Blockchain-based Supply Chains
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Why are Sustainability Benefits not Realized?

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Abstract

The world is constantly evolving, becoming more digital and new technologies are being developed. One such technology is blockchain, which has gained popularity through the cryptocurrency Bitcoin. However, there is much more potential in this technology, for example within supply chains. With its immutable, secure and transparent nature, blockchain has the potential to revolutionize supply chain management. Nevertheless, blockchain-based supply chains have their raison d'être not only for efficiency reasons. Due to the above-mentioned attributes of this technology, it can also make a great contribution in terms of sustainability. The external pressure is growing and forces retailers to become more transparent and act more sustainably along supply chains. This pressure comes both from their own customers, who place an increasing value on sustainable and green products, but also from regulations and laws that oblige companies to operate more sustainably. Even though the advantages of blockchain-based supply chains are evident, the adoption of blockchain is still quite narrow and small-scaled. For this reason, this thesis examines to what extent and why a gap between claimed sustainability potentials and reality exists in supply chains.

A thorough literature review has been conducted which resulted in a capability framework, listing nine sustainability capabilities of blockchain and their associated benefits for sustainable supply chains. Further, six semi-structured interviews were held with experts and companies using or providing blockchain platforms. The findings demonstrate that the claimed sustainability potentials of blockchain platforms are not used to their fullest extent. Moreover, the analysis suggests that there are several barriers hindering the adoption of blockchain in supply chain management. The main bottleneck is found to be the resistance among lower-tier suppliers. This resistance is mainly due to the lack of external pressure, which is disproportionally weighted on retailers in the public eye. It is also due to technical difficulties, making it hard for less digitized companies to adopt blockchain. The analysis results in a number of possible solutions to mitigate inter-organizational issues, where the recommendation is to work collaboratively with suppliers and incentivize adoption by demonstrating efficiency gains and sharing benefits. Through providing the findings and analysis, this research contributes to the literature and practical field by shedding light on the difficulties of making full use of blockchain-based supply chains. Furthermore, this thesis guides future research towards the most essential barrier that needs to be overcome.

Key words:
Blockchain, Supply Chain, Sustainability, Transparency, Traceability, Technology Adoption

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Word Definitions:

Blockchain platform**:** A cloud-based infrastructure solution provided by a third-party where companies can build, operate, and use their applications. It is often referred to as Blockchain-as-a-Service (BaaS) but is based on the same model as a Software-as-a-Service (SaaS).

Blockchain capability**:** Referring to the technological capability of blockchain to improve the performance of a company. Thus, 'technological capability' should not be interpreted as the organizations' capability of developing new technologies.

Organization, company, business: Are all used interchangeably throughout the text.

Chasm vs gap: Both are referring to an adoption gap. However, when using the word 'chasm', it is related to theory. The word 'gap' on the other hand refers to the findings of this study.

1 Introduction

The introductory chapter puts the topic in its background context as well as motivates the relevance of the study. The background section stresses the importance of transparency and sustainability, and how blockchain technology matches the needs. Further, this chapter includes a problem definition and the purpose of the research as well. Lastly, delimitations and the disposition of the study are presented.

1.1 Background

1.1.1 Supply Chain Transparency

Global supply chains grow larger and more complex, while at the same time consumers demand transparency regarding the sustainability of the products they purchase. Thereby, it becomes increasingly important but also challenging for companies to measure their processes in terms of sustainability, as well as being able to disclose this information to the end consumers (Venkatesh et al., 2020; Saberi et al., 2019). However, the pressure stems not only from consumers but also from governments and communities which demand sustainability to an increasing extent, such as contribution to the UN Sustainable Development Goals (Park & Li, 2021).

The importance of achieving sustainable supply chains is highlighted by the United States Environmental Protection Agency (EPA, 2016), who states that supply chain activities account for 40-60% of a manufacturing, and 80% of a non-manufacturing company’s carbon footprint. Hence, it is critical to take measures to ensure that activities are improved in a sustainability perspective. Several bad practices have been revealed in the past, of which one example is the Volkswagen emissions scandal, where lab tests and road tests showed large differences of the emitted pollutants (Siano et al., 2017). Such incidents raise awareness of issues regarding controlling, monitoring, and auditing supplier activities (Venkatesh et al., 2020). What supply chains often lack is an efficient way of tracking and tracing products as well as process information and characteristics. Hence, traceability is becoming a critical differentiator across supply chain industries (Saberi et al., 2019). Venkatesh et al. (2020) highlight that supply chain management has become increasingly strategic due to scandals and incidents across industries that have occurred in the past decade. In addition, meeting sustainability criteria and certifications by verifying products and processes is also something that has grown increasingly important over the years (Saberi et al., 2019). Saberi et al. (2019) confront whether current supply chain information systems are robust and trustworthy enough to manage this.

McGrath et al. (2021) argue in the same direction that global supply chains are now spanning across the globe in an ever-increasing dimension, while large multinational corporations (MNC) are ethically responsible for the whole supply chain. As these supply chains are hard to control and monitor, the MNCs bear a large responsibility and also a risk (Villena & Gioia, 2020). Thus, Mc Grath et al. (2021) state: “Managers now need improved transparency around supplier sustainability practices and processes to better manage these risks…” (p.68). This information has been concerned with quality and quantity amongst other basic measures, but has shifted towards indicators such as water and energy usage, waste management, as well as recycling activities (McGrath et al., 2021).

1.1.2 How Blockchain Matches the Need

With these aforementioned issues in mind, it becomes apparent that measures need to be taken to ensure that supply chain management practices meet the demand of trusted and transparent data. Furthermore, the dynamic relationship between businesses and the environment requires a system that collects real-time data across supply chain partners (Park & Li, 2021). This is where blockchain comes into play, as it offers immutable, distributed, and transparent data. The issues and demands on current supply chain management processes match very well with the characteristics and capabilities of blockchain, which is why companies now have started using this technology in supply chains (Saberi et al., 2019). Apart from improving efficiency, reducing costs and complexity, blockchain has an impact on the sustainability performance of supply chain processes (Kshetri, 2018). European Parliamentary Research Service (EPRS, 2020) highlights the importance of transparency that blockchain brings, as the technology increases the responsibility of each supplier, shifting the accountability from the large MNC and distributing it over all tiers of the supply chain. Furthermore, the transparency capability of blockchain matches very well with the fact that today’s consumers, and especially generation Z, are paying attention to what large MNCs do, how they produce, and how seriously they take the issue of sustainability. This generation is more willing to pay a higher price for sustainability, if they trust that the purchase is as green as it says (Ghosh, 2022).

Another crucial point is that the European Commission plans to set new regulations in their Product Environmental Footprint (PEF) program, which aims at forcing businesses to take responsibility for their carbon footprint to reduce the overall impact (European Commission, 2021). Businesses must not only calculate their footprint correctly but also disclose this information to the customers. The main change from previous regulations is that now organizations have to shift their top-down approach and start measuring sustainability on the product-level instead, which blockchain is a suitable technology for (Venkatesh, 2022). Consequently, traceability and transparency will not only be a competitive and strategic choice of each company, as it is today, but in the future also mandatory according to law. Blockchain may or may not be needed to comply, but it will indeed make it easier for companies to track and trace their products and calculate carbon footprints. Venkatesh (2022) means that traceability and transparency is a technological challenge that companies now must start to manage with blockchain and other technologies such as Internet of Things (IoT) and Artificial Intelligence (AI).

1.2 Problem Definition

While the requirements on organizations to collect and disclose transparent and trusted data increases, the number of platforms and applications for blockchain-based supply chains are increasing as well. In addition, blockchain investments, and the literature on blockchain-based supply chains are growing too (Casino et al., 2019; Statista, 2022). The literature brings up an abundance of benefits that blockchain can offer for organizations striving for improving their sustainability along the supply chain, yet the adoption of blockchain is still quite narrow and small-scaled. This adoption gap between claimed potentials and actual applications is indicated by several authors (Gaur & Gaiha, 2020; Kouhizadeh & Sarkis, 2018; Saberi et al., 2019). To the authors' best knowledge, this gap has not been investigated yet. In line with this, Kouhizadeh and Sarkis (2018) suggest that future research should focus on the adoption and diffusion of blockchain, as it is still in its early phases. Additionally, Saberi et al. (2019) state that "we propose future research propositions and directions that can provide insights into overcoming barriers and adoption of blockchain technology for supply chain management." (p. 2117).

These above-mentioned aspects make it interesting to investigate to what extent blockchain is used for sustainability in supply chain management, and why this presumed gap is present. Previous literature has been focused on the different use cases and application areas for blockchain, however, no investigation has been made on the adoption gap when it comes to sustainability applications.

1.2.1 Research Purpose

With the problem definition in mind, the purpose of this is twofold. First, to investigate and explore how users and providers of blockchain-based supply chains are currently using the technology for sustainability purposes. To assess whether the full potential is used or not, a thorough literature review is conducted to point out the claimed potentials by researchers in this field. The purpose is then to highlight the assumed gap to see what sustainability capabilities are not applied in businesses today. This is done by conducting semi-structured interviews with companies and experts across different industries. The objective of this is to spread awareness and a snapshot of how far the blockchain-based supply chains have come with regards to sustainability applications.

Secondly, the aim is to provide a significant analysis and theory-building by addressing this gap and analyzing why it is present. This is in line with what other researchers have proposed future research to focus on, hence the aim is to contribute to filling this research gap. Therefore, this study investigates driving forces and barriers of adoption and puts them in relation to adoption theories. In particular, the Technology Adoption Life Cycle by Rogers (2003) and The Chasm by Moore (2014). The purpose is to take the perspective of adoption and diffusion and generate a better understanding of current issues regarding blockchain-based supply chains and sustainability use cases. By shedding light on the gap and the most severe barriers, as well as discussing potential solutions, the aim is to guide future research and practice to better target the issues of diffusing and scaling blockchain.

1.2.2 Research Question

With regards to the problem definition and purpose of the thesis outlined in this chapter, two research questions have been formulated. The main research question is:

To what extent are sustainability potentials of blockchain-based supply chains realized?

The second research question is based on the assumption that the answer to the first question will show a gap, as indicated by the literature. Thus, the second question is as follows:

Why is there a gap between the claimed potential and reality?

1.3 Delimitations

To limit the research boundaries and set the scope, several delimitations have been made. First (1), a decision was made to narrow the broad concept of sustainability, focusing on the environmental pillar, leaving out social and economic sustainability. The main reason for this is the authors' interest in environmental sustainability, but also the growing awareness and commitment by consumers and regulatory authorities to mitigate climate change issues. Second (2), the focus has been limited to businesses and the tracking and tracing of their supply chain, thus leaving out financial, governmental and other actors working with the blockchain technology. Third (3) and last, the research focus is on the applications of blockchain without going in depth on the technology itself. The technological aspects of blockchain are summarized in the first section of the literature review, to make it possible for readers with different levels of initial knowledge to comprehend the study. Instead, the focus is on the management of innovation and technology, which is also in line with the academic background of the authors, as well as the presumed main audience.

1.4 Disposition

For clarity, Figure 1 below shows how the thesis is structured and which main chapters it contains.

Figure 1

Disposition of the Study

2 Literature Review & Theoretical Framework

The following chapter provides findings from the literature review and presents the chosen theoretical frameworks. It begins with background literature on blockchain, with the purpose of giving the reader a necessary understanding of the technology. This is followed by literature on supply chain management and sustainability benefits of blockchain-based supply chains. In section 2.2, a summary table with the most essential concepts is presented, which has been important for the guidance of the primary data collection. At the end of the chapter, the theoretical frameworks of technology adoption and diffusion are described.

2.1 Blockchain-based Supply Chains

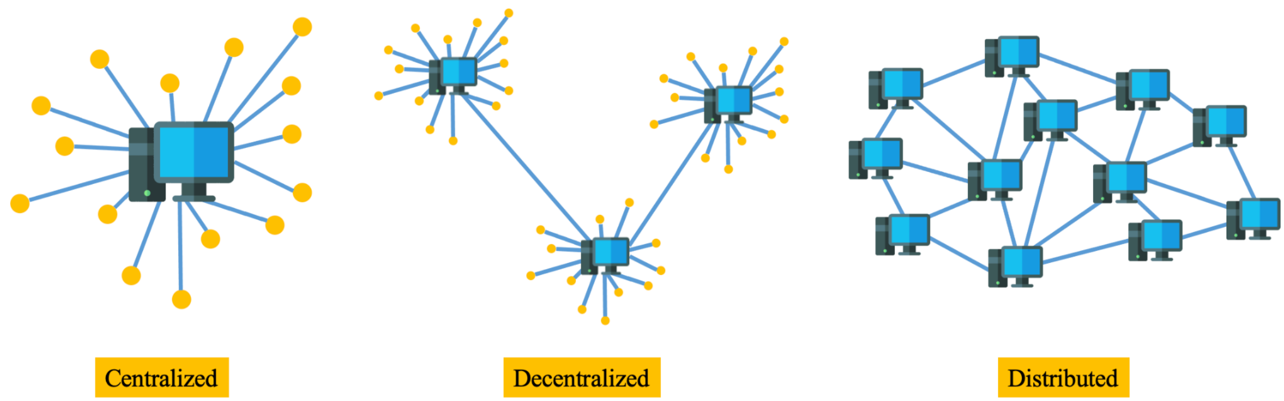
2.1.1 Blockchain Technology

In recent years, vast amounts of money have flowed into the financing of blockchain projects. Many of these projects can be found in the financial industry as well as in blockchain infrastructure (Bocek & Stiller, 2019). The first use case of blockchain technology was within the financial industry where a developer, under the pseudonym Satoshi Nakamoto, invented the cryptocurrency Bitcoin, launched in 2009 (Hayes, 2022). Today blockchain is used across multiple industries, and applications of the technology can be found in health care, banking, voting systems and supply chains (Hayes, 2022).

Blockchain is a type of database that is distributed among multiple users, where no single participant needs to be trusted (Esmaeilian et al., 2020). Therefore, blockchain functions as an immutable ledger that can be used to conduct transactions in a decentralized manner (Zheng et al., 2017). The blockchain data is shared on a peer-to-peer network and validated by a predefined protocol without a central authority (Esmaeilian et al., 2020). This network maintains a common and thus distributed list of expandable data records, so-called 'blocks', which are chained together by means of cryptographic processes. Each block contains the unique value (hash value) of the previous block, a timestamp, and transaction data (Dietrich et al., 2020). In a distributed ledger, data can only be added, but changes and deletions are not possible, hence making it secure and trusted (Bocek & Stiller, 2019). Figure 2 illustrates the differences between centralized, decentralized, and distributed ledgers. This clearly shows the advantages of a distributed ledger, as the data is not held by just one or several users, but is encrypted and anonymized by every user who is part of this network. As all users have a copy of the blockchain, it prevents fraud, hacks and failure of the entire system (Esmaeilian et al., 2020).

Figure 2

Centralized vs. Decentralized vs. Distributed Networks



Note. Compiled from: *Blockchain and Distributed Ledgers: Mathematics, Technology, And Economics* by Lipton & Treccani (2021, p. 3).

Blockchain technology can help solve various problems in the industry, thanks to its characteristics of trust, transparency, security, and reliability of data processing. In addition, blockchain technology has the potential to render obsolete previously important intermediaries and security providers such as banks, accountants, and lawyers (Frizzo-Barker et al., 2020). This stated potential illustrates why blockchain is often seen as a disruptive innovation. According to Fernando and Saravannan (2021), blockchain can even "... disrupt almost every industry due to its ability to create a decentralized tamper proof ledger network and carry out transactions without the need of a trusted third-party intermediary." (p. 88).

2.1.2 Types of Blockchain

A disadvantage that has already been discussed frequently in connection with the cryptocurrency Bitcoin is the enormously high energy consumption (O'Dwyer & Malone, 2014). However, it must be mentioned that the blockchain can be built on different algorithms and accordingly has different levels of energy consumption. Furthermore, there are different ways and possibilities to use blockchain technology, especially to ensure its security. In the following part of this section, the most used algorithms of the blockchain technology will be described in more detail. More precisely, a distinction is made between Proof of Work (PoW) and Proof of Stake (PoS). Furthermore, a differentiation must be made between private and permissioned blockchains.

Blockchain Algorithms: PoW vs. PoS

Bitcoin for example, is based on the PoW algorithm. This decentralized mechanism requires miners to solve cryptographic equations by trial, which consumes a lot of energy due to vast amounts of computations (Frankenfield, 2021; Hertig, 2020). With this mechanism, new blocks can be added to the blockchain and the security can be ensured. Fortunately, the PoW method is not required to create consensus when blockchain is used in a closed system (private and permissioned), hence simpler approaches can be used to determine who is entitled to add the next block (Gaur & Gaiha, 2020).

Another algorithm of the blockchain is the PoS-approach, which basically is a proof of ownership of the blocks (King & Nadal, 2012). Even though both algorithms have similar objectives, they have fundamental differences in validation for new blocks of the blockchain network (Geroni, 2021). With PoS, network participants get selected to add the latest batch of transactions to the blockchain (Hertig, 2020). Thus, the block leaders are not selected by computational power, as with PoW, but based on the stakes that they are holding, rather than running hash functions (Nguyen et al., 2019). PoS can indeed replace most of PoW's functions and is similarly difficult to forge (King & Nadal, 2012). Subsequently, the amount of computational power and, therefore, the energy consumption can be reduced considerably (Geroni, 2021). For this reason, blockchain technology networks based on PoS are considered more sustainable than on a PoW basis (Li et al., 2020).

These two consensus mechanisms are the most important and commonly used ones but there are also other algorithms. For example, Litke et al. (2019) mention Practical Byzantine Fault Tolerance (PBFT), Proof of Elapsed Time, and Proof of Authority. However, they state that there is currently no common approach to use in supply chain management (Litke et al., 2019).

Public, Private and Permissioned

Blockchain systems can be public, private or permissioned, based on who is permitted to be a user or operate a node on the blockchain. In a public system, any computer can join the network and take part in validating data modifications (Pisa & Juden, 2017). According to Chang et. al. (2019) public blockchains permit any node in the chain to transact and participate in the consensus process. Accordingly public blockchains can be inspected by anyone (Pisa & Juden, 2017). The most well-known example is the cryptocurrency Bitcoin, where no permission is needed to join and the users remain anonymous (Androulaki et al., 2013).

Purely private blockchain systems on the other hand, only allow a limited number of approved nodes to participate in the process (Chang et al., 2019). This means that the participants are known, and data is only shared among this certain group of actors (Kouhizadeh & Sarkis, 2018). When using blockchain internally within a single organization, the decentralized and immutable benefits of blockchain are limited compared to other technologies. These benefits are most prevalent when implemented across organizations, where trust issues are present (Chang et al., 2019; Kouhizadeh & Sarkis, 2018).

The permissioned blockchain system is a mixture of public and private blockchain. All participants are known, but they can also come from outside the company if they get permission to join. Hence, in a permissioned system, according to Pisa & Juden (2017), a membership of validating computers is restricted. This means that a permissioned blockchain is a way to secure dealings between a group of entities that pursue a common goal but do not fully trust each other, such as companies that exchange money, supplies or information (Androulaki et al., 2018). Consequently, a private permissioned blockchain with known identities is a valid option for businesses, especially for those wanting to use blockchain within supply chains (Androulaki et al., 2018).

2.1.3 Suitable Blockchains for Supply Chains

The above-mentioned technical aspects make clear that a private permissioned blockchain is most suitable for businesses. This is due to the fact that information is only available for the participants of the blockchain and in this case - the supply chain. There are four key concepts of blockchain for businesses: shared ledger; permissions; smart contract; consensus (Gupta, 2018).

A *shared ledger* records and shares all transactions among all participants in the business network and is known to be the single source of truth (Chang et al., 2019). Shared ledgers are nothing new to the business world. What is new is that the ledger is shared and distributed simultaneously. Consequently, there is an unalterable ledger of all transactions that can be accessed by all network participants, eliminating the redundancy typical of conventional business networks (Gupta, 2018).

The second key concept is *permissions*. As discussed earlier, there are public and private permissioned blockchain systems. By restricting access to transaction details, more transaction details can be kept on the blockchain and participants can state which transaction information they want others to see (Gupta, 2018). In most supply chains, the stakeholders are known and trusted. Additionally, a supply chain network is unlikely to tolerate open access, as its participants do not want to share proprietary details such as demand, capacity, orders, prices, and margins at all stages of the value chain with unknown participants (Alicke et al., 2017). As a result, most blockchain-based supply chains will need to be permissioned, with access centrally regulated and constrained to known parties, who in turn may be restricted to certain segments of data (Alicke et al., 2017).

Another crucial part of blockchain for businesses are *smart contracts*. IBM defines smart contracts as follows: “Smart contracts are simply programs stored on a blockchain that run when predetermined conditions are met.” (IBM, n.d). Cong and He (2019) further state that smart contracts are digital contracts whose terms depend on decentralized consensus, are tamper-proof and are usually self-enforcing through automatic execution. This makes blockchain-based supply chains more efficient and less time consuming than traditional ones.

When it comes to the *consensus mechanism* of blockchain technology within supply chains, it has already been discussed that the PoW method chosen for the public blockchain is not preferred. Instead, blockchain platforms most certainly use the common PoS algorithm. In a business network where nodes are known and trusted, transactions can be validated by consensus (agreement) and recorded in the ledger (Gupta, 2018). According to Gupta (2018), the consensus mechanisms vary from blockchain to blockchain and “requires pluggable consensus - a way to implement whichever consensus mechanism is deemed best for any given industry segment." (p. 17). This shows the range of potential consensus types that can be used for blockchain-based supply chains. It should be noted that what has been elaborated regarding the blockchain technology is only a minor part of this extensive technology.

2.1.4 Blockchain & Supply Chain Management

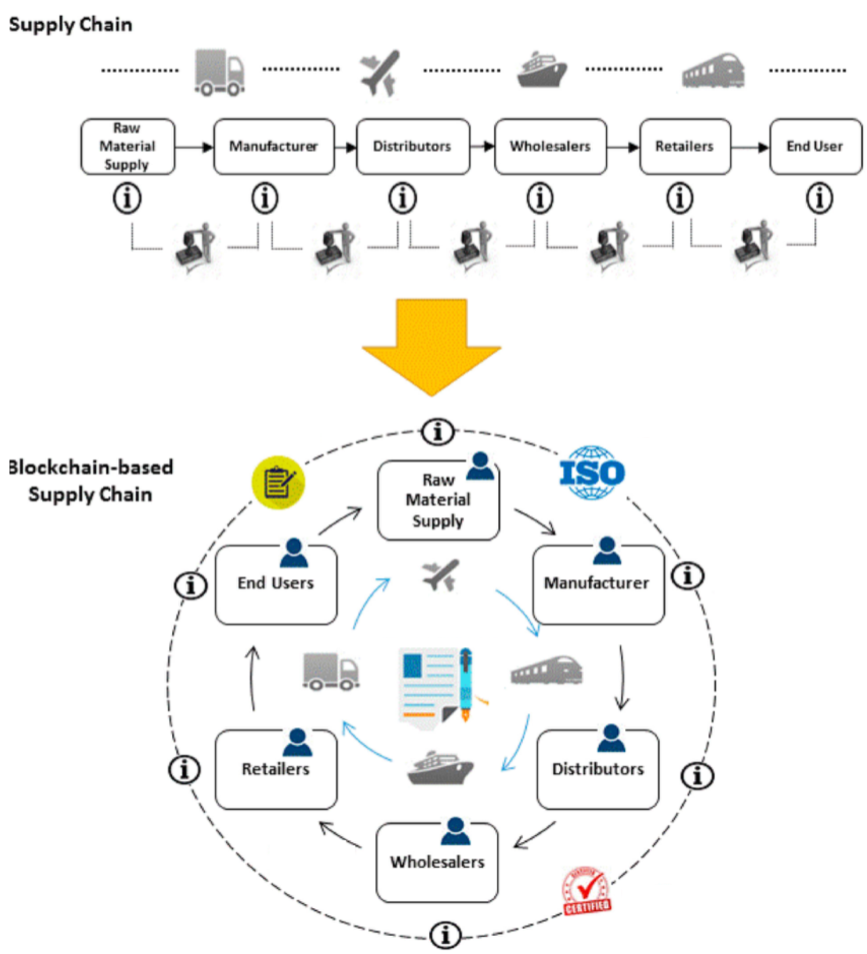
Supply chains deal with large amounts of flows, both in terms of information, products and materials, as well as financial flows, which requires robust and efficient management (Saberi et al., 2018). To achieve excellence in supply chain management, companies strive to build supply chains that respond to sudden and unexpected changes in the market. Thus, flexibility is critical, especially in today's changing markets. Flexible supply chains have the advantage of being able to respond both quickly and cost-effectively, hence minimizing the speed-cost trade-off (Bolstorff et al., 2007).

Flexibility is one of the five common supply chain management objectives. The others are speed, dependability, cost, and quality. However, sustainability is becoming more integrated into the list of objectives - a trend that has been mostly driven by consumers' growing sustainability consciousness (Kshetri, 2018). Saberi et al. (2019) argue that today's centralized Enterprise Resource Planning (ERP) systems lack the security needed to build trust and prevent errors, hacking and attacks. However, there are various ways in which blockchain can improve not only sustainability but all the objectives of supply chain management in a secure and trusted way (Kshetri, 2018). To mention a few: Costs can be reduced by optimizing resource usage; reducing paperwork; and improving targeting of products to be recalled instead of recalling whole product lines. Speed is fastened by replacing human interaction with automation and digital technologies. Greater dependability is introduced as blockchain allows data to be collected on actor activities, ensuring supplier accountability. This further leads to higher quality, as detection of low-quality materials, processes and activities will be visible. Lastly, flexibility is improved thanks to the collection of real-time data that makes it possible to meet consumer demands easier (Kshetri, 2018). In section 2.2, the implications of using blockchain in supply chains on environmental sustainability will be elaborated upon in detail, as this is the purpose of the thesis.

Figure 3 below shows how the structure of relationships between stakeholders transforms as a result of the transition from a traditional supply chain to a blockchain-based supply chain. Instead of having a linear flow of information, data is now decentralized and distributed on a peer-to-peer network. The main change is that now all supply chain parties have direct access to the product profile and all information that it contains (product type, location, quality, quantity, ownership, etc.) (Saberi et al., 2019). Having individual copies of the data means that everyone can check the transaction status, identify inaccuracies and thereby hold each other accountable for possible errors or frauds (Gaur & Gaiha, 2020). Lastly, obtaining access to real-time data across the supply chain affects all of the five main objectives of supply chain management, but also the sixth - sustainability, as already mentioned above (Kshetri, 2018).

Figure 3

Traditional versus Blockchain-based Supply Chains



Note. Adapted from: *Blockchain technology and its relationships to sustainable supply chain management* by Saberi et al. (2019, p. 2121).

According to Bai & Sarkis (2020), IBM has become a pioneer in blockchain-based supply chains. IBM provides blockchain SaaS to businesses who want to use the technological infrastructure without building it themselves. However, there are several other providers as well, offering cloud-based platforms where companies can build and use their own applications (Frankenfield, 2021).

2.1.5 Challenges of Blockchain-based Supply Chains

So far, the literature review has been focused on the positive and beneficial aspects of integrating blockchain technology into the supply chain. However, the downsides must be given attention, otherwise there would be little to no question why many companies are still not using it.

Organizations that want to be innovative will face several challenges while implementing innovations like blockchain. In general, successful innovation depends on a range of capabilities that need to be combined by the company, such as access to financial resources, understanding market needs, hiring highly qualified personnel, and establishing effective interaction with stakeholders (D'Este et al., 2012). Furthermore, Kirsner (2018) states that the main innovation barriers in larger companies are "... politics, turf wars, and a lack of alignment; cultural issues; inability to act on signals crucial to the future of the business; lack of budget; and lack of the right strategy or vision." (p. 1). According to Haag (2014), one of the main barriers to innovation adoption is organizational inertia. This is due to the fact that companies are organized to deliver predictable and robust results (Anthony et al., 2019). Additionally, innovation adoption requires large internal changes, which leads businesses to prefer the status-quo even if it is inefficient (Haag, 2014). Furthermore, Peppard & Ward (2002) mean that before implementing new IT/IS solutions, an organization must do a stakeholder analysis to make sure that intended change and benefits are realized. They continue by stating that:

> Often, projects fail because of the lack of cooperation of parties who were not considered material to the system's success, but whose ability or willingness to accept change or otherwise is essential, requiring their active cooperation in delivering the real business improvements required. (p. 446)

Hence, all parties affected by the new blockchain system for managing the supply chain must be identified and analyzed with regards to their attitude and potential resistance.

Considering the implementation of the blockchain technology in businesses, several authors name similar barriers to the general ones mentioned above. Nevertheless, some are more specific and emphasize barriers with blockchain in relation to supply chain management. According to Saberi et al. (2019) barriers hindering blockchain adoption can be divided into: intra-organizational, inter-organizational, technical and external barriers. The intra-organizational barriers are top-down flaws such as missing commitment, wrong support, lack of awareness and wrong resource allocations. On the contrary, inter-organizational barriers are related to supply chain partners. They further state that integrating an information technology like blockchain along the supply chain can be challenging. The same applies to system-side or technical barriers. New technologies require new tools. This can be very challenging for supply chain participants, especially with a new technology that is still in its early development. Venkatesh (2022) adds another vital technical point which is the fact that blockchain must be combined with other technologies such as IoT and AI to unite the physical and digital world. Lastly, the external barriers are stemming from external actors, organizations or governments that are not directly involved in the supply chain activities and therefore do not benefit economically from the process (Saberi et al., 2019).

Other researchers bring up further barriers to blockchain adoption in organizations. Mathivathanan et al. (2021) argue that data privacy is a major concern for many businesses as well, because as soon as information is uploaded to the digital ledger, it cannot be removed and therefore is available on the blockchain forever. According to Kouhizadeh et al. (2021), the biggest challenge is the lack of awareness among customers regarding blockchain technology in the area of sustainability. In most cases, this is due to ineffective communication and collaboration between different actors. This is partly due to the fact that blockchain technology has a negative reputation, thanks to the very energy-consuming cryptocurrency Bitcoin (O'Dwyer & Malone, 2014).

2.2 The Potential of Blockchain for Sustainable Supply Chains

The potential capabilities of blockchain to reshape supply chain management is discussed and investigated in numerous papers. Park and Li (2021) highlight that the technology behind blockchain, with its distributed ledgers, improves transparency, efficiency, reliability, and traceability, which they argue will have the potential to improve both social and environmental performance. In line with this, Kouhizadeh and Sarkis (2018) mean that of all new technological advancements available, blockchain is the most promising with regards to supply chain management and sustainability.

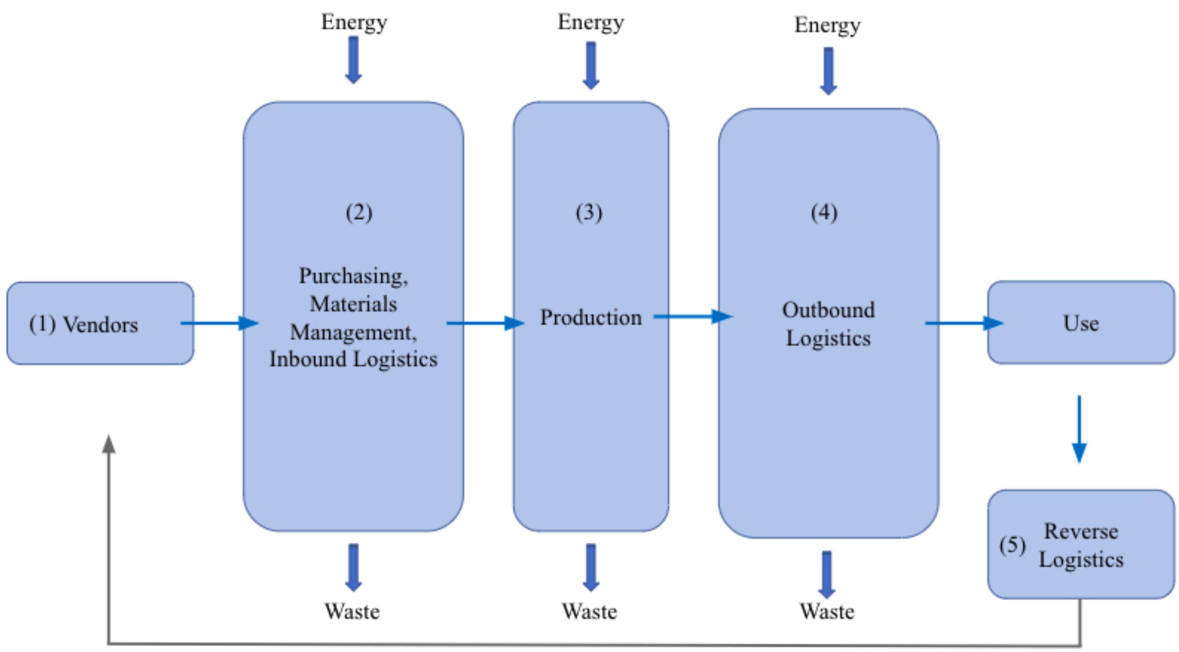
Sustainable supply chain management should emphasize all three pillars of sustainability when setting up the supply chain practices (Svensson, 2007). Several papers investigate the relationship between blockchain and the three pillars of sustainability (Kouhizadeh and Sarkis, 2018). As aforementioned, this paper looks into the environmental aspects of sustainable supply chain management. Park and Li (2021) state that the main criteria that can be assessed when it comes to environmental sustainability are "... utilization of resources, energy efficiency, the amount of waste, and level of emissions from business activities." (p. 6). These and other environmental criteria and characteristics are explored and investigated in this section.

2.2.1 Blockchain-based Supply Chains and Environmental Sustainability

In this part, capabilities of blockchain that bring sustainability benefits to the supply chain management will be described. To make it as clear as possible, different sources of information from various researchers will mostly be presented one by one. The first two sources of potential benefits presented in this paper are the Association for Supply Chain Management (2021) and Kouhizadeh and Sarkis (2018). These two sources exhibit blockchain benefits related to sustainable supply chains in a supply chain model. This model is shown in a simplified version in Figure 4 and the benefits they have identified are presented below. The stages of this supply chain model will later be related to the other sources of potential sustainability benefits that blockchain offers.

Figure 4

Simplified Supply Chain Model



Note. Compiled from: *Blockchain Practices, Potentials, and Perspectives in Greening Supply Chains* by Kouhizadeh & Sarkis (2018, p. 5).

Figure 4 shows a supply chain model that includes five supply chain activities impacting the sustainability of the chain. In the *first stage*, supplier management and vendor selection are important as lower-tier suppliers often have the largest effect on the overall sustainability performance of the supply chain (Kouhizadeh & Sarkis 2018; Villena & Gioia, 2020). Villena and Goia (2020) highlight that controversies often occur at the first-tier suppliers, and where non-compliance with standards is most prevalent. At this stage, blockchain can assist the focal firm in vendor selection based on sustainability performance measures, thus making it easier for the company to select green suppliers (Kouhizadeh & Sarkis, 2018). It can also help the focal company to see when and where suppliers breach sustainability policies, so that they can tackle the issue as soon as possible and work with supplier development (Association for Supply Chain Management, 2021).

In the *second stage*, they bring up purchasing as one of the activities that is affected by the capability of blockchain to collect and store characteristics of product transactions. By making this information transparent, suppliers can make better informed purchasing decisions and select greener products (Kouhizadeh & Sarkis, 2018). According to Kouhizadeh and Sarkis (2018), this capability of collecting reliable sustainability information instead of estimating the data is "a revolutionary contribution of blockchain technology." (p. 7). Furthermore, in the second stage, traceability offers a robust solution to warehousing, materials management, and logistics issues. Blockchain keeps track of real-time data that can lead to better forecasting, waste reduction and more efficient use of resources (Kouhizadeh & Sarkis, 2018). By tracking the transportation performance, blockchain can also improve the driving practices of either their inhouse or third-party logistics and thus reduce greenhouse gas emissions (Kouhizadeh & Sarkis, 2018). Lastly, in this second stage, warehousing and inventory management can be improved and lead to less waste and loss of material.

In the *third stage* of internal production and operations management, there are again multiple ways in which blockchain can contribute to activities being done in a more sustainable manner. For instance, it can help in managing the ISO14001-related data, and other certifications, that are needed to demonstrate compliance with standards, as well as track data related to eco-design and production processes. It is important to note that this stage is influenced by upstream activities, such as resource and inventory management in stage two (Kouhizadeh & Sarkis, 2018). Furthermore, during production, blockchain can measure performance in terms of sustainability and continuous improvement, and also store data for life cycle analysis.

In the *fourth stage*, outbound logistics, the authors refer to warehousing, transportation, distribution and marketing of products, which should be done in a green way. Here, blockchain's capability of real-time data and transparency makes it possible to plan and operate in a more resource-efficient manner. It also contributes to the sharing economy as it enables businesses to share for example warehousing space or transportation capacity to others via crowdsourcing platforms. Furthermore, blockchain can trace the packaging to see whether it is recycled and reused by the company, and thereby incentivize greener packaging that results in more efficient resource utilization (Kouhizadeh & Sarkis, 2018). Lastly, as elaborated on earlier, consumers increasingly demand green products and by having blockchain information easily accessible to consumers on the package of the product, they can see if the product is actually green or not (Kouhizadeh & Sarkis, 2018).

The final *fifth stage* is about reverse logistics, where the main issue that supply chain management struggles with is to locate the product or material that needs to be restored. Here, the tracing capability ensures that the location and ownership information is accessible and hence makes the circular economy approach much easier and efficient to operate (Kouhizadeh & Sarkis, 2018).

The last important capability of blockchain brought up by Kouhizadeh and Sarkis (2018) is tokenization which can be used to create incentive systems. These systems use cryptocurrency tokens to incentivize green behavior along supply chains. For example, consumers and organizations can be rewarded for purchasing green products and energy, or for recycling the waste materials. Another application of tokenization is to change drivers' behavior during transportation by rewarding sustainable driving (Kouhizadeh & Sarkis, 2018).

Another article by Esmaeilian et al. (2020) brings up four related sustainability capabilities of blockchain technology: "(1) promoting green behavior; (2) enhancing product lifecycle visibility; (3)

improving operations and systems efficiency; and (4) improving sustainability reporting and monitoring." (p. 8). Green behavior refers to the whole life cycle of a product, from purchasing decisions to usage and to the post-use handling of the product. Blockchain can be used to create incentives and reward sustainable behavior through this life cycle by using tokenization (Esmaeilian et al., 2020). For example, a company can be rewarded with crypto tokens if they behave in an eco-friendly manner on the blockchain platform, for instance when buying a green product or recycling used ones. However, it is important that the blockchain platform is designed in a way so that the earned tokens can only be spent on eco-friendly products and services (Esmaeilian et al., 2020). Enhancing visibility, which is the second point by Esmaeilian et al. (2020), is instead about collecting data on the product throughout its life, by taking the necessary sustainability measures in order to reduce its footprint. This process is something that has been hard or even infeasible to track prior to blockchain technology. By managing and analyzing this data, organizations can improve eco-design, manufacturing, logistics and other phases of the product's life cycle to make it more sustainable (Esmaeilian et al., 2020). As Park and Li (2021) mention, enhancing visibility is mainly about transparency, where blockchain enables valuable real-time information sharing within the network. The third potential benefit brought up by Esmaeilian et al. (2020) is increased efficiency and reduced costs, especially the cost of verification and networking. A sustainability benefit of this is that companies can achieve increased efficiency in energy trading on peer-to-peer energy markets (Esmaeilian et al., 2020). Lastly, Esmaeilian et al. (2020) emphasize the importance of sustainability reporting and monitoring, which is improved by blockchain technology. Being able to disclose trusted information is appreciated by both stakeholders and end consumers as it reduces information asymmetry (Esmaeilian et al., 2020).

The third source of the potentials of blockchain is Saberi et al. (2019) who emphasize four main environmental sustainability application benefits that blockchain offers in supply chain management. These four potential benefits are: (1) by its tracking capabilities, it can more efficiently trace deficient products and thereby reduce rework and recall, thus reduce waste, resource consumption and emissions; (2) through tracing and transparency, it enables the verification of allegedly green products; (3) it can incentivize and improve recycling by using tokenization and financial rewards in recycling programmes; (4) it enables a more efficient and secure process for emissions trading (Saberi et al., 2019).

Moreover, Park and Li (2021) have identified three main areas where blockchain can improve the environmental aspect of supply chain management. First, it can lead to a reduction of emissions along the supply chain, as it keeps track of where and how much of different substances have been emitted. For example, it is possible to track carbon emissions, water usage, chemical usage, and other environmental indicators. Thus, participants along the supply chain get incentivized to operate more sustainably, and if any of the participants are not complying with regulations, it is easier to detect and take corrective actions to solve the problem. Second, as blockchain allows for obtaining the exact origin of raw materials, it can help in avoiding degradation of resources and reach a more sustainable 'resource-use rate'. Third, it improves waste management by keeping track of the amount of waste, and recycling practices, along the supply chain, which offers both cost reductions and a better environment (Park & Li, 2021). In contrast to the previously mentioned sources in this literature review, Park and Li (2021) only highlight potential sustainability benefits related to blockchain capability number one and two in Table 1.

As an end to this section, it is important to once again point out that energy consumption is needed to run the blockchain technology and the amount can be extremely high depending on the algorithm used. However, blockchain has the potential to improve energy utilization by establishing internal energy & emission trading systems (Kouhizadeh & Sarkis, 2018). Sharing information about energy consumption among the blockchain network participants helps to facilitate resource allocation, as well as reduce the overall energy consumption (Kouhizadeh & Sarkis, 2018). A similar application is brought up by Saberi et al. (2019) who emphasize the capability of blockchain to facilitate better carbon asset trading. With real-time and secure data, organizations can more efficiently collaborate and trade carbon assets amongst each other. In other words, blockchain can be used to establish distributed, peer-to-peer trading systems internally among the supply chain partners in a more trustworthy and secure way than before (Kouhizadeh & Sarkis, 2018; Saberi et al. 2019).

2.2.2 Literature Review Summary: Capability Framework

In this section, a summary of the previous-mentioned benefits identified in the literature will be presented in Table 1. The supply chain model presented above (Figure 4) will be used to locate not only the potential benefits that the Association for Supply Chain Management (2021) has presented, but also the benefits brought up by the other authors listed above (Esmaeilian et al., 2020; Park & Li, 2021; Saberi et al., 2019). In total, nine capabilities have been identified with potential for improved sustainability outcomes in supply chains. The list of potential benefits is non-exhaustive and the relation between capabilities and benefits may overlap in reality. This means that a capability can lead to other benefits not brought up here, and, a benefit can be realized thanks to one of the other nine capabilities too. Thus, it is not a strict outcome of merely one of them. However, Table 1 represents the common pattern that has been identified in the reviewed literature.

Table 1

Capability Framework: Blockchain's sustainability capabilities

Blockchain capability	Activity	Sustainability benefits	SC location	Author(s)
1. Tracking environmental performance of suppliers	Vendor selection & Supplier development	Reduced footprint due to pressure to comply with regulations and policies	1	Esmaeilian et al. (2020); Park & Li (2021); Kouhizadeh & Sarkis (2018)

2. Tracking the materials & waste management	Resource & Waste management	Avoiding degradation of resources & reducing waste along the SC	All	Park & Li (2021); Kouhizadeh & Sarkis (2018)
3. Tracking logistics information	Warehousing & Transportation	Reduced greenhouse gas emissions during transportation and reduce material loss	2 & 4	Kouhizadeh & Sarkis (2018); Esmaeilian et al. (2020)
4. Collecting data on sustainability of production	Production & Operations management	Improved eco-design, easier management of certifications, continuous improvement	3	Kouhizadeh & Sarkis (2018); Esmaeilian et al. (2020)
5. Collecting data on packaging material	Packaging management	Improved packaging practices: re-use and lengthen its life.	4	Kouhizadeh & Sarkis (2018)
6. Decentralization of energy & emissions management	Energy & emissions trading	Reducing energy consumption/shift to renewable energy, and improve resource allocation	2,3,4	Saberi et al. (2019); Kouhizadeh & Sarkis (2018)
7. Verification & transparency of green products	Green purchasing	Reducing information asymmetry and false greenwashing	2 & 5	Kouhizadeh & Sarkis (2018); Esmaeilian et al. (2020); Saberi et al. (2019)
8. Trace location of products	Reverse logistics	Reduce rework and recalls	5	Kouhizadeh & Sarkis (2018); Saberi et al. (2019); Esmaeilian et al. (2020)
9. Tokenization	Building incentive / Reward system	Greener consumption and behavior	All	Kouhizadeh & Sarkis (2018); Saberi et al. (2019); (Esmaeilian et al. (2020)

Table 1 presents the label put on the identified sustainability potentials of blockchain. Further, it states what type of business activities are related, as well as the most relevant outcome improvements that the capability can facilitate. In the third column, it is shown where in the supply chain this improvement is most prominent, referring to Figure 4 above. The last column indicates which authors have mentioned this capability. Important to note is that the blockchain capabilities can certainly lead to other benefits related to economic and social sustainability. However, these will not be brought up in this study as the focus will be on environmental sustainability.

2.3 Technology Adoption & Diffusion Frameworks

2.3.1 Technology Adoption Life Cycle

"Getting a new idea adopted, even when it has obvious advantages, is difficult." (Rogers, 2003, p.1). With this quote, Rogers (2003) initiates the first chapter of his well-known book *Diffusion of Innovations*, first published in 1962. Diffusion is defined by Rogers (2003) as the process of communicating new ideas, in particular innovations, within a social system. This process can face numerous challenges, thus making diffusion slow. It lies in the very nature of the definition of diffusion - it is something new that is communicated, which means that the uncertainty is high. Some innovations are diffused rapidly, others take more time, and some will fail and never reach the majority of the social setting they target (Rogers, 2003). Diffusion failure can be due to several reasons. One famous example is the 'Dvorak keyboard' layout that failed to reach the mass market due to the already established standard of using the QWERTY layout instead, even though the latter was inferior in terms of efficiency (David, 1985). Rogers model of adoption and diffusion of new technologies was initially developed for the business-to-consumer relationship, however, researchers have used it in business-to-business contexts as well. For example, Hameed et al. (2012) and Rhein (2021) use it to describe how organizations adopt innovations. For the purpose of this study, all theoretical frameworks will be used and analyzed in a business-to-business context. Adoption decisions by organizations will always be made by individuals, and thereby perceptions, attitudes and expectations will affect the adoption processes. Rogers (2003) acknowledges that the adopter might be another unit than an individual:

> Most research on the attributes of innovations and their rate of adoption utilized individuals as the units of analysis, but this need not be the case. For instance, why not use organizations, communities, or some other systems as the unit of analysis? (p. 139)

Rogers (2003) continues with examples of researchers that have used the framework for analyzing innovation adoption at the organizational level. Additionally, it can be noted that all respondents using a blockchain platform in this study are customers of a SaaS, and can therefore be seen as consumers and users of this technology. As a last point, Rogers (2003) states that when using the model on the organizational level, it should be considered that the speed at which innovations are adopted can take longer time, as more individuals are involved in the decision process.

Driving Forces and Barriers

To understand why some technologies succeed, whereas others fail, it is necessary to be aware of factors affecting the adoption decision. As with all decisions, there are both advantages and disadvantages that need to be considered when deciding whether to adopt a new technology or not. However, in this thesis it is not the question whether to adopt blockchain or not, but rather about its different capabilities which are listed in Table 1. Nonetheless, in this research, the same logic and reasoning is behind such adoption decisions as well. This paper has already gone through several positive effects of integrating blockchain into supply chains. In addition, challenges and barriers to keep in mind have been described in section 2.1.5. More general driving forces and barriers when it comes to adopting innovations are emphasized by Rogers (2003) who takes the reader through the 'innovation-decision process'. This process starts with the knowledge stage, where the individual or organization becomes aware of the new technology. Next, the decision-making unit builds and forms an attitude towards it, before making an adoption or rejection decision in the last stage. What is a crucial aspect that permeates this process is the uncertainty that must be dealt with, as innovation in its essence is something new and often relatively untested.

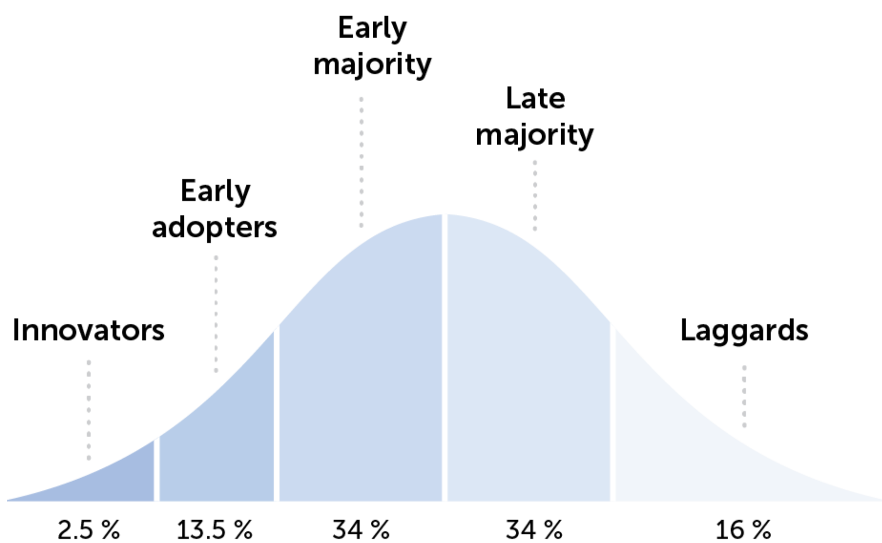
There are, according to Rogers (2003), five main characteristics of innovations that make adoption rates different, hence they can either be driving forces or barriers for adoption. First (1), the relative advantage of the innovative technology per se. Second (2), how compatible it is with existing values and norms within the social system. Third (3), the complexity of the innovation and thus how easy it is to understand it. Fourth (4), trialability, meaning to what extent one can experiment and test the innovation at a small scale. And last (5), to what degree one can observe the result of using the innovation (Rogers, 2003). What Rogers (2003) highlights is that innovation diffusion is often viewed from the perspective of differences among potential adopters, for example risk appetite, taking the innovation as given and equal. This is a dangerous simplification to make, according to Rogers (2003). Instead, he indicates that innovations are different in all five characteristics as mentioned above, which in turn affects the adoption rate and magnitude. As a summary, Rogers (2003) means that innovations with greater relative advantage, more compatibility, less complexity, greater trialability and observability will be adopted faster. Thus, leading to a greater and more rapid diffusion. In other words, these five are drivers of the adoption rate, yet they can easily be turned into barriers if the innovation instead had the opposite attributes. As an example, if the innovation was perceived as having low instead of great relative advantage, it becomes a barrier to adoption. It is important to note that even though these five attributes are considered objective, decision-making units will have subjective perceptions that will affect the adoption and diffusion (Rogers, 2003).

These five characteristics can be seen as being on a scale, where it could be either a barrier or a driver for adoption, or somewhere in between. This is how Moore and Benbasat (1991) used Rogers's framework to study the implementation problems of IT systems in organizations, which has become a well-known study with over 12,000 citations. An interesting aspect of the study by Moore and Benbasat (1991), is that they added two characteristics, which can be seen as driving forces to adopt a new IT technology. These two were 'image' and 'voluntariness of use'. The first is described as “the degree to which use of an innovation is perceived to enhance one’s image or status in one’s social system” (Moore & Benbasat, 1991, p.195). This aspect has been defined by Rogers (2003) and other researchers to be part of the relative advantage, which is already one of the five characteristics. The second added attribute is defined as “the degree to which use of the innovation is perceived as being voluntary, or of free will." (Moore & Benbasat, 1991, p. 195). Both of these two additional attributes relate well to the blockchain technology, as status might be given to those organizations able to implement such a complex technology and make use of its sustainability capabilities in order to achieve transparency towards consumers. Voluntariness can as well be related to driving forces of implementing blockchain in the sense that organizations might feel pressured to trace and disclose sustainable information in a reliable and transparent way.

As a next step to construct a model for adoption and diffusion, Rogers (2003) divides adopter categories into five distinct groups who all share a certain degree of innovativeness within each group. Innovativeness in this sense is described as “...the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system” (Rogers, 2003, p. 22). These categories are shown in Figure 5, and typically follow the normal distribution.

Figure 5

Technology Adoption Life Cycle



Note. Adapted from *Diffusion of Innovations* by Rogers, (2003, p. 171).

Rogers (2003) points out that this distribution of adoption is typically followed when innovations are successful, thus not taking failed innovations into consideration. The underlying logic is that technologies are thought to be absorbed by different organizations and individuals in stages associated with different social profiles and attitudes towards innovations (Moore, 2014). Innovative technologies are said to be diffused from left to right, starting with the innovators (Moore, 2014).

To Rogers (2003), innovators are those who are willing to try out new ideas and innovations and experiment with them, when success is still uncertain. They are often characterized as ‘technology enthusiasts’. Early adopters are also early purchasers of a new technology, but do not adopt due to enthusiasm, but rather because they find it easy to imagine the benefits of a new product. Additionally, as they are among the first in the market to adopt, they expect to see competitive advantages (Moore, 2014). They are more likely to be role models in the social system and thereby, they are important for the adoption rate. They seldom seek feedback from other users but are instead relying on their own intuition and visions (Moore, 2014). The early majority instead, has a more wait-and-see approach and prefer to stay with the status quo. They emphasize the practicality of the technology and adopt only when it works properly (Moore, 2014). This group is essential to attract as it makes up roughly one third of the adoption life cycle, but they need trustworthy references before they purchase (Rogers, 2003). The late majority adopters are more cautious and might need to be persuaded by their network or see some proof of success before they adopt. They are less comfortable with new technologies and oftentimes wait until it has become a standard in the market (Moore, 2014; Rogers, 2003). Laggards are the last ones to adopt. They are skeptical and oftentimes not interested in new technologies, both for personal and economic reasons (Moore, 2014). Due to the fact that this group is hard to attract in combination with being a relatively small part of the market, it is often not worth pursuing them (Moore, 2014).

As a summary to the Technology Adoption Life Cycle, and Roger’s framework in general, one can state that the adoption decision when it comes to innovative technologies will be driven or barriered by two factors. First, the characteristics of the innovation itself, which are objective measures but subjectively assessed, and secondly, the type of adopter category to which the decision unit belongs.

Critique Against the Technology Adoption Life Cycle

There are different views on the diffusion of innovation model and several papers discuss its usefulness. Particularly related criticism is posed by Lyytinen and Damsgaard (2001) who argue that Rogers model and framework is of less use for complex IT technologies. The main argument in their paper is that “...complex IT solutions should be understood as socially constructed and learning intensive artifacts…” (p. 173), implying that these technologies can be adopted for various reasons that are not covered by the Technology Adoption Life Cycle (Lyytinen & Damsgaard, 2001). In short, they propose a new framework for analyzing the adoption and diffusion of IT innovations, with regards to its characteristics of being less distinct and precise compared to traditional innovations such as hardware products (Lyytinen & Damsgaard, 2001). However, this framework will not be discussed in detail as it is newer, less tested and less well-known than the theories chosen in this study[1]. Their model is addressed to show awareness that other researchers have criticized Rogers model for being inapplicable when it comes to IT innovations. Nevertheless, the aim is not to find the best model, but rather to use general, easy-to-understand and reputable models to guide the reasoning of why adoption of blockchain capabilities might be slow.

[1] Assumption is based on the number of citations, according to Google Scholar.

Another form of critique is posed by Moore (2014), who developed a re-work of Roger's model, after evidence had shown that there was something 'wrong' with the initial Technology Adoption Life Cycle. He proposed that there were cracks in the curve, meaning that the diffusion process is not as smooth as the model suggests. Section 2.3.2 will elaborate on this in more detail.

2.3.2 The Chasm

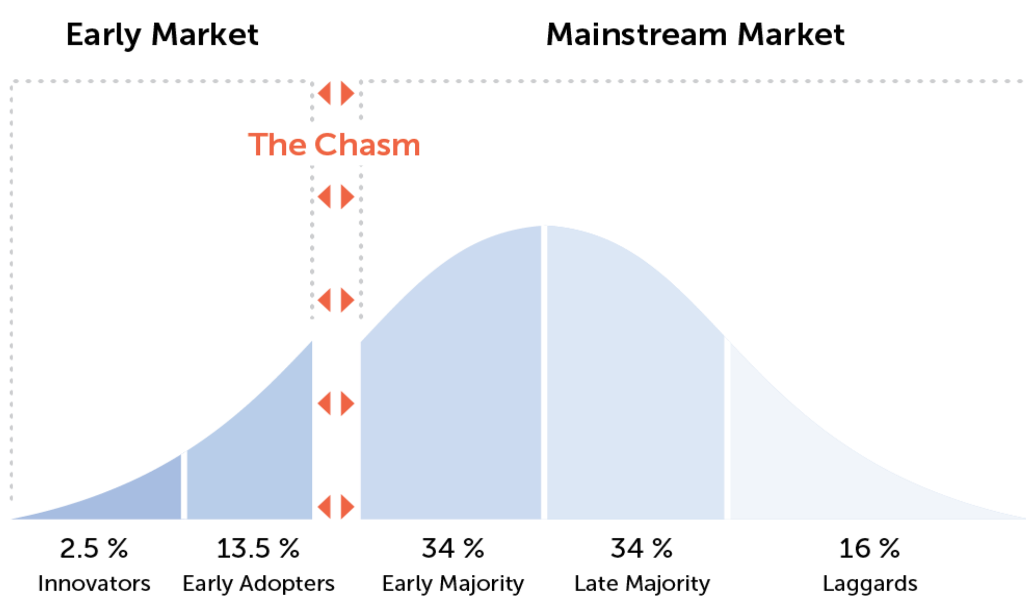
Between the categories of early adopters and early majority, researchers have identified a so-called 'Chasm', where innovations sometimes get stuck and do not reach the majority (see Figure 6). Geoffrey Moore, organizational theorist and management expert, is known for his book *Crossing the Chasm* (first published in 1991) where he, as a response and further work on Rogers model, highlights the difficulties for new innovations to be adopted by the mass market:

> To be specific, the point of greatest peril in the development of a high-tech market lies in making the transition from an early market dominated by a few visionary customers to a mainstream market dominated by a large block of customers who are predominantly pragmatists in orientation. (Moore, 2014, p. 6)

Moore (2014) continues to indicate that this gap is often ignored, but that crossing the chasm should be a priority for businesses selling an innovation, as it is required for success and profitability.

Figure 6

The Chasm



Note. Compiled figure based on *Crossing the Chasm* by Moore (2014, p. 21).

The difficulty Moore (2014) emphasizes is that the group of adopters to the right of the chasm must use the left group as a reference, however, they are fundamentally different and purchase new technologies for different reasons (Moore, 2014). The early adopters take on a new technology and integrate it into their business because they expect to improve their competitive position. The technological innovation is seen by these adopters as disruptive and it changes their way of working, which is exactly what these visionary individuals and organizations want. On the other hand, the early majority wants to adopt an incremental and sustaining innovation, thus they do not want to change their way of working to the same extent. This difference creates two problems in the adoption and diffusion process: First, the early majority do not trust the early adopters enough to make an adoption decision as they do not make a good reference for the early majority. Second, as the early majority do not want to revolutionize their ways of working, they demand a good reference before adopting a new technology. Consequently, there is a catch-22[2] situation, which creates a gap that innovative companies must try to close or bridge (Moore, 2014).

2.3.4 Application of the Theoretical Frameworks

This paper has taken the reader through a vast range of capabilities and associated sustainability benefits that blockchain offers in supply chain management which is nothing new in the literature. However, a summarizing table (Table 1) has been presented where these capabilities and benefits from different papers and authors have been highlighted and positioned into different supply chain management activities. What the current literature lacks is an assessment of to what extent these capabilities are used and which corresponding benefits are realized. Thus, the aim of this thesis is to investigate this possible gap and relate to the theories presented above. If there is indeed a gap between the claimed technological capabilities and real applications across industries, then the question is "why?". The theories gone through, Technology Adoption Life Cycle and The Chasm will both guide the analysis regarding the stated research questions. Relating these frameworks to the aim of this study, it becomes apparent that some of the capabilities of blockchain for sustainable supply chains might be stuck in this chasm. The authors of this paper therefore believe that these models and the logic behind them can help to identify possible barriers to adoption.

With the purpose of the study - investigating to what extent and why there is a gap in the adoption of sustainability capabilities of blockchain - a decision has been made to look at this potential gap from the perspective of adoption and diffusion. Thus, the traditional and well-known frameworks by Rogers (2003) and Moore (2014) are used to guide the analysis of this study. They both explain technology adoption and diffusion from slightly different perspectives. Rogers (2003) focuses on the innovativeness of different adopter categories and the perception of innovation attributes. Moore (2014) on the other hand is more concerned with trust issues across adopter categories and why technologies fail to reach the majority market. Regarding the framework by Moore (2014), this research applies the overall logic and general elements that builds on Rogers (2003). As already pointed out, blockchain is a possibly disruptive technology, with the potential to disrupt many industries (Fernando & Saravannan, 2021). Moore (2014) states that attitudes toward technology

[2] A dilemma or difficult situation where the solution is dependent on conflicting conditions.

adoption are mostly evident for disruptive technologies. These arguments make the Technology Adoption Life Cycle model a relevant framework for this study, as it is concerned with these attitudes and psychological factors.

The theories presented help in reasoning and analyzing the data, so that the authors know what signs and signals to look for. However, theories are also to some extent utilized to see if a pattern emerges that is consistent or inconsistent with the data. In other words, the frameworks have two functions: First and primarily, to support the way towards an understanding of the potential gap, by analyzing adoption drivers and barriers. Second, to see if the theories are consistent with the data or if there is a need for new theories to be developed. This aspect of applicability and usefulness of the presented theories is already brought up regarding the uniqueness of IT innovations, which could make these general theories inappropriate to use in the context of blockchain. As mentioned earlier, authors like Lyytinen and Damsgaard (2001) and Moore and Benbasat (1991) have criticized or reworked Rogers's model of adoption and diffusion. However, a choice has been made to use the two theories presented in this paper due to their characteristics of being well recognized and reputable in this research area. Furthermore, the vast number of citations and applications of the models, speaks for their robustness and generalizability even for new technologies, such as blockchain.

Even though a decision was made to use the frameworks by Rogers (2003) and Moore (2014), several, several frameworks and models have been encountered during the process, such as the Technology Acceptance Model (TAM) and other models focusing more specifically on IT adoption. However, a decision was made to focus on these two models because of three reasons. First, because they are both focusing on the adoption of new technologies. Rogers (2003) defines adoption as "a decision to make full use of an innovation" (p. 171). In contrast, TAM is focusing more on the acceptance of a new technology, which is an insufficient definition for the purpose of the thesis. Secondly, Moore's model is interesting as it builds upon Roger's work and introduces the Chasm, which is specifically related to the second research question. Furthermore, Gartner's Hype Cycle has been encountered. This model is concerned with expectations and market promotions of a new technology, and how these are misaligned with the technological performance of an innovation (Gartner, 2018). Again, a decision was made to omit this model as it could not assist in answering the research questions. This is because it does not provide any explanations to why technologies are not adopted, but merely states whether it is hyped or not.

3 Methodology

This chapter will go through the methodology used in conducting the research. The choices will be explained as well as motivated. The first part describes the research strategy, followed by the research design. Later, the methods used for data collection and analysis will be explained. At the end of the chapter, the quality of the study will be assessed and discussed.

3.1 Research Strategy

Research strategy is defined as the general approach that the researchers take in order to conduct the study (Bryman & Bell, 2011), and for the purpose of this thesis, an explorative approach was used to fit the research needs. Exploratory research is useful when a phenomenon has received limited or no systematic investigation (Stebbins, 2001). Research literature on the possibilities of blockchain to transform industries, including supply chains, is growing (Queiroz et al., 2019). However, research on practical evidence and to what extent the possible sustainability benefits are realized is relatively unexplored. Hence, an explorative orientation is needed to fill the literature gap.

Furthermore, a qualitative approach was chosen to investigate the stated research question, which suits an exploratory research well. This is highlighted by Bryman and Bell (2011), who state that when little research has been done on a topic, it is difficult to conduct a quantitative study as there is no robust basis to stand upon and draw leads from. Hence, an exploratory and qualitative research strategy was preferred as it allows a less structured approach where theory can more easily emerge. Additionally, Yin (2016) points out that qualitative research is an appropriate research strategy when conducting in-depth studies of topics in which the authors have a personal interest. Qualitative studies allow for a wide range of structures and designs, unlike quantitative research which often follows a predetermined structure (Yin, 2016). This potential for openness leaves room for new insights and aspects that could not be considered in advance of a research in terms of standardization (Flick et al., 2000). Especially in the case of a new technology, such as blockchain, this openness is an important aspect.

Qualitative research can have either a deductive or inductive relationship to theory, however the latter is the most common approach (Bryman & Bell, 2011). The inductive approach is concerned with generating theories rather than testing them, which is more suitable for qualitative research (Bryman & Bell, 2011; Stebbins, 2001). Accordingly, this thesis has an inductive relationship to theory, with the aim of contributing with generalizable explanations based on empirical observations from the data collection. Furthermore, inductive research goes well together with the explorative approach when the purpose is to uncover new ideas (Stebbins, 2001).

Consequently, the mix of explorative, qualitative and inductive approach matches with the stated research questions, as the study seeks an understanding of the adoption of a fairly new technology. For example, it would be hard to answer the ‘why?’ without being able to ask follow-up questions, discuss, and dig deeper into each of the subjects' situations. These questions can best be answered qualitatively by interacting with the social world and collecting data based on words, rather than numbers (Bryman & Bell, 2011; Yin, 2016).

3.2 Research Design

The choice of research design plays an important role as it gives a framework for the collection and analysis of the data, which can be used to draw generalizations from multiple individuals to larger groups (Bryman & Bell, 2011). Moreover, the research design helps to strengthen the credibility of this paper and can ensure that the gathered data will properly address the topic and helps to answer the research question (Yin, 2016).

The research design of this study is a cross-sectional design with case study elements, hence it can be seen as dichotomous. It was designed to capture data on more than one case, from different perspectives at one single point in time, which is a characteristic of a cross-sectional research design (Bryman & Bell, 2011). However, Adér and Mellenbergh (1999) state that in most cross-sectional research, quantitative and larger sample size data is used to systematically examine relationships between variables. On the contrary, Bryman and Bell (2011) state that cross-sectional designs can be used when conducting qualitative research with semi-structured interviews, which justifies the design of this study. However, a limitation of this choice is the small sample size, and therefore multiple case study can be considered to match the research of this paper. This research design is often used to answer in-depth questions which require insights from different cases on a certain issue (Creswell et al., 2007). As all interviewees are engaged with blockchain and thus are similar in this aspect, a multiple case study can be conducted, according to Yin (2016). Further, a multiple case study allows to compare and contrast the results of the individual cases which in turn encourages consideration of the particularities and commonalities of each case (Bryman & Bell, 2011). Again, in this paper, the different answers of the respondents regarding blockchain and sustainability can be compared and contrasted. However, the depth of each case was limited due to the scope of this project and the total number of interviewed companies and experts. Nevertheless, for some of the case companies, additional documentation was provided, which allowed a more in-depth understanding.

With the above-mentioned definitions and characteristics of these two research designs, it can be deduced that the research design of this work is a cross-sectional design with elements of a multiple case study. The decision to use this mix was not made from the beginning, but rather emerged with the process of this work. It was intended to be a pure cross-sectional design, however, with the difficulties of finding interview respondents together with time constraints, the design needed to be altered. In total, more than 50 individuals and companies were contacted, of which the resulting number of interviews were only six. Unfortunately, additional interviews were canceled with short notice. However, the provision of additional sources of information, such as PowerPoint presentations, enabled the cross-sectional design with focus on interview data to bring in case study components. This is in line with Bryman and Bell (2011) who state that case studies are often intensely focused on a certain case where data is gathered from multiple sources, not only interviewing. Thus, this study is somewhere in-between these two designs, and it can be concluded that it is a mixture. After all, the primary design is cross-sectional as the focus lies on the cases as a group rather than the context of each case.

3.3 Research Method

Given our research questions, the following project has been designed and performed: The process started with screening the three topics of blockchain, sustainability, and supply chain management, as well as the intersection of them. After reaching an understanding of the literature in this field, a more systematic and comprehensive review of the literature was carried out. Later, primary data was collected through six semi-structured interviews with companies and individuals with experience in blockchain-based supply chains. The interviews have focused on the three main topics: The aim and driving forces behind the decision to use blockchain; the barriers experienced with the adoption and scaling of blockchain applications; and lastly, how and to what extent the different sustainability capabilities of blockchain have been used in their supply chain management. Thus, the research has focused on analyzing how and why certain use cases and applications of blockchain have been adopted and implemented among respondents, while others have not.

3.3.1 Identification & Collection of Literature

The collection of literature was divided into two different processes. The first process aimed at achieving a better understanding of the blockchain technology, sustainable supply chain management, as well as how blockchain can reshape the traditional way of managing supply chains. This process was explorative and narrative, taking a wide approach with the aim of building an understanding of the topic. This is a preferred approach for a literature review when following the inductive approach, as it can be problematic to set out all key concepts and terms in advance when the aim is to generate theory. However, for the second part, presented in section 2.2.1, a more systematic approach was taken as it was important to get a thorough and unbiased overview of blockchain capabilities. This was particularly important for section 2.2.1 as the purpose of that literature review section was to serve as a basis for both primary data collection, and for the analysis of potential adoption gaps. In other words, this part followed a systematic literature review (SLR) approach. The key characteristics which made the method systematic is that it followed certain steps, involving keywords and criteria to make sure that the outcome was unbiased (Bryman & Bell, 2011). Bryman and Bell (2011) highlight the unbiasedness advantage of SLRs: "Proponents of systematic review argue that it is more likely than the traditional review to generate unbiased and comprehensive accounts of the literature, especially in relation to fields where the aim is to understand whether a particular intervention has benefits." (p. 96). As part of the secondary data collection served as the basis for answering the research question, i.e., providing a basis for the gap between claimed potentials and real use of blockchain-based supply chains, it was of utmost importance that the literature review was unbiased. Thus, the choice of doing the SLR for this part, instead of a traditional narrative review arguably strengthened the quality of this study.

When searching for literature in the field, several databases were used of which the main ones were Google Scholar, Business Source Premier, Science Direct, JSTOR, Springer, ResearchGate as well as University of Gothenburg's 'Supersearch'. As mentioned above, when conducting an SLR, the use of key words and specific terms is a way to systematically go through relevant literature. The key words used for the SLR (second part of the literature review) were: *Blockchain, supply chain,* and *sustainability*. Except for these three main keywords, *transparency* and *traceability* were used in two additional searches together with the previously mentioned terms. However, as the literature on the three main keywords is still quite narrow, especially as the study is limited to the environmental aspects of sustainability, additional articles that were cited or referenced in the initially chosen literature were also included.

Using exclusion and inclusion criteria is a part of the SLR to objectively assess whether an article should be included or not, and to steer the authors towards relevant literature (Bryman & Bell, 2011). It is also used to be transparent about the research process to the reader. The criteria used to ensure quality in the study of section 2.2, regarding blockchain capabilities, are presented in Table 2.

Table 2

Inclusion and Exclusion Criteria

Systematic Literature Review Criteria	
Inclusion	- Peer-reviewed - Published in academic journals - Published by acknowledged consultancy firms
Exclusion	- Not written in English, Swedish or German - Articles not related to environmental sustainability - Articles mainly about cryptocurrencies

3.3.2 Primary Data Collection

In order to answer the research questions, primary data was collected through interviews with individuals who are either providers or users of blockchain platforms for supply chain management. Interviewing is a suitable data collection method when the focus is to understand the reality of respondents without the need to understand reactions or interpret gestures and social interactions. In such a case, observing the participants would have been preferred (Yin, 2016). In this study, interviewing served the aim well, as the core of the research is to analyze spoken words and reported insights from respondents (Yin, 2016).

The interviews were conducted in a semi-structured way which means that an interview guide was used to keep consistency, but still allowed for flexibility (Bryman & Bell, 2011). Consistency was important to be able to examine the frequency and depth of the discussed topics later in the analysis. However, flexibility was of utmost importance, as respondents came from different industries and different maturity levels when it comes to the integration of blockchain. Thus, it was important to be able to ask follow-up questions and adapt to each interviewee's specific situation, to broaden the information obtained (Given, 2008). Semi-structured interviews further allowed for the emergence of new-to-the-researcher areas, which were of interest in this study as blockchain is still in its infancy. Thus, not having too strict scripts was necessary for the explorative nature of the study, as well as to keep an unbiased approach (Bryman & Bell, 2011). As theory building was the desired outcome of the research, it was important to allow for new concepts to emerge during the interviews. It was vital to allow for both depth and breadth for quality purposes and for being able to answer the research question properly. Therefore, an overly structured approach could have resulted in a less nuanced analysis and overall study. It is seldom the case that blockchain brings the exact same benefits across industries, and that the same barriers are experienced, and these disparities were important to find. Still, structure was needed since the secondary data collection had brought up key concepts (see Table 1 - Capability Framework) which the authors wanted to investigate in each of the interviews. Given (2008) highlights that semi-structured interviews are suitable for studies where the authors have a clear research goal, hence suitable for investigating these key concepts and capabilities from the literature review done in the secondary data collection.

Selection of Interviewees

The interviewees of this study represent different industries: Fashion, automotive and food. Covering different industries gave the research a breadth that was important for the study. It helped in reaching a comprehensive understanding of the extent to which blockchain is used in sustainable supply chain management. Incorporating different industries was also important for the generalizability of findings, as stated by Eisenhardt (2021). Furthermore, it was of utmost importance to get in contact with companies and projects who are using blockchain in supply chain management. Therefore, it was necessary to strategically reach out to potential participants, hence purposive sampling was used. According to Yin (2016), purposive sampling can be highly purposive if the sampling is based on certain criteria, which is the method used in this paper. A less purposive sampling is one where the researcher has only used it to ensure greater variation in an otherwise random sample (Yin, 2016). In this paper, it was necessary to apply the criteria sampling to collect data from those who have experience of using blockchain-based supply chains for sustainability purposes (besides efficiency purposes that most certainly all organizations aim for). In other words, the criteria used when sampling were: The individual or organization has experience with blockchain; the interviewee needs knowledge of how their blockchain technology is used in the supply chain; and lastly, the interviewee needs to know to some extent what blockchain can do for the organization's sustainability work. The size of organizations and projects in which the interviewees are employed, is not taken into account as it is believed to be of less importance. Adopting blockchain and making full use of the technology could be easier in large companies with more capital, but could on the other hand be easier in smaller projects with less complex supply chains. Thus, size was not a criterion when searching for interview subjects. Bryman and Bell (2011) highlight that purposive sampling is useful when researchers need to interact with specific actors to achieve the research aim. Despite the fact that purposive sampling oftentimes is said to be biased (Etikan et al., 2016), it was necessary to perform the sampling through this strategy.

However, during the sampling process where in total 50 individuals and organizations were contacted and asked to participate, snowball sampling was also used to some extent. For example, some companies did not want to take part in interviews due to various reasons (lack of time or blockchain experience, confidential information etc.), but suggested other organizations that are using blockchain-based supply chains. However, the main sampling strategy was purposive. The search process was primarily done on LinkedIn and through personal contacts, but Google Search was also used. Additionally, blockchain platforms often advertise their use cases, which was another way of finding relevant companies to contact.

As sustainability can be considered a sensitive topic to some respondents, they all had the opportunity to be anonymous. This option was important as the name of the individual and organization was regarded as less important, compared to the information given by the respondent. Anonymization was believed to benefit the depth and honesty of information provided. On the other hand, some companies want to expose themselves, their sustainability work and innovativeness, thus it was also important to give the respondents this opportunity.

Interview Guides

Before the interview process began, two interview guides were created; one for users of blockchain platforms and one for providers. The interview guides were created with the aim of being as similar as possible to make the analysis and comparison among interview subjects manageable. The guide made for the provider of the platform was created with the intention of getting an understanding of what capabilities and benefits they offer, but also to find out how their users adopt the different capabilities. The other guide, made for the users, was directly addressing the way they adopt, apply, and use the blockchain platform in their daily businesses.

An interview guide should not be strictly followed, but instead be used as a guideline of what needs to be covered to answer the research questions (Bryman & Bell, 2011; Yin, 2016). Thus, the interview guides, shown in Appendix 2 and 3, should be seen as a guide and not a strict questionnaire. They were followed to varying degrees across interviews, depending on how much the interviewee were touching upon the main topics already in the introductory, more open questions. This approach is in line with the choice of conducting semi-structured interviews (Bryman & Bell, 2011). Consequently, the interview guides were used mainly to keep consistency among interviewees and to ensure that the research questions are answerable with the information given by the respondents. The most important questions to cover were marked with a star in the interview guides to make sure that they were asked during the interviews.

The guides were created with questions in a specific order, beginning with introductory questions regarding the interviewee's role and background. Bryman and Bell (2011) recommend that questions should follow an order that gives the interview a smooth flow, therefore the order of questions was based on the funnel structure of the literature review. Thus, it started with blockchain technology, then blockchain together with supply chain management and lastly the focus steered towards sustainability applications in more detail.

Conducting Interviews

All but one of the interviews were held online, via Zoom or Microsoft Teams. This was due to two reasons: First, a majority of respondents were not located in Gothenburg, the city in which the authors live and perform their research. Second, online interviews save time and have become what some call 'the new normal' after two years of the COVID-19 pandemic. Moreover, online meetings are generally preferred over phone interviews as they allow for better connection when the participants are able to see each other face-to-face (Bryman & Bell, 2011). One of the interviews was conducted on site, as the interviewee invited the authors to their office in Gothenburg. The interviews were conducted in English, as this is the official language of the studies and the thesis. Furthermore, it was decided that both authors should attend each interview, as it was considered of high value to have four ears listening and two alert minds present to get the most out of each interview. Thus, as English is the language in which the authors communicate with each other, it became natural and necessary to conduct the interviews in English, even though this was not the mother tongue of respondents. Thereby, there was no need to address the potential issues with translating interviews, such as linguistic differences (Xian, 2008).

The settings of the interviews are presented in Table 3 below, where organization, role, location, date and duration of each interview is displayed. In the following presentation of empirical findings and analysis, the references P# (platform provider) and C# (company users) will be used to refer to each interviewee. The distinction between platform provider and company user was not always easy to make, especially in cases where the respondents were working on projects with blockchain-based supply chains and could be deemed both a supplier and a user. However, for the sake of this study, it was not considered crucially important to make the distinction completely correct, as the answer to the research question would not be affected by this. After all, it is the application and usage of the blockchain platform that is of interest, regardless of whether the respondent is a user or a provider.

Table 3

Interviewee Table

Interviewee	*Ref.*	*Organization*	*Role*	*Location*	*Date & Duration*
Anonymous	P1	University of Zurich	Researcher in Blockchain Business Models	Online (Zoom)	2022-03-09 38 min
Mats Hälldahl	P2	ATEA	National Blockchain Lead	Online (Teams)	2022-03-14 54 min
Anonymous	P3	University of Gothenburg	Researcher in Informatics	Online (Zoom)	2022-03-15 48 min
Jan Carlson	C1	Volvo Cars	Procurement Sustainability	Face-to-face (Head Office in Gothenburg)	2022-03-23 54 min
Anonymous	C2	Fashion industry company	Head of Marketing	Online (Teams)	2022-03-01 38 min
Mattis Bergquist	C3	Coop	Head of Sustainability	Online (Zoom)	2022-04-21 45 min

Note. Column two, "Ref.", shows how the different interviewees will be referred to in the remainder of the text. The P stands for platform provider, and C stands for company user (a company using a blockchain SaaS platform).

All interviewees accepted to be recorded, which was appreciated as it enabled the interviewers to focus on the conversation. Bryman and Bell (2011) suggest that interviews are recorded so that the interviewer does not need to take notes, but can instead focus on the dialogue, ask follow-up questions, and be alert on addressing possible inconsistencies. Furthermore, recording enabled the full conversation to be captured, without missing important details. Each interview was then transcribed word for word, by the help of the online transcribing tool 'Otter.ai'. Bryman and Bell (2011) highlight the vast amount of time that transcriptions often consume, hence using this online tool helped saving a lot of time. However, the authors carefully listened through the interviews and made corrections in the text produced by the tool and made sure that the sentences were accurately transcribed. It was important to transcribe every word, as analyzing words is in line with qualitative research (Bryman & Bell, 2011). Poland (2003) raises the issue of quality aspects when it comes to transcribing interviews and highlights common problems such as: Structuring sentences, using quotation marks, as well as interpreting words and phrases incorrectly. These problems can give rise to large misinterpretation of the data (Poland, 2003). The issues were mitigated by having both authors listen to each recording on their own, while correcting the software-produced transcription, to make sure that everything is correctly captured. In case of missing words, where it was unclear what the respondent said, the mark {???} was used, as suggested by Bryman & Bell (2011). Furthermore, to add clarification within citations, square brackets were used. Square brackets were also used to cut out less relevant information from citations, this was marked with [...].

3.4 Empirical Analysis

The transcribed interviews were analyzed through a thematic analysis where the data was sorted into different codes and themes. Coding is the process of highlighting interesting and significant data in the transcripts and serves as a first important step in theory building (Bryman & Bell, 2011). The aim of doing this thematic analysis, including the coding, was to find concepts that together could build a theory around the research question. The advantage of using thematic analysis is that it offers a way of approaching unstructured data in a more structured way. It made it easier to find important information as well as highlighting similarities, differences, frequency and depth of topics across the interviews (Bryman & Bell, 2011).

Furthermore, an iterative process was taken to the collection and analysis of data, meaning that the empirical analysis began when the data collection process was still in progress. This helped shape the way in which data was collected, for example in guiding the authors towards interesting topics that should be addressed in upcoming interviews. This iteration is in line with grounded theory, which is a common approach in qualitative data analysis described as being "concerned with the development of theory out of data *and* the approach is *iterative*, or *recursive*, as it is sometimes called, meaning that data collection and analysis proceed in tandem, repeatedly referring back to each other" (Bryman & Bell, 2011, p. 576). This approach was taken to some extent, as described above, where moving back and forth between data and analysis was part of the research process.

Coding was done in a software tool called Atlas, which enabled a structured way of coding the qualitative data collected through the interviews. The coding overview is illustrated in Appendix 4. It is however important to be aware of the limitations of using software prior to the start of the coding process. Yin (2016) emphasizes that the researchers must make all the analytical decisions themselves, whereas the software is only supporting the organization of data. In addition, the more familiar the researchers are with the software, the less attention will be needed to follow its terminology and processes (Yin, 2016). Hence, learning the tool before starting the coding process was important for the authors of this paper, so that full attention could be given to the analysis of the qualitative data. However, the advantage of using software tools like Atlas is that it makes it easier to analyze the interviews, as you can get a holistic overview and spot where a certain code has been used across multiple interviews (Bryman & Bell, 2011). The coding process entailed the breaking down of data into smaller components to make the large unstructured data easier to understand. However, an issue with the process is that one can easily lose the context while coding (Bryman &

Bell, 2011). Furthermore, the coding process entails subjective interpretations by the authors. To mitigate these issues, both authors coded the data separately and later compared and discussed potential disparities in interpretation. This way, a higher degree of objectivity was achieved.

Instead of having the codes categorized into emerging themes, the broader themes were already set from the theoretical framework and literature review. However, the coding process was instead concerned with letting codes and subcodes emerge to generate the empirical findings and theory-building. This is especially true for the latter part of the empirical findings and analysis where driving forces and barriers are addressed. In that part, the codes were identified from what was found interesting, relevant and consistent across the interviews, which is in line with the inductive approach. The first part is concerned with the Capability Framework (Table 1), where both codes and themes were already defined prior to the coding process. It had more of a check-list structure as the aim was to see which applications of blockchain were used in the case organizations. Consequently, both open and selective coding have been performed, according to the definitions of Bryman and Bell (2011). Further, due to the iterative process of going back and forth between empirics and analysis, codes were revised, deleted and added throughout the process to make sure that all codes are consistent with the aim and research question. The analysis was then based on the final codes and themes and their relationship to the purpose of the thesis. The aim of the analysis was to identify similarities and differences within the interviewed group. It was also driven by the frequency and depth of mentioned and discussed capabilities of blockchain, as well as adoption forces and barriers. By doing so, the aim was to be able to highlight the potential gap of blockchain usage stated in the research question, and different explanations to why this potential gap exists.

3.5 Research Quality

The following chapter focuses on the evaluation of this paper's research, which is important to achieve high quality. The assessed criteria of this study are reliability and validity. Despite critique against these measures for being developed for quantitative research, the criteria are still considered useful in an adapted form proposed by LeCompte and Goetz (1982). These are first explained in general and then applied to this research. Great emphasis has been placed on maintaining these criteria throughout the whole research to ensure the best possible research quality and trustworthiness.

Reliability

According to Roberts and Priest (2006), reliability in qualitative research describes the extent to which a particular procedure, such as a questionnaire or interview, produces comparable results under different conditions, provided that nothing else has changed. In qualitative research in particular, reliability can be separated into *external reliability* and *internal reliability.*

External reliability can be seen as the aforementioned definition of reliability in general, which is concerned with the replicability of the research (LeCompte and Goetz, 1982). As semi-structured interviews have been used for this research, external reliability can be weakened, as replicability is hard to achieve. Therefore, standardized interview guides have been used and are presented in Appendix 2 and 3 to increase trustworthiness. By star-marking questions that according to the authors must be asked to answer the research questions, the replicability (external reliability) is strengthened. Both measures have been chosen to increase the trustworthiness of this research. Internal reliability, on the other hand, describes to what extent the members of the research team agree about what they observe (Bryman & Bell, 2011). In order to avoid a bias in internal reliability between the two researchers, both have attended all the interviews and the recordings from the interviews have been listened to multiple times. Afterwards, the authors were discussing the results and analysis on an ongoing basis to make sure that what is written is agreed on by both. Moreover, the findings of the interviews have been objectively summarized and analyzed after a coding scheme (see Appendix 4). Through this process, internal reliability as well as credibility of this research is guaranteed.

Validity

Validity is according to Maxwell (2013) "the correctness or credibility of a description, conclusion, explanation, interpretation, or other sort of account" (p. 122). Yin (2016) explains that a valid study is one that has properly interpreted its findings so that the conclusions precisely reflect and represent the real world that was studied. Furthermore, Bryman and Bell (2011) again divide the term validity into *internal validity* and *external validity*. Internal validity assesses the degree to which the researchers' observations and data match the generated theory of the results. In order to guarantee internal validity in this paper, the interview guide has been designed with star-marked questions to make sure that the sample can be approached similarly and thus be treated as a group. By doing so, instead of focusing on differences across multiple entities, it is believed that congruence between observations and the emerged theory is strengthened. Additionally, both authors have transcribed, coded and analyzed the interview data to ensure that bias is minimized and that as correct picture as possible of the blockchain-based supply chain industry is captured. On the contrary, external validity is according to Bryman and Bell (2011), "the degree to which the findings can be generalized across social settings." (p. 395). The general downside of this criteria in qualitative research is that oftentimes, like in this study, small samples have been used and therefore makes it difficult to draw generalizable conclusions (LeCompte & Goetz, 1982). However, the external validity can be argued to improve by the fact that interviewees are representing different industries, which may raise the generalizability of results. Further, this paper focuses on why the gap between claimed sustainability potentials and real implementation exists and focuses on the cases as a group. The generalizability is then improved by finding similarities and frequency of mentioned topics across these cases and industries.

4 Empirical Findings

In this chapter, findings and results from the interviews with blockchain users and providers are presented. The chapter is structured according to the research questions: First, it will be presented to what extent the respondents are using the sustainability capabilities in blockchain-based supply chains. This will be done by giving examples of how they are using it. Sometimes examples are given to show how they are using the technology indirectly or how they aim to use it, thus every example is not a proof of adoption. In the second and third part, driving forces and barriers to implementation discussed by the interviewees will be summarized by giving examples.

4.1 Sustainability Capabilities of Blockchain

The nine sections below are related to the nine capabilities in the framework presented in Table 1. This list represents what was perceived to be the most prevalent use cases according to the literature. In these nine sections, the results from the primary data collection will be presented. The amount of text and content vary across the nine capabilities, due to respondents having different amounts of experience related to each of them. In the beginning of each section, a short repetition of the capabilities will be provided, to remind the reader of what the literature has brought up.

4.1.1 Tracking Environmental Performance of Suppliers

The first capability mentioned by the literature is tracking the environmental performance of suppliers. This tracking can help reduce the overall economic footprint by choosing green suppliers or working with supplier development to make them more sustainable. Researchers state that this sustainability benefit can be achieved by internal motivation as well as pressure from regulations, policies and consumers.

P2 explains that they have realized a benefit from tracking fish suppliers in Norway. With blockchain technology they were able to analyze current working methods and develop more efficient and sustainable ways of working. In this case, the fishers changed from fishing far outside the coast of Norway to fishing closer to the shore. This made it possible to take care of the smaller fish and breed them in fish farms on land, instead of throwing them back as rest products. This way, less fish become waste and the process becomes more efficient. Further, this waste reduction in combination with fishing closer to land generates sustainability benefits, e.g., lower CO_2 emissions.

Both interviewees P3 and C2, state that blockchain can help to investigate sustainability and sustainable acting within the fashion industry supply chains. P3 will develop an app where workers in factories in the global south can assess their well-being and work conditions. This way, brands and end consumers can in real time see how the workers feel and are treated. Even though this is related to social sustainability, it can be relevant for environmental issues as well, according to P3.

C1, who is an actor in the automotive industry, has a very large supply chain where they struggled to get an overview. Investigations made by Amnesty International revealed unsustainable behavior in the sourcing of battery materials, which according to C1 led to many OEMs being hurt. C1 was not involved in this investigation as it took place before they started producing their batteries. However, this put pressure on the whole car industry to take better control over their sourcing and C1 stated that:

"We need to have control over the supply chain and we tried to find a way how we can have some traceability." - C1

The transparency with suppliers made it easier for C1 to understand how environmentally sustainable their suppliers work and choose them accordingly. As explained by C1, it helped them to see how much CO_2 their suppliers emit and to calculate the CO_2 balance of their cars. He also highlighted that organizations oftentimes have little knowledge about the raw material industries and that blockchain can improve this knowledge but also improve the control.

"So, I mean normally, if you have a supply chain, and you buy a battery for example, you have no clue about the mining industry - if they are using 14,001 [ISO standard], for example, or if they have the certification. But here we really are under the skin, all the way." - C1

By having this data on suppliers, C1 means that organizations can improve their knowledge but also improve their position to influence the suppliers. Further, P3 believes that tracking suppliers and thereby shifting more responsibility to them, will in turn lead to higher pressure on their subcontractors to work more sustainably. P2 agrees that tracking suppliers can increase pressure to comply with environmental policies. As a result of the transparent handshake of sharing data on origin and production, the supplier is incentivized to be sustainable. P2 gives an example of breeding chickens and explains that when a chicken supplier starts sharing the data, they want to show that their breeding has a low impact on the environment and that no antibiotics have been used.

Another example C1 brings up is that for one of their batteries, the cathode material was transported from Poland to Michigan because their supplier had free capacities, which was a route that C1 was not aware of. Thanks to the traceability of blockchain, they detected this undesirable transportation and were able to initiate changes to match the process with their sustainability goals.

"So, it's not only here, you can find out that the blockchain traceability helps to know where the material is coming from, but also to make sure that it's a responsible source." - C1

With blockchain, C1 starts to be more directly involved with the suppliers of raw materials and can consequently choose or influence their suppliers according to their sustainability aims. Lastly, C3 believes that blockchain can help them trace origin and better target each batch with blockchain. He states that current auditing methods in the food industry are insufficient, as they take place only once a year. With blockchain, they can instead collect real-time data and follow the development of their suppliers so that unsustainable behavior can be detected faster.

4.1.2 Tracking Materials & Waste Management

Another capability of blockchain-based supply chains with regards to sustainability, brought up by the literature, is the tracking of materials and waste management. More specifically, on the one hand, it is about preventing the degradation of resources, where blockchain can help with its traceability of origin. On the other hand, waste management is about reducing waste along the supply chains.

According to P2 and C3, blockchain technology can help significantly to minimize waste, especially within the food industry. P2 brings up an example of food that becomes too hot during the process. Instead of having to recall and throw away an entire product line, blockchain's trackability makes it possible to trace and identify individual batches or specific products. Accordingly, these defect goods can be identified and disposed of in a very targeted manner, thanks to blockchain. As a result, less food has to be thrown away than before (P2). C3 describes a similar example where blockchain can help to better target food that has been affected by diseases, such as salmonella. In such a case, C3 agrees with P2 that blockchain is a valuable technology to trace back the exact batches that are affected, so that waste can be reduced. Yet, the use of blockchain in waste management in the food industry can achieve more. According to P2, it offers the possibility to see in real time how much product is currently in the supply chain and to better control how much is really needed.

"How much merchandise you have in different levels of a supply chain, you get control of all of that. And when you see that something is missing or you see you have too much of something in the supply chain delivery, you can manage that. So, you minimize the waste." - P2

P3 on the other hand, working on a project within the fashion industry, sees slightly different waste reducing potentials of blockchain. With the help of blockchain, the fashion industry can produce products with better quality. This is mainly due to the transparency of the different suppliers and knowing which fabrics are used along the supply chain. The increased quality of the fabrics thus increases the longevity of the end products:

"So, it's not going straight from first use to recycling or throwing away. It continues living for a long time. And we think that blockchain, and there we don't see any really other technology that could help us do that." - P3

C1 on the other hand, uses blockchain in a more indirect way to reduce waste. They select and audit their suppliers in the mining industry based on IRMA (Initiative for Responsible Mining Assurance) standards. They in turn commit to dispose of the waste carefully and sustainably according to the IRMA standards. Blockchain has helped C1 to have an overview of their suppliers and thus select the more sustainable ones, however, they do not use blockchain for waste management directly. Moreover, C3 states that waste is very hard to quantify as there is no standard way of measuring:

“And then it's really tricky to sort of measure the amount of waste. Is it kilogram? Is it volume? Is it per material? It's really tricky.” - C3

This lack of standardization leads to incomparable measurements, as different companies will have different figures for the same amount of waste (C3). In line with this, C2 describes that they have been tracking their waste for several years and categorized it into eight different waste types, such as paper, plastic, garden waste, etc. It is measured in tons, however, C2 means that it is oftentimes hard to quantify the exact amounts.

All in all, the respondents agreed that waste management is an important topic for the future. However, only two of them (C2 & P2) are using blockchain to keep track of the waste, how it is recycled and reused. Instead, several respondents (C1, C3, P3) were discussing the indirect benefits of waste reduction and management through blockchain’s traceability capability.

4.1.3 Tracking Logistics Information

As brought up in the literature section, tracking logistics is mainly about reducing greenhouse gas emission during transportation. This can be achieved either by detecting unsustainable driving or shipping routes, but also through incentivizing the driver to operate more efficiently and sustainably.

Tracking the transportation of products along the supply chain appeared to have various benefits experienced by different respondents. Two respondents (P2, C1) brought up that they had identified extremely long transportation routes by the help of blockchain. First, P2 explained how they could follow the journey of the fish by tracking the transportation with sensors connected to the blockchain. By doing so, they recognized that the fish was traveling from Norway to China for processing and then back to Sweden. However, this transportation route could be adjusted thanks to blockchain, as P2 highlighted:

“But I think you minimize the travel for the transportation. You can, for example, not go to China instead directly from Norway to Sweden. That's, that's a huge benefit, right?” -P2

P2 also states that the driver can be incentivized to transport the goods in a more sustainable way, as the driver will know that the route is tracked. Similarly, C1 brings up a case of materials being transported long and unsustainable routes, which was detected when they started to take a closer look into the traceability of battery components. They thought they had good control of where the material was going:

“So, for one of our batteries, we know that battery production is in Poland and we are producing the cars in Ghent for example. And we are using a supplier in Europe for the cathode material. So, I mean, we thought we had a quite good connection and control but when we were starting to dig in

really in blockchain traceability for this type of battery, we found out that the cathode material was not going to Poland it was going to Michigan" - C1.

Furthermore, P1 states that they are not using this type of tracking at the moment, but that it is a goal for the future. It is believed that tracking how a car is typically used by the owner and how much gas is consumed, will bring value to the company in the future. It should also create incentives for the owner and driver of the car to behave more environmentally-friendly as unsustainable driving will reduce the value of the car. Another angle brought up by P1 is that when cars are tracked in terms of their usage, it becomes easier to perform maintenance and service works, which prolong the lives of the cars. This is then translated into sustainability benefits as the owner can use the car for a longer period of time (P1). Lastly, C2 states that they have been tracking logistics and calculating the emissions for each type of transportation method for more than ten years. These calculations have been outsourced to a third-party organization. C2 means that they already have good control of their transportations, and is unsure whether blockchain can help calculate the emissions more accurately.

4.1.4 Collecting Data on Sustainability of Production

Tracking production processes is often done for efficiency purposes, however the literature talks about how this data can be put on the blockchain to incentivize more eco-friendly processes. These improved outcomes can be in terms of better eco-design, manufacturing processes and storing data for carbon footprint measurements. This data can then be used to easier manage application and compliance with standards and certificates.

P2 states that when collecting data on production processes along the supply chain and storing it on a blockchain, it becomes easier to calculate it correctly:

"Yeah, you trust the data, but you also calculate it more correctly, because if islands calculate their own carbon footprints, it turns out that it could be 20% wrong when you pool it all together. But if you pool all the data into one system and calculate it from there, you will be more precise. So, that's also a benefit we'll have from the blockchain." - P2

C3 agrees that calculating a more accurate carbon footprint can become easier with blockchain. Furthermore, he emphasizes the importance of making production processes more sustainable as they account for 96% of their products' footprints. Instead of using the industry-wide standard measurements developed by RISE (Research Institutes of Sweden), blockchain can help C3 to calculate the footprints more precisely. Correspondingly, C2 highlights the importance of tracking their production processes for the same reason:

"It's important for us to track the production and how much CO2 we emit there because we have seen that the production itself accounts for most of our emissions." - C2

In the battery supply chain of respondent C1, the tracking capabilities of blockchain make sure that data is stored from the first process of mining raw materials up until the battery is complete. Both direct and indirect measurements on emissions and energy consumption goes into the carbon footprint calculation:

"So, from the mine for example, here you have direct emission from production and also indirect emission from purchasing electricity and other material which is used in the process but does not belong directly to the material itself. So, we have the CO2 footprint when the material is leaving DRC mining and the smelter for example. And when that's coming into the next refiner, it will add up to a complete battery pack in the end, also of the of the CO2" - C1

So, this is an example of how blockchain can help store the data during the whole supply chain and all production processes it involves. Moreover, P2 brings up a related and important factor: As data collected during production is often used towards standards organizations, when applying for certifications, companies who are already environmentally friendly will be most eager to start using this capability. Those operating unsustainably, will instead look worse if they become transparent (P2). P2 means that sustainable companies can benefit from blockchain transparency because they achieve a higher degree of trust:

"If they have a certificate on their product, they want it to also be trustworthy or not to be cheated with. This is even better than a certification." - P2

To conclude, not all respondents are tracking their production processes at the moment. However, those who are, agreed that tracking the production phase is important for improving the calculations of carbon footprints of their products.

4.1.5 Collecting Data on Packaging Material

The literature states that data regarding type of packaging material, how it is reused, and recycled can be put on the blockchain. This is closely linked to resource and waste management, however in this case the emphasis is on incentivizing more sustainable packaging practices.

Even though, none of the respondents were using this capability at the moment, a majority believed that it could be valuable for sustainability purposes in the future:

"We have not used it for the battery material so far. But it can absolutely be interesting in the future" - C1

Furthermore, C3 states that this is something they are discussing and believes that it is important, especially with regards to the use of plastic materials which is regulated within the EU.

4.1.6 Decentralization of Energy & Emissions Management

The literature presents that blockchain can help to decentralize and ease the energy and emissions management of companies. To be specific, it can help to create a more efficient green energy marketplace. This again allows organizations to monitor their carbon footprints and meet quotas by buying carbon credits from low emitters.

In order to set up an internal trading system, all supply chain participants need to calculate their CO2 footprint and share the data, which is a difficult task to perform, according to P2. However, P2 continues that calculating the carbon footprint becomes more precise with blockchain and states:

"You put in all the data from different kinds of supply systems into a blockchain. You can more correctly calculate the carbon footprint, right?"- P2

C1 brings up another perspective, which asserts that this type of trading system will only work if it is restricted to the supply chain participants. Otherwise, suppliers can easily buy their climate neutrality and therefore keep working unsustainable:

"But what we try to avoid is that a company buys some certificate and walks away with the energy consumption in that perspective. We would like to have more clean energy, I mean, that is what we're aiming for, that is what helps the earth." - C1

However, none of the respondents were using blockchain in a decentralized trading system to control the internal emission and energy consumption. P3 states that she had heard about this capability but indicated that she was not the right person to talk about it. Other respondents had not heard about this trading system and were not able to elaborate on the topic.

4.1.7 Verification & Transparency of Green Products

Using the collected information to verify whether a product is 'green' or not, and being transparent with this information towards customers, is a blockchain capability brought up in the literature.

The empirics have shown that this capability is highly prioritized among respondents and almost all of them believe it is an important feature. C1, for example, has proposed this as a selling point to the management team, and describes a scenario where the customer should be able to scan a code at the window of the car, to access the supply chain and CO2 data in an app.

"*You can see here is the battery supply chain, and here is the CO2 footprint and so on, and we can prove that we have a green supply chain and no child labor or whatever involved here. So, we are collecting information, and you can do something with it, but we don't have it for the moment.*" - C1

P2 also appreciates this capability of blockchain, saying that it is the illustration of the collected data that makes it interesting to consumers. He highlights the importance of visualizing the blockchain for the consumer by developing a QR code, so that the buyers are able to see what they are consuming:

"*The next part is that you want to visualize, it's pretty boring to look at numbers, right?*" - P2

P3 also talks about visualization and verification of data that makes it easier to purchase green products in the fashion industry. She means that customers should be able to see where every piece of garment comes from and how it is produced. As pointed out by P2, it makes greenwashing more difficult, as the organization can no longer cheat and manipulate the numbers on the immutable blockchain. Likewise, C3 states that there is a customer's demand to visualize the product's origin and sustainability data. Therefore, they have introduced an app, in which the customers can scan a barcode and get a full sustainable declaration of the certain product. However, this data and sustainability declaration is not yet put on a blockchain, but the aim is to do so in the future.

When it comes to the management and compliance with standards, P3 believes that it can be easier to handle these processes with blockchain. Interestingly, P3 also introduces another perspective to the discussion when she states that these standards might also need to be adapted and changed as blockchain becomes more widely used. P3 indicates that these standards may become stricter and better from a sustainable perspective. Thus, whether a product can be labeled as 'green' or not may be evaluated on stricter criteria in the future.

Lastly, C2 states they have developed a green label for their products which evaluates each piece of clothing according to sustainability criteria. However, after implementing blockchain, they are now able to show this more transparently towards the customers. This verification is believed to generate more trust in their relationship with customers:

"Yes, we comply with 14001 [ISO standard] and other standards too. And as I said before, I think consumers buy our products partly because they are sustainable, and if they did not really trust our claims before, maybe they do now. Because now everything is stored in the blockchain system." - C2

4.1.8 Tracking Location of Products

Tracking the location of products goes somewhat hand in hand with tracking logistics, as was elaborated on in section 4.2.3. According to the literature, the difference is: Tracking logistics is more related to the driving routes and driving habits, whereas tracking location of products is more about efficiency. Further, efficiency is about being able to see where goods have gone lost, been sent to the wrong location, and trace from where defective products have been produced etc. This will make it easier for a company to plan and schedule deliveries, but also to rework and recall goods that are defective.

P2 and C3 state that tracking product location is important in the food industry as it enables the company to trace back the origin to where the product was produced, how it was produced and where it is at the moment. Consequently, with blockchain it becomes easier to call back food that has become damaged during transportation.

> *"If there are diseases on the food, you need to sort of have the possibility to follow it and backtrack all the way actually. So, that's the part that is already done in the food industry."* - C3

Further, P2 gives an example of fish that gets too hot during transportation. With blockchain, the company will better know the quantity and location of the damaged goods, take corrective measures to solve the issue, and deliver fresh fish more efficiently. The same applies to restaurants and other commercial kitchens. If they connect their business to a blockchain platform and buy food from suppliers that are connected too, it becomes easier to handle issues regarding food that has become inedible (P2).

Even though C3 has not started making use of this capability at the moment, he believes that blockchain will be important to track the exact origin of products. For example, C3 explains that within the meat industry, they are taking DNA tests on samples to verify the origin. Some samples every year show different origins than stated on the packaging. This problem can according to C3 be mitigated with the help of blockchain traceability.

Tracking the location is not only valuable in terms of reducing the work with recalls, but it can also help to signal when something seems to be wrong considering delivery dates. For example, C1 explains that they scan the battery components as soon as they arrive and leave a specific factory location. Hence, if the same barcode is scanned in another location at the same time, something has gone wrong (C1). Lastly, P3 continues by stating that tracking the location of products is not something that they have planned to do for now, but that it will probably be relevant in the future of the project.

4.1.9 Tokenization

Tokenization was brought up by multiple sources in the literature as a way to incentivize green and sustainable behavior. The logic is that the organization builds up an internal reward system along the supply chain in which each participant can be rewarded with tokens when acting sustainably.

During the interviews, it became clear that this capability was not implemented yet, in either of the organizations. However, most of the interviewees (C1, C3, P1, P2, P3) thought that tokenization was an interesting element of the technology and started discussing different applications of it. P2 and C1 mentioned that tokens is an area in which they will not go into today, but perhaps in the future. C1, for example, agrees that even if they are not in the position to start working with tokens at the moment, it can be an interesting feature to add later on.

P3 believes that it is important to bring up and discuss these technological ideas so that new perspectives are introduced to challenge the industry. She mentioned that another organization, working for sustainability across multiple industries, “loved this idea” but had not thought about it themselves. Furthermore, the organization of P3 has an idea of connecting the first-tier supplier and producers to the circular supply chain by giving back some of the sales revenues when the clothes are being resold many times. P1 addresses the issue of designing the tokenization system so that the tokens can only be used in a sustainable way:

“We were also discussing how to create a car coin. But then the question is: What do you use this car coin for? […] But here, you really need to think through how you implement and how you design this token.” - P1

To conclude, none of the respondents had implemented this capability at the moment. The reason is low awareness of this capability, and because it is not considered to be a feature that you implement in the first phase.

4.2 Driving Forces for Blockchain Adoption

The driving forces of a new technology and innovation have already been touched upon in the theoretical part. Rogers (2003) lists some characteristics which can be drivers in the adoption of a new technology. With the help of interviews from different areas and industries, driving forces behind blockchain adoption have been identified in this study. Similarities and consistencies across interviews led to the emergence of different subcategories. These are summarized and highlighted under the following headings to provide a clear overview.

4.2.1 Efficiency

Without exception, all interviewees cited efficiency reasons for adopting blockchain technology. In fact, it has emerged that the adoption of blockchain was mainly for efficiency reasons. According to all respondents, automation, unified and decentralized storage, as well as simplified traceability were cited as main reasons. P2, for example, states that the introduction of blockchain and the accompanying automations through smart contracts will save a lot of time along the supply chain. P3, on the other hand, experiments with blockchain for economic efficiency and sees a sustainable benefit as resource utilization improves. C2's processes, as well, have become more efficient:

"I mean before the introduction of TrusTrace [blockchain SaaS], we used Excel to manage our suppliers. Since then, we are much more efficient and we can track our suppliers better." - C2

According to P1, blockchain technology has increased the efficiency of their processes. Instead of having several actors handling documents before the next phase can access them, they can now manage them all at once. Furthermore, blockchain technology can help to avoid information asymmetry between different parties of P1 and therefore lead to more efficient processes as well.
When asking why companies are adopting blockchain technology, she gives the following answer:

"It's more about efficiency and innovation. And also maybe customizing products and services, but mainly about efficiency gains, yes. Through the sharing of processes that can increase the efficiency of many of their processes." - P1

For C3, the traceability of single food batches is very important. In this process, blockchain helps to locate and eliminate the batches of the possibly spoiled goods.

"In the food industry, you need to know where things are coming from. If you get sick from the food, you need to stop the food, and then you need to know where it's coming from." - C3

According to C3, this is much more effective, since large quantities of goods do not have to be discarded, as it would be the case without blockchain, and thus a lot of food waste can be avoided. In doing so, blockchain can simplify the search for specific products and make it more efficient.

4.2.2 Sustainability

In addition to efficiency reasons, many of the interviewees also cited sustainability reasons as driving implementation. P3, for example, talks about sustainability issues in the fashion industry and how frustrating it was that hardly anyone was doing anything about it. So, they took the initiative and started a project to solve these problems. They quickly encountered blockchain technology, which with its traceability capability could eliminate many of these challenges.

"We want to create a model that can actually trigger some kind of more drastic change. [...] So, that's when we learned more about blockchain. We started thinking this is perhaps the key to all these issues like unequal relationships in supply chains and all this non-transparency. All these black box activities going on, and that it can continue going on for years, without anyone acting on it or trying to change it." - P3

For P2 the possibility of calculating a better and more accurate CO_2 footprint is one of the main drivers for implementing blockchain. C1's argumentation, which aims to introduce CO_2 traceability, goes in the same direction. Blockchain has helped them to learn more about their supply chain and trace the materials they use. For C2, sustainability reasons were one of the main drivers for using blockchain, along with efficiency reasons. In general, C2 focuses a lot on sustainability in the production of their products, where the traceability of blockchain has been helpful to better realize this goal. The most important criteria for them are the selection of environmentally friendly suppliers, and the selection of sustainable materials for their products. C3 follows a similar approach and focuses a lot on sustainable products and being able to visualize it for the customers in their app. As food sellers, they naturally pay attention to the environmental impact in the product's country of origin and how sustainably it is produced. This is important to satisfy customers but also for C3's own sustainability declaration:

"We are gathering information about the product's ingredients and the origin of the production country. And if we could make that better or finer information, gathering with also blockchain to what spot they are actually growing things on or what spot they're actually having the cattle on, and so on. That will be really, really great for us. Because then we could have even better information for calculating this sustainable declaration." - C3

C3 continues that knowing the country of origin of the product is not sufficient. It is much more important to know the exact circumstances and conditions at the specific production site. For example, Argentina is a large country with different climate problems and water shortages in different regions. Therefore, it is important for C3 to be able to retrieve more exact information from their suppliers with the help of the blockchain. Thus, a driving force for C3 is to gather more precise information that can be used in their sustainability declaration.

4.2.3 Tech Enthusiasm

Another interesting part that is brought up by the interviewees is tech enthusiasm of individuals within their organizations. Especially the interviewed blockchain platforms (P1, P2, P3), bring up this as a main driver for implementing blockchain technology. However, blockchain user C2 also states that the overall technology interest and innovation enthusiasm within the company was a driving force for the use of blockchain. Moreover, P3 gives an example of another organization where interest in new innovations and technologies was a potential driver:

"It's that they have been interested in thinking differently and thinking in new ways. And doing, not only talking about it. They're trying things, they dare to and they put economical resources on this. I mean, they invest in these kinds of ideas. Not only waiting until they know 100%." - P3

Furthermore, P3 states that firms have to be interested in digitization in general and how new technologies can potentially change businesses and ways of working even before thinking of implementing new technologies. P1 goes on to elaborate that one of the strongest driving forces behind the adoption of blockchain was the hype of the technology itself:

"In the beginning everybody was excited because it's a new technology. It was a hyped technology at that time in 2018. It was also good for companies to build on that technology, because they could get some more funding for blockchain projects." - P1

P2 on the other hand, speaks more of the individuals within companies, who are personally interested in the technology and therefore want to introduce it. P2 continues by stating that blockchain technology in particular is quickly and easily understood by CDOs and CIOs. This makes it easier to get enthusiastic about it and to promote it in their companies.

"One is that the CDOs, the CIOs, are very interested in the new technology, right? To develop that and understand it. [...] If you explain it in like 20 minutes, the CIO or the CDOs really understand it

very quickly, even though they didn't have a clue before, they understand it very quickly. And they bring it to the heart and are very eager and they understand the values and the benefits fast." - P2

4.2.4 External Pressure

When the interviewees were asked about the aims and drivers for implementation, almost all of them mentioned different forms of external pressure (P2, P3, C1, C2, C3). These external factors can be divided into two areas, namely customer demands and regulations. P2, C1 and C2 mention EU regulations as a force to become transparent, which they believe blockchain can support them with.

"We can say that the 2030 goals that everybody has on the table, that is the big driver." - P2

C1 also sees governmental regulations and laws as a main driver for the implementation of blockchain. And not only for their own company, but also for the suppliers that have to meet certain requirements as well. This also gives C1 more influence over their suppliers.

"Because it's a regulation, it's the law. So, you have to fulfill that if you want to put a car on the European market" - C1

P3 on the other hand says that in the fashion industry, the main drivers for adopting blockchain are customer demands, along with regulations. Growing awareness of the problems of fast fashion and environmental issues play a crucial role. This is also the case with C3 in the food industry. In addition to legal requirements, for example in the meat industry, where it must be clearly traceable where and how the meat was processed, customer pressure plays a major role. C3 goes on to say that an increasing number of customers are showing interest in sustainable and green products:

"Of course, you as a customer want to have the right information, or you will have better information and so on in your app. So, there is a demand from customers. [...] Also, in the food industry, as a buyer or customer, you want to know where your stuff is coming from, how it is produced, and so on. And if we can tag it, then you can scan a barcode or QR code and see what it is. It's really interesting and that is really coming now." - C3

All in all, it can be said that the main sources of external pressure at the respondent's organizations are regulations and customer demands in regard to sustainability.

4.2.5 Security

The fact that the blockchain is a distributed ledger and accordingly a very secure technology has already been explained in this paper. Therefore, it is not surprising that some of the interviewees mention security as one of the main reasons for using blockchain (P1, P2, C2, C3). On the one hand, these security reasons are associated with a lack of trust in the large multinational platforms:

"We don't want to have another centralized Google or Facebook that is owning the whole data about the car. We want to have it decentralized and that was one of the main reasons why we chose blockchain technology. Because it allows us to decentralize the power over such a big database system." - P1

On the other hand, blockchain gives security and trustworthiness of the data along the supply chain. P2 for example states that with blockchain any kind of cheating along the supply chain can be prevented. C2's argumentation goes in the same direction. With the introduction of blockchain, suppliers' data can now be trusted more. This was arguably not the case in C2's company before the implementation and they had to question the accuracy of some actors' data. Additionally, C3 argues that without blockchain, data can become inaccurate due to human errors to a larger extent, which is why they favor the centralized and immutable solution of blockchain. However, C3 believes that blockchain systems need to be even more automated to reduce human interaction, which will be elaborated on later under section 4.3.2.

4.3 Implementation Barriers to Blockchain Adoption

The literature review addressed different types of implementation barriers, both for innovations in general and also for blockchain in particular. Throughout the interviews, difficulties of implementing and scaling blockchain internally and across the supply chain were discussed. Additionally, other issues that make blockchain hard to work with and hence might slow down implementation processes are addressed. Some of the barriers from the interviews confirmed those already brought up in the literature review, whereas others were new to the authors and gave new perspectives and insights to the findings.

4.3.1 Blockchain Adoption by Suppliers

An interesting and widely discussed issue was the scaling of the technology. All respondents have faced difficulties in widening the blockchain area. In this part, the focus lies on the scaling across organizations, hence barriers to getting upstream suppliers to use blockchain are highlighted. To begin with, P2 who runs a blockchain platform stresses the importance of starting small and build add-ons later to scale successively instead of an all-at-once implementation:

"From an actor's perspective, if you can see, what we usually recommend is that you think big, but you start small, and now." - P2

He explains that starting with the aim of implementing blockchain along the whole supply chain at once, will be a hard and complex integration to perform. There are multiple actors that must be aligned and sometimes the organization needs to replace some of the supply chain participants. This could be the case if some of the participants are operating unsustainably or are having suspicious activities going on. P2 indicates that in such a case, there might be actors in the network that do not want to share the data, hence they need to be replaced, which is often a massive undertaking.

Therefore, P2 suggests that organizations start off with an initial phase of implementation where they only build an internal blockchain to track their own production, and enlarge it later on to build the blockchain network. In line with this, P3 and C1 agree that some companies do not want to share their data, which then becomes a barrier for implementing blockchain along supply chains. Both C1 and C2 mention that they needed to have top management meetings at the suppliers' sites to convince them to use blockchain.

"And that has been a lot of work. We have to involve our senior management to have top meetings and so on." - C1

P3 states that it is important to have a collaborative relationship with the suppliers, instead of having a top-down approach, because then resistance will become a barrier to implementation. This is agreed on by C2 who states that they regard the collaborative relationship with suppliers as essential to implementation of environmental technologies. Also, P1 mentions that all organizations within the system must benefit from the blockchain implementation, otherwise organizational barriers might hinder implementation and scaling. Another factor to consider is that the organizations connected to the blockchain platform must have incentives and drivers that make them actually use the technology. This is stated by P1:

"Also how to bring the different stakeholders to really use the infrastructure layer that we built up. And on top, their own applications." - P1

Managing these incentives across organizations is not always easy and building the network can be complicated. This is brought up by P2, who believes that building the industry networks might be the main barrier for blockchain implementation. This is especially true in the food industry, as a single product may consist of multiple ingredients, thus a whole network of suppliers must be connected. C3, who is also operating in the food industry highlights this problem:

"That's also a bit tricky because if you have a broccoli pie or a complex product, that has more ingredients and also ingredients that are seasonal. I mean, there is a lot of countries of origin in that product" - C3

Thus, it is not only one supply chain, but rather a whole industry network that needs to be built and integrated on the blockchain. Both P2 and C3 mean that this poses a critical challenge for the implementation of blockchain along supply chains.

In general, all respondents highlighted the difficulties of getting all the supply chain participants on board with the blockchain technology. C1 talks about how they have found it difficult to onboard Chinese suppliers. Both because they do not trade directly with them, but also because they are not under the same regulatory framework. For example, the new EU regulation (PEF) which will require a higher degree of transparency when it comes to CO_2 footprints, is a law and a must to comply with for the European market, but not for the Chinese. Thus, there are sometimes conflicting interests that need to be managed:

"But it's not easy, you know, when you're coming into a company in China, and the only thing they are doing is delivering material to another company in China. So, they don't care about the European communities and EU regulations." - C1

C1 continues to state that it can take a long time to convince the suppliers to start using blockchain and implement the scanning processes that are needed. This is also mentioned by C3 who means that suppliers need to be reassured that this is beneficial for both sides. Further, C2 explains that it took a long time to convince their suppliers as well. C2 indicates that the more the suppliers understand the benefits, the faster they are willing to get onboarded.

"In the beginning we found it hard to convince the suppliers. But as soon as we talked about all the dangers that the old and current methods did, both to the people and to the environment, they were convinced to do this implementation. But yeah it was not easy at first." - C2

Onboarding suppliers is also a challenge for C3, who mentions the barrier of building a network within the supply chain ecosystem. This is according to C3, exceptionally complicated in the food industry. Not only due to the reason stated above, but also because the industry is characterized by short term contracts that can vary not only yearly but oftentimes even seasonally.

"And then if you build up a blockchain technique and some of the suppliers put in time or money, and then they don't use it in the next year. They won't do [implement] it. I'm sure." - C3

Also, C1 agrees that it is a long and complicated process to implement blockchain when trade agreements are written with new suppliers. He means that they do not always understand the benefits, but instead only see the costs:

"Then you have a completely new supply chain. And that takes six months to set up this supply chain and get the onboarding [...]. That is something we are struggling with. Because there is an annual fee and service agreement between Circulor [blockchain SaaS] and the different companies, and they haven't seen the benefits so far. It's only work and cost for them." - C1

Lastly, considering that blockchain will store immutable data, companies that are cheating on environmental factors will be more reluctant to implement it. This is pointed out by P2 and P3. Consequently, it is important to be aligned with the sustainability aims across the supply chain.

"First of all, it's about picking those who want to do the same things as you, and you kind of have an agreement from the beginning. Because [...], how can you even try to make any change together if you don't have the same basic ideas about sustainability?" - P2

However, P2 also points out that it is not always possible to choose the most sustainable suppliers. Therefore, it becomes a barrier to implement blockchain when lower-tier suppliers do not care about sustainability, or as stated above, when they are not regulated by law to the same extent (C1, P3).

4.3.2 Internal Issues - Management & Time

Barriers towards blockchain adoption are not only present across organizations but also within companies (C1, C2, P1, P3). For example, C1 describes that internal issues arose when they decided to start using blockchain in their supply chain. One such example is the feeling of being encroached by co-workers since they had to start talking directly to lower-tier suppliers, hence, approaching suppliers that were previously under the control of another employee. C1 means that some colleagues felt intruded:

"Hey, this is my supplier, you don't go in there and touch anything." - C1

In general, C1 could not see any disadvantages of implementing blockchain, it only required hard internal and managerial work to solve issues, get over hinders and reach thresholds. Within the organization, it is also important to have the right leaders for this kind of project, as well as having time to run it. The issue of lack of time is brought up during the interviews with P2 and P3. As an example, P3 describes another company which are in the forefront when it comes to environmental sustainability, but have not implemented all the sustainability capabilities due to time constraints:

"But we have talked to for example [organization] and they loved this idea and they hadn't thought about it themselves, they are so fully occupied with what they are doing so it's very difficult to think one step ahead." - P3

For C2, an internal barrier is the lack of a specific team managing the implementation and development of blockchain. Within C2's organization, different departments are responsible for managing the blockchain-based supply chain. Thus, it requires collaboration across the marketing, IT, supply chain and sustainability departments:

"You know, we have knowledge about some parts of it in one department and then other IT experts in another. It's hard to find time and to, you know, talk to each other as we all have the main business tasks going on." - C2

In general, internal management barriers were not discussed to a large extent by the interviewees.

4.3.3 Technical Issues & Skills

The perception of whether blockchain is a difficult technology to implement with regards to technical complexity, differed across respondents. This variation is because the respondents' organizations have implemented blockchain to varying extent and have different experiences with the technology. For example, a technical barrier mentioned by P3 is the challenge with the type of technology that blockchain is. She explains that one must understand that blockchain is not a tool, but rather an infrastructure that needs to be connected to other technologies and tools. Furthermore, P3 indicates that there are no best practices yet, as blockchain in supply chains is still in its infancy. Blockchain being complex and new, are barriers that are brought up by others as well. For example, C3 indicates several times that blockchain is still very new, and he also highlights the importance of connecting blockchain to other tools and technologies to get the most out of it.

"*You need to use different kinds of techniques like geographical information systems and satellite data or [...] drones. So, you need to sort of mix them and see if we could get rid of the people and only use the automatic thing. So, I think that's the thing that I'm a bit worried about.*" - C3

From the previous section on driving forces, respondents expressed that managers often find it easy to understand blockchain technology. However, at the same time, it can be technically difficult to implement it in order to derive the full potential value (C2, C3, P3). Interviewee P3 brings up the importance of having the right base to build upon, and means that it is almost essential to have undergone a digital transformation before implementing blockchain:

"If you have kind of jumped over some previous technologies or innovations or digitalization eras, then it [implementing blockchain] will not be possible." - P3

Further, P3 states that it is important that the organization itself, or the project leader, is interested in new technologies. If there is no previous knowledge within the organization, it will be hard to start using blockchain. In line with this, P1 expresses that a functional IT/IS infrastructure is needed to implement different use cases with blockchain. The infrastructural layer sets the base that one can build the platform on. On this platform, the organization will later build the application layer, where the use cases are implemented (P1). On this topic, C3 highlights the need for skilled employees who can manage the data analysis. Furthermore, C3 states that immense amounts of data will be stored on blockchain, and someone needs to make sure that the data becomes understandable within the organization:

"There are different departments analyzing this kind of data, I think that's a problem, actually, who should host the data that we bring in?" - C3

Furthermore, even if the above-cited issue is solved, C3 also points to the problem of having the right analytical skills:

"So you need some new skills, I think, that we don't have. And maybe we don't know what kind of skills we need to analyze this kind of data and see the options with it and the possibilities with this kind of data. So, I think that's an obstacle for us." - C3

Thus, C3 points to the problem of sorting the data into valuable information so that it becomes manageable. This requires data analytical skills that they lack today. Additionally, he mentions that they have good information about sustainability but are still not using the full potential of it because of these issues. Similarly, C2 mentions that this lack of technical skills is the reason why they have not started using blockchain's full potential, as it is technically hard to implement some of the use cases. These technical barriers are somewhat linked to the internal barriers, where the focus is on the internal management and culture of the organization.

4.3.4 Human-Technology Interaction

Human-technology interaction issues are stressed by both C3 and P3. P3 emphasizes that blockchain itself will not solve all trust issues, as we are still dependent on the individual who puts the data on the chain. If organizations are unable to trust the people, blockchain will not generate its full value:

"Some part of the problem comes before it even comes into the blockchain. I mean, how can we guarantee that the data that is put on the blockchain is correct?" - P3

Moreover, C3 indicates the problem of the human factor, which can disturb the data and lead to incorrect numbers and figures. C3 believes that blockchain-based supply chains must become more automatic, so that less human interaction is present, in order for blockchain to be a more attractive solution to implement. However, this requires that blockchain is connected to other tools and technologies, as pointed out previously under the technical barriers.

"There is still human impact on the result. If you miss tracking scores, or if you miss tracking along the line, then it's not working. So, you need to be even more automatic. - C3

4.3.5 Other Issues

As mentioned earlier, C3 needed to travel to the suppliers' locations and have in-person meetings in order to get them on board. However, during the COVID-19 pandemic, this has been very difficult, which is an external barrier to blockchain implementation.

"This has been a challenge with the pandemic, of course, because in the beginning, we had the meeting face to face, with the sub-suppliers, together with the first-tier supplier, and Circulor [blockchain SaaS] which is the provider here. [...] And we could have a walk through the process and how we do the scanning process. And we could do this onboarding in two days, more or less. And now it takes months." - C1

Thus, having the meetings online instead, with different people coming into the digital meeting every time has been a real challenge in terms of efficiency and speed of implementation (C1).

Furthermore, another barrier that is already addressed under technical barriers, but which is worth mentioning again: Blockchain is still a new technology, especially in this application area. The newness of the technology does not pose a technical challenge per se, however, the newness of blockchain is a challenge regarding best practices and standards - there are no best practices for implementation and use of blockchain. This is mentioned by several respondents (C1, P2, C3) who all are pioneers in their industries. C1 for example, mentions that it can be quite demanding to always be at the forefront and never have the opportunity to learn from others first. Similarly, C3 indicates that they do not know of any other (Swedish) grocery chain that has implemented blockchain.

A summary table of the empirical findings and how they have been coded and analyzed is displayed in Appendix 4.

5 Analysis & Discussion

The following chapter will provide an analysis and a comparison of the findings in relation to the literature and theoretical frameworks. To answer the first research question, the empirical findings will be analyzed and compared to the claimed potentials of blockchain, brought up by the literature. This is followed by an adoption analysis with focus on driving forces and barriers, to answer the second research question. Lastly, a discussion regarding possible solutions for the main barrier is presented. The literature, empirics, as well as the authors' interpretations help to find solutions for this bottleneck.

5.1 What Benefits are Realized?

By comparing the empirical findings with the literature, it can be concluded to what extent the claimed potentials of blockchain-based supply chains are realized. This is summarized in Table 4. The first column represents the identified capabilities of blockchain-based supply chains from the literature (Table 1). In the second column, it is shown if and how many (given in brackets) of the six respondents have adopted the sustainability capabilities. The last column presents which of the identified potentials are not used at all by the respondents. The table demonstrates a holistic view of blockchain adoption and where the gap is present, according to the empirical findings.

Table 4

Blockchain Applications and Realization of Benefits

Capability	Identified by the literature & realized by respondent(s)	Only identified by the literature
1. Tracking Environmental Performance of Suppliers	✓ (5)	
2. Tracking Materials & Waste Management	✓ (2)	
3. Tracking Logistics Information	✓ (2)	
4. Collecting Data on Sustainability of Production	✓ (4)	
5. Collecting Data on Packaging Material		X
6. Decentralization of Energy & Emissions Management		X
7. Verification & Transparency of Green Products	✓ (4)	
8. Tracking Location of Products	✓ (3)	
9. Tokenization		X

Note. The number given in the brackets (#) shows how many of the six respondents are realizing sustainability benefits from this capability.

It can be seen that *tracking the environmental performance of suppliers* is a capability adopted and applied by five of the respondents. Therefore, this is one of the main potentials of blockchain's tracking and tracing ability and is already used by most of the respondents. Since all respondents have already been exposed to blockchain in supply chains, this finding is not surprising and was predicted by the authors of this paper. The potentials *collecting data on sustainability production* and *verification & transparency of green products* were already used by four of the six interviewees. It should be noted that these potentials are very closely linked to the tracking of suppliers and can also be used with the advantages that blockchain brings with it. Nevertheless, it is apparent that not all interviewees make full use of the mentioned potentials. For example, only three respondents use the capability *tracking location of products*. The limited application becomes even clearer with the capabilities *tracking materials & waste management* and *tracking logistics information* which only two organizations are making use of. The gap between literature and reality is actually largest for *collecting data on packaging material*, *decentralization of energy & emissions management* and *tokenization*. The latter is very interesting as tokenization is already used in many other areas and more and more companies are issuing their own coins.

The analysis in the preceding paragraph clearly indicates that there is a large gap between the sustainability potentials of blockchain-based supply chains and reality. None of the capabilities from the literature were used by all respondents and most of the capabilities were used by less than 50 percent of the respondents. However, it needs to be said that this fairly new technology is only used by a small number of organizations within supply chains. Whether this small group is what Rogers (2003) and Moore (2014) call 'innovators' and 'early adopters' will be elaborated further in the following sections. Moreover, the reason why this gap is so evident and the measures that can be taken to reduce it are discussed in the subsequent sections of the analysis.

5.2 Major Driving Forces and Barriers

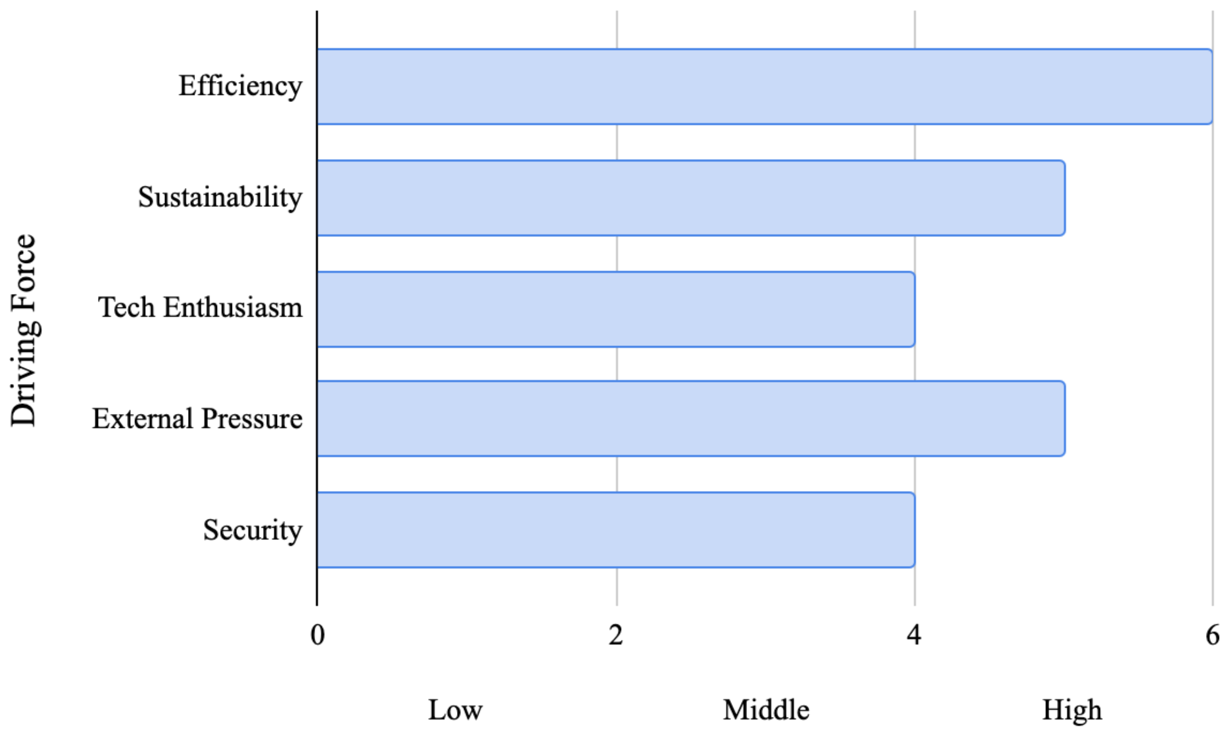
To understand why some capabilities of blockchain are not used, or to a low extent, the respondents were asked about the aims and objectives of the implementation of blockchain. They were also asked about the issues they encountered which made it difficult to implement or scale the applications and use cases of the technology. One should bear in mind that the coding process entails subjective interpretation by the authors. However, the mitigation to this issue is already explained in the methodology section. Lastly it needs to be said that the interview questions regarding forces and barriers were asked open-ended.

5.2.1 Aims and Driving Forces

Starting with the driving forces and aims behind the implementation of blockchain, Figure 7 shows the share of respondents who mentioned the different identified drivers of implementation. It does not show the strength of the force but merely at which frequency these topics were discussed across interviews. It is apparent that there is a high consistency across interviews as each category was mentioned by several of them. This means that there is likely a mix of forces that drives companies to adopt blockchain, and seldom is there only one thing that is important for organizations when making the adoption decision.

Figure 7

Discussed Driving Forces & Aims of Implementation



What makes this distribution interesting is that even though the questions were asked open-ended, there is still a great consistency in what the respondents brought up. Regardless of the industry, prior knowledge, and degree of implementation the findings show that the blockchain adoption-decision seems to be driven by the same set of driving forces.

All of them were implementing blockchain for efficiency purposes and the empirics brought up several ways in which blockchain can contribute to efficiency in the supply chains. These examples are all closely related to what Kshetri (2018) brought up in the literature regarding supply chain objectives, especially in reducing cost, being more flexible and ensuring high quality. Furthermore, sustainability was brought up as a new, sixth, objective of supply chain management (Kshetri, 2018), which is confirmed by the findings in this study. It seems like sustainability is important for today's supply chains as almost all of them intended to implement blockchain for this reason. However, the authors' interpretation of the empirical findings is that sustainability was more of a positive side-effect and not a primary driver behind blockchain adoption. Fortunately, economic benefits, including efficiency, often goes hand in hand with sustainability benefits, as indicated by the findings. This is promising for the applications of sustainability capabilities, as organizations that are mostly driven by efficiency aims may still see sustainability benefits. For example, reducing waste and CO2 emissions are sustainability benefits that can also increase overall efficiency of the organization.

The external pressures that companies face today were highlighted in the background of this study, where both regulations and customer demands are putting pressure on companies to become more sustainable (Park & Li, 2021; Saberi et al., 2019; Venkatesh et al., 2020). This is consistent with the findings in this study, as almost all mentioned external pressures as a reason and driver to implement blockchain. However, this driver is inconsistent with the adoption theories as these are more concerned with a voluntary adoption decision process. Instead, the external pressures make the decision less voluntary. Moore and Benbasat (1991) added two driving forces to the Adoption Life Cycle: *voluntariness of use* and *image*. Here, there is a clear link between the driving force of 'voluntariness of use' and 'external pressure'. Perhaps, 'image' could be said to match the 'sustainability' driver. However, the findings propose that it is not only for marketing and branding that organizations adopt sustainability applications of blockchain. Instead, the empirics show that most of the organizations are already working with sustainability matters, where blockchain can make these processes more efficient. Furthermore, as mentioned above, the external pressures found in the empirics are divided into customer demands and regulations. Interestingly, both of these sides are concerned with the demand for transparency. Consumers want to know exactly what they buy and regulations force companies to transparently show how goods are produced and the effects on the environment. Several of the interviewed organizations point out that blockchain is, to their knowledge, the right and perhaps only solution for this. These external pressures go beyond what the traditional adoption theories by Rogers (2003) and Moore (2014) discuss, hence adding a new dimension to technology adoption. First, because it transcends the voluntariness of adoption, as stated above. Second, because this external dimension goes beyond the technology itself and its attributes.

Even though security was only mentioned by four out of six respondents, it is still a majority that adopted blockchain partly due to its characteristic of bringing trust and security to the data. This is in line with Saberi et al. (2019) who stated that blockchain will improve this aspect compared to the most used ERP systems that businesses use today. The empirics show that in supply chains with many actors, blockchain can improve security through its immutability and transparency.

Lastly, tech enthusiasm seems to be driving a majority of respondents. Several mentioned that they are interested in trying out new technologies and are still experimenting with blockchain. The respondents gave the impression that they are not yet fully familiar with how they can use it, which is also confirmed by the findings in the first section of this chapter where the gap was highlighted. The empirical findings suggest that the technology is not yet mature, which could lead to resistance among early majority adopters, according to Moore (2014). Relating this to the driving force of 'tech enthusiasm', it becomes clear that those organizations which have adopted blockchain, are not the majority but rather innovators or early adopters. With the definition of the early majority in mind, it is evident that this group has not yet adopted blockchain, as they prefer to wait until a fully working solution is available and used by a trustworthy reference. Several respondents stated that they were the first in their industry to implement a blockchain-based supply chain, which implies that there are few trustworthy references to use in the adoption-decision. Consequently, linkages can be seen between empirics and theory, where it seems like blockchain SaaS is indeed in what Moore (2014) calls the chasm. However, this statement can only be based on the interpretation of what these supposedly innovators and early adopters have said, as it is believed that none of the respondents belong to the early majority category. What supports this statement is that none of the respondents mentioned that they mentioned that they started using blockchain because they had seen other successful implementations. Neither did they start using blockchain because they believed that the solution is fully developed and productive. Instead, they all had a strong tech enthusiasm and wanted to experiment to see what it could do for their supply chain management.

So far, it has been analyzed to what extent the respondents were making use of the sustainability capabilities and what made them adopt blockchain-based supply chains in the first place. From the findings, it is evident that the full potential of blockchain is not used, and that mainly innovators and early adopters have implemented the technology. The next section will discuss why the claimed potentials have been difficult to adopt, by analyzing adoption barriers.

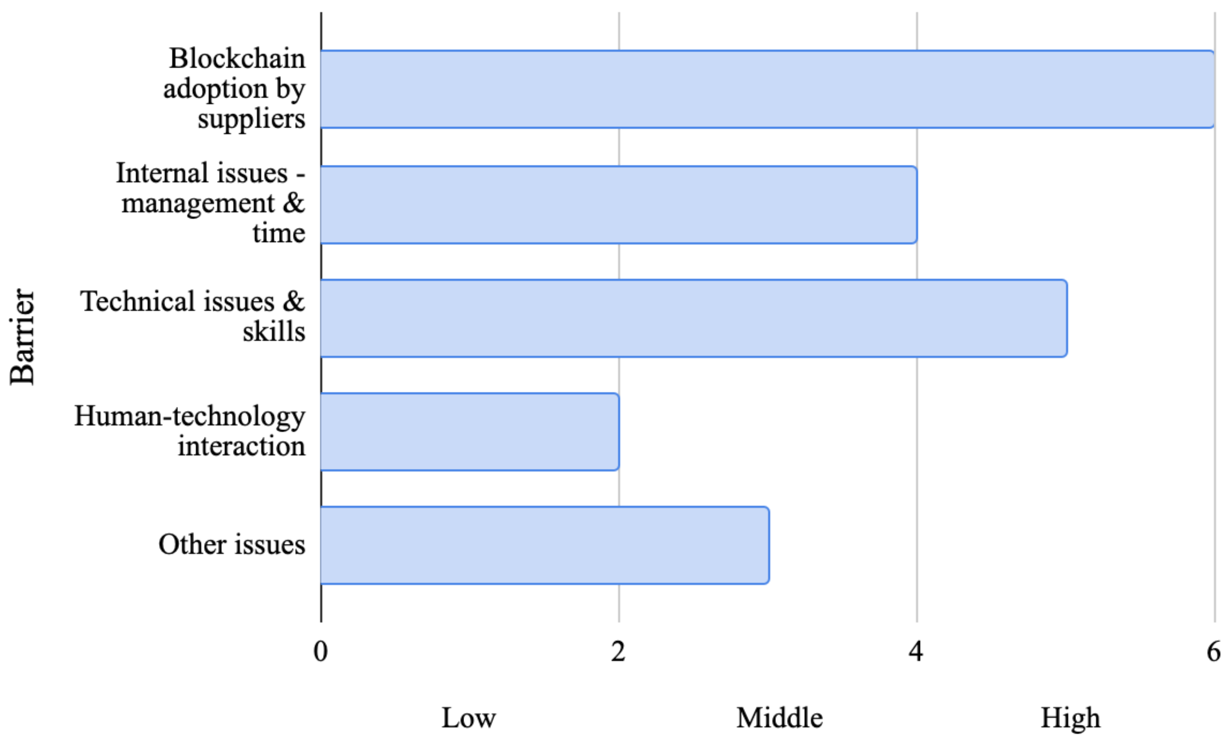
5.2.2 Issues and Barriers

Five different categories of adoption barriers were identified in the empirical findings of this study. These are shown in Figure 8, where the share of respondents who have mentioned related issues, is displayed. As discussed, three of the technological capabilities are not adopted and none of the applications are used by all studied cases. Thus, there is indeed an adoption gap and the question is "why?". As the respondents have already adopted blockchain technology, it is rather the adoption of capabilities and the barriers to full use of the technology that will be discussed. The empirical findings show that it is mainly due to the *blockchain adoption by suppliers* as well as *technical issues & skills* that create obstacles for adopting blockchain to its full extent. These two barriers are considered as major barriers, since almost all respondents mentioned issues related to them. Therefore, they could be interpreted as high barriers to overcome. If a barrier was easy to overcome, it should not be brought up by a majority of respondents and hence could be interpreted as low instead.

The third largest barrier is *internal issues - management & time*, which is mentioned by four of the respondents, as seen in Figure 8. As all of the case organizations have started using blockchain to some extent, the question in this study is not why companies have not adopted blockchain per se, but rather why it is not adopted and integrated to its fullest. Kirsner (2018) and Haag (2014) highlight issues regarding internal management, lack of alignment and organizational inertia, which poses barriers to innovation adoption. However, as the organizations have already adopted the technology and expressed their tech enthusiasm, organizational inertia is likely not the reason why they have not scaled it to further applications. Internal management issues are instead linked to lack of time and due to responsibilities being dispersed across organizational departments. Furthermore, *human-technology interaction* as well as *other issues* are considered less significant as they were only discussed to a limited extent by a few respondents. These barriers are therefore considered as low and middle and will not be discussed in detail.

Figure 8

Discussed Barriers to Implementation



The two major issues, interpreted as high barriers (see Figure 8), must be given attention as they are most likely to contribute to the chasm issue. When asking open questions regarding issues and obstacles, a clear consistency was identified in the empirical findings. First, *technical issues & skills* is a barrier for implementing blockchain and applying it to further use cases because it requires technical and analytical skills that not all organizations have. This is in line with Venkatesh (2022), who stated that a technical barrier for blockchain is the necessity to combine it with other technologies such as IoT, AI, and the existing IT systems of the organization. The empirical findings confirm this and suggest that organizations who lack the right competencies, or have not yet gone through a digital transformation, will have high technical barriers to overcome. Furthermore, the empirics emphasize the importance of connecting blockchain with other tools, as blockchain per se is not a solution on its own, since it is merely a way of storing transactional data.

The highest barrier of the empirical findings is the adoption by suppliers. The question arises how this barrier significantly affects the applications of the case companies. It could be assumed that the companies would be able to use the technology to its full extent without their suppliers. But that is simply not possible. The interesting aspect of blockchain-based supply chains and adoption theory is that in this regard, they match poorly because of the interrelationship between organizations. The decentralization of data shifts the supply chain relationships from top-down to a peer-to-peer network, which means that the retailer becomes increasingly dependent on the data management of its suppliers. Thus, having the suppliers on board, and making sure that they adopt, integrate and use the blockchain technology correctly is crucially important. This is related to what Saberi et al. (2019) call inter-organizational barriers who state that it can be hard to implement blockchain along the supply chain. The findings of this study confirm Saberi et al. (2019), as it seems indeed like inter-organizational barriers are hard to overcome. These interrelationships lead to a situation where the adoption by one company is also dependent on the adoption by others. The findings suggest that organizations are not only dependent on the adoption along the supply chain but also on the industry network, including competitors. The inter-organizational barrier becomes even more severe when companies have short contracts and therefore change the supply chain partners frequently, as it is not worth investing in onboarding processes. Taking these interrelationships into account is especially important for the emergence of industry standards, which will be an essential development in the upcoming years, according to the empirical findings.

As already stated, it is believed that the early majority has not yet adopted blockchain-based supply chains. This argument is based on the fact that none of the respondents made statements that are typical for an early majority individual, according to Rogers's (2003) description of that adopter category. Thus, when trying to understand why the early majority has not yet adopted blockchain, the technical issues are apparent. The blockchain technology is probably not mature enough for supply chain management regarding all claimed sustainability capabilities. Even though the findings suggest that blockchain is easy to understand, it still requires a lot of skills and knowledge to integrate it with other technologies and make full use of it. Since the findings show the gap in blockchain adoption of capabilities, it is quite clear that blockchain is not mature enough for the early and late majority. As the findings suggest that the technical issues are present even for those who can be regarded as innovators and early adopters, it might be an even greater challenge for the majority market. Additional arguments for why the respondents of this study are innovators and early adopters, and hence why it is likely that blockchain has not reached the majority market yet, are the following: First of all, some of the interviewees indicated that other companies from the same industries are facing the same challenges. Second, the fact that few companies have yet explored this complex technology demonstrates that many are facing these challenges and are waiting to see if others are successful. Third, the difficulty in finding suitable interview partners for this paper reinforces this argument from the discussions with the companies. All these arguments indicate that the companies interviewed for this research can be seen as early adopters or innovators according to the Technology Adoption Life Cycle by Rogers (2003).

Another important perspective brought up by Rogers (2003) is that the perception of the technology with regards to five attributes has the potential to slow down the adoption process, hence posing barriers to adoption and diffusion. However, the empirics show that most of these attributes are perceived as advantageous rather than barriers. First, the relative advantage seems to be high, since several respondents mentioned that there is no other technology that can solve the traceability and transparency in this secure and trusted way. Second, the compatibility can be regarded as high for the case organizations in this study as it fits well with how they prefer to work with new technologies. Third, complexity is defined as the difficulty of understanding the technology, which according to the findings is not a problem for the case organizations. Fourth, the trialability attribute is perhaps the most challenging, as it requires large investments both in terms of time and money to implement blockchain-based supply chains. Fifth and last, the observability is low as few companies have implemented blockchain on a full scale, which makes it difficult to see whether it is successful or not. The main barriers in relation to these attributes are according to the findings the trialability and observability. However, as all case organizations have already started experimenting with blockchain, it seems like they are not hindered by these challenges. As innovators and early adopters, they have already overcome the challenge of trialability without having the opportunity to observe existing use cases. Thus, it does not seem like these attributes are slowing down adoption from the perspective of the case organizations. However, as mentioned above, the adoption by suppliers is the main barrier according to the findings, and these attributes are most certainly perceived differently from their perspective.

To sum up, the findings propose that the chasm contains two issues: (1) The early majority has not adopted blockchain in supply chain management yet. (2) Within innovators and early adopters, there is a chasm regarding the use cases and applications of capabilities. The second point is important as it could potentially solve the first issue. If those who have adopted blockchain can better make use of it and demonstrate this, the early majority might be convinced. This argument is in line with the adoption theory regarding The Chasm, developed by Moore (2014). Moore (2014) argues that the chasm is caused by the fact that the early majority do not want to use the early adopters as a reference group for how well the technology performs. They are so fundamentally different with regards to their motivation for adoption. Assuming that those who have adopted blockchain SaaS today are prior to the majority, their willingness to try out the technology should not hinder them from using it to its full potential (Esmaeilian et al., 2020; Kouhizadeh & Sarkis, 2018; Park & Li, 2021; Saberi et al., 2019). Instead, what the empirics propose is that the main issue that prevents blockchain-based supply chains from using the full potential, is the suppliers' resistance. How the suppliers can create such barriers to the organizations' usage of blockchain will be discussed in the following section, which will be devoted fully to this barrier as it is considered the main finding and contribution of this study.

5.3 The Bottleneck of Blockchain Adoption within Supply Chains

So far, the discussion has been concerned with relating the identified gap to theories and providing analytical perspectives to why the gap is present. It is derived that the participating organizations of this study are most certainly within the innovators and early adopter categories. This statement is backed up by several arguments. Further, this gap has been linked to what Moore (2014) calls The Chasm, as the majority market has not yet adopted blockchain. The suppliers' adoption of blockchain is highlighted as the main barrier for the case companies' implementation of all claimed sustainability use cases. This barrier will be analyzed in more depth and detail in section 5.3.1. In section 5.3.2 potential solutions will be discussed.

5.3.1 The Challenges of Adoption by Suppliers

The authors' belief was that this study would provide different reasons to why some capabilities were adopted, and others were not. Indeed, there are several reasons which together create barriers for adoption and making full use of the technology. However, it was also found that most issues were centered around one main barrier – *blockchain adoption by suppliers*. Thus, the bottleneck for organizations who want to adopt blockchain to its fullest extent, is the suppliers' resistance. This further hinders developing industry networks and standards for blockchain-based supply chains.

The empirical findings offer a range of examples regarding issues with implementing blockchain along the supply chain. It is evident that the suppliers in general are less motivated to adopt blockchain as they are not driven by the adoption forces to the same extent as the retailers. First, suppliers based in distant geographical areas are not driven by the same regulations, meaning that they are not exposed to this external pressure to the same extent. The new PEF regulation which will force businesses to take better control over the transparency and calculation of carbon footprint, will not affect suppliers outside of the European Union (European Commission, 2021). However, it is crucial for European companies to trace back the origin and follow the production regardless of where the suppliers are based. Thus, this is a driving force that affects the supply chain in an unbalanced way, especially for the lowest-tier suppliers who do not directly trade with European companies. Second, the external pressure from consumers will again put pressure disproportionally on the retailers in Europe. These companies will from the consumers' point of view bear the whole responsibility for showing their supply chain activities in a transparent way. Along these lines, the external pressures in general will not affect the suppliers' adoption as long as the retailers are unable to shift responsibilities over to the other tiers. This is in line with Villena and Gioia (2020) who argue that the massive sustainability responsibility that MNCs bear today is a large risk that needs to be managed. These external demands affect the companies who are operating in the market, closest to the customers, which also puts them in a risky position. This is also in line with McGrath et al. (2021) who highlight the ethical responsibility that the MNCs carry in today's global markets.

Furthermore, the driving force of *tech enthusiasm* is perhaps of less strength within the supplier organizations. As the findings show, the suppliers often see the cost and work with the implementation but find it hard to understand the benefits of the technology. This hesitative approach goes hand in hand with the lower degree of innovativeness that characterizes the majority market. Further, the resistance is linked to the fact that most of the benefits are achieved by the retailer who gains consumers trust and compliance with regulations. It is reasonable that the less benefits an organization gains from implementing a new technology, the less interested they are. Thus, the tech enthusiasm should, according to the authors, be lower in traditional production and raw material industries, which enhances this barrier of suppliers' resistance to adoption.

Lastly, the strengths of the security, sustainability and efficiency drivers are presumably diminishing the lower in the supply chain the supplier is. The efficiency and sustainability benefits of tracking phases of the supply chain prior to the organization's position in the chain, reduce as there is less information to obtain in the lower tiers. For example, tracking transportation and location, as well as collecting data on production and emissions might not be relevant if there are no or very few prior suppliers. All in all, it is claimed by the empirics that the suppliers do not have the same aims and forces to adopt blockchain, and in fact they might have very few or no driving force at all. This poses a crucial issue to solve for the large retailers who want to implement blockchain along the whole supply chain.

Relating suppliers' resistance to theory, it can again be seen from the perspective of the five attributes of an innovation, which Rogers (2003) argues will affect the adoption-decision process. For the interviewed organizations, these technology-focused barriers seemed to be of less relevance, as discussed in the previous section. However, for the suppliers, the empirics suggest that the resistance indeed has connections to these attributes, especially the complexity, compatibility, and trialability. As the findings propose, it will be a high barrier to implement blockchain if the organization has not gone through a digital transformation, as blockchain needs to be connected with other technologies as well. Thus, complexity, compatibility and trialability will most certainly slow down adoption by lower-tier suppliers if they are still working traditionally and manually without digital tools, as it becomes difficult to understand and try blockchain at a low cost. Furthermore, as observability is an issue for the respondents of this study, it is inevitably an issue for the suppliers too.

Relating back to Rogers (2003) and the Technology Adoption Life Cycle, as well as The Chasm (Moore, 2014), the resistance posed by the suppliers indicate that these organizations are likely to be within the majority market adopter categories. Thus, with the empirical findings in mind, it is expected that the market for blockchain-based supply chains is in the chasm. Whether suppliers in general are categorized as the majority market, is difficult to state and it probably varies from supplier to supplier. However, the findings suggest that it is likely that suppliers are majority market adopters, which is indicated by showing this resistance; focusing on the cost rather than the expected benefits; and being hard to convince. As we have these interdependencies along the supply chain, it affects those who have already adopted blockchain negatively, as it makes it difficult for them to make full use of the technology. For example, it is hard to calculate a precise carbon footprint if all processes along the chain are not included. Further, the findings indicate that tracing the use of packaging material is not implemented, which undoubtedly is hard if those lower-tier suppliers who package the first material do not use blockchain. Consequently, this inter-organizational barrier is perceived as the bottleneck of this adoption process as it makes the diffusion vulnerable and dependent on the attitudes of the suppliers.

As an end note to this section, it can again be argued that the empirical findings go beyond what the Technology Adoption Life Cycle as well as The Chasm tell us about innovation adoption and diffusion. The models are mainly concerned with technological attributes and psychological attitudes towards innovations. However, the external pressures, which were discussed above, as well as these interrelationships along supply chains, add new dimensions to the adoption process. These dependencies across organizations means that for a technology like blockchain, which is based on connecting companies, the decision to which extent the technology is adopted becomes more complex. It is not purely up to each individual organization itself to decide to what extent it is adopted, as they are all reliant on each other. This is highlighted by one of the respondents who brings up the importance of making sure that the infrastructural layer is integrated in all organizations and that they use the application layer. Consequently, the adoption of blockchain capabilities in supply chains might be more complex than what Rogers (2003) manifests.

5.3.2 Possible Solutions for the Bottleneck

To solve the issues around this bottleneck, two main aspects brought up by the empirical findings need to be considered. First, to implement blockchain along the whole supply chain, suppliers in the lower tiers must be convinced or incentivized to adopt the technology. Second, there might be a need for industry standards to develop so that common platforms can be used that are tailored for the specific needs of different industries.

The given analysis and results stated above should be taken into account when trying to implement blockchain technology along the supply chain. The before-mentioned inter-organizational issues have been identified as the bottleneck in blockchain adoption and therefore this paper will give practical solutions on how to solve or mitigate these issues. The findings suggest that collaboration with suppliers works best if they either share the same goals or are subject to the same external pressures. Since retailers are in the public eye, they are naturally more interested in selling transparent and sustainable products. As the suppliers are not affected by the pressure from customers to the same extent, it is important to encourage suppliers to become more transparent and to use the blockchain accordingly. As blockchain is a decentralized technology, it has the potential to shift sustainability work from being only top-down management to also include bottom-up initiatives. It is highlighted both in the literature (Esmaeilian et al., 2020; Kouhizadeh & Sarkis, 2018; Saberi et al., 2019) and in the empirical findings, that blockchain has several advantages when it comes to incentivizing workers and organizations in general. For example, creating incentives can be done by implementing tokenization and building the internal reward system where sustainable behavior is rewarded with tokens. Tokenization is also one of the blockchain capabilities brought up and discussed in this paper. Through tokenization, the first suppliers could also benefit from the introduction of the blockchain and thus even increase their profit. After all, companies are economic entities that are ultimately concerned with making profits. If the suppliers are only told that the blockchain technology is to be introduced, which leads to higher costs and breaks up routines but does not create any actual added value, it will be almost impossible to get them onboard. Making sure that the adoption of blockchain benefits all tiers of the supply chain is the key. Another incentive can be to increase efficiency through blockchain as more efficient and leaner processes lead to cost reduction, which justifies the initial investment. As the empirics suggest, organizations are mainly driven by efficiency, hence emphasizing efficiency gains when convincing suppliers is crucial. The proposed solution is about letting the lower-tier suppliers benefit from blockchain and to work closer with all tiers regardless of whether the organization does business with them directly or indirectly. Collaboration is believed to make the adoption and diffusion of blockchain along the supply chain easier, according to the findings.

Moreover, it has been discussed how the perception of the five attributes of an innovation from Rogers (2003) affect the suppliers' adoption negatively and slows down the diffusion. Here, it is essential for the retailers who want their suppliers to adopt blockchain, to mitigate these issues. First, the complexibility can be reduced by developing clear onboarding processes at the suppliers' sites. This is suggested by the findings to be an important part of the diffusion process. Second, the compatibility issues can be mitigated by making sure that other technologies necessary for the implementation of blockchain are introduced successively in a logical order. Both literature (Venkatesh, 2022) and empirics highlight the importance of other digital tools. Hence, it is important to have patience and introduce tools and technologies stepwise to alleviate the resistance to overwhelmingly large changes. Third, it is vital to demonstrate the usage and benefits of blockchain on a small scale to mitigate both the observability and trialability obstacles. Again, it needs to be stated that the suppliers are not early adopters and thus, according to Rogers (2003) they are less innovative and more practical. Therefore, it is important to mitigate these issues so that suppliers' perception of blockchain becomes more favorable. Furthermore, from Moore's (2014) perspective, bridging the chasm can be done by focusing on specific supplier groups within the early majority, and then expanding to other actors along the supply chain. As the early majority does not want to use the early adopters and innovators as a reference, but prefer to listen to others within the majority market - it is essential to win over suppliers successively. Therefore, organizations should strive for getting the largest and most influential suppliers onboard first. According to Moore (2014) and the empirical findings, it is important to start stepwise and expand later on.

This paper has also brought up geographical differences between the retailing companies and suppliers, which leads to differences in external pressure regarding different regulations and laws. Thus, the disproportional pressure on the retailers, stemming from stricter European regulations, must be shifted over to suppliers from other parts of the world as well. In an ideal world, this issue could be solved by global regulations that hold for all the companies. However, as global regulations are hard to achieve, another possibility is to consciously choose suppliers that legally fall under the same regulations. Lastly, organizations could set up stricter internal policies demanding more transparency from suppliers, or give lobbyists the responsibility to manage local policies.

Furthermore, even if suppliers become less resistant to implement blockchain, a problem regarding incompatible systems will eventually emerge within industries. This issue is related to the discussion in the previous section regarding the interrelationships across organizations, together with the decentralization characteristic of blockchain, which makes them highly dependent on each other. The findings suggest that building industry standards will be a crucial task for the future, as companies nowadays are so intertwined with each other that all must agree on a common platform. In line with this, Moore (2014) proposes that standard solutions are developed so that most requirements among users, in this case suppliers, are met. The empirics highlight the complicated situation within the food industry, where a single product contains ingredients from several different suppliers which in turn are also suppliers to other grocery chains. Additionally, the issue with short contracts and changing supply chains, which would lead to frequent and heavy investments in onboarding processes, can be mitigated by developing standards. If all retailers use a common platform, there is less work for each single organization to onboard every supplier, if they share the same suppliers in the network. To develop standard platforms used within entire industries, the empirics suggest that actors must collaborate industry-wide, even with competitors. Thus, taking an open-innovation approach will be crucial.

6 Conclusions

This final chapter will present the reached conclusions and provide answers to the stated research questions. It will also present what implications the drawn conclusions have for practice and theory. Lastly, this chapter provides suggestions for future research, based on the limitations of this study.

6.1 Answering the Research Questions

This research aimed to identify if there is a gap between the claimed sustainability potentials of blockchain-based supply chains and why this gap is present. For this purpose, an extensive literature review was conducted and a total of nine sustainability potentials of blockchain-based supply chains were identified (Table 1). To analyze whether and why a gap between claimed potentials and applications exists, a total of six semi-structured interviews with companies and experts who are engaged with blockchain in supply chains were conducted. To the knowledge of the authors, previous research has not shown the relationship between literature and reality within this topic. Thereby, the aim of this paper was to contribute to literature by shedding light on the gap and to understand why it is present from the perspective of adoption drivers and barriers. Accordingly, the first research question was formulated as:

To what extent are sustainability potentials of blockchain-based supply chains realized?

Based on this qualitative study and analysis, it can be concluded that there is a gap between claimed potentials and reality. Due to the empirical nature, it is hard to answer to what extent the capabilities are used with the compiled empirics. However, it can be concluded that blockchain-based supply chains are not used to their full potential with regards to sustainability applications. As discussed in section 5.1, most claimed potentials are not adopted by the majority of respondents (Table 4). Thus, the purpose of identifying a potential adoption gap within this group of respondents is achieved. However, a clear answer where a quantitative figure on the extent to which blockchain-based supply chains are used can unfortunately not be provided due to the low generalizability of findings.

The second research question is based on the first one, which assumes that a gap exists between the claimed potentials and real applications of the technology. This assumption was made due to the infancy of blockchain, indications from the background literature, and was confirmed by the empirics of this study. Therefore, the second research question was derived as:

Why is there a gap between the claimed potential and reality?

To reach a conclusion regarding why this gap is present, the study has taken the theoretical perspective of adoption and diffusion to analyze actors engaged with blockchain-based supply chains. Thus, it has been concerned with identifying driving forces and barriers to adoption. The driving forces help to understand the reasons why companies are adopting blockchain-based supply chains. It can be concluded that companies adopt blockchain based on a mix of different underlying reasons. Both because of external pressures, but also due to the internal desire for efficiency. What emerged from this analysis was that companies mainly make use of the capabilities that are closely related to efficiency, cost and waste reduction. Interestingly, sustainability was rarely cited as a reason for adopting or implementing blockchain in the first place, but was often mentioned as a positive side-effect. Furthermore, the analysis discussed the newness of blockchain in combination with the tech enthusiasm seen in the empirical findings. According to Rogers (2003), this indicates that innovators and early adopters have implemented blockchain, however not the more practically driven majority market. Consequently, these linkages between empirics and theory imply that blockchain SaaS is indeed likely to be in what Moore (2014) calls The Chasm. This research has found that there are two dimensions to this chasm: (1) The early majority has not adopted blockchain in supply chain management yet. (2) Within innovators and early adopters, there is a chasm regarding the use cases and applications of capabilities.

Furthermore, it has been derived that this potential gap is present due to several issues brought up by the interviewees. The majority of respondents mentioned similar barriers for the adoption of blockchain-based supply chains even though all questions were asked open-ended. Barriers to technology adoption, such as internal problems or technical problems, were frequently cited. These go hand in hand with the intra-organizational and technical barriers mentioned by the literature. The greatest challenge for the case organizations that this research has identified is the blockchain adoption by suppliers. It turns out that this barrier is the bottleneck of blockchain adoption along supply chains and the reason why the analysis of this thesis has focused particularly on this barrier. These inter-organizational barriers are in line with previous research, and add a whole new dimension to the adoption and diffusion theory. Especially because blockchain links different companies with different requirements, goals, geographic regions, and regulations together. Therefore, the complexity makes it particularly difficult to integrate a unified technology such as blockchain. Not only do suppliers have different goals, but the complexity of supply chains as well as changing suppliers due to short contracts makes the integration very costly and a major barrier. Even if the retailers want to bring transparency and sustainability into the supply chain, they are still dependent on their suppliers, of which the lowest-tier suppliers are especially difficult to manage.

It can be summarized that the adoption of blockchain in supply chains is far more complex than a pure technology implementation within an organization. The authors of this paper have therefore come to the conclusion that the gap between claimed potentials and reality is mainly due to the infantry of the technology in supply chains as well as the difficulties to overcome inter-organizational barriers. The infantry of blockchain can be seen as reinforcing the issues of suppliers' adoption as the observability and complexity is low, hence increasing the resistance among suppliers. This resistance must be mitigated, for example by creating incentives and benefits, and by having a more collaborative instead of top-down approach.

6.2 Implications from Conclusions

This research is based on the existing literature regarding sustainability potentials of blockchain-based supply chains. Even though blockchain is a fairly new technology within supply chain management, several sustainability capabilities have been identified by researchers. However, this research provides new insights to the claimed capabilities. Although these are implementable in theory and have great potential in the area of sustainability, the adoption by the companies is lagging. This insight from the empirical findings, together with the analysis, has derived several practical and theoretical implications and contributions.

Practical Implications

Throughout this paper, several barriers have been identified and analyzed, whereby the bottleneck is the inter-organizational cooperation between retailers and suppliers. This is in line with the findings of Saberi et. al (2019) who have already emphasized the importance of this barrier. In section 5.3.2, possible solutions were discussed to overcome this barrier and accelerate adoption by suppliers. After all, what this study has concluded is that organizations who have already adopted blockchain will find it difficult to implement all capabilities due to suppliers' resistance. The suggestions discussed to mitigate the bottleneck issue are also practical implications.

Furthermore, another practical implication worth mentioning is the internal management. Even though this barrier was not considered as one of the highest, solving the bottleneck issue through supplier management will require improvements regarding the internal management. What the study has already highlighted in the empirical findings and analysis, is the lack of cohesion and collaboration among those responsible for different tasks related to the blockchain-based supply chain. Thus, a practical implication, and a proposal from the authors, is that companies should set up an agile team around blockchain so that employees from different departments can merge together and collaborate closer. Agile teams can improve the internal usage of blockchain, diffusion along the supply chain, and mitigate technical issues.

Finally, this research has contributed to the industry by inspiring organizations how they can use blockchain-based supply chains for sustainability purposes. Furthermore, it has contributed with a discussion around adoption barriers and possible solutions on how to overcome them.

Theoretical Implications

The underlying theories are the Technology Adoption Life Cycle from Rogers (2003) and The Chasm (Moore, 2003), which have helped the authors in guiding the analysis of drivers and barriers affecting the adoption process. In many aspects, there are clear linkages between the empirics and theory. In particular, the theories have been helpful to understand different psychological attitudes across adopter categories, and identifying innovators, early adopters and the majority market. However, this study shows that blockchain is a very complex technology with regards to the interdependencies across organizations. The adoption of blockchain-based supply chains, and the adoption of sustainability applications, are decisions that each organization itself does not have full control over. These interdependencies go hand in hand with the decentralization of data that characterizes blockchain. Accordingly, the implication for theory is that the frameworks by Rogers (2003) and Moore (2014) cannot fully explain the identified adoption gap. Neither can other, more IT-focused theories (Moore & Benbasat, 1991), explain the bottleneck issue that is highlighted. The critique against the theories used in this paper was mainly about the complexity of IT solutions. However, this study finds that it is rather the difficulties of managing interrelationships that makes the theories less applicable. Thus, there might be a need for new theories to be developed that takes into account the interdependencies of blockchain-based supply chains. Traditional theories regarding adoption and diffusion can still be used, but in a critical and careful way.

Finally, this study contributes to filling the identified research gap, brought up by Kouhizadeh and Sarkis (2018) who stated that future research on blockchain adoption is needed. It also contributes to investigating barriers to blockchain adoption in supply chains, as proposed by Saberi et al. (2019). Whether the findings are in line with previous studies is hard to say, due to this research gap. While previous research has focused on identifying blockchain capabilities, the results of this work demonstrate the difficulties of adopting them, and highlight the most significant barrier.

6.3 Limitations

Although this study contributes to the literature, as well as the practical field in many ways, it is not free from limitations. First, the data collection is limited by the few number of respondents who can be seen as innovators and early adopters of blockchain technology. As the perspective from the majority market is missing, it might make the findings less generalizable. Further, the collected data is derived from companies operating in Europe, mainly in Sweden. This limits the study to provide a snapshot of the extent to which blockchain-based supply chains are used, that only mirrors the European market. It might be the case that other continents, such as America, have come further in the application of blockchain. Therefore, the collected data is generally subject to improvement.

Second, this research found that blockchain adoption is mainly hindered by inter-organizational barriers and a whole section (5.3.2) is devoted to proposing possible solutions. Those solutions are mainly based on interpretations of the empirical findings. However, generating solutions was not the aim of the study, but was included to provoke a discussion regarding solutions.

6.4 Future Research

Blockchain is a fairly new technology and applications are constantly discovered and developed, which is also seen in blockchain-based supply chains. According to several interviewees, blockchain is still in its infancy when it comes to supply chains. This rapid change, results in relatively little scientific work on the sustainability potential of blockchain-based supply chains so far. This paper has filled this gap to some extent. Nevertheless, there are undoubtedly additional scientific studies needed in order to further elaborate on the topic. The authors of this paper recommend two topics that should be analyzed in the near future.

Firstly, a work of similar nature but with a larger data set, should be conducted, that addresses the early majority. Preferably including data from other continents as well. Such a study should serve to confirm the adoption barriers identified in this thesis from the perspective of the early majority. This in turn will help to fully understand and sustainably close the gap described in this paper. Ultimately, it is the resistance by the early majority that hinders blockchain diffusion along the supply chain, hence including their perspective to why they resist, or what they are "waiting for", is important.

Secondly, the authors of this study have identified the inter-organizational barriers as a bottleneck for the incomplete adoption of blockchain. Therefore, future research should analyze this main barrier in relation to blockchain adoption along supply chains more profoundly. The results could lead to a better understanding of this barrier, why it exists and most importantly, how it can be overcome. Furthermore, from this future analysis, the authors would hope to see additional practical solutions to better implement the adoption of blockchain. For example, collaborations between industry and research could help to develop practical solutions regarding industry standards.

References

Adèr, H. J., & Mellenbergh, G. J. (Eds.). (1999). *Research Methodology in the Social, Behavioural and Life Sciences*. SAGE. https://methods.sagepub.com/book/research-methodology-in-the-social-behavioural-and-life-sciences/d61.xml

Alicke, K., Davies, A., Leopoldseder, M., & Niemeyer, A. (2017). Blockchain technology for supply chains—A must or a maybe? *McKinsey Insights*. https://www.mckinsey.com/business-functions/operations/our-insights/blockchain-technology-for-supply-chainsa-must-or-a-maybe

Androulaki, E., Barger, A., Bortnikov, V., Cachin, C., Christidis, K., De Caro, A., Enyeart, D., Ferris, C., Laventman, G., Manevich, Y., Muralidharan, S., Murthy, C., Nguyen, B., Sethi, M., Singh, G., Smith, K., Sorniotti, A., Stathakopoulou, C., Cocco, S. W., & Yellick, J. (2018). Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains. *EurpSys '18: Proceedings of the Thirteenth EuroSyS Conference*, *30*, 1-15. https://doi.org/10.1145/3190508.3190538

Androulaki, E., Karame, G. O., Roeschlin, M., Scherer, T., & Capkun, S. (2013). Evaluating User Privacy in Bitcoin. *Sadeghi, AR. (eds) Financial Cryptography and Data Security. FC 2013. Lecture Notes in Computer Science*, *7859*, 34-51. https://doi.org/10.1007/978-3-642-39884-1_4

Anthony, S. D., Cobban, P., Nair, R., & Painchaud, N. (2019). Breaking Down the Barriers to Innovation. *Harvard Business Review*, *97*(6), 92-101. https://hbr.org/2019/11/breaking-down-the-barriers-to-innovation

Association for Supply Chain Management. (2021, August 10). *Blockchain technology for sustainable supply chains*. Youtube. Retrieved March 15, 2022, from https://www.youtube.com/watch?v=ZO20QrDj-8w

Bai, C., & Sarkis, J. (2020). A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research*, *58*(7), 2142-2162. 10.1080/00207543.2019.1708989

Bocek, T., & Stiller, B. (2019). Lieferketten dank Blockchain überwachen. *Die Volkswirtschaft*, *92*(5), 15-17. https://doi.org/10.5167/uzh-184622

Bryman, A., & Bell, E. (2011). *Business Research Methods* (3rd ed.). Oxford University Press.

Casino, F., Dasaklis, T. K., & Patsakis, C. (2019, March). A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telematics and Informatics*, *36*, 55-81. https://doi.org/10.1016/j.tele.2018.11.006

Chang, Y., Iakovou, E., & Shi, W. (2019). Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities. *International Journal of Production Research*, *58*(7), 2082. https://doi.org/10.1080/00207543.2019.1651946

Cong, L. W., & He, Z. (2019). Blockchain Disruption and Smart Contracts. *The Review of Financial Studies*, *32*(5), 1754–1797. https://doi.org/10.1093/rfs/hhz007

Creswell, J. W., Hanson, W. E., Plano Clark, V. L., & Morales, A. (2007). Qualitative Research Designs: Selection and Implementation. *he counseling psychologist*, *35*(2), 236-264.

David, P. A. (1985). Clio and the Economics of QWERTY. *The American Economic Review*, *75*(2), 332-337. https://www.jstor.org/stable/1805621

D'Este, P., Iammarino, S., Savona, M., & von Tunzelmann, N. (2012). What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy*, *41*(2), 482-488. https://doi.org/10.1016/j.respol.2011.09.008

Dietrich, F., Ge, Y., & Palm, D. (2020). Einsatz von Blockchain-Technologien im Supply-Chain-Management: Smart-Contract-basierte Lösungen zum Management von Lieferketten. *Zeitschrift für wirtschaftlichen Fabrikbetrieb*, *115*(9), 567-569. https://doi.org/10.1515/zwf-2020-1150906

Eisenhardt, K. M. (2021, February 4). What is the Eisenhardt Method, really? *Strategic Organization*, *19*(1), 147-160. https://doi.org/10.1177/1476127020982866

EPRS. (2020). *Blockchain for supply chains and international trade*. European Parliament. 10.2861/957600

Esmaeilian, B., Sarkis, J., Lewis, K., & Behdad, S. (2020). Blockchain for the future of sustainable supply chain management in Industry 4.0. *Resources, Conservation and Recycling*, *163*, 1-15. https://doi.org/10.1016/j.resconrec.2020.105064

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1-4. 10.11648/j.ajtas.20160501.11

European Commission. (2021, December 16). *Environmental footprint methods*. European Commission. Retrieved April 6, 2022, from https://ec.europa.eu/environment/news/environmental-footprint-methods-2021-12-16_en

Fernando, Y., & Saravannan, R. (2021). Energy Efficiency and Ethical Compliance. *Journal of Governance and Integrity*, *4*(2), 88-95. https://doi.org/10.15282/jgi.4.2.2021.5872

Flick, U., Steinke, I., & Kardorff, E. v. (2000). *Qualitative Forschung: ein Handbuch*. Rowohlt-Taschenbuch-Verlag.

Frankenfield, J. (2021, March 31). *Blockchain-as-a-Service (BaaS) Definition*. Investopedia. Retrieved May 2, 2022, from https://www.investopedia.com/terms/b/blockchainasaservice-baas.asp

Frizzo-Barker, J., Chow-White, P. A., Adams, P. R., Mentanko, J., Ha, D., & Green, S. (2020). Blockchain as a disruptive technology for Business: A Systematic Review. *International Journal of Information Management*, *51*(102088). https://doi.org/10.1016/j.ijinfomgt.2019.10.014

Gartner. (2018, August 20). *Understanding Gartner's Hype Cycles*. Gartner. Retrieved March 3, 2022, from https://www.gartner.com/en/documents/3887767

Gaur, V., & Gaiha, A. (2020). Building a Transparent Supply Chain. *Harvard Business Review*, *May - June 2020*. https://hbr.org/2020/05/building-a-transparent-supply-chain

Geroni, D. (2021, June 20). *Blockchain Security Algorithms Used to Protect the Blockchain Security*. 101 Blockchains. Retrieved March 4, 2022, from https://101blockchains.com/blockchain-security-algorithms/

Ghosh, S. (2022, March 15). *The Kids Are Alright: How Generation Z Is Pushing Others To Demand Supply Chain Sustainability*. Forbes. Retrieved April 05, 2022, from https://www.forbes.com/sites/forbesbusinesscouncil/2022/03/15/the-kids-are-alright-how-generation-z-is-pushing-others-to-demand-supply-chain-sustainability/?sh=a05a52157442

Given, L. M. (2008). *The Sage encyclopedia of qualitative research methods*. Sage publications.

Gupta, M. (2018). *Blockchain for Dummies*. John Wiley & Sons, Incorporated. https://www.ibm.com/downloads/cas/36KBMBOG

Haag, S. (2014). Organizational inertia as barrier to firms' IT adoption–multidimensional scale development and validation. *Twentieth Americas Conference on Information Systems, Savannah, 2014*.

Hameed, M. A., Counsell, S., & Swift, S. (2012). A conceptual model for the process of IT innovation adoption in organizations. *Journal of Engineering and Technology Management*, *29*(3), 358-390. https://doi.org/10.1016/j.jengtecman.2012.03.007

Hayes, A. (2022, March 5). *Blockchain Explained*. Investopedia. Retrieved March 9, 2022, from https://www.investopedia.com/terms/b/blockchain.asp

Hertig, A. (2020, December 16). *What Is Proof-of-Work?* CoinDesk. Retrieved March 3, 2022, from https://www.coindesk.com/learn/2020/12/16/what-is-proof-of-work/

IBM. (n.d.). *What are smart contracts on blockchain?* Smart contracts defined. Retrieved March 10, 2022, from https://www.ibm.com/uk-en/topics/smart-contracts

King, S., & Nadal, S. (2012). Ppcoin: Peer-to-peer crypto-currency with proof-of-stake. *self-puplished paper*, *19*(1). https://bitcoin.peryaudo.org/vendor/peercoin-paper.pdf

Kirsner, S. (2018). The Biggest Obstacles to Innovation in Large Companies. *Harvard Business Review*, *30*. https://hbr.org/2018/07/the-biggest-obstacles-to-innovation-in-large-companies

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, *231*, 1-21. https://doi.org/10.1016/j.ijpe.2020.107831

Kouhizadeh, M., & Sarkis, J. (2018). Blockchain Practices, Potentials, and Perspectives in Greening Supply Chains. *Sustainability*, *10*(10), 1-16. https://doi.org/10.3390/su10103652

Kshetri, N. (2018). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, *29*, 80-89. https://doi.org/10.1016/j.ijinfomgt.2017.12.005

LeCompte, M. D., & Goetz, J. P. (1982). Problems of Reliability and Validity in Ethnographic Research. *Review of Educational Research*, *52*, 31-60. https://doi.org/10.3102%2F00346543052001031

Li, A., Wei, X., & He, Z. (2020). Robust Proof of Stake: A New Consensus Protocol for Sustainable Blockchain Systems. *Sustainability*, *12*(7), 1-15. https://doi.org/10.3390/su12072824

Lipton, A., & Treccani, A. (2021). *Blockchain And Distributed Ledgers: Mathematics, Technology, And Economics*. World Scientific Publishing Company.

https://books.google.se/books?id=glBBEAAAQBAJ&printsec=frontcover&dq=book+distributed+ledger&hl=en&sa=X&ved=2ahUKEwinyKD00JD3AhUQQ_EDHUnhByUQ6AF6BAgHEAI#v=onepage&q=book%20distributed%20ledger&f=false

Litke, A., Anagnostopoulos, D., & Varvarigou, T. (2019). Blockchains for Supply Chain Management: Architectural Elements and Challenges Towards a Global Scale Deployment. *Logistics*, *3*(1), 1-17. 10.3390/logistics3010005

Lyytinen, K., & Damsgaard, J. (2001). What's wrong with the diffusion of innovation theory? *Working conference on diffusing software product and process innovations*, 173-190. Springer. https://doi.org/10.1007/978-0-387-35404-0_11

Mathivathanan, D., Mathiyazhagan, K., Rana, N. P., Khorana, S., & Dwivedi, Y. K. (2021). Barriers to the adoption of blockchain technology in business supply chains: a total interpretive structural modelling (TISM) approach. *International Journal of Production Research*, *59*(11), 3338-3359. https://doi-org.ezproxy.ub.gu.se/10.1080/00207543.2020.1868597

Maxwell, J. A. (2013). *Qualitative Research Design: An Interactive Approach*. SAGE Publications.

McGrath, P., McCarty, L., Marshall, D., & Rehme, J. (2021). Tools and Technologies of Transparency in Sustainable Global Supply Chains. *California Management Review*, *64*(1), 67-89. https://doi.org/10.1177/00081256211045993

Moore, G. A. (2014). *Crossing the Chasm, 3rd Edition: Marketing and Selling Disruptive Products to Mainstream Customers* (3rd ed.). HarperCollins.

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information systems research*, *2*(3), 192-222. https://doi.org/10.1287/isre.2.3.192

Nguyen, C. T., Hoang, D. T., Nguyen, D. N., Niyato, D., Nguyen, H. T., & Dutkiewicz, E. (2019). "Proof-of-Stake Consensus Mechanisms for Future Blockchain Networks: Fundamentals, Applications and Opportunities,". *IEEE Access*, *7*, 85727-85745. doi: 10.1109/ACCESS.2019.2925010.

O'Dwyer, K., & Malone, D. (2014). Bitcoin Mining and its Energy Footprint. *China-Ireland International Conference on Information and Communications Technologies*, 280-285. 10.1049/cp.2014.0699

Park, A., & Li, H. (2021). The Effect of Blockchain Technology on Supply Chain Sustainability Performances. *Sustainability*, *13*(4), 1-18. https://doi.org/10.3390/su13041726

Peppard, J., & Ward, J. (2002). *Strategic Planning for Information Systems* (3rd ed.). Wiley.

Pisa, M., & Juden, M. (2017). Blockchain and Economic Development: Hype vs. Reality. *CGD Policy Paper*, *107*. https://www.cgdev.org/publication/blockchain-and-economic-development-hype-vs-reality

Poland, B. D. (2003). Transcription Quality. In *Inside Interviewing: New Lenses, New Concerns* (pp. 267-287). Sage Publications.

Queiroz, M. M., Telles, R., & Bonilla, S. H. (2019). Blockchain and supply chain management integration: a systematic review of the literature. *Supply Chain Management*, *25*(2), 241–254. 10.1108/SCM-03-2018-0143]

Rhein, F. E. (2021). *The Dynamics of Green Innovation in B2B Industries*. Springer Gabler. 10.1007/978-3-658-32148-2

Roberts, P., & Priest, H. (2006). Reliability and validity in research. *Nursing standard*, *20*(44), 41-46. link.gale.com/apps/doc/A149022548/HRCA?u=anon~5f31bc4f&sid=googleScholar&xid=fc0e7edc

Rogers, M. E. (2003). Diffusion of Innovations. *Free Press*, *5th Edition*.

Saberi, S., Kouhizadeh, M., & Sarkis, J. (2018). Blockchain technology: A panacea or pariah for resources conservation and recycling? *Resources, Conservation and Recycling*, *130*(March 2018), 80-81. https://doi.org/10.1016/j.resconrec.2017.11.020

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117-2135. https://doi.org/10.1080/00207543.2018.1533261

Siano, A., Vollero, A., Conte, F., & Amabile, S. (2017). “More than words”: Expanding the taxonomy of greenwashing after the Volkswagen scandal. *Journal of Business Research*, *71*, 27-37. https://doi.org/10.1016/j.jbusres.2016.11.002

Statista. (2022, March 18). • *Global blockchain market size 2017-2027*. Statista. Retrieved April 13, 2022, from https://www.statista.com/statistics/1015362/worldwide-blockchain-technology-market-size/

Stebbins, R. A. (2001). *Exploratory research in the social sciences* (Vol. 48). Sage.

Svensson, G. (2007). Aspects of sustainable supply chain management (SSCM): conceptual framework and empirical example. *Supply Chain Management*, *12*(4), 262-266.

United States Environmental Protection Agency. (2016). *Improving Environmental Sustainability in Supply Chains: Best Practices Webinar*. Center for Corporate Climate Leadership. Retrieved February 18, 2022, from https://www.epa.gov/sites/default/files/2016-09/documents/improving_sustainability_in_supply_chains_091516.pdf

Venkatesh, M. R. (2022, March 18). *Why Fashion Supply Chain Traceability Is A Tech Challenge That Begins With AI*. Forbes. Retrieved April 06, 2022, from https://www.forbes.com/sites/forbestechcouncil/2022/03/18/why-fashion-supply-chain-traceability-is-a-tech-challenge-that-begins-with-ai/?sh=4df267285f6d

Venkatesh, V. G., Kang, K., Wang, B., Zhong, R. Y., & Zhang, A. (2020). System architecture for blockchain based transparency of supply chain social sustainability. *Robotics and Computer-Integrated Manufacturing*, *63*, 1-9. https://doi.org/10.1016/j.rcim.2019.101896

Villena, V. H., & Gioia, D. A. (2020). A More Sustainable Supply Chain. *Harvard Business Review Magazine*. https://hbr.org/2020/03/a-more-sustainable-supply-chain

Xian, H. (2008). Lost in translation? Language, culture and the roles of translator in cross‐cultural management research. *Qualitative Research in Organizations and Management*, *3*(3), 231-245. 10.1108/17465640810920304

Yin, R. K. (2016). *Qualitative research from start to finish* (2nd ed.). The Guilford Press.

Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017). An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. *IEEE International Congress on Big Data (BigData Congress)*, 557-564. 10.1109/BigDataCongress.2017.85.

Appendix

Appendix 1: Notes for Interview Guides

1. The interview guide is just a guide and not all questions have been asked to all participants, depending on what is already brought up in the more broad introductory questions.

2. Some questions are stated as yes/no-questions. However, in such cases, the respondents were asked to give examples and elaborate more on the topic.

3. Starred questions (*): these are the most important questions for answering the research questions and were asked to all interviewees. Other questions were used more as a guide and as a back-up.

Appendix 2: Interview Guide for Companies/Users

Introduction:
We are Rebecka Otter & Roman Schubert from the master program Innovation & Industrial Management at the School of Business, Economics and Law in Gothenburg. As already mentioned in the email, we are writing our master thesis on the three concepts: blockchain, sustainability and supply chain management. The purpose of the thesis is to investigate the gap between what blockchain theoretically can do for companies in their supply chain when it comes to sustainability and what is actually realized. We will not judge or be critical regarding the benefits you are not realizing, every benefit or improvement that you see at your company is just a plus and something positive. Hopefully the results can help guide future research and the participating companies when the report is finished.

Research Questions:

To what extent are sustainability potentials of blockchain-based supply chains realized?

Further, the second research question is as following:

Why is there a gap between the claimed potential and reality?

Without mentioning any companies, we will or have conducted interviews with organizations linked to IBM's Foodtrust platform, the TrustTrace platform, and also people within the car industry.

We will start off with some questions about you, how your company works with blockchain and later dig deeper into the sustainability benefits that you have seen and realized with the use of blockchain.

First, we just want to ask:

- Is it okay for us to record this interview?
- Do you as a person wish to be anonymous?
- Does your organization wish to be anonymous?

Introductory Question:

1. Thank you for being here today and conducting the interview with us to help us answer the research questions. Could you first introduce yourself briefly.

Blockchain Background:

2. Please tell us about how your organization works with blockchain in the supply chain.
3. What was the aim/goal of implementing blockchain?*
   - Did you experience any external pressure to become more transparent?*
4. What are the perceived disadvantages of implementing blockchain in your supply chain? Something you were skeptical about?*

Blockchain & Supply Chain Management

5. How has blockchain technology made your processes within the supply chain more efficient?
6. How does blockchain make you more competitive?
7. Do you think blockchain technology is used at the fullest at your company? Why? Are there things you want to achieve but are hard to implement?*
8. Do you think other technologies or tools can be as efficient? If so, which ones?

Blockchain & Sustainable Supply Chain Management

9. What sustainability goals do you have that blockchain can help you achieve?
10. What are the main sustainability advantages that blockchain brings to your supply chain management?*
11. We have talked about sustainability as well as blockchain. Very often those two concepts are called to be a paradoxon, as the blockchain needs lots of energy. What is your view on that? Why?
12. What sustainability benefits have you experienced by using blockchain related to traceability? If yes, give examples.*
13. What sustainability benefits have you experienced by using blockchain related to transparency? If yes, give examples.*
14. Have you been able to detect unsustainable behavior/production at your suppliers that you needed to handle? If yes, give examples.*
15. Do you use blockchain to trace the resource and waste management? If yes, give examples.*
16. Are you using blockchain to track the transportation and location of products? If yes, give examples.*

17. Are you tracking your production processes? If so, does it make it easier for you to manage compliance with sustainability standards? If yes, give examples.*
18. Do you track the packaging material of your products on the blockchain? If yes, give examples.*
19. Are you using blockchain to calculate the CO2 footprint of your products? And, then use this for energy and emission trading systems? If yes, give examples.*
20. Are you using blockchain to verify that a product is sustainable to promote green products towards customers? If yes, give examples.*
21. Are you using tokenization to incentivize sustainable behavior in the supply chain? If yes, give examples.*

Summary / Outlook

22. What do you think are the main implementation barriers for different blockchain applications?*
23. Is there anything that we haven't asked that you want to add regarding blockchain and sustainability?

Appendix 3: Interview Guide for Blockchain Platform Providers

Introduction:
We are Rebecka Otter & Roman Schubert from the master program Innovation & Industrial Management at the School of Business, Economics and Law in Gothenburg. As already mentioned in the email, we are writing our master thesis on the three concepts: blockchain, sustainability and supply chain management. The purpose of the thesis is to investigate the gap between what blockchain theoretically can do for companies in their supply chain when it comes to sustainability and what is actually realized. Hopefully the results can help guide future research and the participating companies when the report is finished.

Research Questions:

To what extent are sustainability potentials of blockchain-based supply chains realized?

Further, the second research question is as following:

Why is there a gap between the claimed potential and reality?

Without mentioning any companies, we will or have conducted interviews with organizations linked to IBM's Foodtrust platform, the TrustTrace platform, and also people within the car industry.

We will start off with some questions about you, and your experience with blockchain and later dig deeper into the sustainability benefits that blockchain can offer along supply chains.

First, we just want to ask:
- Is it okay for us to record this interview?
- Do you as a person wish to be anonymous?
- Does your organization wish to be anonymous?

Introductory Question:

1. Thank you for being here today and conducting the interview with us to help us answer the research questions. Could you first introduce yourself briefly.

Blockchain Platform Background:

2. Please tell us about how your organization works with blockchain in supply chains.
3. What is the aim of this blockchain platform?*
   - Did they experience any external pressure to become more transparent?*
4. What are the perceived disadvantages of implementing blockchain from your actors' perspective? Something they are or were skeptical about?*

Blockchain & Supply Chain Management

5. How has blockchain made your actors' processes within the supply chain more efficient?
6. How does Blockchain make your actors more competitive?
7. Do you think blockchain is used at the fullest at your actors' companies? Why?*
8. Do you think other technologies or tools can be as efficient? If so, which ones?

Blockchain & Sustainable Supply Chain Management

9. What are the main sustainability goals that your actors' are trying to achieve when using your platform?
10. What are the main sustainability advantages that blockchain brings to the actors of the platform?*
11. We have talked about sustainability as well as blockchain. Very often those two concepts are called to be a paradoxon, as the blockchain needs lots of energy. What is your view on that? Why?
12. What sustainability benefits have your actors experienced by using blockchain related to traceability? Give examples.*
13. What sustainability benefits have your actors experienced by using blockchain related to transparency? Give examples.*
14. Have your actors been able to detect unsustainable behavior/production at their suppliers thanks to blockchain? If yes, give examples.*
15. Do your actors use blockchain to trace the resource and waste management? If yes, give examples.*

16. Are your actors using blockchain to track the transportation and location of products? If yes, give examples.*
17. Are your actors tracking their production processes? If so, does it make it easier for them to manage compliance with sustainability standards? If yes, give examples.*
18. Do your actors track the packaging material of their products on the blockchain? If yes, give examples.*
19. Are your actors using blockchain to calculate the CO2 footprint of their products? And, then use this for energy and emission trading systems? If yes, give examples.*
20. Are your actors using blockchain to verify that a product is sustainable to promote green products towards their customers? If yes, give examples.*
21. Do your actors use tokenization to incentivize sustainable behavior in the supply chain? If yes, give examples.*

Summary / Outlook

22. What do you think are the main implementation barriers for different blockchain applications?*
23. Is there anything that we haven't asked that you want to add regarding blockchain and sustainability?

Appendix 4: Coding Overview for Empirical Analysis

Code	Primary Data Examples	Theme
1. Tracking Environmental Performance of Suppliers	– Collecting real-time data on suppliers – Detecting unsustainable suppliers – Influencing suppliers	Sustainability Capabilities of Blockchain
2. Tracking Materials & Waste Management	– Trace defect products – Improved product quality – Tracking amount of different waste categories	
3. Tracking Logistics Information	– Tracking transportation routes – Incentivizing sustainable driving – Tracking emissions	
4. Collecting Data on Sustainability of Production	– Calculating carbon footprint	
5. Collecting Data on Packaging Material	– Use of plastic material – Interesting for the future	
6. Decentralization of Energy & Emissions Management	– CO2 footprint – Energy consumption	
7. Verification & Transparency of Green Products	– Visualizing for consumers (scanning app) – Reducing the occurrence of greenwashing – Trustworthy compliance with standards	
8. Tracking Location of Products	– Tracing origin – Recalling affect batches – Detecting logistical errors	
9. Tokenization	– Car coin – Giving back sales	

Code	Primary Data Examples	Theme
Efficiency	– Efficiency for processes – Economic efficiency – Efficiency through automation	Implementation Aims & Driving Forces
Sustainability	– Possibility of calculating CO2 footprint more accurate – Traceability of product's origin – Achieving internal sustainability goals	
Tech Enthusiasm	– Tech affine individuals within the companies – Organizations with general openness for new technologies	
External Pressure	– Governmental regulations – Customer demands	
Security	– Data security of blockchain – Decentralization of data – Unchangeable system without possibility of fraud	
Intra-Organizational	– No dedicated blockchain-team – High workload for top managers – Knowledge spread over different departments	Implementation Barriers
Inter-Organizational	– Complex and changing supply chains – Actors are reluctant to share data – No direct benefits are seen	
Technical	– Complex and new technology – Hardly any best practices – Needs to be implemented in line with existing IT	
External	– Being forced to online meetings prolongs the process	
Other Barriers	– Possibility of human errors – Trust issues with first-tier suppliers	