Lauri Virtanen

NOW YOU SEE ME, NOW YOU DON'T: INCREASING TRANSPARENCY AND RELIABILITY OF INFORMATION IN SUPPLY CHAINS WITH BLOCKCHAIN

JYVÄSKYLÄN YLIOPISTO
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TIIVISTELMÄ

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Nyt näet minut, nyt et: läpinäkyvyyden ja informaation luotettavuuden lisääminen tuotantoketjuissa lohkoketju teknologian avulla.
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Tuotantoketjut ovat globaalin yhteiskunnan pohja. Kaikki käyttämämme esineet tuotetaan näiden monimutkaisten ja läpinäkymättömien ketjutettujen tuotannon osien avulla mahdollistaen ennennäkemättömän resurssitehokkuuden. Tämän tehokkuuden vastapainona on entistä läpinäkymättömämpi ja vaikeammin hahmotettava kokonaisuus. Tämä läpinäkymättömyys johtaa jokaisen toimijan toimimaan epätäydellisen informaation pohjalta ja tämä on johtanut lisääntyneen informaation jaon tunnustamiseen yhtenä tapana lisätä tehokkuutta jatkossa. Tässä tutkielmassa tutkitaan mahdollisuuksia, joita lohkoketjuteknologia on jo mahdollistanut ja mahdollistaa tuotantoketjuista saadun informaation määrän sekä luotettavuuden lisäämiseksi. Lohkoketjuteknologian keskeisenä ideana on kryptografisesti luotu jaettu kirjanpito, jonka muokkaaminen ilman muiden hyväksyntää on mahdotonta. Lohkoketjun implementaation tavoitteena on luoda mahdollisimman läpinäkyvä sekä luotettava läpileikkaus tuotteen matkasta tuotantoketjussa. Tämä tutkielma on toteutettu kirjallisuuskatsauksena ja tarkastelee, miten lohkoketjuteknologia voi parantaa ja miten se on parantanut tuotantoketjujen läpinäkyvyyttä sekä niistä saatavan tiedon luotettavuutta. Tutkielman pohjalta voidaan olettaa lohkoketjuteknologian omaavan positiivisen vaikutuksen läpinäkyvyyden sekä informaation luotettavuuden lisäämisessä tehostaen samalla tuotantoketjuja. Tunnistetuista hyödyistä huolimatta lohkoketjujen implementaatio kohtaa silti monia haasteita, jotka uhkaavat niin hyötyjen saavuttamista kuin implementaation onnistumista.

Asiasanat: lohkoketju, tuotantoketju, läpinäkyvyys, luotettavuus, informaatio, kirjallisuuskatsaus

ABSTRACT

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Now you see me, now you don’t: Increasing transparency and reliability of information in supply chains with blockchain.
Jyväskylä: University of Jyväskylä, 2022
Information Systems, Bachelors’ thesis
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Supply chains form the basis for the functioning of the global economy as they are connecting every part of the world to be a part of the global economy and have enabled unforeseen resource efficiency. The counterbalance of this efficiency is an ever more opaque and complex entity. This has led every party to act on imperfect information with the consequence of acknowledging increased information sharing as a way to increase efficiency within supply chains. This thesis outlines how blockchain technology could and has been used to improve the availability and reliability of information in supply chains. The premise of blockchain is to cryptographically generate a distributed ledger that is not mutable without a consensus decision between users in the network. The objective of implementation of blockchain is to generate as transparent and reliable ledger of the items journey through the supply chain as possible. This thesis is being completed as a literature review and examines how implementing blockchain technology can increase transparency and reliability of information in supply chains. Based on the research conducted in this thesis blockchain can be thought to be capable of having a positive effect in increasing transparency and reliability of information in supply chains thus being capable of increasing efficiency. Nevertheless, the implementation still faces a lot of challenges that threaten the realisation of these benefits.

Keywords: blockchain, supply chain, transparency, reliability, information, literature review

FIGURES

TABLES

CONTENTS

1 INTRODUCTION

As supply chains have revolutionised the way in which the goods that we consume are produced and with more than two thirds of global trade being made possible by these chains (Marcin, 2021) the lack of transparency that supply chains have is astonishing. The lack of transparency is so dire that less than two percent of companies know actors in their supply chains beyond their supplier's supplier (Knut Alicke et al., 2021). This lack of transparency manifests itself in cases where bottlenecks are formed within supply chains, but the lack of visibility renders efforts to resolve these disruptions obsolete (Helper & Soltas, 2021). As increased information sharing has been stated to increase efficiencies in supply chains (Lee et al., 2004) a technology that can suffice all the requirements that actors within a supply chain have could solve these dire problems in systems that the world is reliant upon. Blockchains have been proposed as one possible technology as the attributes that are presented by Yli-Huumo et al. (2016) and Iansiti & Lakhani (2017) answer to many of the challenges that currently hinder information sharing within supply chains. When increased information sharing has been identified to increase the efficiency of supply chains research should be conducted of how information could be shared within actors of supply chain. The purpose of this study is to give the reader understanding of how blockchain can enable more transparency and reliable information in supply chains. This study is aimed for people that work with supply chains who wish to increase their knowledge of blockchains and how it can increase transparency and reliability of information in supply chains. In this research the following research questions are answered:

- How blockchain can increase transparency in supply chains?
- How blockchain can increase the reliability of information within supply chains?

The research is conducted as a literature review. In a literature review a plentiful amount of literature regarding the subject is examined to form answers to the research questions. The research gathers views of what supply chain and blockchain as well as research literature concerning the implementation of blockchain into supply chains. The intent is to form a coherent thesis that addresses the ways in which blockchain technology can increase transparency and reliability of information in supply chains. Corresponding research has been conducted prior. Literature has been mainly sourced from JYKDOK database and google scholar using, but not limited to, the following words and their combinations: 'blockchain', 'supply chain', 'transparency' and 'blockchain implementation into supply chains'.

The thesis is divided into five chapters of which three are content chapters. The first chapter is introduction which states the theme of the research, opens the research questions and how the topic will be discussed in subsequent chapters as well as the structure of the thesis. The second chapter is about supply chains. Supply chains are defined, and the bullwhip effect is explained. The chapter also addresses the information flow which is the concept that ties blockchain into supply chains. The third chapter is concerned with blockchain. In this chapter the definition and basic principles of blockchain are discussed with a more in-depth technical look which explains why blockchain can increase the reliability of data that is present in supply chains. Technical terms and concepts are introduced and talked in this chapter. The fourth chapter is at the intersection of blockchain and supply chains. This chapter briefly addresses what needs to be taken into account in order to implement blockchain into supply chain in order to increase the chance of successful implementation. This chapter also answers the research questions "How blockchain can increase the reliability of information within supply chains?" and "How blockchain can increase transparency in supply chains?" Even though there is a rather substantial amount of research of blockchain implementation into supply chains and its benefits, a lack of real-life case studies was apparent. In the fourth and last chapter a summary of the whole thesis is presented along with the conclusions that have been drawn from the research.

2 SUPPLY CHAIN

The aim of this chapter is to try and form a definition of supply chain and introduce supply chain management related theories that come up later in the research. This chapter tries to give the reader a basic understanding of what supply chains are and how they are managed through flows and what complexities arise in the current form that supply chains have taken.

2.1 Defining supply chain

Supply chains have had a profound effect on how the global economy works. More than two thirds of global trade is made possible by these chains (Marcin, 2021). Even though the modern society couldn't function without these just-in-time delivery chains that have made stockpiling a thing of the past, people only notice them when they are disrupted (Carson, 2022). This lack of inventory is visualized in Figure 1, which is the inventory to sales ratio and its development in the United States.

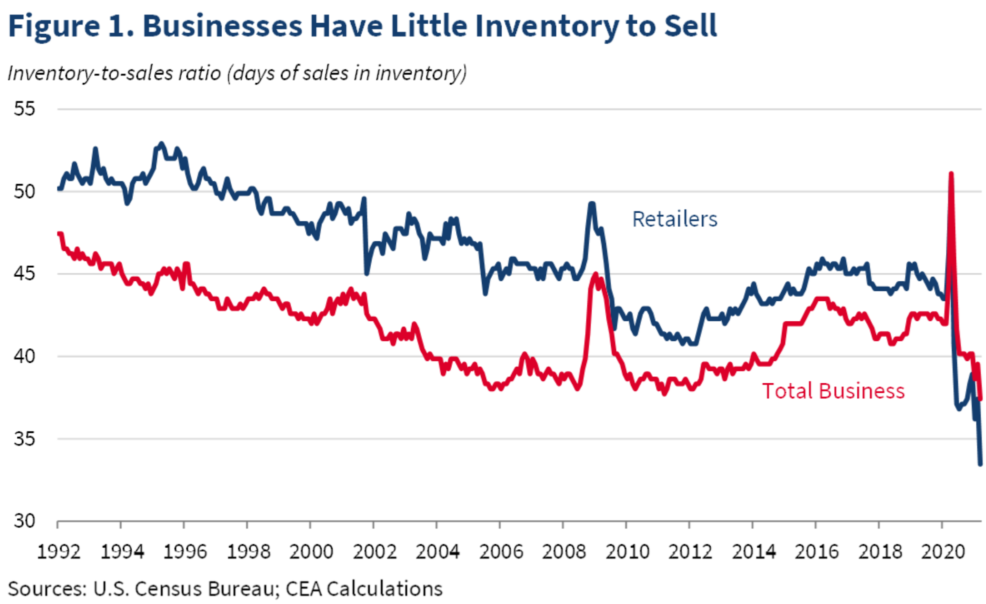

Figure 1, Businesses have little inventory to sell (The White House, 2021)

The definition of supply chain is not completely agreed upon either. As supply chains vary between products and companies a singular definition is impossible to come by, but two main branches of definitions remain: the first one is more focused on the actual parts of a supply chain and can define it as "A network of businesses, resources and suppliers used to manufacture and distribute a specific commodity "(Avetta LLC., 2021). Other definitions in this branch can be found in the work of Wessel J. Pienaar (2009) where he defines supply chains as: “a general description of the process integration involving organizations to transform raw materials into finished goods and to transport them to the end-user”.

The second branch of definitions is more focused on flows. As Drane & Faramarzi (n.d) define the three main flows are “flow of goods/materials, flow of money/cash and flow of information.” Other definitions define these flows as information, finance and physical (Vanpoucke et al, 2009) or flows of goods, information, and finance (Wuttke et al., 2013). For this study, these two definitions can complement each other to form a more comprehensive definition of physical supply chains being a network of resources with flows of information, financials and goods used to manufacture and distribute a commodity.

2.2 Supply chain management and the bullwhip effect

Jay W. Forrester is a pioneer in realm of supply chain management and his book *Industrial Dynamics* (1961) is a foundational piece this field of research because it is the first piece of research where the bullwhip effect, referred as the Forrester effect in the book, is presented and this theory is according to Wieland (2016) “undoubtedly the single most important theory in supply chain management”. *Industrial dynamics* can be thought of as the starting point of supply chain management as it is the first publication that anchors the modern foundation for flows which need to be managed through different oscillations, delays, and amplifications (Sahin & Robinson, 2002).

Expanding upon the foundational principles of Forrester we can turn to Porter who in *Competitive Advantage* (1985) establishes the systems view. According to Porters views the value creating extends beyond the boundaries of the firm. Looking through Porter’s systems view we can establish a gestalt which connects all the parties that are affected by the flows present in Forrester’s work.

What this extended view of value creation means is that the whole supply chain must not only to be thought of as a singular entity but also managed as one complete structure (Currie, 2000). This understanding of extended value creation presents an ample opportunity to define and understand what is trust as it is the foundation upon which relationships are built on. According to Mayer et al. (1995) a definition with widespread adoption is that trust can be defined as one’s willingness to expose them vulnerable to the actions of the other party irrespective of the trustors ability to monitor such action. This is then defined in the context of supply chains as an actor’s belief in their supply chains partners acting in a consistent manner and doing what is being promised (Spekman et al., 1998). This definition can be then framed in two different ways (Poppo et al., 2016). The first is calculative trust where trust is based on risk-based calculations and is not concerned of the relationships between each actor (Gambetta, 2000). The second one is relational trust which analyses the beliefs of each party and “social embeddedness” (Granovetter, 1985). A notable element of social embeddedness is the power dynamics between actors in the supply chain (Cox, 1999). Both of these definitions need to be taken into account when we explore trust and define it as actors in the supply chain face risks when increased transparency and information sharing happens but the relationships between each actor also make an impact in how much risk each actor is willing to take. Therefore, in this thesis trust can be looked at as one's willingness to expose themselves to the actions of others while considering the risks associated and relationship characteristics between parties in the supply chain.

As Currie (2000) states that each supply chain needs to be managed as one complete structure and when looking through Porters (1985) systems view the understanding of value creation beyond the boundaries of a single company is introduced. This means that to produce value the actors within a supply chain must work together and trust each other to provide truthful information as this enables actors to work more as a singular entity with shared knowledge. This shared knowledge can be seen to require transparency in supply chains.

If there is no transparency then a supply chain can be called a "black box" meaning that there is no visibility into what is being done with resources in a supply chain to produce a commodity which poses problems for overall value creation in the supply chain (Grant, 1991). A proposition for a general definition of what transparency can be comes from Awaysheh & Klassen (2010) who define transparency as being the extent to which there is readily available information to parties involved. Francisco & Swanson (2018) take this into a narrower context of supply chains and define transparency in supply chains as the information available to actors involved in a supply chain. Another definition of transparency in supply chains is by Kim & Laskowski (2018) propose that transparency in supply chains can be thought of as knowledge of how commodities were manufactured, stored, and delivered to customers and to be capable of proving provenance. Antony et al. (2006) found out that the capability of being able to prove provenance can increase customers trust and reduce perceived risks which can be looked at as an argument to incorporate both definitions of transparency into one as in a supply chain each downstream actor is a customer. Thus, we can define transparency as a supply chain actors' knowledge, that is based on shared information, of where a commodity is from and what has been done to it. In this thesis the idiom "increased visibility" refers to a supply chain having increased transparency.

As trust is a prerequisite for increased transparency since increased information sharing exposes each actor to be more vulnerable there need to be tangible benefits for increased information sharing. Some of the business benefits of increased information sharing can be found when examining the bullwhip effect (Chen et al., 2000). According to Wieland (2016) the most important theory in supply chain management is the bullwhip effect. The bullwhip effect is established on the notion that variability in customer demand causes even larger variability the more upstream we move up the supply chain (Forrester, 1961). What is also crucial about the bullwhip effect is that the magnitude of variability increases on each level that we move away from the original source of variability i.e., customer demand. The effect is named after the graphical illustration of this increasing variability which represents a bullwhip (Chen et al., 2000).

One idealized illustration of the bullwhip effect is shown in the *Beer Distribution game*, the game was developed by Forrester in MIT in the 1960's and it is based in his work on system dynamics (The Beergame, 2019). The idea of the Beer Distribution Game is to demonstrate the bullwhip effect in a very simplified supply chain with 4 actors. Figure 2 demonstrates the process in which turns are taken in the game. Simple explanation of how the game goes is that each player is an actor in a different level of the supply chain. Players can't exchange information with levels of the supply chain that they have no transactions with, and they can't hold infinite inventories of beer. This means that when the consumer demand at the lowest level starts to fluctuate the increased demand doesn't transfer through the system immediately but rather takes multiple turns. This starts to clog the system when some players inventories fill up and at other places shortages may occur. This demonstrates the severity and impact that bullwhip effect can have (Oliver Grasl, 2015).

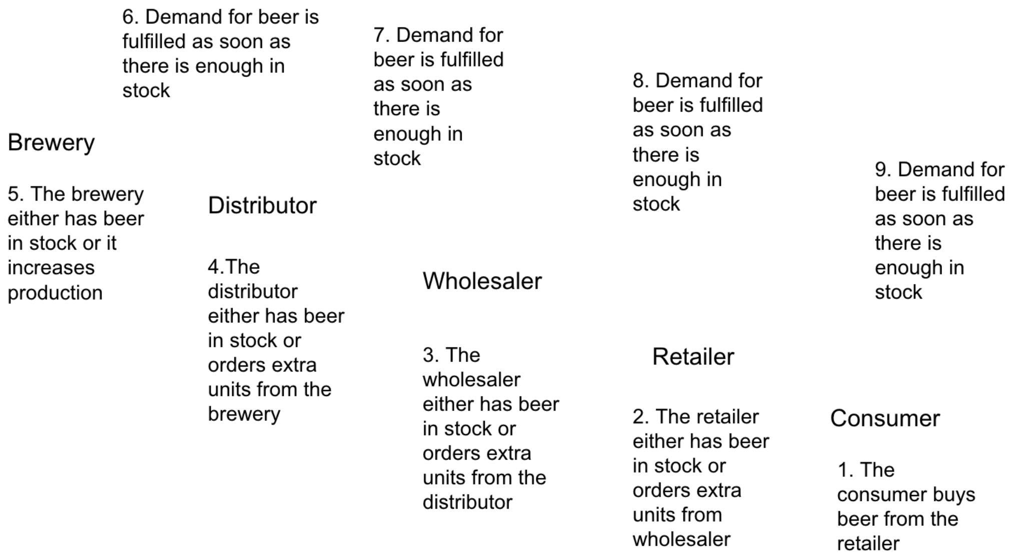

Figure 2, Understanding the Beer Distribution Game (Transentis, 2015)

Many of the effects of the bullwhip effect are the result of difficulties between coordinating flows within a supply chain as demonstrated in the *Beer distribution game*. The difficulties in flow management are also exuberated by rigidity in inventory and capacity limitations within each level of the supply chain (Sahin & Robinson, 2002). Bullwhip effect can also occur in any point of the supply chain and move into any direction that the variability of demand has implications on. This suggests that more fragmented they are, they become also more vulnerable to bullwhip effects (Boute et al., 2011). However, by sharing customer demand information vertically in supply chain, the severity of bullwhip effect can be reduced. (Chen et al., 2000). To tackle the issues that arise from the bullwhip effect, we can come back to the definition of supply chain in which there are resources and flows. Every independently operating resource must understand the flows that are coming through the supply chain in any given time to optimize their efficiency and in doing so improving the efficiency of the whole supply chain.

2.3 Complexity of supply chains

Expanding supply chains into global supply chains, the international environment hosts plethora of uncertainties that effect the supply chain. To combat this firms, need to react quickly to changes. Many of these attempts to increase agility often led to increases in complexity which hinders the agility of an organization (Prater et al., 2001).

Supply chains can be broken into three different layers of complexity with different drivers. Operational supply chain complexity (OSCC), Downstream supply chain complexity (DSCC) and External supply chain complexity (ESCC). These layers express all complexities that can be found within the supply chain or outside of it. As the level of complexity is continually rising because of the geopolitical tensions, trade wars and changing regulations the burden is taking a toll on the efficiency of supply chains (Chand et al., 2020).

Complexity drivers for supply chains are also amplified during times of economic uncertainty (Prater et al., 2001). This has been shown to be true on a macro level during the 2008 financial crisis in developed economies and in emerging economies like China in 2015. This macroeconomic volatility in supply and demand is also made more volatile because upstream supply is also hindered due to reduced production or bankruptcies which leads to more volatility in supply chains (Boute et al., 2011).

Uncertainty causes more demand fluctuation thus leading to more severe bullwhip effects and the more global a supply chain is the more complexity drivers can cause uncertainty that affects it thus making the fluctuations more severe and the supply chain more fragile in general. (Boute et al., 2011) The risk is more prevalent the more a supply chain relies on a single contractor to produce a vital sub-component in the supply chain (Alvarado-Vargas & Kelley, 2020).

To control increased uncertainty and complexity more frequent and richer communication would create more responsiveness within the gestalt (Gereffi & Lee, 2012). Increasing communication can feasibly be done with technology and as uncertainty with demand forecasting is a significant reason for the bullwhip effect a new way of sharing information within the supply chain could help with these issues (Arora & Rahman, 2017).

2.4 Information flow

Forrester (1961) implies that the understanding of how industrial companies succeeds depends on the interaction between flows of information, materials, money, manpower and capital equipment. For the purposes of this thesis, it is worth taking a deeper look into the information flow, as it is the flow upon which blockchain applications for supply chains are built on.

As information sharing is mandatory to form a functioning supply chain, the level of importance that proper sharing of information and managing the information flow are crucial to the smooth functioning of the supply chain. This means that the management of information flow is mandatory (Badenhorst et al., 2013).

Even though it has been generally accepted that sharing information within a supply chain makes it perform more efficiently as supply chains that share information face less costs associated with inefficiencies in the system (Lee et al., 2004), the information flow strategy needs to consider the relational characteristics between each party and the business context to produce the wanted benefits (Vanpoucke et al., 2009).

Another problem that arises when discussing how to control information flow in supply chain is the fact that companies don't know the actors in their supply chain (Knut Alicke et al., 2021). What this means is that even if a company has sufficient strategy for information flow, the lack of visibility into the supply chain can render the efforts to solve bottlenecks obsolete (Helper & Soltas, 2021). The lack of visibility can be partly attributed to the fact that supply chain performance can be a critical competitive advantage for an organization (Collier & Sarkis, 2021) and to the deep-rooted distrust between parties in the supply chain as these parties' fear that the information could lead to them being replaced or used for bargaining a better price (Helper & Soltas, 2021).

In other cases, the information that comes out of the supply chain is just plain wrong, in Chile of the studied points of sale for salmon 23% of products were mislabeled and further 18% were misnamed (Prida et al., 2020).

To combat these shortcomings in the information flow within a supply chain it has been found that as trust in other parties in a supply chain increase, the risk decreases and as an addition high trust relationships within a supply chain are characterized by more open information sharing which increases the visibility for both parties within a supply chain (Fawcett et al., 2012).

Other approach that can be applied is the application of systems that use trustless technology such as blockchain. Blockchains can also be viewed as a system of distributed trust as the integrity of the system is not in the hands of a single entity but rather it is distributed between all actors within a system (Collier & Sarkis, 2021). Speculations of the consequences that implementation of blockchain and trustless systems into the supply chain include dramatic implications into the buyer-supplier relationship (Saberi et al., 2019).

With the mismanagement of information that occurs in supply chains and the inherent lack of trust in supply chains, trustless systems can offer new solutions and enhance the efficiency in supply chains as each resource in the supply chain can trust the information flow that is presented to them and act in the most efficient manner.

3 BLOCKCHAIN

In this second content chapter blockchain is examined, first on a more general note while trying to form a comprehensive definition and then in more technical detail. The aim of this chapter is to prepare the reader with needed knowledge of blockchain technology and its functioning in order to better understand how blockchain can enable transparency and reliability of information within supply chains.

3.1 Basics of blockchain

During the 2008 financial crisis as the world experienced financial collapses based on bad debt and even worse administration (Hughes et al., 2019) the founding article of blockchain by Nakamoto *Bitcoin: A Peer-To-Peer Electronic Cash System* (2008) was published. The paper is based on an idea that the current financial system which is laid on the foundation of trust is inadequate as it demands a third-party who must be trusted by all the parties that take part in a transaction (Nakamoto, 2008) and as such blockchain is most applicable in systems where there is currently a need for a trusted third party (Nofer et al., 2017).

One of the most widely accepted definitions of blockchain is a distributed public ledger (Kim & Laskowski, 2018). To understand where this definition stems from the inner workings of blockchain can be studied deeper. A blockchain consists of pieces of information, or blocks, which form a chronologically linear chain that is tracked in a public ledger that is shared with all the participants in the peer-to-peer network that the blockchain runs on (Hughes et al., 2019).

Other notion that is also made of blockchains is that they are a new way of combining multiple computing paradigms that were invented prior and this can be seen in the usage of hashing algorithms and private and public software keys which have existed for decades (Hughes et al., 2019). This usage of prior technologies in a novel manner brings forth another definition of blockchain technology which is defined by Mougayar (2016) as a *metatechnology* which means a technology that is comprised of multiple other technologies. As these two definitions do not contradict each other they can be thought of as an extension of each other. The expanded definition of blockchain can then be thought to encompass the metatechnological aspect as well as the functional aspect and thus the expanded definition for blockchain that is used in this research is a distributed ledger that is built on novel usage of prior technological innovations.

3.2 Technical aspects of blockchain

To be technically more precise of the functioning of blockchain they can be thought of as cryptographically secured peer-to-peer distributed networks to which new information can be appended only and only updatable through peer consensus (Bashir, 2017). When new information is logged into the blockchain it is done in blocks which contain the new information. These blocks also contain a hash which locks the block in its place in the blockchain (Laurence, 2019). In the original blockchain proposed by Nakamoto (2008) each electronic coin is defined to be a chain of digital signatures and as ownership is transferred the seller signs the hash of the previous transaction and the public key of the next owner and adds these to the end of the coin. This is also the basic principle of adding any kind of information into the blockchain and as such a transaction can be thought of as appending a piece of information into the chain. As a new block of information is appended into the blockchain it contains an immutable timestamp and this provides a proof of what has happened previously and as each block references the block prior to it, as is shown in figure 3, this makes the blockchain tamper resistant as each block is validated by prior blocks (Hughes et al., 2019). In figure 3 it is visually shown how the timestamp is used to validate the validity of the appended block.

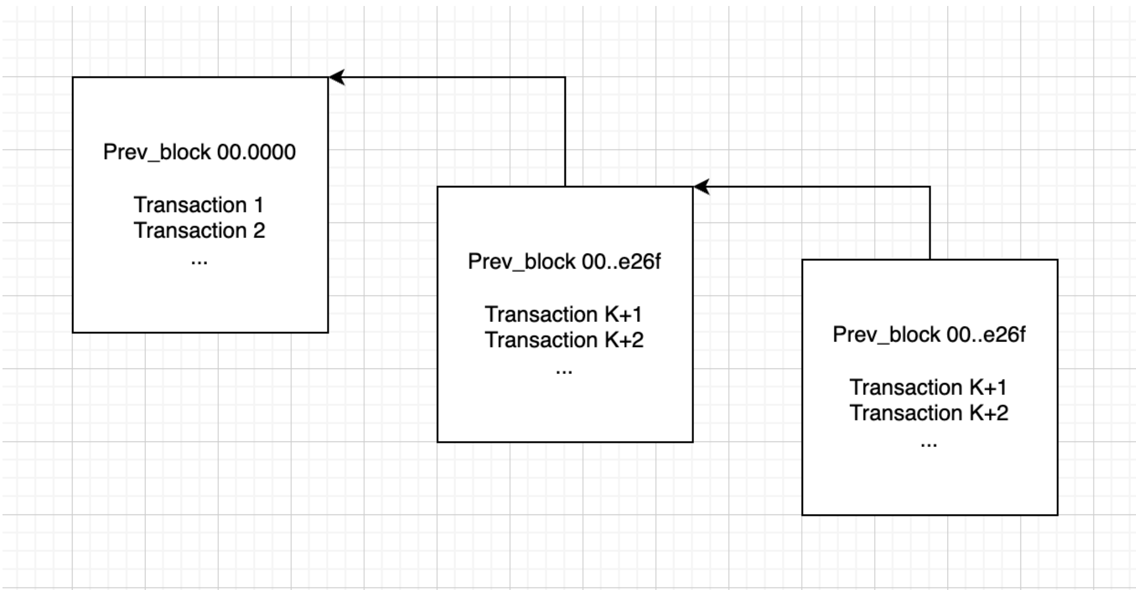

Figure 3, Bitcoin blockchain in Ada: Lady Ada meets Satoshi Nakamoto (Kanig, 2018)

After the information has been appended to blockchain the verification and management of that data is given to automation and shared governance protocols (Swan, 2015). The verification is done by all the nodes, users, in the network and each node contains the complete ledger and no single node controls the data but rather the control is divided between all participants and then validated by all (Wang et al., 2019). When a new block is tried to be appended into the blockchain or a block is tried to be edited majority of the nodes need to process algorithms to verify the history of the proposed block and if most of the nodes come to an agreement of the new block being valid, then the new block is accepted into the chain, this is called the consensus mechanism (Laurence, 2019). This distributed validation and governance model gives blockchain key attributes that can be summarized as (Yli-Huumo et al., 2016; Iansiti & Lakhani, 2017):

- Disintermediation by proposing a peer-to-peer solution and thus reducing reliance on third parties.
- Transparency with pseudonymity as the information within a blockchain is viewable by all participants and cannot be mutilated by a single entity. Users can preserve their anonymity within a blockchain but can provide proof of their identity if needed.
- Security is provided by deploying various approaches to ensure the permanent nature of the records, chronological order, and availability to all users.
- Automation provides transparent and efficient ways to complete transactions when certain conditions are met. This also enables adoption of smart contracts, computerized transaction protocols which activate when their conditions are met, within a blockchain.

Blockchains can be divided into two different groups based on the access control mechanism associated with it. Public blockchains are permissionless protocols in that anyone can access them. The other group consists of permissioned blockchains which require in invitation or another way of validating permission to access these blockchains, access to these blockchains is usually controlled by a consortium or a single entity (Wang et al., 2019). Distributed ledgers are also not reliant upon a single entity to uphold the system. In the event that some of the nodes break down the blockchains functionalities are still intact and as such the users don't need to assess the trustworthiness of an intermediary but can rather trust the system as a whole (Nofer et al., 2017). Even though distributed databases have been thoroughly researched for decades (Lake & Crowther, 2013) trusted databases suffer data loss and inconsistencies in writing and reading due to various shortcomings (Hughes et al., 2019). Blockchains have addressed this issue by artificially making an artificial rate limit on how much data can be ran through its consensus algorithms. Put in another way blockchain is designed in a way that requires the user that wishes to append information to spend time and resources to solve a mathematical function before the information can be appended. This limits the rate of writes on the database but there are less inconsistencies in reads and writes (Hughes et al., 2019).

4 IMPLEMENTATION OF BLOCKCHAIN INTO SUPPLY CHAINS

In this chapter the ways in which blockchain implementation into supply chains can increase reliability of information and transparency within supply chains is discussed. The chapter also briefly covers challenges and critical success factors that should be considered when implementing blockchain in order to reap the benefits that can be obtained from it. Towards the end real life examples of blockchain implementation are brought forward.

4.1 Blockchain implementation into supply chains

Blockchain being a technology means that it needs to be implemented successfully to realise the benefits, increased transparency and more reliable data, that it proposes. In this chapter some of the challenges and critical success factors that are being perceived in literature are presented and briefly looked at. The implementation of blockchain faces challenges and Wang et al., (2019) interviewed 14 industry professionals about the implementation of blockchain into supply chains. Table 1 shows most mentioned challenges that blockchain implementation faces according to these professionals.

Table 1, Perceived challenges of blockchain usage in supply chains (Wang et al., 2019)

Perceived challenges of blockchain usage in supply chains	Number of entries by experts
Confidence and related necessity issues	7
Cultural, procedural, governance and collaboration issues	10
Data input and information sharing issues	8
Technological and network interoperability issues	9
Cost, privacy, legal and security issues	10

These problems effect the whole supply chain as a whole and are not industry specific which makes tackling them rather important when conducting blockchain implementation into supply chains. These implementation challenges are nothing new to IT and as blockchain is a database in which data can be shared, other database implementations, i.e. ERP systems, can be found to have similar struggles as blockchain implementation. To combat these changes organizations can adopt pre-adoption processes to make better sense of the decisions that they are making regarding technological decisions that have tangible but unpredictable effects (Weick et al., 2005). Of the perceived challenges that are presented in Table 1, the focus will be on technological aspects and technological hurdles related to transparency and reliability of data that blockchain implementation faces. Even though each block of data that is being put into the blockchain network is validated prior to appending (Nofer et al., 2017) the data can be manipulated with when it is being added into the block (Hastig & Sodhi, 2020). This poses problems as guidelines and processes don't follow the same standards across the global supply chains which opens the door for fraudulent actors (Hastig & Sodhi, 2020).

Even though supply chains are complex, and each novel supply chain is different from the one before it Hastig & Sodhi (2020) have proposed critical success factor themes and sub-themes that were inferred from their thematic analysis. These themes and sub-themes can be seen in Figure 4.

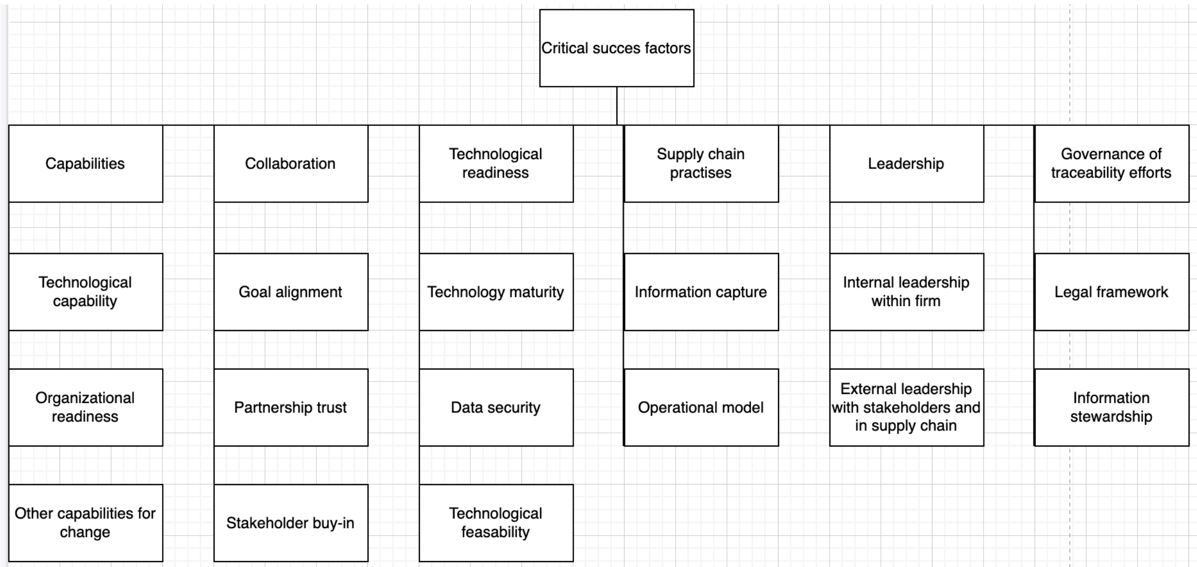

Figure 4, Critical Success Factor Themes and Sub-Themes, as Inferred from Thematic Analysis (Hastig & Sodhi, 2020)

To further understand how blockchain adoption into supply chains can be done successfully further examination of the themes and sub-themes proposed by Hastig & Sodhi (2020) in Figure 4. Sufficient understanding of these critical success factors can have a positive impact in the successfulness of blockchain implementation.

Capability can be defined as the competence that a company has to complete a certain objective (Baruffaldi & Sternberg, 2018) and the lack of technical capability is a hinderance to many blockchain implementations that could improve traceability (Kaushik & Jain, 2021).

As a supply chain consists of multiple actors in different layers with flows that connect them, collaboration is required in order to successfully implement blockchain into a complex supply chain (Kim & Laskowski, 2017). The skepticism that supply chain partners possess is also a threat to the adoption of traceability measures (Britchenko & Polishchuk, 2018) and as such supply chain partners need to agree upon standards of what is recorded, where and how (Chow, 2018.).

Currently the technological readiness of blockchain is still not very robust and it possesses shortcomings that more mature technologies don't possess (Zheng et al., 2017). Blockchain is also only a technology and as such each implementation needs to be thought through and if it is even feasible in some instances (Tseng et al., 2018).

The practices within supply chains are not standardized and as such data structures may also differ between parties (Francisco & Swanson, 2018) and without implementing a standardizing effort as a solution this hinders the capabilities of interoperable traceability systems (Mattila et al., 2016). If multiple traceability systems emerge without a standardization process in the same industry, some suppliers may refuse to implement any solutions (Hastig & Sodhi, 2020).

Companies implement blockchain solutions more if there is leadership buy-in already present in the industry that they are operating in (Petersen et al., 2018) this could lead to companies needing to take a leadership role and engage with their supply chain to implement blockchain solutions in a successful manner (Bateman, 2015).

Petersen et al., (2018) conducted a survey of 155 supply chain experts and 56% of respondents view "regulatory uncertainty" as the biggest hurdle for blockchain adoption. Existing laws and regulations are insufficient to regulate cryptographic activities with a review of current legislature being needed in the future (Badzar, 2016). The general implementation of blockchain networks into supply chain require careful study of critical success factors and challenges that arise from them, and these principles need to be looked at when implementing blockchain solutions to every participant in a supply chain but also when looking at the supply chain from systems view and planning the implementation process into the whole supply chain. If each of these critical success factors is considered and handled in a convincing manner, the project has a higher likelihood of successful completion (Hastig & Sodhi, 2020). Without the implementation of the complementing strategies and technologies companies cannot fully exploit the capabilities that blockchain technology offers regarding increased transparency and reliability of information (Min, 2019). As with all novel technologies that are implemented into existing systems the critical success factors and difficulties need to be accounted for in order to have a successful implementation which enables the exploitation of benefits that the technology possesses. By failing at implementation none of the benefits can be realised as the new technology will not be utilised.

4.2 Blockchain enabled increase in transparency and reliability of data

As supply chains consists of flows that connect individual resources to produce and transport commodities the implementation of blockchain into the supply chain can be thought of in two different layers: the supply chain as a whole and each individual user as a separate entity. The importance of transparency and reliable information in food related supply chains is of great importance as adulteration incidents and other forms of food safety related infringements are regularly discovered (Katsikouli et al., 2021). An issue that arises from the fact that supply chains were not designed with visibility in mind is the fact that the original design emphasises the efficient conversion of resources into the final product thus making the implementation of supply chain transparency costly (Kamble et al., 2020).

At the current state of transparency into supply chains only two percent of companies have visibility beyond the second layer of suppliers (Knut Alicke et al., 2021) when this fact is coupled with Porters (1985) idea of a system and the lack of transparency within supply chains becomes apparent very quickly which then can lead into uncertainty between actors and amplify the bullwhip effect (Alvarado-Vargas & Kelley, 2020). As supply chains are coupled with the idea of them being contributors to the competitive advantage of companies (Collier & Sarkis, 2021) and participants being afraid of being replaced if information of their business comes available to other participants within a supply chain (Helper & Soltas, 2021) and according to Vanpoucke et al., (2009) in order to form efficient information flow within a supply chain the relational characteristics between each participant need to be understood. This understanding can be applied in blockchains can be built in different ways regarding who can become a user and permissioned blockchains only permit chosen users to join (Wang et al., 2019). This reduces the number of participants that can access information stored in the network and coupled with the capability of remaining pseudonymous, only the public key of the user is visible to other participants and as this is generated randomly a user cannot be identified by only knowing their public key, information can be shared without explicitly exposing anyone (Yli-Huumo et al., 2016; Iansiti & Lakhani, 2017). Gaur & Gaiha, (2020) also claim that by understanding what is important to other actors within the supply chain, not relevant information such as purchases, and payments which some companies might want to keep to themselves, can be stored in a separate database thus encouraging companies that are afraid of sharing competitive data to participate in sharing information. This would help with the findings of Helper & Soltas (2021) that the lack of visibility into the supply chains render efforts to resolve bottlenecks within a supply chain. To put simply blockchain can enable businesses to share information in a way that increases their efficiency and profitability.

The reliability of data in blockchain is also increased by the design of the distributed ledger. As each block needs to have a consensus made of it being appended before it is appended (Laurence, 2019) it means that fraudulent would need to possess more processing power within the network than honest actors in order to insert not-valid blocks of information into the system (Nakamoto 2008). Other attributes that blockchain has making third parties obsolete, having a strong emphasis on security and automation capabilities that are visible to all participants (Yli-Huumo et al., 2016; Iansiti & Lakhani, 2017) increase reliability of information by reducing reliance on single actors to validate actions that are taken within a supply chain. This means that trust can be laid upon the whole system and all participants without having absolute trust in single actors (Nofer et al., 2017) as when data is added to the network the verification and management of that data is given to a automated protocol that has transparent rules for all participants to see (Swan, 2015). The design of blockchain makes it also more capable of providing more consistent reads and writes of the database. As blockchains have a built-in rate limiter by requiring a more significant amount of resources and time to be expended in order to write something than a regular shared database would (Hughes et al., 2019). The limiter makes the reads and writes more constant, thus increasing reliability of information, by simply limiting the number of writes and reads it needs to execute.

One significant challenge that is brought forward by Hastig & Sodhi (2020) is that even though blockchain ledgers are tamper resistant (Nakamoto 2008) and as such the validity of each data block within it can be verified thus increasing the reliability of the data, the information that is being put into these blocks of information need to be validated as well (Hastig & Sodhi, 2020). According to the work of Min (2019) to increase the reliability of data to its fullest extent that blockchain technology can increase it, complementing technologies need to be put into place. As Montecchi et al., (2019) state of IoT usage being one way of solving the problem of what information is being added into blocks of data that are tried to be appended into the blockchain. By creating a standard of how different data should be gathered to increase the reliability of data that is being appended into the blockchain some of the challenges and critical success factors could be tackled as well while increasing transparency.

4.3 Current implementations of blockchain into supply chain

The current state of blockchain adoption into supply chains is still rather immature. Even though especially since 2017 the number of research papers published has increased tremendously, the tangible implementations into supply chains have not been very well researched. In this chapter some of the current use-cases and implementations of blockchain into supply chains are studied and reasoning for the lack of studies relating to current implementations. To understand how blockchain has been used to improve traceability and reliability of information within a supply chain, it is important to understand how it has been applied in different layers of the supply chain. Food related supply chain was chosen as the focus as it has been one of the industries that have real-life applications of blockchain enabled transparency solutions (Mearian, 2018) and these supply chains being unique in that most food products are perishable which exuberates the need for transparency and reliable information. (Lakkakula et al., 2020).

The importance of food related transparency has been noticed by corporations such as Walmart and Carrefour who have partnered with IBM to produce IBM food trust ledger – which enables supply chain partners to distribute data to other participants as well (Mearian, 2018). The four layers of users chosen to be examined further are producers, commodity traders, transporters, and vendors. The layers were chosen based on the work of Lakkakula et al., (2020) who proposed a typical flow of grain to domestic and international markets as shown in Figure 5. The figure is made from the perspective of a commodity trader and three different groups of actors can be found in it: producers, transporters, and vendors. As the flowchart is representative of an agricultural commodity that requires little to no processing to reach the global markets, this can be thought to be a basis for supply chains that produce food related end-products that require more processing, and these processes can be included within the flowchart by adding more layers into it, but these four basic layers are still found within these more complex supply chains as well.

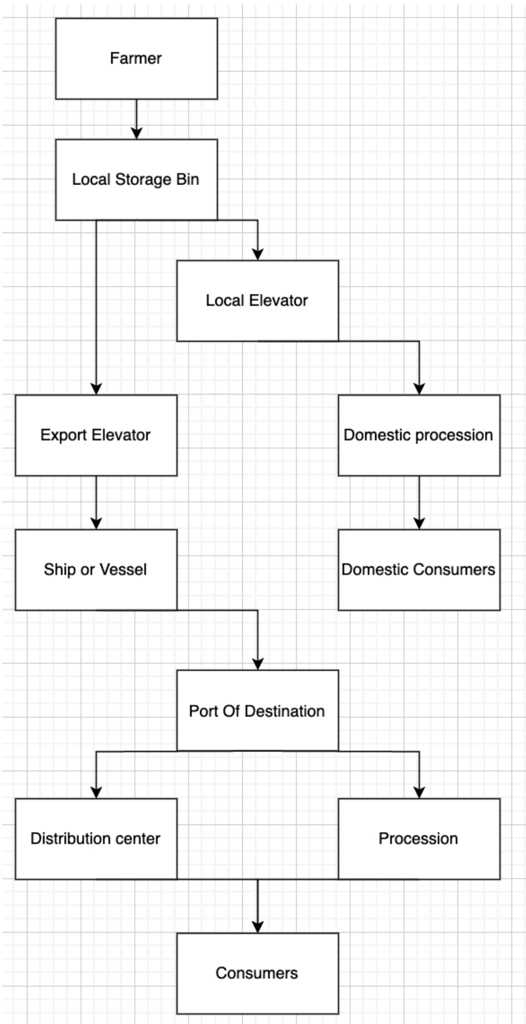

Figure 5, Typical flow of grain to domestic and international markets. (Lakkakula et al., 2020)

To emphasize the importance of transparency into food related supply chains the 2015 E. coli outbreak at Chipotle Mexican Grill outlets can be examinded. As Chipotle relies on complex supply chains with multiple actors the supply chain contains a severe lack of transparency and accountability which resulted Chipotle in not being able to monitor their suppliers in real time and as such containing the outbreak or preventing the contamination outright was impossible (Casey & Wong, 2017).

Many applications that are proposed to increase transparency and reliability of information in the agricultural sectors producers include the usage of complementary technologies such as IoT devices to track what is being done (Fortuna & Risso, 2019) and RFID tags to ensure that the data corresponds to the crops it is supposed to (Sander et al., 2018). Another complementing technology to combat blind spots that has been proposed is artificial intelligence which when implemented with blockchain has been stated to increase product traceability (Chen, 2018). Another technology that has been thought to fully help realize the value addition of blockchain is IoT. The granularity and information that has been stated to come from IoT and blockchain technologies has birthed companies that provide transparency services, tracking and provenance of everyday goods (Montecchi et al., 2019). As blockchain is merely a way to store and distribute information, a database, the full extent of the benefits that blockchain possesses can be accessed when blockchain is accompanied with complementing technologies. The applications for blockchain that have been proposed in operations and supply chain management literature tend to work well with cutting edge technologies (Wamba & Queiroz, 2020) and further research tends to point out that blockchain can be accompanied with artificial intelligence (Dwivedi et al., 2021), big data (Chae, 2019) and IoT (Kshetri, 2018

Antonucci et al., (2019) studied how blockchain has been implemented in agri-food sector and found examples of blockchain implementations that can be applied into the supply chain present in Figure 5. The first is the platform that was studied by Lucena et al., (2018) where they enabled better communication between parties within the Brazilian agricultural exports. The value that their blockchain automation gave was that it gave every participant a full view into the quality assurance network and improved the reliability of the data that was stored there. This was the only research enabled solution that they examined and further commercial applications with their respective commodities can be found in table 2. At the current stage agricultural supply chains have been made more transparent by showing where the product has been produced and handled (Fortuna & Risso, 2019). Fortuna & Risso (2019) propose horizontal collaboration between resources in a supply chain to combat the barriers that hinder the current capabilities of producers in agricultural supply chains to employ blockchain based solutions for transparency to their full extent. Collaboration efforts would increase producers' capabilities and other critical success factor completions, shown in figure 4, to aid in the successful implementation of blockchain into the source of the supply chain.

Table 2, Blockchain commercial applications in the agri-food supply chain. (Antonucci et al., 2019)

Food	Aim
Coffee	To accompany coffee with reliable unmodifiable documentation and guarantee of absolute transparency from the plantation to the coffee cup
Fish	To track caught fish with verified socieal sustainability claims from the sea to the tuna cans
Beef	To develop and implement blockchain-based technologies into their supply chains to eliminate food fraud
Beer	DOWNSTREAM beer is now the first beer product using blockchain technology in order to reveal info about ingredients and brewing methods
Bio and DOCG	To guarantee traceability in the whole agri food- chain [for bio and DOCG (Designation of Origin Controller and Guaranteed) products]
Beef (pork)	To guarantee brand protection and security
Fresh food	Information on product origin including sensor data permitting data transparency transferring this from farm to farm
Mil	To tackle food fraud in the dairy supply chain automating the acquisition and the registration of information
Pasta	To identify the whole supply chain (i.e manufacturer, products and flours used, type of drying, transport)

Moving up the supply chain the next applications can be found in the transport sector and those leading the way are Maersk with their blockchain solution to track containers and vital information of the conditions that it has (Jackson, 2017). UPS and Walmart have also tested with their own blockchain applications (Lehmacher & Mcwaters, 2017.). Other notable retailer to experiment with blockchain applications to improve traceability and reliability of information regarding products is JD which plans to better traceability of their frozen meats (Huang, 2017).

Another set of real-world implementations of blockchain int supply chains that fit into the model presented by Lakkakula et al., (2020) we can look to the research of Gaur & Gaiha, (2020) who examined seven major U.S companies which are on the leading edge of supply chain management and are studying the implementation of blockchain into supply chains. Two of these companies wished to remain anonymous but the ones that agreed to get identified were: Corning, Emerson, Hayward, IBM and Mastercard. In their study a large pharmaceutics company applied blockchain to adhere to legislation that required them to follow drugs journey to combat fraud and counterfeit drugs. The drugs were tagged using electrical product codes and then followed through the supply chain. IBM also utilizes their blockchain solution the Foodtrust to ensure the transparency and reliability of information of goods that flow through supply chains utilizing this system. Walmart uses IBM: s solution to track their fresh food and fresh produce. Emerson has utilized blockchain to increase transparency to increase efficiency through more complete visibility into the supply chain. Vitasek et al., (2022) studied how Walmart Canada uses blockchain. and discovered that Walmarts DL platform which is used by 70 carriers automatically contains data related to transportation and payments making it visible to participants that interact with the transport to increase transparency and make the process less prone to disputes during processes. Gligor et al., (2022) studied how a blockchain startup implemented blockchain into a coffee producers supply chain. The perceived benefits that were gained from the implementation was the reliability of artisanship that is present in the way that the coffee is produced by documenting the coffees journey. They also state that their study of a singular implementation is significant and important as only a handful of such research papers of implementations were done prior to their work

Current studies that are done of real-world applications of blockchain into supply chains need to contend with the fact that supply chains are viewed as a way to gain competitive advantage (Collier & Sarkis, 2021). This means that as companies produce more efficient ways for traceability and reliability of information these solutions are viewed as critical for the supply chain (Shankar et al., 2018). This is coupled with the fact efforts to utilize blockchain and new sensors require significant capital investment (Fortuna & Risso, 2019) which can lead to even more willingness to remain secretive as the benefits that come from capital expenditure into solving the implementation want to be preserved to the company itself. This secrecy is can also be found in the study of Gaur & Gaiha, (2020) where out of seven companies two wanted to remain unnamed. That means that out of the major players in the industry over 28% wish to remain anonymous when talking of how they have implemented blockchain into supply chains.

This could lead to the conclusion that the reason for limited research is the fact that companies see blockchain enabled solutions to be significant contributors to their competitiveness and wish to exploit their advantage rather than make information of it public.

5 SUMMARY AND CONCLUSIONS

5.1 Summary

The purpose of this study was to find out how blockchain can enable increased transparency and reliability of information of supply chains. The study was conducted as a literature review, and it answered two research questions:

- How blockchain can increase transparency in supply chains?
- How blockchain can increase the reliability of information within supply chains?

Material that was used in this thesis was mainly sourced from JYKDOK and Google Scholar with some supplementing non-scientific sources found from the internet. The scientific research that was used in this thesis is peer-reviewed or is used as a source in peer-reviewed research. Almost all non-scientific source material has also been cited in peer-reviewed research. The journals that the material was sourced did mostly have a Jufo ranking of 1 or 0 thus hindering the reliability of a single source. It also must be said that even though the trustworthiness of a single source is not great, the sources mostly have the same conclusions and thus could be considered, at least in the sample of sources present in this thesis, the predominant view of their respective topic. Most of the sources are rather new which in turn reduces the number of citations that could have been made of them and as such some of the sources are not widely citated. Material was sourced from JYKDOK database with multiple different searches and terms including the following or combinations of these: 'blockchain', 'supply chain', 'increasing transparency', 'blockchain enabled transparency in supply chains' and 'blockchain implementation into supply chains. The sourcing started with individual search terms and more complex searches were formed when the less complex searches were not able to find material that discussed aspects of the topics that were included in this thesis. Sources were also sourced from peer-reviewed research papers. Research was chosen as a source if it had a relevant remark of the topic that was discussed and if possible, the remark had been cited in peer-reviewed research. Remarks that were not cited in peer-reviewed research were also used in situations where a previously cited remark was not found in a reasonable time frame and as such increasing discretion in the process of choosing sources.

The research in itself is not very replicable as discretion was used in the process of finding sufficient research material but the findings that were made from the research material follow the same guidelines as much of the literature that has come prior. The relative novelty of the research also hinders the reliability of each source as there has been rather lot of research conducted within the last five years and as such individual research initiatives have not faced as much scrutiny as more mature fields have expressed on prior research. Some of the complimentary sources that were used were also relied upon when making claims in this thesis which can have the effect of making the claims less academically robust. This thesis was also constrained in its ability to present a very in-depth view of current blockchain implementations due to the current lack of research surrounding real world applications. The applicability of the results on the benefits that blockchain could bring regarding increases in transparency and reliability of information is also constrained as the implementation takes considerable resources and collaboration within a supply chain.

The research started with trying to conclude definitions for the two main terms that were used: supply chains and blockchain Two opposing views of how supply chains are defined were brought forward, (Vanpoucke et al, 2009) who emphasized flows that come through the whole system and a definition that emphasises different actors within a supply chain as proposed by Avetta LLC., (2021). Out of these a combining definition of supply chains being a network of resources with flows of information, financials and goods used to manufacture and distribute a commodity. Blockchains are defined as distributed public ledgers (Kim & Laskowski, 2018) and metatechnologies (Mougayar, 2016) meaning that they are not novel inventions but rather a new way of combining existing technologies to create a distributed public ledger.

After defining supply chain, the work of Forrester (1961) and the bullwhip effect is presented. Bullwhip effect demonstrates the fact that if an actor in the supply chain faces a demand disruption the severity of the disruption increases as we move away from the initial actor that faced the disruption (Forrester, 1961). This effect increases the more uncertainty is associated with it (Boute et al., 2011). One possibly way to decrease the bullwhip effect is richer communication between parties in a supply chain (Gereffi & Lee, 2012) and this could be feasibly done with implementing new technologies that could increase transparency within a supply chain to ease demand forecasting (Arora & Rahman, 2017). With blockchain being a peer-to-peer distributed ledger (Nakamoto, 2008), it can be thought of as a new technology that could ease the shortcomings of current information sharing practises.

The technical aspects of blockchain were then explored starting with the fact that blockchain is a temper resistant database because each block of new information needs to be validated by all blocks of information that are in the network prior to it (Hughes et al., 2019). The studies of Yli-Huumo et al., (2016) and Iansiti & Lakhani (2017) proposed three advantages that blockchains have over traditional shared ledgers: disintermediation, automation, security, and pseudonymity with transparency. The disintermediation of trusted third parties happens because each block that is being added needs to go through a consensus mechanism during which the majority of nodes connected to the network need to agree that the new block is added thus reducing the control that a singular entity can have on the network (Laurence, 2019). Once the data is added into the network the verification and management are transferred to a set of rules and automations that can be viewed by the actors in the blockchain (Swan, 2015). This enables each actor to transparently see what will happen to their data and overall, in the blockchain thus mitigating the need for a trusted third party. The security of blockchain can be traced back to the research of Nakamoto (2008) who explains very thoroughly the security aspect upon which consequent blockchains have been built on. Pseudonymity with transparency provides blockchain with the ability to not identify each participant by their name but still provide important information to the blockchain.

In the third chapter the ways in which blockchain can enable increases in transparency and reliability of information and look at what needs to happen in order for these benefits to be exploited and what real-life examples there are. The findings of Hastig & Sodhi (2020) propose critical success factors for implementation of blockchain. These success factors can be looked at when implementing blockchain solutions as well as a list by Wang et al., (2019) that comprises perceived challenges of blockchain implementation. Even though this research doesn't focus on the implementation process, it is important to highlight the importance of successful implementation as blockchain is only a database and the benefits surrounding increased transparency and reliable information require successful implementation processes to be fully exploited as well as complementary technologies such as IoT (Min, 2019).

The basic value proposition of increased transparency is that because increased information sharing increases efficiency in supply chains (Lee et al., 2004) implementing technologies that can enable more transparency will increase efficiency thus increasing profit for actors involved. According to Vanpoucke et al., (2009) in order to form efficient information flow within a supply chain the relational characteristics between each participant need to be understood. This understanding can be applied in blockchains as the access protocols can be configured and permissioned blockchains only permit chosen users to join (Wang et al., 2019). This reduces the number of participants that can access information stored in the network and coupled with the capability of remaining pseudonymous even to all the actors within a supply chain can increase actors willingness to be transparent as supply chains are generally viewed as contributors to the competitive advantage of companies (Collier & Sarkis, 2021) and actors being afraid of being replaced if information of their business comes available to other participants within a supply chain (Helper & Soltas, 2021). With limiting the amount of contextual information that is being given around the information that is actually relevant to perform business functions, more information can be exchanged without infringing anyone's competitive advantage.

This research is concluded with a look into how blockchain has been implemented in real life examples mostly in the context of food related supply chains focus as it has been one of the industries that have real-life applications of blockchain enabled transparency solutions (Mearian, 2018). As stated by Min (2019) that to fully exploit the abilities that blockchain promises complimentary technologies need to be applied and applications in agricultural sectors producers include the usage of complementary technologies such as IoT devices to track what is being done (Fortuna & Risso, 2019) and RFID tags to ensure that the data corresponds to the crops it is supposed to (Sander et al., 2018). Gaur & Gaiha, (2020) examined seven major U.S companies which are on the leading edge of supply chain management and are studying the implementation of blockchain into supply chains and IBM was one of these with its Foodtrust – solution that tracks goods through supply chain and it also uses IoT to collect this data in order to facilitate better reliability of the data.

Another noteworthy thing to point out from Gaur & Gaiha's (2020) study was that two of the seven companies interviewed wished to remain anonymous and these were seven major companies. This could be attributed to the assumption that supply chains are viewed as a way to gain competitive advantage (Collier & Sarkis, 2021). This means that as companies produce more efficient ways for traceability and reliability of information these solutions are viewed as critical for the supply chain (Shankar et al., 2018). These could be some of the reasons why not more in detail studies of real-life examples of blockchains being implemented into supply chains are not around.

According to the research blockchain can in fact increase transparency within supply chains by offering a technology which has the technical capability to enable increased information sharing without compromising each actors needs for non-disclosed information. Blockchain can presumably also increase the reliability of information by having a requirement for consensus action to be taken before appending new information thus ensuring the validity of each appending and accompanied with a need to exhaust extensive resources, compared to traditional shared databases, for each write and read request making the writes and reads less prone to be inconsistent.

5.2 Conclusions

As currently supply chains lack transparency that could be thought to be required from an industry that is as important to the function of the modern society as supply chains. The value proposition that blockchains have in increasing transparency is the fact that it provides a way for companies to share information within a supply chain without compromising competitive advantages that they have. The fact that blockchain is also only a database model must also be pointed out and as such it can only act as a tool that enables other functions. Blockchain in itself is a way to increase reliability in the data as the data cannot be mutilated once it is appended into the network and the information needs to go through the consensus protocol thus ensuring that the majority of the nodes need to agree on the appending but to increase reliability of the data that is being appended complementary technologies, frameworks and standards need to be in place to ensure that the data is collected in a trustworthy manner.

The incentive of each company in a supply chain is to produce value to their shareholders and a way to increase profits is increased efficiency. If companies have previously deemed the risk/reward ratio of information sharing within supply chains not too enticing, blockchain can be configured in ways that protect users' information that is being deemed important for the companies' competitive advantage in its respective situation. This proposition of pseudonymous information sharing that is configured to not include all the information that is being produced can tip the risk/reward ratio in favour of increasing information sharing within a supply chain.

As the barrier to successfully implement blockchain solutions to supply chains is considerable due to capital, capability and stakeholder alignment requirements, major players within this space could boost the adoption of blockchain by making their own standards and procedures. Partnerships, horizontal or vertical, could be an effective way of increasing adoption rates in cases where individual actors' resources are not sufficient in implementing a solution by themselves. Increased collaboration, standards and stakeholder leadership could also have the potential of narrowing the number of different blockchain enabled solutions thus lowering the barriers for adoption by reducing the number of solutions in the market.

The main conclusion that can be drawn from the literature review is that as each actor's motive in a supply chain is to be profitable the adoption of a more transparent supply chain needs to be economically beneficial and blockchain as a technology can be a way for companies to increase information sharing with a way to control the possible economic risks associated with increased transparency.

This research didn't explore implementation challenges or critical success factors in depth but briefly covered them as a successful implementation is a necessity to reap the benefits that a technology has. It also must be pointed out that in order to have more transparency within a supply chain all actors must adhere to a common set of rules and standards. This along with other requirements demonstrate that blockchain implementation faces a lot of challenges before it is able to increase transparency and reliability of information within supply chains. Another topic that was only very briefly discussed were the real-life examples of blockchain implementation to increase transparency in supply chains. Future research around blockchain implementation could centre around these two topics as current research is mostly based on simulations, frameworks and theory and lacks case examples and studies of real-life implementations of blockchain into supply chains. This lack of studies of successful and failed implementations can probably be attributed to the lack of maturity with blockchain as a technology and the fact that companies are still seeing the implementations too valuable to be researched and published to the public but nevertheless with increased studies of real-life implementation the barriers for adoption of blockchain technology into supply chains could be lowered thus increasing adoption.

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