominant paradigm could be, so that you are ready when a new technology comes and disrupts your field of industry. (Stanton, 2018, p. 26-27)

Collaboration is the fourth supply chain management principle. Supply chain management cannot be done correctly if it is isolated from the rest of the organization. It is important to work across the company and with customers and suppliers outside the company. In supply chain management it is key to forget the short-term opportunities and focus on the bigger long-term effects. Short-term focus in supply chains is most likely just going to increase the costs because it tends to lead to reduced trust and unwillingness to make compromises with the supply chain parties. A supply chain with high trust between parties and good collaboration for mutual success will be more profitable in the long run than a system where parties are concerned only about their own success. (Stanton, 2018, p. 27)

3.4.2 Flexibility

Next is flexibility. Supply chains must be flexible because as a supply chain managers can't always predict what is going to happen. Supply chain flexibility can be defined as measurement of how rapidly the supply chain is able to react to sudden changes, such as sudden decrease or increase in sales or a supply disruption. Greater flexibility usually means alternative transportation forms, excess capacity, and several supply sources. The increased flexibility is not at any means cheap, so it is key for a supply chain manager to know when an investment in better flexibility is economically sensible. It is true that flexibility costs and commits resources, but it can help to think of flexibility as an insurance policy. For example, buying material from only one supplier can be cheaper, but if that supplier is for any reason unable to deliver the product it is wise to have other suppliers although the bigger unit costs. (Stanton, 2018, p. 27-28)

Next supply chain management principle is technology. Because of the quick progress of technology in information processing and movement of products have totally changed the way that supply chains work. Not so long-ago people ordered things from catalogs and waited many weeks for the product to arrive. Nowadays products are ordered by phone, customers get quick delivery and real-time updates where the

products are going. Supply chain managers must know how new technologies work and how the technologies in each step of the supply chain are creating value to the customer. (Stanton, 2018, p. 28)

Global perspective is the seventh supply chain management principle. For a company to succeed in the modern global marketplace, it must be able to share information instantly and move products across the globe quickly and cheaply. Today, this is possible for almost every company because of the new technology and globalization. Supply chain managers must understand how their business depends on global factors. Just from nowhere can come a competitor from the other side of the globe and disturb your business. (Stanton, 2018, p. 28)

3.4.3 Risk management

Risk management is the eighth supply chain management principle. Risk management is important because when you are combining complex technologies, depending on suppliers and global customers, and high-performance requirements there is a big chance for chaos. Many things can go wrong because there are so many variables affecting the supply chain. For example, if just a small shipment is lost or delayed it can bring many much bigger problems down the supply chain. Supply chain managers must be aware of these risks and make plans on how to detect these threats. Risk management is a key factor when ensuring the smooth operation of the supply chain. When risk management is on a good basis the company can even get good opportunities for value creating when times are uncertain. (Stanton, 2018, p. 29)

The two last principles are visibility and value creation. Visibility is important for supply chain managers because it is hard to manage if you can’t see what you are managing. The decision process comes better and faster if the information is as close to real time as possible. It is key that the supply chain is designed in a way that receiving information from different steps in the process will go without any hiccups. Supply chain visibility

provides managers the correct and up to date information that they need for making decisions that are based on facts instead of guesses. Good visibility allows the company to keep lower inventory through the supply chains, which also cuts costs. Finally, an important principle in supply chain management is value creation. Supply chain management's purpose is to create value to the customer, by fulfilling the customer needs. This requires being able to deliver the product in the right place, at the right time at right quality and with lowest costs as possible. This is the most important thing in supply chain management. (Stanton, 2018, p. 29)

3.5 Supply Chain Traceability, Transparency and Visibility

International Organization for Standardization defines traceability*:" The ability to identify and trace the history, distribution, location, and application of products, parts, materials, and services. A traceability system records and follows the trail as products, parts, materials, and services come from suppliers and are processed and ultimately distributed as final products and services."* (ISO 9000, 2015)

Traceability dates to the 1930s when certain European nations had a need to prove the origin of high-quality foods, for example such as champagne. In recent decades traceability considering food has become more important because of numerous food scandals such as Asian bird influenza and mad cow disease. After this the need for traceability has gradually expanded to other industries beyond food safety because of issues considering safety, product quality and security. Suppliers, consumers, and governments want better information under which conditions their products were produced and which materials and ways of transport were used along the whole value chain. This increased need for information is due to the rise in demand for fair trade and environmentally friendly materials and products. This has led to the massive increase in the need of traceability systems and technologies. (United Nations Global Compact, 2014)

A separate system is needed to ensure supply chain traceability. The system must follow and record the trail when parts, products, and raw materials arrive from suppliers and are processed and made to end products. These systems must provide information about all the components of products, materials, and parts as well as all the information about the transformations along the whole supply chain. For example, the information about product safety, quality, and labeling are endured by traceability. Traceability has also a lot to offer to the context of sustainability by helping to verify and assure sustainability claims made by companies, which usually are practices considering workforce and environment through the supply chain. (United Nations Global Compact, 2014)

The global economy is dependent on numerous supply chains that are providing goods and services from producers to customers. Company's supply chain management is focused on execution and planning, integrated with enterprise resource planning systems. The purpose of these systems is to optimize the flows in the supply chain so that goods can move in the value chain at the lowest cost and in the least amount of time. To a company to accomplish these goals it needs track keeping of the movements in the supply chain. (Laudon J & Laudon K, 2011)

A traceability system provides information such as location, originality, or components during distribution and production, thereby enabling tracking. Usually, product suppliers and dealers want government-certified third-party traceability service providers to examine the products through the supply chain. The product's originality and quality get a certificate if the product passes the traceability service providers requirements. To uncover data and to create certificates, the traceability service providers also utilize a traceability system. Because of this information security is important for the accountable and forensic data. These traceability systems usually are storing data in a traditional database which the providers control by themselves. This kind of centralized information storage can be a possible point of failure and it can also be a risk because of the possibility of information manipulation. (Qinghua & Xiwei, 2017, p. 21-27)

The retailers and suppliers have different reasons why they are using traceability services. For retailers it is important that they can prove the products origin and quality. Suppliers on the other hand want certificates to prove to the customers the origin and quality of the products as well as comply with the regulation. Traceability is very adaptable, the figure 1 shows the dynamism of the traceability certification process. (Qinghua & Xiwei, 2017, p. 21-27)

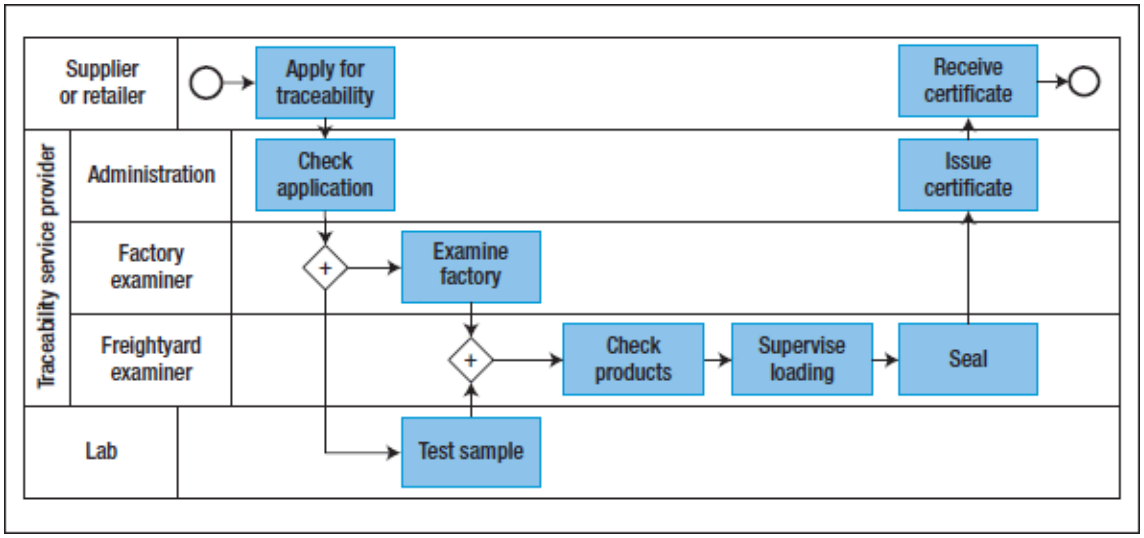


Table 5. Traceability certification process (Qinghua & Xiwei, 2017)

3.5.1 Transparency

Transparency in the context of supply chains can be described as the level of which a supply chain party has access to important information about processes, products, and capital flows without any noise, loss, distortion, and delays. Supply chain transparency indicates the quality, accuracy, availability, accessibility, and actuality of the supply chain data. Supply chain is transparent when the information can be accessed simple and fast. It is also important that when needed, the information can be easily revealed to supply chain parties such as customers, stakeholders, and regulatory authorities in a rapid, comprehensive, comprehensible, and credible manner. (Bastian & Zentes, 2013 p. 553-570)

Transparency is one of the most important factors that affect whether a supply chain is successful or not. Transparency means the transference and capture of important information such as components, suppliers, facility locations, and certificates along the supply chain. Good transparency lets a company map its whole supply chain, getting a clear visibility into the supply chain operators. Better transparency helps the business to ensure that all the operators are compliant with sustainability, safety, and social responsibility requirements. The accountability also improves in the supply chain because due to transparency each operator can access and upload information and data. When it is easy to access and share information each supply chain party can more easily see the updates in processes which results in fever delays, shorter lead times, and reduced redundancy. (Langer, 2019)

Nowadays it is common that global sourcing is a part of companies' procurement strategy. When companies outsource manufacturing to other vendors, and these vendors also outsource some of their manufacturing to other vendors the supply chains become very long. Track keeping of the quality control process becomes harder when the supply chain becomes longer. The supply chain visibility can be described as transparency and traceability of the supply chain process. Normally companies design the products, procedures, quality control standards, and testing standards to their suppliers. In traceability there must be documentation that provides that the suppliers are following all the procedures through the whole value stream of the product. (Tse & Tan, 2012, 49-57)

3.5.2 Visibility

Supply chain visibility is also described as the transparency of the information sharing between supply chain members. The supply chain visibility is achieved by understanding what is happening in other parts of the supply chain such as in pipeline inventory, finished goods, and order status. The lack of visibility and control procedures can cause the situation where supply chain parties start to make their own decisions without

having clear detailed knowledge of the activities in the rest of the supply chain. (Tse & Tan, 2012)

Clear visibility into supply chain material flow and the traceability of material properties guarantees that quality is made a high priority. With real-time and accurate visibility, companies can actively operate their projects and gain better confidence in schedules, assurance of outcomes, and costs. (Langer, 2019)

4. Current use of blockchains

Usually, blockchain applications are classified in two categories, financial and non-financial applications. Because most blockchain applications are represented by cryptocurrencies. (Crosby et al. 2016) Blockchain technology applications can also be classified with blockchain generations. Blockchain has evolved step by step. First was Blockchain 1.0 which was for digital currency, and it took many years to mature after starting in 2008 from Satoshi Nakamoto's Bitcoin. Second blockchain version is Blockchain 2.0 for digital finance. Third classification is Blockchain 3.0 for digital society. There are several experimental blockchain 2.0 and 3.0 projects, but it will still take some years before Blockchain 2.0 and 3.0 to take hold and make some true economic impacts. (Zhao, et al. 2016)

4.1 Blockchain technology in financial applications

Nowadays blockchain technology is used in a wide variety of financial applications such as business services, prediction markets, settlement of financial assets, and economic transactions. It is expected that blockchain technology will have a key role in the development of a sustainable global economy which brings benefits to current banking systems, customers, and to society in general. (Nguyen, 2016)

The financial system is seeking new blockchain based applications for financial assets such as fiat money, securities, and derivative contacts. Blockchain technology can be used to change capital markets and a more effective way for doing operations such as derivatives and securities transaction, digital payments, loan management schemes, general banking services, cryptocurrency payment and exchange and financial auditing. Many of the world's largest banks, such as Goldman Sachs and Barclays have established a blockchain-based structure for the financial market. Another example from the banking field is the Global Payments Steering Group, which consists of members such as, Bank of America, UniCredit and Santander. (Casino, et al. 2019)

Prediction marketplace systems (PMS) is also a promising field for blockchain technology. Blockchain technology can be already found in prediction marketplace systems such as Viacoin, which are a totally open-source cryptocurrency. Viacoin provides faster transaction speeds than Bitcoin. Other financial areas for blockchain adaptation could be for example casualty claims and commercial property processing, proxy voting, automated compliance, syndicate loans, contingent convertible bonds and over-the-counter market. Blockchain implementations in the financial sector have cost saving potential in areas such as business operations, centralized operations, finance reporting, compliance. (Casino, et al. 2019)

4.2 Blockchain technology in integrity verification

Integrity verification is a promising field for blockchain technology. The purpose of integrity verification is to store transactions and information associated with the manufacturing and the lifecycle of the product or service. Potential applications are for example: insurance, provenance and counterfeit, and intellectual property management. (Casino, et al. 2019)

There are already mature solutions such as Medichain which uses blockchain technology for linking digital content with their authors. Medichain stores metadata to the blockchain to permit media recovery and querying. (Labs, 2016)

One promising blockchain solution for monetisation problems is called Monegraph, which enables profits sharing around the value chain of the media distribution for image reels, broadcasts, video clips, licenses, and other brand sponsored content via blockchain. (Monegraph Inc, 2014)

4.3 Blockchain in healthcare

Healthcare data is very sensitive in nature and managing it properly can be quite difficult. The healthcare systems are disconnected, which means that the health data is in separate silos. Disconnected systems cause many inefficiencies in the whole healthcare system, and it is a big obstacle for healthcare research. Usually, the professionals working in healthcare do not have the obstacle free access to the entire data of patients. This slows down and hampers the treatment and diagnosis process. The research in the healthcare field is also affected because of the hard access to the needed data. (Katuwal, et al. 2018)

The blockchain technology might be able to offer very efficient sharing of healthcare data while still ensuring data integrity and the privacy of the patients. Although a cost-effective, efficient, and interoperable healthcare information exchange can be created with other technologies. But blockchain technology can speed up the implementation of patient-centric healthcare information models where patients can control their own healthcare data. The biggest obstacles in the way of data sharing in the both traditional and patient-patient centric healthcare models are the lack of incentives to share and the lack of trust. In this situation blockchain technology comes handy for these problems by providing incentive mechanisms by rewarding crypto tokens for data sharing and acting as a trust layer. Blockchain can also help with the integration of the medical device data. (Katuwal, et al. 2018)

Blockchain technology enables incentive and trust structure. But there are still many obstacles in the way of wider blockchain technology implementation. One of the biggest obstacles is the lacking standards for healthcare data. It can be difficult to make an interoperable healthcare information exchange system if the data is in separate silos. But there is a chance that blockchain technology gives relief to this situation because of the incentive structure that can speed up the creation and development of common healthcare data standards. Another major obstacle is the regulations that differ between countries. (Katuwal, et al. 2018)

4.4 Blockchain in pharmaceutical industry

Counterfeit medicines are a huge problem in the pharmaceutical industry. Counterfeit drug industry has been growing. It is estimated that counterfeit medicines are responsible for 100 000 to 1 000 000 deaths annually. (Zakari et al, 2022 p.2-3) The counterfeiting is not the main issue itself, rather the fact that these counterfeit drugs are compared to real drugs because the counterfeits produce totally different side effects. These counterfeit drugs may not give any help at all for the patients. Rather than curing the patient, the patients' health may be seriously affected by the side effects of these drugs. (Jamil F. et al, 2019, p.1-2)

Blockchain technology has been noticed in the pharma sector. The properties of blockchain and the way it enables trust, transparency, decentralization, stability, and anonymity has been noticed to have potential for fighting against counterfeit drugs. Blockchain technology could be used to trace the true origin of drugs, the transportation of pharmaceuticals, and the procurement of raw materials. (Zakari et al, 2022, p.3)

There have already been promising new blockchain applications for the pharmaceutical industry. For example, MediLedger Network. It launched in 2017 and it has already attracted many pharmaceutical manufacturers and wholesalers onboard. MediLedger are examining the potential of blockchain technology to meet Drug Supply Chain Security Act -requirements for a track and trace system. (Schofield H. & Thasarathakumar L., 2021)

4.5 Blockchain technology in supply chains

Although most supply chains operate well without blockchain technology, at least in most cases the new technology has still riced a lot of excitement in the supply chain and IT worlds. There are already many very promising pilots considering blockchain technology in supply chains. For example, Walmart has tested a blockchain application

focusing on the tracing of Chinese pork from China to the United States. This helps Walmart to get more accurate and efficient record keeping and authenticate transactions. Maersk and IBM are also working on a plot project where cross-party, cross-border transactions which use blockchain technology in improving process efficiency. A company called BHP is establishing an application where blockchain technology replaces spreadsheets for tracking samples externally and internally from a wide range of providers. (Alicke et al 2017)

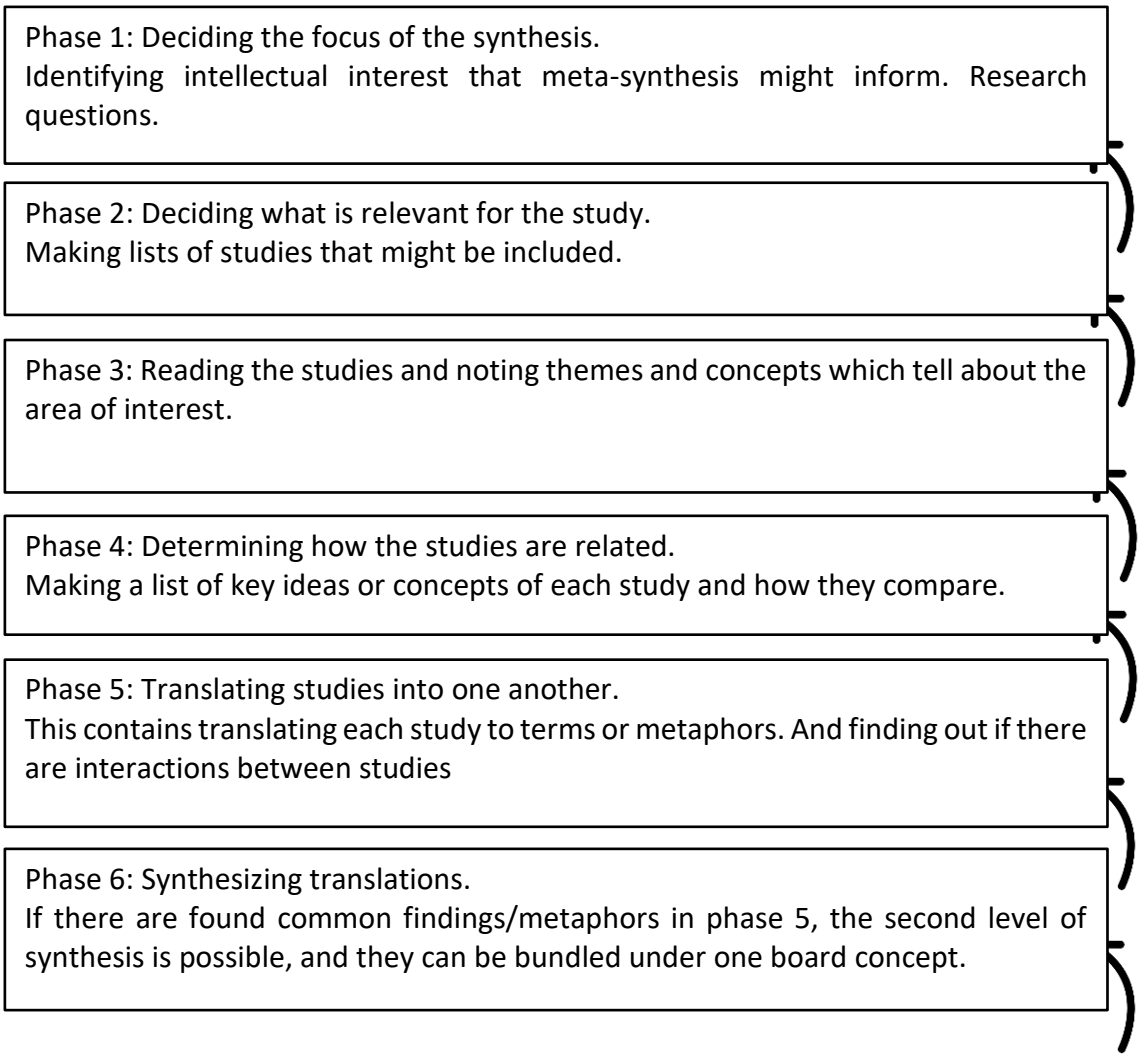
The blockchain technology hasn't yet been widely adopted in supply chain applications. This raises a question: can blockchain technology be successfully adapted in supply chains? Most of today's supply chains can already transport data between supply chain parties in real time. To evaluate the value of the blockchain technology for supply chains we must look at the areas in supply chains where blockchain implementation could add benefits. (Alicke et al 2017)

Blockchain technology could for example replace slow manual processes. In many supply chains there are still a lot of lower tiers that are slow and rely entirely on paper. Another area where blockchain technology could add value for supply chains is in strengthening traceability. Better traceability could offer improved product information to customers, and it would help companies to meet the increasing regulation considering product traceability. Better traceability of the blockchain technology could also add value by lowering the costs of quality issues such as recalls and reputational damage. (Alicke et al 2017)

5. Introducing to the qualitative meta-synthesis method

The research method used in this study is called qualitative meta-synthesis. Qualitative metasynthesis has a lot in common with systematic review. It dates to the 1980s, so it is a relatively young method. As a hermeneutic approach, metasynthesis seeks to understand and explain the phenomena under study. In metasynthesis, the basic idea is to combine research on the same subject, so that their nuances and assumptions can be revealed. These nuances and assumptions are viewed in the light of differences and similarities striving for a convincing picture of the overall topic. (Walsh & Downe 2005. p. 204–205)

Phases of meta-synthesis according to (Noblit & Hare, 2011, p.2-4):



Phase 7: Expressing the synthesis.
Expressing the results of the synthesis.

The articles selected in the metasynthesis are read carefully and highlight key metaphors, phrases, ideas, and concepts that are compared with each other. The aim is to use comparisons to obtain concepts and find similarities in the results of the studies. (Walsh & Downe 2005.p.208–209) Metasynthesis brings together findings systematically and formally from qualitative studies. Meta-synthesis interpretatively integrates these qualitative findings. Metasynthesis is still much more than the sum of its parts in the sense that it offers a new interpretation of the findings, whose result it is. (Sandelowski & Barroso 2007. p.17-18)

In the last phase of meta-synthesis studies are compared for similarities that are bundled under one board concept. But this cannot be done by force because differences in findings might also result in a completely new concept. Synthesis is a matter of verbal densification, in other words, the language of the results is unified as far as possible. (Salminen A. 2011. p.13)

6. Various available blockchain platforms used for supply chain management

The objective of this thesis is to compare blockchain technologies in various segments of supply chain management. In recent years the rising blockchain technology excitement has been noticed in the field supply chains. There have been many articles written about different blockchain platforms and how these platforms could suit the needs of supply chains. Different companies and industries also have different needs, so there is not just one blockchain platform that suits everybody.

There are certain limitations and differences between blockchain platforms considering for example centralization, consensus mechanism, cost, performance, and security. Different blockchain platforms can have different consensus protocols, which all bring with them certain trade-offs among efficiency, security, performance, and scalability. Blockchain platforms have different sets of strengths and weaknesses, and it is important to choose a platform that can fulfill needs and offer solutions. (Wahab A. & Mehmood. 2018. p9)

6.1 Finding relevant articles

According to (Sandelowski & Barroso 2007. p. 35) before starting to find relevant articles, it is important to set four parameters for your search. First parameter is topical (what). In my case the topical parameter is blockchain technology in the supply chain. Second parameter is population (who). The population of my search will be supply chain segments and blockchain platforms. Third parameter is temporal (when). So that outdated information is not included in the study, articles done before 2018 are excluded. Last parameter is methodological (how), in this study I will include only qualitative articles.

I did the search in the Tritonia Finna search engine which has access to countless databases, such as Web Of Science, Business Source Premier etc. The search was done using previously mentioned parameters and using the words: Blockchain platforms supply chain. The search gave 5658 results, with filters set to material type articles from 2018, and language of the articles set to English.

Five commonly used blockchain platforms for supply chain operations were chosen. The selection criteria were to use commonly used and studied platforms including both private and public blockchains. The platforms chosen for this study were: Ethereum, Corda, Hyperledger, Bitcoin, and Multichain. When studying articles from blockchain platforms, these five platforms came up frequently.

Ethereum is a public blockchain based, open-source distributed platform that offers digital money and data services. It has a cryptocurrency called Ether. Ethereum was launched in 2015. Ethereum platform uses Proof-of-Work consensus protocol named Elthash. (Polge et al. p.230) Hyperledger fabric is an enterprise grade cross-industry permissioned distributed ledger platform supported by IMB. In Hyperledger Fabric everyone can't enter the network. Hyperledger Fabric has enabled a network of networks. Businesses need some of their data to be private and some data to be seen by the members of the network. (Hyperledger.org)

Multichain is an open source blockchain platform which is a fork of Bitcoin. Multichain is developed by Coin Sciences. Distinct from Bitcoin Multichain lets blockchain users freely configure parameters such as maximum block size, network access permissions, privacy of the chain, and mining incentive. Multichain doesn't currently support smart contracts. (Polge et al. p230) Corda is a permissioned open source blockchain platform which is developed by R3. Corda network is made by many or one notary nodes whose purpose is to validate the transactions. Corda is following the know your customer

principle which means that every node must prove their identity before they can join the network. (Polge et al. p230)

Following eight articles shown in the next chat were chosen. The chosen articles had to include the correct supply chain perspective and the articles had to include most of the chosen blockchain platforms. These articles were a good match for the research. There were also other good articles available but only eight articles could be included. Excluding had to be made, other vice the research would become too extensive.

1. Hongru et al. Comparison of Smart Contract Blockchains for Healthcare Applications. 2019.
2. Kunpeng Li et al. Blockchain in food supply chains: a literature review and synthesis analysis of platforms, benefits and challenges. 2021.
3. Kawaguchi N. Application of Blockchain to Supply Chain: Flexible Blockchain Technology. 2019.
4. Uddin M. Blockchain Medledger: Hyperledger fabric enabled drug traceability system for counterfeit drugs in pharmaceutical industry. 2021.
5. Bringas et al. BlockChain Platforms in Financial Services: Current Perspective. 2020.
6. Hewa et al. Survey on blockchain based smart contracts: Applications, opportunities and challenges. 2020.
7. Polge J. et al. Permissioned blockchain frameworks in the industry: A comparison. 2020
8. Agbo C. C. & Mahmoud Q. H. Comparison of blockchain frameworks for healthcare applications. 2019.

Table 6. Selected articles.

6.2 Meta-summarizing

Next phase is to extract the findings of each article. This is done by gathering sentences and statements from the chosen articles. This includes all statements considering what the writer thinks is wrong, what is known, perspectives, theoretical frameworks, assumptions etc. (Sandelowski & Barroso 2007. p. 82-100) For this study a total of 247 statements/findings were gathered.

Next step is to edit findings so they would be as accessible as possible to readers. In this it is important to stay close to the words of authors/researchers, so that their original intention is preserved. The focus is to present the findings to readers with understandable sentences with only minor editing. These edited findings are called abstracted findings. The frequency effect size on the table tells how many percent of the articles contained each finding. (Sandelowski & Barroso 2007. p. 155-156)

Abstracted findings (N=25)	**Frequency effect sizes**
1. Choosing a blockchain platform is a tradeoff.	62,5%
2. Hyperledger Fabric permissioned operation gives flexibility to stakeholders and improved privacy, no transaction cost but can suffer for scalability issues.	50%
3. Ethereum has many benefits such as safety, quick setup, and support and development of the platform, drawbacks are slow transaction approval, energy consumption, and Ethereum gas cost.	50%
4. Hyperledger Fabric blockchain platform offers a more complete set of features for supply chain applications compared to other platforms.	37,5%
5. Ethereum natively supports smart contracts, unlike bitcoin.	37,5%
6. Corda is using only notaries involved in proofing the transactions which saves computational resources, most suitable for legal smart contract handling and for financial operators.	37,5%
7. Blockchain technology can offer cost savings, automation, better visibility, better efficiency, increased transaction transparency, reduced waste, and fraud.	37,5%
8. Many new blockchain based applications are emerging and increasingly implemented in today's industry.	37,5%
9. Off-chain data storage will help blockchain data handling limitations.	25%

10. Blockchain technology has problems to fit together with different industries laws and regulations.	25%
11. A single party cannot implement blockchain in a supply chain. The agreement and contribution of all parties are needed.	12,5%
12. Blockchain based smart contract systems require further optimization to integrate with logistics systems.	12,5%
13. The error handling for inconsistent blocks requires improvement.	12,5%
14. Finding and choosing the best-suited blockchain platform is not an easy task as most of the solutions are not fully developed and need optimization.	12,5%
15. Blockchain technology is still seen as complex technology and there haven't been a vide scale implementation of the technology.	12,5%
16. The design of Bitcoin limits the possibility to add smart contracts to the platform.	12,5%
17. Permissioned private blockchains are more useful as they offer wider access control mechanisms, allow for better innovative solutions and have better executing and processing efficiency as well as better computing power across the blockchain network when compared to permissionless public blockchains.	12,5%
18. Some platforms use Proof of Work consensus protocol which have disadvantages in scalability and transaction execution times.	12,5%
19. Hyperledger Fabric contains more layers in its network to increase manageability and security, which can result in long setup time compared to other platforms.	12,5%
20. Multichain is quick and easy to set up, compared to other platforms.	12,5%
21. Choice of platform must be made with the requirements of the application in mind.	12,5%
22. Plenty of room for improvement of the private blockchains because there are often bottlenecks.	12,5%
23. Although Bitcoin and Ethereum don't support private channels they can still be used to manage private information.	12,5%

24. In off-chain databases some advantages considering security and data availability are lost. 8	12,5%
25. A majority of the existing blockchain platforms are untested and unregulated to provide scalability services at a large scale with high success rates. 4	12,5%
26. The transaction speed is an obstacle in many platforms, if the chain can't handle the transactions at the rate they occur, users will look for different alternatives. 5	12,5%

Table 7. Edited findings

I collected 26 edited findings from the articles. The most important articles for this study were the Hewa et. al (9 findings), Hongru et al. (8 findings), and Bringas et. al (8 findings). The least important article ended to be the Kawaguchi N. The low effect size of the Kawaguchi N. article was caused by the fact that it was the only article offering solutions to the blockchain supply chain data storage problems with InterPlanetary File System (IPFS), and because of that It was essential to include this article to the study.

In the following table there are the effect sizes of the abstracted findings. The effect size can be used to assess the relevance of each article to the research. It is calculated by dividing the abstract findings of the article with the sum of all total numbers of abstracted findings. High effect size means that the article contains a lot of key findings to the research. (Sandelowski & Barroso 2007. p.160)

Article	**Abstracted findings (N=26)**	**Effect sizes**
1. Hongru et al. Comparison of Smart Contract Blockchains for Healthcare Applications. 2019.	8	17,2%

2. Kunpeng Li et al. Blockchain in food supply chains: a literature review and synthesis analysis of platforms, benefits and challenges. 2021.	3	6,38%
3. Kawaguchi N. Application of Blockchain to Supply Cain: Flexible Blockchain Technology. 2019.	1	2,13%
4. Uddin M. Blockchain Medledger: Hyperledger fabric enabled drug traceability system for counterfeit drugs in pharmaceutical industry. 2021.	7	14,89%
5. Bringas et al. BlockChain Platforms in Financial Services: Current Perspective. 2020.	8	17,2%
6. Hewa et al. Survey on blockchain based smart contracts: Applications, opportunities and challenges. 2020.	9	19,15%
7. Polge J. et al. Permissioned blockchain frameworks in the industry: A comparison. 2020	7	14,89%
8. Agbo C. C. & Mahmoud Q. H. Comparison of blockchain frameworks for healthcare applications. 2019.	4	8,51%

Table 8. Effect sizes of the findings

6.3 Findings

When studying abstracted findings, it is obvious that blockchain technology still has its issues for example in scalability and performance. The choosing between these blockchain platforms is a tradeoff. The tradeoff between public and private or permissioned blockchains causes the biggest differences between the platforms, because permissioned or private blockchains offer better scalability which is an important factor with smooth supply chain operation. (Hongru et al, Bringas et al, Hewa

et al, Polge J. et al, Agbo C. C. & Mahmoud Q. H.) When blockchain technology is implemented successfully it offers cost savings, automation, better visibility, better efficiency, increased transaction transparency, reduced waste, and fraud (Kunpeng Li et al, Uddin M., Hewa et al.).

Many benefits of blockchain technology are the root cause of the emerging new blockchain platforms and applications. A recurring factor in studied articles was the generally accepted matter that blockchain technology has a lot of potential to benefit supply chains and a wide variety of other applications. But articles still found many problems before blockchain technology could be widely applied in supply chains. Blockchain technology still has problems fitting laws and regulations of different industries (Kunpeng Li et al, Uddin M.).

A single party cannot implement blockchain technology because there are many different players in supply chains, who all must agree and implement the new technology (Kunpeng Li et al.). There are still room for improvement for integrating blockchain to logistics systems, also the error handling of inconsistent blocks need improvement (Hewa et al.). The transaction speed is an obstacle in many platforms, if the chain can't handle the transactions as the rate they occur, users will look for different alternatives (Bringas et al.). Supply chains could benefit from blockchain technology but because the technology is in its early phase, there is not any wide scale adoption Hongru et al.).

Hyperledger Fabric comes on top in many articles because of its permissioned operation that gives flexibility to stakeholders and improved privacy, and it can operate without transaction costs. But it can still suffer from scalability issues. Hyperledger Fabric (Kunpeng Li et al, Uddin M., Hewa et al., Uddin M., Agbo C. C. & Mahmoud Q. H.). Hongru et al, Uddin M, and Agbo C. C. & Magmoud Q. H. pointed out that Hyperledger Fabric blockchain platform offers a more complete set of features for supply chain applications compared to other platforms. The downside of this platform compared to

others is that Hyperledger Fabric contains more layers in its network to increase manageability and security, which can result in long setup time compared to other platforms (Hongru et al.).

Ethereum has many benefits such as safety, quick setup, and support and development of the platform, drawbacks are slow transaction approval, energy consumption, and Ethereum gas cost. Ethereum also supports natively smart contracts, unlike bitcoin. Ethereum requires more computational power, and it has much lower throughput when compared to private platforms. (Hongru et al., Bringas et al., Hewa et al., Polge et al.)

Bitcoin suffers also from the fact that it is a public blockchain, high computational power requirements, high energy consumption, and slow execution of transactions. Bitcoin platforms aren't especially suitable for large scale supply chain adaption. It is better suited in virtual-money transfer applications where nobody can trust anybody. Bitcoin platform designs are limiting the possibilities to add smart contracts. Adding smart contracts is possible but it must rely on external code outside the platform, which can cause some trust problems when executing smart contracts. (Bringas et al.)

Corda supports a wide range of industrial applications, although it was initially designed to serve the banking industry. Corda uses only trusted notaries which causes some drawbacks when compared to other platforms. It can be said that notaries drive Corda platform towards third party features. (Hewa et al.)

Multichain is the easiest and quickest to set up when compared to the other four platforms. But on the other hand, Multichain is lacking a fully functional smart contract capability. (Hongru et al.) There are no possibilities to add complex logic to the Multichain platform because of the lacking support of smart contracts. But the Multichain 2.0 which is now in beta phase will introduce Smart Filters which enable smart contract functions. (Polge et al.)

7. Conclusion

Blockchain technology in supply chains has the potential to disrupt common practices. A company interested in implementing blockchain technology has many different blockchain platforms to choose from. In this thesis I compared five well known blockchain platforms Hyperledger Fabric, Ethereum, Corda, Multichain and Bitcoin using meta-synthesis in supply chain applications. Choosing a platform is not easy because there are so many and new platforms are emerging continuously. In addition, blockchain technology hasn't yet been widely adopted in supply chains because it is still a new technology.

There have already been many successful implementations of the technology, but in the bigger picture blockchain technology in supply chains is not yet commonly used. Meta-synthesis of the chosen articles showed that currently Hyperledger Fabric and Ethereum are the two most mature platforms.

Hyperledger Fabric did show better performance in supply chain applications compared to the Ethereum and other platforms. Choice of platform must be made with the requirements of the application in mind, because the choosing between these blockchain platforms is a tradeoff. There are still few obstacles with these blockchain platforms before they can be widely deployed. These obstacles are lack of governance, storage- network and computational overheads, scalability, and data privacy. But I’m confident that in the future a solution to these obstacles can be found.

7.1 Future work

In future work, when platforms become faster, scalable, and more mature in terms of fault tolerance, throughput, security, scalability, and latency it would be interesting to benchmark these platforms to existing centralized systems.

7.2 Managerial implications

The results show that managers should think carefully before making decisions considering implementation of Blockchain to the supply chain. There are big differences between scalability between platforms. This study demonstrated that Hyperledger Fabric and Ethereum had the best performance of the five compared platforms.

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