LUND UNIVERSITY
SCHOOL OF ECONOMICS AND MANAGEMENT

Could blockchain tracing help textile managers achieve the UN Sustainable Development Goals?

A study on blockchain implementation in the textile industry

by

Sebastian Riveiro and Adam Turesson

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Supervisor: Tanya Kolyaka
Examiner: Stein Kleppestø

Abstract

This paper examines how blockchain tracing can be implemented in the textile industry through an exploratory and inductive qualitative multi-methodological approach. First, it provides an extensive background relevant to the field of blockchain tracing implementation in textile retailers. Then, the literature review provides an overview of the academic findings on the subject. Thereafter, a more in-depth understanding of blockchain tracing implementation is provided through six semi-structured interviews with two groups, blockchain experts and managers.

The findings in this study through qualitative analysis indicate that there are several benefits with the implementation of a blockchain tracing system such as immutable distributed ledger, security and decentralisation that could aid in creating a more transparent and traceable supply chain. Adoption of a blockchain-based traceability system is one of the possible solutions to address transparency issues and ensure seamless information sharing among supply chain partners in order to work towards UN sustainable development goals. Further this paper identified several potential implementation challenges that need consideration, presented as a theoretical model, the Blockchain Tracing Implementation Model (BTIM).

Keywords: Blockchain, Fashion, Supply chain, Sustainability, Distributed ledger technology, Blockchain tracing, Traceability, Transparency, Management, Digitalization.

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Abbreviations and concepts

API - Application Programming Interface
BCT - Blockchain Technology
DoI - Diffusion of innovation
DLT - Distributed Ledger Technology
EU - European Union
Fashion industry - see Textile industry
GHG - Greenhouse gases
NGO - Non-Governmental organisation
RQ - Research Question
SAC - Sustainable Apparel Coalition
SDG - Sustainable Development Goal
Textile industry - The industry that involves the sections like research, design, development, manufacturing and distribution of textiles, fabrics and clothing
UN - United Nations

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1 Introduction

The ongoing digitalisation and the fourth industrial revolution (Industry 4.0) has created new possibilities to achieve more flexible, efficient productions and services (Fu, Shu & Liu, 2018). Textile retailers and producers have advanced, created competitive technological tools to design, produce with the aim to deliver products to customers on time (Norton et al., 2014). With technological advancements in some areas such as production, automation and computerization has increased efficiency, on the other hand textile industry companies are still subject to environmental and reputational risks, which can impact brands in a negative way (Hader et al., 2022).

An example of this is how the industry has been involved in scandals in their supply chain regarding poor working conditions or workspace safety, as seen in the Rana Plaza scandal[1] where over 1100 workers lost their lives. This scandal involved several of the world's biggest names in fashion (Koenig & Poncet, 2019). One of the contributing factors to this scandal was the lack of *transparency* and *traceability*[2] in the supply chain of fashion companies. A study reported that 80% of the fatal and nonfatal work related accidents in producing countries are attributed to European fashion brands and the lack of a transparent due diligence process (Malik et al., 2021).

With the increasing trend of globalisation by moving production from developed to developing countries, supply chain management becomes more challenging (Lam & Lei, 2019). One of the issues for industry managers in this globalised market is to provide consumers with inexpensive clothing resulting in opaque supply chains (Melissa J, Zhang & Radziwill, 2018). The industry produces billions of garments every day, through global

[1] "The 2013 Rana Plaza building collapse, resulting in 1132 deaths and many injuries, confirming accusations of ineffective public regulation and corporate irresponsibility." (Frenkel, Rahman & Rahman, 2022 p.273).
"...major labour law amendments were enacted. Disquiet about labour regulation in supply chains is a response to intensified competition as lead firms (multinational retailers and brands) have expanded internationally based on 'fast fashion' and low garment prices" (Frenkel et al., 2022 p.273)

[2] **Transparency** is about *visibility*: Accurately identifying and collecting data from all links in your supply chain, and *disclosing* communicating information internally and externally, at the level desired (Harbert, 2020).
Traceability "the ability to identify and trace the history, distribution, location and application of products, parts, and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labour (including health and safety), the environment and anti-corruption" (United Nations Global Compact and Business for Social Responsibility, 2014, p.6).

complex supply chains, with several layers from the origin of raw materials to the final customer (Hader et al., 2022). Considering the above with new regulations regarding supply chain transparency, external policies such as internal Corporate Social Responsibility (CSR) policies and the UN sustainable goals create a challenge for industry managers.

With the launch of Bitcoin in 2009 blockchain technology became well known (Hader et al, 2022), and since then attracted the attention of industries and academia (He et al, 2016). Blockchain, the underlying technology behind bitcoin, has enormous potential for enhancing the trustworthiness of data in a distributed environment (Joshi et al, 2019).

Blockchain is a distributed ledger (DLT) that works without a central authority and allows the creation of a decentralised and unchangeable ledger of transactions which are verifiable and traceable (Agrawal et al., 2021), these unique features have been found useful in applications in the financial sector, such as Bitcoin and other cryptocurrencies, yet more novel applications in the context of supply chains have been observed to create transparency and traceability, with the potential of blockchain smart contracts gaining efficiency (Lohmer & Lasch, 2020), and could be a promising solution for the textile industry.

One recent publication from McKinsey and Company (2022) on implementation of technologies in the textile industry lists distributed ledger technology, such as blockchain, to have an estimated yearly market growth of over 50% compound annual growth rate (CAGR). These numbers are comparable and surpass the growth rates of other novel technologies such as 5G and AI(Machine learning) according to the report (McKinsey & Company, 2022). In this paper we will examine the use of blockchain tracing in the textile industry and how it could be of use for managers and challenges associated with implementing such a solution.

1.1 The Gap

The field of blockchain tracing in the textile and fashion industry is still in its early stages, which is why there is scarce literature on the subject and why there are several research gaps that are waiting to be filled. One such gap is what Petersen, Hackius and von See (2018) refers to as a “striking gap between the huge expectations on short-term disruptive change and ready-to-use solutions on the market”. This view is further supported by Queiroz and Wamba (2019) who identified blockchain-supply chain management integration as a field that lacked research. There is a clear need for research that focuses on demonstrating blockchain implementation (Agrawal et al, 2021). During the last decade, there has been an increase in blockchain pilot projects within the textile industry (Lacity, 2018). Unfortunately, there seems to be little to no literature that has studied these projects since there is still a lack of empirical

cases in the literature (Ahmed & MacCarty, 2021). Studies just like the one from Hader et al (2022) and others have focused on blockchain applications in the textile industry but rather on creating blockchain frameworks than models of actual case studies on the implementation of blockchain tracing. This is troublesome since it is the adoption and application that are the most challenging (Wamba & Quieros, 2020). Therefore the aim of this paper will focus on the implementation of blockchain from an organisational implementation perspective and examine if it could be a tool for managers and what implementation challenges are associated with it.

1.2 Aim and Objectives

Following this direction, this study aims to examine the implementation challenges for blockchain tracing technology in the fashion industry and how it could be of use in organisations sustainability efforts by reviewing literature to date and collecting interview data, this report is intended to:

- Create a high level overview and basic understanding of blockchain technology and how it could be of use in a textile industry context.
- Identify the benefits and challenges of blockchain technology.
- Identify the common challenges associated with implementing blockchain tracing technology in a textile industry's supply chain.
- Develop a model to aid textile managers to successfully implement the technology into their organisations.

1.3 Research Purpose

This thesis has two main purposes. First to provide insights of how Blockchain tracing could be a tool for organisations and managers in their work towards meeting sustainable goals, Secondly to provide insights on implementation challenges of experiences in the industry to date. Both objectives will be answered though the following research questions:

RQ 1: How could blockchain tracing be a managerial tool in making decisions about suppliers and progressing towards meeting UN sustainability goals?

RQ 2: What are the challenges in applying blockchain tracing technology in a company's supply chain?

1.4 Delimitations

This thesis focuses on the implementation of blockchain tracing in the textile/fashion industry and not other industries that might be of interest such as food supply chains, aviation or other industries identified by Dutta et al. (2020) claim could benefit from BLT implementation. Our study will be limited to the aspect of the manager perspective and not focus on the more technical aspects of blockchain implementation such as deeper system theory or coding behind BCT, rather an overview of terms and technologies needed for managers to be able to get an understanding of how the technology works and practical implementations.

The study focuses on the sustainability aspect based on UN SDGs of supply chain management and managerial challenges from an organisational level.

1.5 Outline of the Thesis

This thesis consists of seven chapters with the first one being this introduction Chapter 1 that explains the overall purpose and aim of the paper, including delimitations and this outline. The purpose of this chapter is to give the reader an overview of what the thesis is about and bring to light the research questions that we are trying to answer in this paper, and explaining to whom this paper will be of value to.

The second part is the background Chapter 2 with the aim to create an explanatory theoretical frame that will help the reader understand the subsequent chapters. This chapter aims to increase the readers familiarity with the concepts described (see table of contents). Following this will be the methodology part Chapter 3 that explains the methods used in this thesis in our literature review and interview study, and the limitations of our methodology.

Furthermore presentation of the literature review Chapter 4 where we present a more in-depth review of the current literature on blockchain tracing in the textile industry. Later we present the interview study Chapter 5 that consists of the findings from interviews with experts and industry professionals. The aim in this chapter and the preceding chapter is to present the data found in an objective way.

Finally in Chapter 6 we introduce our analysis and discussion of the data collected in the previous chapters answering the research question, followed by Chapter 7 where overall conclusions from this paper will be presented. Other relevant material will be presented at the end of this paper as appendixes.

2 Theoretical background

This chapter is dedicated to give an explanation of the field, context and theories used in this paper. It is aimed to give an overview of the textile industry, give background of how industry supply chains are composed from raw materials to end customers, understand transparency and traceability, further also explaining regulations that are of interest for textile managers in the context. Finally this chapter will explain the technology implementation framework used in this paper.

2.1 The textile industry

Textiles is one of the oldest manufacturing sectors and its industry is a main contributor to the global economy, in 2021 it had a value of 994 billions (Report M, 2017). However, the industry has high opacity and low transparency that might conceal inhumane working conditions, emissions and other problems along the supply chain (Agrawal et al, 2021; Rusinek et al, 2018; Human Rights Watch, 2017; Fashion revolution, 2020). One big challenge towards achieving more sustainable practices is the short lifespan of garments in today's fast fashion culture. This is caused by rapidly changing trends, colours and new collections every season (Thomassey, 2010; Fulton, 2013). As a result, countless textiles are produced daily and shipped across the world multiple times in the process of turning virgin materials into garments (Hader et al, 2022). On top of this, big challenges come with the numerous materials, the complicated processes and the long complex global supply chains that are common in this industry (Muthu,2017; Agrawal et al, 2021; Hader et al, 2022). A cost breakdown makes this complexity in garment supply chains more evident (see figure 1). All these characteristics of the textile industry and its supply chains have contributed to many scandals and tragic events such as the Rana Plaza incident (see section 1.0 for more details)(Agrawal et al, 2021). It has also been shown that the production of one kg fabric produces 23 kg of greenhouse gases (GHG) (Kumar et al, 2017).

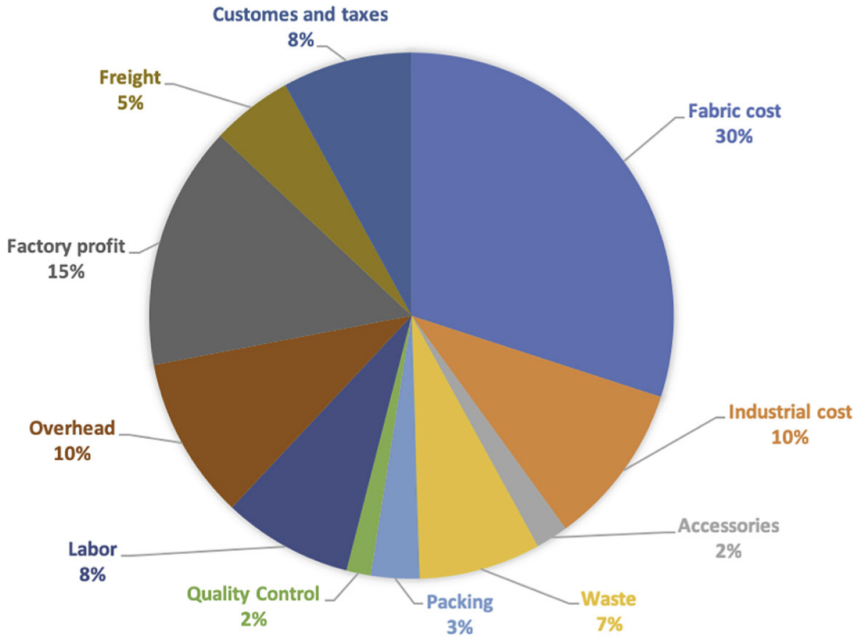

Figure 1 - A breakdown of the cost elements in garments (ElMesseiry et al, 2019)

Further on, fashion brands are usually the focal firms in textile supply chains and therefore deemed responsible for everything that occurs upstream in the chains (Agrawal et al, 2021). During the last few years have consumers become more and more aware of these issues (McCarty, 2012; Rana, 2021). As a result, the demand for ethically and environmentally produced garments have increased rapidly (Cognizant, 2018; Agrawal, 2021). Many big brands such as H&M have responded and now provide their customers with information on their suppliers (H&M Group, 2021). Several governmental and non-governmental organisations (NGOs) have tried to aid the industry by starting projects that can offer potential solutions to these challenges in the textile industry (SAC, 2022).

As mentioned earlier, there are a lot of steps involved in the life cycle of garments, from their material origin to their grave. Osber (2015) proposed the following five phases for textile transactions (see figure 2):

1. Raw material: Raw material suppliers with information on the origin of the material and its physical attributes.

2. Fabric manufacture: Here, yarn is either woven or knitted into garments. Provides information on the attributes of the fabric such as strength and humidity level.

3. Garments assembly: Fabrics are combined through the usage of design, data sheet, pattern and data about the desired garment to be made.

4. Distribution and sales: The product is marketed and sold to different actors in the network such as agents, buying offices and brands.

5. The end customer: The garment reaches its destination, the end customer.

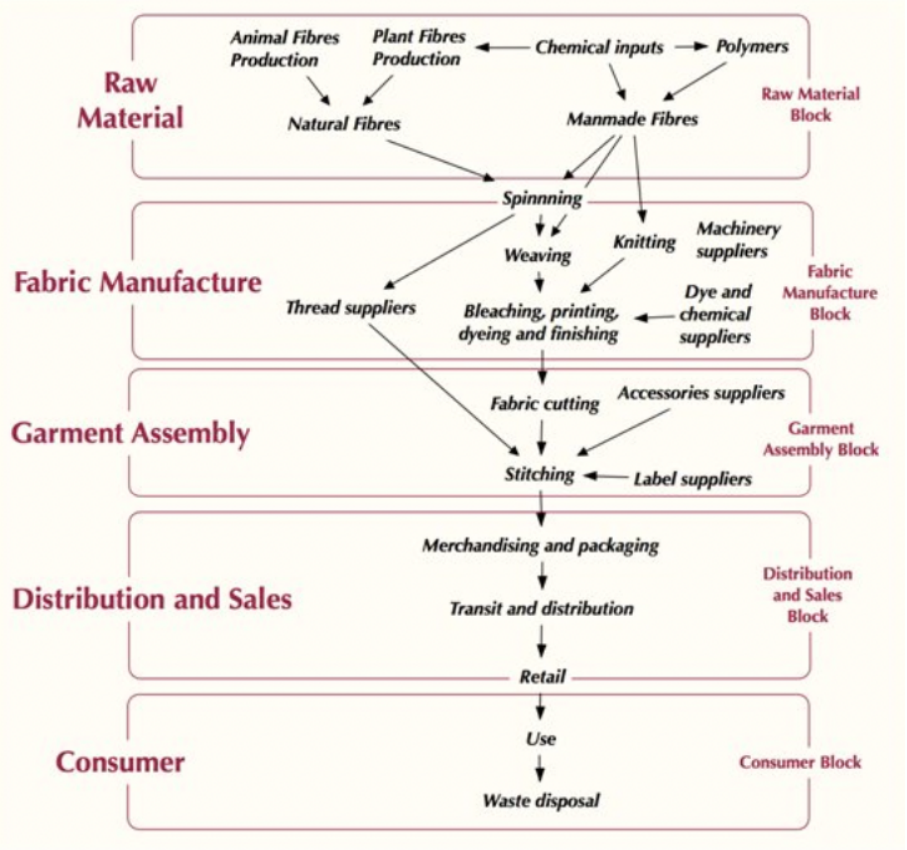

Figure 2 - The supply chain of a ready-to-wear garment (Perez et al, 2020)

2.2 CSR in the textile industry

CSR refers to businesses' responsibilities for issues that are, directly or indirectly, caused by their operations (Caroll, 1991). In practice, CSR covers not only social topics but many areas such as the triple bottom line (TBL) which entail both environmental, social and economic sustainability. There are various CSR definitions but one of the most frequently used ones is from the European commission (2001, p.1): *"a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis."*

The challenges that exist within the fashion industry (see 2.1) shows that fashion brands could benefit by improving their corporate social responsibility (CSR) in several areas (Chan et al, 2020). CSR activities in the textile industry have increased in importance during the last decade, the number of S&P Index Companies that published sustainability or CSR reports rose from 20% in 2011 to 86% in 2018 (Governance and accountability institute, 2019). One reason for this surge is the increased awareness in society, a result is that scandals have heavily affected the revenue streams at big fashion chains worldwide and forced them to adopt more sustainable practices. CSR is now common practice at most fashion brands but also a tremendous challenge.

Different firms use different guidelines on how to do their reporting, the most commonly adopted one is the Global Reporting Initiative (GRI) (Nikolaeva & Bicho, 2011). There is a lack of evaluations of fashion companies CSR reporting in academia (Yu, 2008; Kamal & Degan, 2013; Chan et al, 2020). It has been shown that a large issue is how well suppliers' code of conducts live up to international standards (Turker & Altunas, 2014). However, it is important to note that CSR reporting is a voluntary practice (Cambell et al, 2003). Companies view CSR differently, some simply see it as a competitive advantage while others are aware of its significance in terms of their long-term success. Global Fashion agenda and Boston Consulting Group (2017) have concluded that fashion companies could potentially increase their revenues with up to 160 billion if they resolve their societal and environmental risks.

2.3 The UN SDGs

The awareness that induced an increasing amount of CSR in the business world was one of the reasons why “The 2030 Agenda for Sustainable Development” was adopted by the UN in 2015. It is a shared vision for a better future and is based on 17 sustainable development goals (SDGs) that collectively serves as an urgent call for action by all countries. The SDGs also emphasise that deprivations, strategies and sustainability issues must go hand-in-hand (UN, 2022). The goals focus on solving different global challenges, everything from poverty to partnerships (see appendix A for a list of all the SDGs).

The UN SDGs are important as they act as a blueprint and shared agenda for future peace and prosperity for the planet and its population (Hughes et al., 2019) emphasising business practices that favour the planet as a whole. In the collective effort to reach SDGs, software plays an important role as Calero, Moraga and Garcia (2022) identified it as a key factor in global sustainability efforts. Hughes et al. (2019) found that BCT has the potential to contribute to several SDGs within a number of industries. In a textile industry context this could be relevant relating to work, economic advancement and the growth of the industry as low paid workers often are exploited by middlemen and 3rd party suppliers, at times unknown by the contracting organisation. The transparency of transactions and immutable

characteristics of BLT can enhance wage protection and reduce exploitation amongst workers (Hughes et al., 2019)

2.4 Transparency and Traceability

"Greater transparency empowers consumers to make better- informed consumption choices, as they have more reliable information about the sustainability and circularity claims about products and processes. As a result, traceability and transparency have great potential to build trust among all industry actors." (United Nations, 2022, p1)

Transparency is often used without a definition (Gartner et al, 2018). However, it is viewed as a tool with the potential to eradicate asymmetries in the information that different actors in supply chains have access to (Human Rights Watch, 2017). A possible definition in a supply chain context is provided by Harbert (2020) is that it is about visibility by identifying and disclosing information. The term often is viewed as positive and as an emancipator that can solve a wide range of issues (Mol, 2010).

General sustainability awareness, CSR and the SDGs within the textile industry have made traceability more important than ever. Nowadays, customers want to know who, where, when and how a product has been manufactured (Pigny et al, 2007). That is where traceability comes in, it is defined as*"the ability to identify and trace the history, distribution, location and application of products, parts, and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labour (including health and safety), the environment and anti-corruption"* (United Nations Global Compact and Business for Social Responsibility, 2014, p.6).

Academia has not fully followed this trend since the literature on the area lacks empirical basis and defines transparency inconsistently (Egels-Zandén, 2015), particularly in the textile and clothing industry (Perez et al, 2020). The result is limited transparency descriptions on companies' supply chains, which is unfortunate since there is a clear need for transparency in the complex supply chain of garments (see section 2.1). Both supply chain traceability and transparency are core priorities in order for textile companies to achieve sustainable supply chains (Jordan & Rasmussen, 2018).

2.5 Legal policies and regulations

Even though the UN SDGs are not of mandatory nature, they have induced support for increased transparency and traceability in supply chains through new policies and regulations that are being passed by governments around the world (Goswami, 2014). One example of such is the new Norwegian transparency act that "require companies that sell products and/or services in Norway to carry out human rights due diligence in line with the OECD Guidelines from July 1st, 2022". It forces large companies to transparently provide the public with information on how to follow up their CSR and requires them to identify and solve negative impacts of their business (Worldfavor, 2022).

Additionally, several institutes and voluntary organisations have created guidelines that favour traceability in certain sectors such as the Italian union of chambers of commerce that encourages traceable supply chains in many sectors (Gobby & Massa, 2015; Hader et al, 2015). Another example is the Dutch government with the Dutch Child Labour Due Diligence Act. The act requires businesses that sell products and/or services to Dutch customers to investigate whether child labor occurs in their supply chains. If that turns out to be the case, they must combat it and send out a due diligence statement with information on their investigation and plan of action (Business & Human Rights Resource Center, 2022; Hoff, 2019).

Another example is the Garment Worker Protection Act by the state of California which will ensure that garment workers in California are paid hourly and not by piece rate. It will hold brands accountable for labour rights violations all along their supply chains, including outsourced suppliers (Garment worker protection act). On a larger scale, the European Union (EU) created the Non-Financial Reporting Directive (NFRD) in 2014. The NFRD requires large companies to publish information related to social matters, workers rights, diversity, anti-corruption, human rights, bribery and environmental matters. This is thought to aid stakeholders to evaluate companies based on their non-financial performance (European Commission, 2022).

Krajewski, Tonstad and Wohltmann (2021) explain that some of these new laws and policies impose new due diligence requirements for companies, with the scope to promote human rights, decent work conditions and reduce environmental damages. New information and reporting requirements include that organisations need to be transparent with risks in their supply chains and include plans of how to mitigate these risks as well as made publicly available on the companies website (Krajewski et al, 2021). In conclusion, there are several new regulations that focus on transparency and traceability. This pro-traceability environment has given birth to many innovations, one such is the use of distributed ledger technology

(DLT) to enable verification of products. That is what fashion brand Babyghost did with one of their collections that they showed during the Shanghai Fashion Week in 2017 (Perez et al, 2020).

2.6 Blockchain Technology

One way to mitigate these risks would be through the use of blockchain technology (BCT). It is a type of distributed ledger technology (DLT) (Nakamoto, 2008) and is best described as a distributed ledger that maintains a secure record of all the transactions in a network/supply chain. Originally, BCT was introduced by Nakamoto in 2009 where he defined it as a new technology to develop data structures and encoding transaction information (Nakamoto, 2009). Nakamoto invented BCT to enable the well-known crypto-currency bitcoin and the technology has since then been a base that various online currencies depend on (PWC, 2022). However, the technology can be used in other areas as well, a notion supported by Lu (2018, p.2) who stated: *"Blockchain technology is not limited to crypto currency and capital markets. It also conducts in-depth practice on smart contracts, network security and privacy, and other applications and platforms"*. One of these areas is the textile industry where the technology has gained traction during the last years. Many entrepreneurs have built their businesses around this new interest and have created blockchain solutions that they provide to fashion retailers, examples of such platforms are Everledger, TrusTrace and FiberTrace (Everledger, 2022; TrusTrace, 2022; FibreTrace, 2022) that offer ready to use solutions.

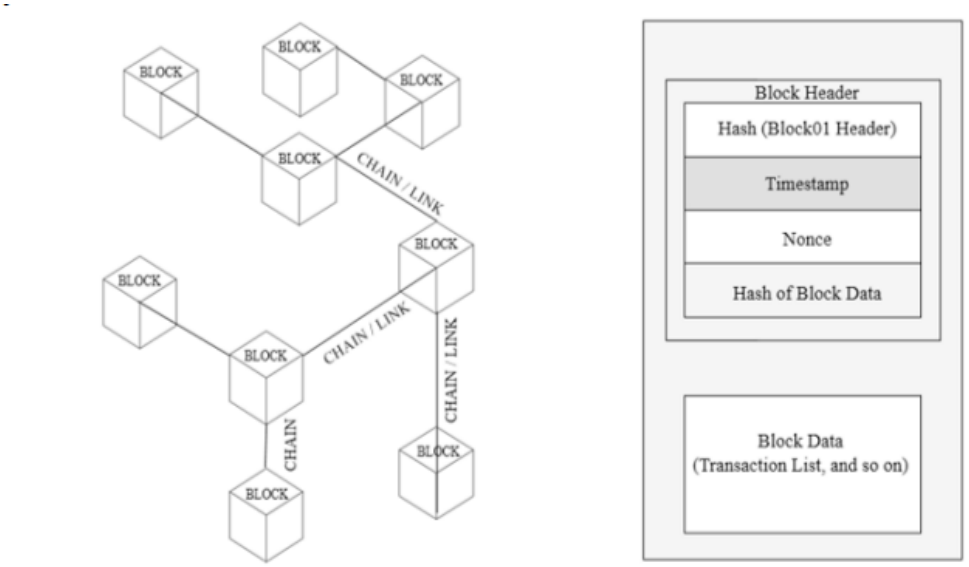

Figure 3 - Structural parts of a blockchain DLT network (Pal & Yasar, 2020).

All platforms have DLT systems with different types of networks, however, all DLT networks have a similar structure. They are maintained by a network of nodes that executes and records all entries, that is why any node/participant in a public blockchain network can read the transactions (Pal & Yasar, 2020). Figure 3 illustrates how a blockchain DLT network is structured. In its simplest form, blockchain technology (BCT) is a way to track and store information in a series of data blocks that are linked together in a way that only allows the sender and the participants in the chain to view the information that the blocks contain.

There are generally two main applications that fashion retailers and other actors in fashion supply chains have for blockchain tracing solutions. First, to tackle counterfeit products and fraud. Second, to ensure and improve sustainability performance (Ahmed & MacCarty, 2021). No matter which one of these applications that the system is used for, other information than transactions can be stored though DLT. The entries could represent anything that can be expressed digitally such as contracts, assets or identities. As can be viewed in figure 3 above, the data inputs/transactions are time stamped and divided into the blocks where each has its own code/cryptographic hash. The blocks are then placed in a line where every block references the hash of the previous block, that is how a "block-chain" is formed (see figure 4) (Agrawal et al, 2021; Perez et al, 2020; Pal & Yasar, 2020). The addition of new transactions/information in the blocks needs to be agreed upon by the participants. Once information has been added to the chain, it cannot be edited (Hader et al, 2021; Pal et al, 2020). This connection through the hashes results in that any changes of the information in a certain block would alter all the following ones which makes it quick and easy to locate blocks that might have been tampered with (Agrawal et al, 2021). Therefore, BCT has great potential in solving trust issues between parties since it has the characteristics of high reliability and high confidentiality (Chen et al, 2020).

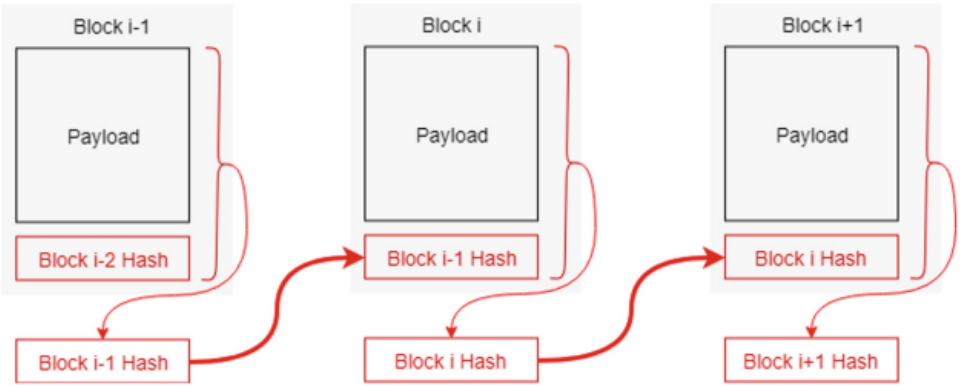

Figure 4 - A conceptual illustration of a blockchain (ElMessiry & ElMessiry, 2018)

The key characteristics of BCT, decentralisation, transparency, traceable and unforgeable transactions, anonymity and credibility, makes it attractive to a lot of different industries and businesses, including textile (Lu, 2019; Schmidt et al, 2019). Creating these time stamped

data blocks of all transactions in the supply chain of , e.g. a t-shirt, could enable consumers to trace items from their origin to the store. This would eliminate the consumers' need to rely on labels that could be misleading and it would enable retailers to hold their suppliers accountable to a higher degree than ever before (Agrawal et al, 2021; Pal & Yasar, 2020).

Further on, there are four important components in blockchains: Distributed shared ledger, smart contracts, permissions and consensus algorithms (Agrawal et al, 2021). A distributed shared ledger is a ledger (record of transactions) that records all transactions occurring between multiple parties in a blockchain. As mentioned above, an additional feature of blockchains is that changes in one block affects all the following ones in the chain. It enables blockchain ledgers to be immutable, which means that the record of transactions that are saved in individual blocks can not be changed since they are binded by cryptography (Swan, 2015). This binding is made through functions that turns the information in each block into a number, combines with new data and turns it into another number without a clear pattern. It is usually referred to as a one-way encryption since it is extremely hard for outsiders to turn the numbers into the original information. Especially so, in a distributed ledger which only records each transaction once. Further on, the ledger is of great importance in a blockchain since it contains a record of all information that has been traded since the chain was created and therefore serves as a source of truth for all parties. It therefore creates transparency and trust among the parties involved in the chain (Gupta, 2018; Swan, 2015; Agrawal et al, 2021).

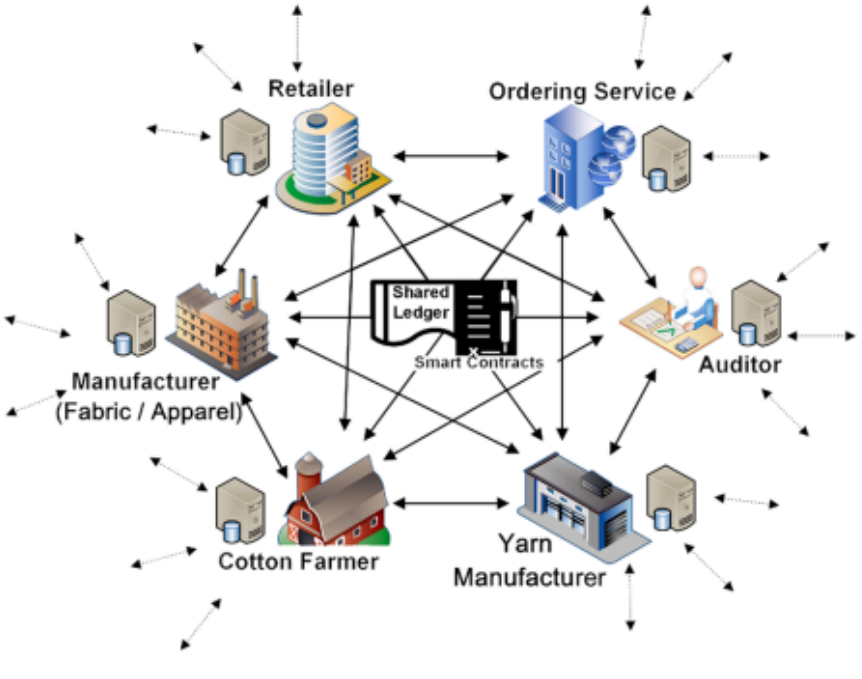

Figure 5 - An illustration of a blockchain-based decentralised network for information sharing (Agrawal et al, 2020).

Smart contracts normally contain the rules for business transactions and are programmable terms with extremely strict implementation (Fu et al, 2018). These terms are agreed upon in advance by all nodes/actors in the network. When new transactions occur in the supply chain, the contracts ensure that they are verified against the rules before they are added to the shared ledger (Luu, Chu, Olickel, Saxena, & Hobor, 2016). In practice, this means that each node is updated based on the results the contract shows after the verification (see figure 6). This process offers great potential to control decentralisation (Fu et al, 2018). At large, there are two common methods used in BCT. First, the Account/Balance model where each ID of the actors in the chain is viewed as an account with a balance. Transactions between different accounts are only confirmed and recorded in the chain when the value of the sender's account is equal or higher than what shall be transferred in the transaction. Second, the Unspent Transaction Output (UTXO) model where there are no accounts associated with the actors in the chain. Instead, transactions are inductively trading and spending the outputs that were created by all previous transactions (Agrawal et al, 2021; Zahnentferner, 2018).

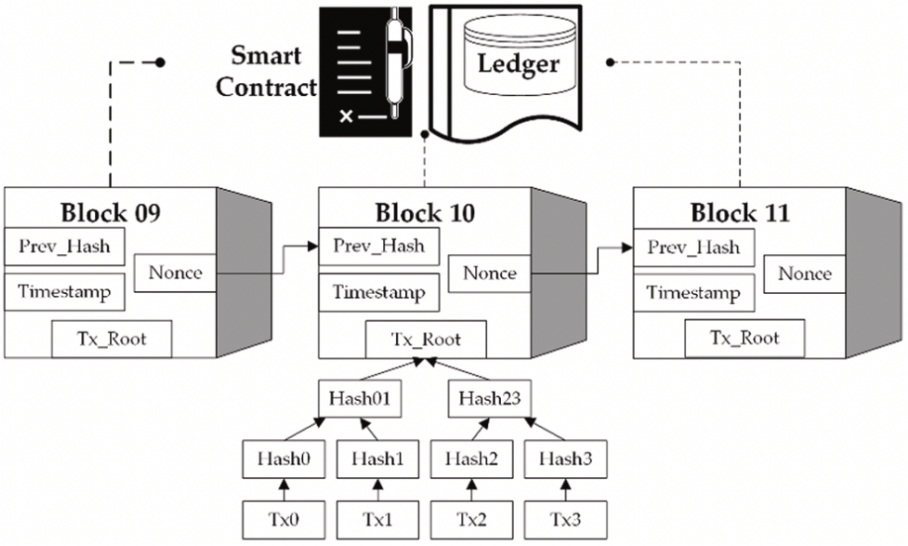

Figure 6 - An illustration of a blockchain application that shows how smart contracts influence the chain (Agrawal et al, 2021).

There are different types of BCT networks that decide the permissions that the different actors in the supply chain have to access the ledger data. These are generally either private, public or consortium networks. Private networks often contain known actors that have some level of trust among themselves. Every actor has an identifier that determines the type and extent of their access to the data in the BCT network, the private identifier is only known to its owner.

That is why this type of network has high control of the information that exists on the network's shared ledger. Public networks, on the other hand, are open to everyone (the public) and anyone with internet access can take part in the network and perform transactions. Consortium networks choose certain actors to be in charge of the validation process while the access to the ledger can be either private or public (Buterin, 2015; Farah, 2018).

The last important part in BCT is how the different blocks are logged in the ledger, it is the consensus rules that decides how information is saved in the blocks (Agrawal et al, 2021). These rules are agreed upon in advance and are designed to ensure that all new blocks are correct. There are various types of consensus algorithms, the most used ones are:

- Proof of Work (PoW) is an algorithm that initiates a probabilistic competition that requires a lot of energy and computational power (work) to solve. The one that solves the problem first is the winner and is able to validate the next block. Even though the puzzle is hard to solve, it is easy to validate for all the other nodes in the system. This consensus rule is used by bitcoin and other cryptocurrencies to process transactions since it is very safe(Hader et al, 2022; Kang et al, 2016; Wang et al, 2019) . However, PoW could be challenging for businesses to implement, since it is costly and has high latency (He et al, 2019).
- Proof of Stake (PoS) is an algorithm where the node that will be able to validate a block is selected randomly, the likelihood is greater for nodes that have higher value in the system. This results in PoS requiring a low amount of energy; the algorithm was in fact designed to solve the large energy waste that occurs in PoW (Hader et al, 2022; Kang et al, 2016; Wang et al, 2019).
- Proof of Authority (PoA) is an algorithm that selectively gives the ability to validate blocks to a select few nodes in a network. As a result, it requires low amounts of energy just as PoS. It does, however, limit the number of validators (Hader et al, 2022).

On an endnote, it is important that a blockchain tracing system has a way to avoid a Byzantine fault, an insertion of wrong data into the distributed ledger. A solution could be to verify every transaction through the current data in the shared ledger before the data is added to a block. This verification can be done by a single or multiple nodes in the blockchain. (Castro & Liskov, 2002; Agrawal et al, 2021).

2.7 Technological adoption

In order to understand implementation and adoption of a technological innovation such as BCT, Smith (2015) states the necessity to understand that a key aspect of innovation is the way in which new products and services are adopted by potential users. Several theories exist today in academia in the direction of adoption, a major contributor to this field is Rogers

(1962) Diffusion of innovation (DoI) theory, with the aim to explain why, how and the rate at which new technology is spread by categorising adopters as innovators, early adopters, early majority, late majority, and laggards (Figure 7), and used to describe the rate these innovations are adopted and come to general use (Smith, 2015).

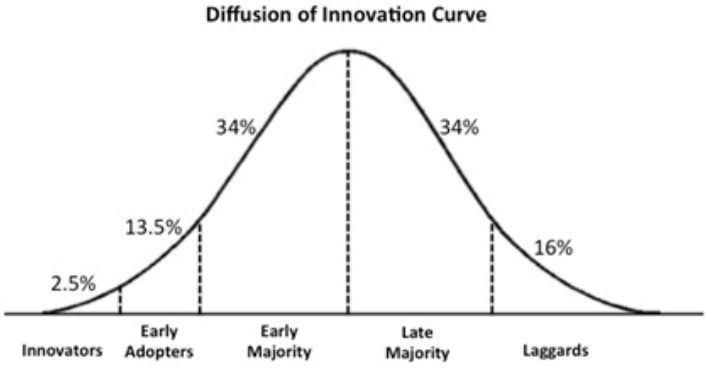

Figure 7. The Diffusion of Innovation Curve (Rogers, 1962).

DoI theory aids in examining adaptation but is mainly a linear process not taking into account other factors that are relevant in complex systems (Malik et al, 2020). In contrast, the TOE (Technological - Organisational - Environmental) model introduced by Tornatzky and Fleischer (1990) provides a useful analytical framework that can be used for adoption of different types of IT innovations (Oliveira & Martins, 2011). Taking into consideration other organisational theories, TOE provides a better foundation when explaining organisational adoption of new technologies and most theories in the field today are considered variants of the TOE framework as argued by (Malik et al.,2020) as it overcomes or supplements shortcoming in other existing theories, a view further shared by Baker (2012) describes how the TOE framework has been widely used in adaptation studies of emergent technologies, therefore the TOE framework is deemed relevant for Blockchain tracing implementation in a complex context such as the textile industry from an organisational standpoint and has a solid theoretical basis, empirical support, and widely used in information system adaptation studies (Oliveira & Martins, 2011). With regards to the novelty of the field studied in this paper there are limited models used in the context of blockchain implementation. Malik et als (2020) study on Blockchain implementation in Australian organisations further developed the TOE model in a blockchain technology context (figure 8) by adding BCT-related variables into the TOE models three main contexts (Technological, Environmental and Organisational) (Malik et al., 2020).

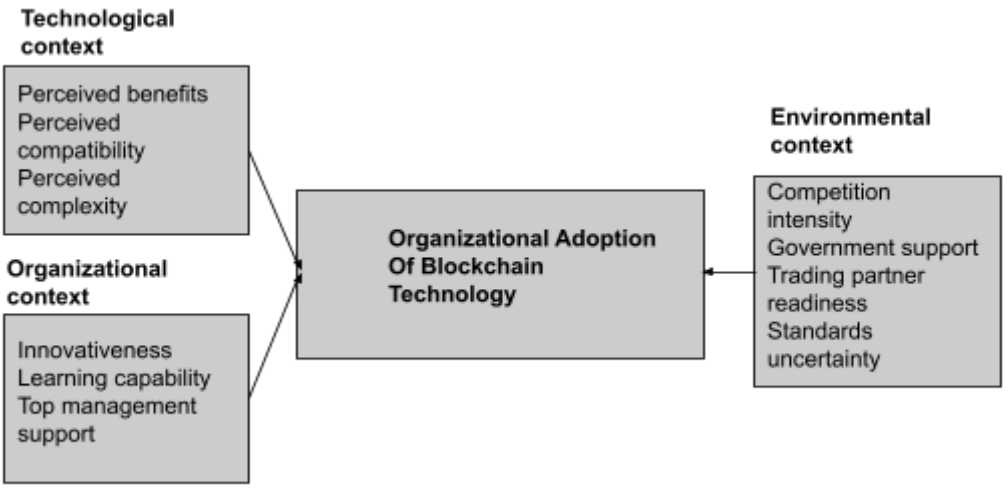

Figure 8. Blockchain adoption model (Malik et al, 2020, p.6) developed from TOE model (Tornatzky & Fleischer, 1990)

3 Methodology

This chapter is a detailed description of the research methodology that was used to gather the information in the following chapters. This report gathers data from two sources. The first source is a literature review that is designed to get a theoretical overview, inspire the theoretical background chapter of the thesis (see chapter 2) and gather data on blockchain implementation in the textile industry as well as act as a help when formulating the interview questions. The second source is a number of semi-structured interviews with people actively involved either with blockchain tracing implementation (managers) or the technology behind it (blockchain experts)(see 3.3.2 for more details). Finally, the reasoning behind the data analysis as well as the validity, reliability and limitations of the methodology are described.

3.1 Research Approach

Before beginning with the research design it is beneficial to clarify the approach that will be used for the research (Sue & Ritter, 2012). However, before doing so, Sheard (2018) argues that a good start is to gain a deeper understanding of the data that needs to be collected. As stated earlier, Blockchain tracing in supply chain management is a field in its early stages. The result is a low amount of available literature on the subject, especially when it comes to research on how textile managers can implement blockchain tracing systems (see section 1.1). Therefore, this thesis is using an exploratory inductive qualitative research approach. The choice of such an approach will be explained in the following paragraphs.

The lack of a theoretical background in this field led the authors to choose an inductive approach for this paper rather than an deductive or abductive approach. Is believed to be best suitable to achieve our aim and objectives. The deductive approach was considered to be less suitable for this study since it depends on an existing theoretical background and then tests if it correlates with the collected data (see table 1). Another reason for this choice is that the authors believe that the contribution to the field would be larger by looking at empirical findings to develop a model specifically for blockchain implementation in the textile industry (Brito & Laan, 2010; Saunders, Lewis & Thornhill, 2012). The abductive approach is similar to the inductive one since both base their conclusions on empirical studies but due to that it aims at furthering an existing theory, inductive were viewed as more suitable since a new model was to be developed.

At large, there are two general types of research: Quantitative and Qualitative. Quantitative research mainly focuses on collecting large amounts of data while qualitative research prioritises collecting high-quality data (Berk, 2015). A preliminary evaluation of the chosen field was conducted and concluded that there was little data available in both academia and in practice since few textile companies have implemented blockchain tracing. With this as a base, the authors of this report decided to focus on a qualitative research method.

Table 1 - Clarification of the differences between abductive, inductive and deductive research approaches (Brito & Laan, 2010).

Reasoning	Departing point	Aim	Drawing conclusions
Abduction	Empirical observations (unmatched by/deviating from theory)	Developing new understanding	Suggestions (for future directions, theory/paradigm/tool)
Induction	Empirical observations (theory is absent)	Developing theory	Generalization/ Transferability of results
Deduction	Theoretical framework	Testing/evaluating theory	Corroboration or falsification

Following the two research approaches chosen above, there is one remaining. The choice between exploratory, descriptive and explanatory research. The characteristics of the field along with the choice of an inductive and qualitative approach resulted in an exploratory approach. Exploratory research strives to form hypotheses and/or to clarify concepts rather than to test them and their data is often qualitative. Another choice could have been explanatory research which typically is used to figure out why phenomena occur and the research hypotheses generally specifies the characteristics of the relations between the variables that are focused on. This type of research approach was considered less suitable for this thesis since it focuses on the “how” in blockchain tracing implementation (Sue & Ritter, 2012).

3.2 Research Design

This study employs a multi-method approach to investigate how blockchain tracing can be implemented in the fashion industry. It enables the data to provide a more comprehensive view of the topic that is more likely to provide a more in-depth understanding than the single method. Further support to this choice is the fact that it is a common method within the field of supply chain management, circular business models, sustainable supply chains and blockchain adoption (Huynh, 2021; Chan et al, 2020; Caldarelli et al, 2021). The two chosen

methodologies are a literature review and semi-structured interviews, the following two paragraphs will describe why these were chosen.

First, the literature review. It is one of the most common methodologies within academic research since it is stable and can be replicated relatively easily in comparison to other methods such as for example case studies. Another strength is its exactness due to the fact that it clearly states all important information in the references. Lastly, it enables researchers to choose the language, country of publication, publication year and so on which gives the research broad coverage (Yin, 2003).

Second, semi-structured interviews. Yin (2003) describes two strengths of interviews. First, that they can target and focus directly on the chosen topic. Second, that they are insightful since they provide perceived causal inference. It is important to note that there are two other interview structures that are frequently used, structured and unstructured interviews. The reason why semi-structured interviews were chosen is because they allow the interviewer to adapt to the interviewee and therefore gather more information than what would have been possible with structured interviews. In addition, the interviews still have a clear base structure with the main questions and the topics of interest that the researchers want to gather which makes the method more replicable than unstructured interviews.

This choice of semi-structured interviews also allowed the researchers to adapt to if the interviewee was a blockchain expert or a manager, the ad hoc questions to the different group were quite different. Appendix C shows the participant list and how the data was collected, the interview guide that the researchers used can be found in Appendix E. For more information on this process see section 3.3.2.

3.3 Data Collection Method

This paper collects both primary (interviews) and secondary (literature study) data. Creswell and Poth (2016) argues that interviews are better to gain a deeper understanding of processes since they generally collect more in-depth information in comparison to research methods that collect simpler information through text or numerical data. This in combination with the fact that the chosen field still is in its early stages and low amounts of data can be found (see 3.3.1) resulted in that the primary data was collected through semi-structured interviews. This type of interview was selected since it gave the interviewed participants of this paper the opportunity to speak more freely about the topics they feel are relevant and important (Bell, Bryman and Harley, 2019).

3.3.1 Literature review

This thesis starts off with a literature review based on two goals. First, to provide the authors and the readers of this report with a sound background and understanding of its focus areas: Blockchain tracing, the United Nations (UNs) sustainability goals and challenges in the textile industry. Second, to gather data that can be used to answer the RQs (see chapter 4.0). Tranfeld et al (2003) suggested a five phase structure to conduct research, this method was applied and used in the literature review. The five phases are:

1. Identification of research
2. Selection of studies
3. Study quality assessment
4. Data extraction and monitoring process
5. Data synthesis.

Phase one, identification of research, started off with a search on “Blockchain tracing textile” in Lund University's library search engine LUBsearch. The search had only 4 search results and only one of them was considered to be relevant. However, that one paper provided a lot of information on relevant subject terms that was used to continue the search. The following search string was then used to find more relevant papers and to further develop the search string.: (“blockchain”) AND (“tracing” OR “traceability”) AND (“supply chain”).

The string resulted in 86 results in LUBsearch, the titles, abstracts and content of these reports were then used in combination with expert interviews to create the following and final search string of the literature review that produced 14 results:

Search string 1: (“blockchain” OR “distributed ledger technology” OR “DLT”) AND (“tracing” OR “traceability”) AND (“supply chain”) AND (“textiles” OR “textile industry” OR “clothing”)

Since the results were very limited, the method of backwards snowballing was applied using search string 2: (“blockchain” OR "distributed ledger technology” OR “DLT”) AND (“textiles” OR “textile industry" OR "clothing”) and resulted in 11 additional reports. However, the researchers were unable to find one of these reports since it seemed to only exist in an academic book that was unobtainable.

The amount of 24 resulting reports were considered too few to provide an accurate representation of the field. That is why the original search string (search string 1) was

widened by removing the (“tracing” OR “traceability”) and forming search string 3: (“blockchain” OR “distributed ledger technology” OR “DLT”) AND (“supply chain”) AND (“textiles” OR “textile industry” OR “clothing”). That search resulted in 46 results.

Phase two, selection of studies, focused solely on selecting the papers that were the most relevant to our study among the ones found in phase one. This process was completed by first removing duplicates and then following on the inclusion criterias in (see table 3), this resulted in a final number of 28 reports.

Table 3 – The inclusion criteria and the causes for inclusion

Inclusion criteria	**Reason for inclusion**
Peer reviewed academic journals	A way of ensuring a higher level of quality in the chosen literature in comparison to books, seminars, and other sources.
Papers written in English	This thesis is written in English, and this was a way of avoiding potential misunderstandings with translations.
Published between 2015-2021	The most recent published reports were deemed to be most relevant to the topic of this thesis, therefore, only papers published 2015 were included.

Phase three, Study quality assessment, looked over the reports/papers selected in phase two and narrowed them down to a lesser amount. Here, the titles and abstracts (in some cases even the entire report) were looked through in order to determine which ones would be excluded according to the criteria in table two (see table 2). The final total amount of reports included in the literature study was thereby 17 (see appendix B).

Table 2 - The exclusion criteria and the causes for exclusion

Exclusion criteria	**Reason for exclusion**

Articles that are focused on another industry than textiles.	The purpose of this study (see section 1.3) was to investigate the use of blockchain tracing in the textile industry.
Articles that focused on other blockchain aspects than the supply chain and/or the tracing of products.	This report partly focuses on blockchain tracing in textile industry supply chains, other blockchain aspects are therefore not of interest for this paper.

Phase four, Data extraction and monitoring process, were completed by manually reading the reports and extracting the necessary information such as key results and bibliometric data. Phase 5, Data synthesis, gathers all the data and summarises it in chapter 3.0.

3.3.2 Interview study

Interviews could be conducted in a way that gives researchers a deeper understanding of the field in focus. In this paper, this is done through the access of first hand data of actors at businesses that have experience in the field of blockchain or have been involved in the implementation of blockchain tracing solutions (see subchapter *sampling* below). This thesis will include one interview study and it was designed in the following steps: defining its aim, defining the relevant target group, formulating the interview questions, conducting the interviews conducted and lastly, the responses were summarised and analysed (explained in chapter 3.4).

The aim of the interviews is to get an insight to how businesses in the industry utilise blockchain tracing to give them the ability to overlook their supply chains and thereby enable them to do their fair share of efforts to reach UNs SDGs. The selected individuals for these interviews will therefore be knowledgeable within this field and have a lot of valuable experiences.

Sampling

The authors choose two groups of participants that were of interest for the interview study. The first group *Blockchain Experts* as these would provide insights on technological aspects of Blockchain tracing. The second group used in this study were *Managers* that have knowledge or have been involved in the implementation of blockchain tracing solutions as this could provide empirical knowledge.

The authors choice of sampling was based on judgement sampling, as Sekaran and Bougie (2016) suggest that judgement sampling subjects are selected on the basis of their expertise in

relation to the subject that is studied and could sometimes be the only meaningful way to investigate. As this study had a limited time frame of 10 weeks, authors deemed it necessary to find relevant interview candidates in the limited time available that had the best chance of providing useful information. Limitations of this method is described in 3.6

The interview participants were selected and found through the following process: Google's search engine was used to find all textile businesses that currently invest in blockchain tracing. Thereafter, an in-depth review of these businesses work on blockchain tracing were conducted and then, the list of businesses was narrowed down. All remaining businesses were then contacted and the ones that agreed to be interviewed became part of this study. Authors also attended an online webinar on transparency in the textile industry and made some contacts that way. Finally the authors used their available network to find suitable interview candidates within these groups (Blockchain Experts and Managers).

The intention was to interview five candidates, due to the limited amount of time available. The final number interviewed were six, a participant list is available in appendix C. Some participants wanted to remain anonymous for this paper, in order to speak more freely about the topic, therefore a decision was made to not disclose information about interview participants; limitations of this approach will also be discussed further in section 3.6.

As a result of this they will be referred to as participant 1-6. The interviews are summarised within appendix D with the intent to not disclose participants identities while giving the readers an idea of their main points and context to the summarised information presented in table 4 in chapter five.

Recording and Transcription

As two authors wrote this paper, one acted as the interviewer while the other took notes and made sure that the data was collected in a meaningful way. The first two interviews were manually transcribed by the authors and the remaining four were transcribed with a voice recognition software called Tactiq. After each interview occasion the authors reviewed the transcripts to review the quality of the notes and transcripts, as the *interviewers should not rely on memory, because information recalled from memory is imprecise and often likely to be incorrect* (Sekaran & Bougie, 2016, p.119).

3.4 Data Analysis

Data analysis incorporates several elements (Bell, Bryman and Harley, 2019). In order to analyse the primary and secondary data extraction and monitoring process, the authors found

that a structure would help in the data analysis. Both literature review and semistructured interviews were analysed by the means of thematic analysis, as it is one of the most common approaches to qualitative data analysis (Bell, Bryman and Harley, 2019). The process was aided by the TOE model (figure 8) that acted as a theoretical lens described by Cresswell and Cresswell (2017) to aid authors in exploring phenomena that are unknown or where literature is limited on the topic. The authors used it as a starting point but not limited to the theoretical frame of reference; findings are of emergent nature based on the thematic analysis of primary and secondary data.

Literature review

Secondary data was collected as explained in section 3.3.2, the data was first read through by the authors, later further analysed after gathering key statements and conclusions using a spreadsheet. This spreadsheet and its categories was selected to find patterns in the theory applicable to answering relevant research questions, but also provide a structure that helped develop this paper. By gathering the data in a single spreadsheet, the authors could show *progressive coherence*: showing where there is consensus around a topic, but also aided in displaying *non-coherence*, that there are disagreements between different researchers (Bell, Bryman and Harley, 2019). Literature review data analysis also aided as explained by Bell, Bryman and Harley (2019) show the gap in the literature related to our research questions. The secondary data was then further categorised into sub-categories from technological, organisational and environmental context, but also other emergent categories that were of found in the thematic analysis that emerged and were of interest for the paper.

Semi structured interviews

By an initial review of interview notes and transcripts the authors were able to find patterns in the respondent’s answers and presented in section 5.0. Notes and transcripts were analysed by identifying common themes in the participants' answers. As a part of the analysis the authors looked for repetition and similarities (Bell, Bryman and Harley, 2019). As Ryan and Bernard (2003) suggest looking for themes in qualitative research analysis include: repetitions, categories, metaphors, similarities and differences but also missing data are of interest, repetition being probably the most common criteria for establishing a theme (Bell, Bryman and Harley, 2019). This approach was applied in this thesis, and it resulted in seven themes divided into four main dimensions (Organisation, Technological, Environmental and Supply chain integration) (see chapter 5). The themes are related to the chosen scope, research questions and provide the authors with a basis for a more extensive understanding of the field (Bell, Bryman and Harley, 2019).

3.5 Validity and Reliability

Validity is concerned with the integrity of conclusions that are generated from research, and reliability is a question of whether the results of the study are repeatable (Bell, Bryman and Harley, 2019). As this is a qualitative research of nature some researchers as Lincoln and Guba (1985) suggest that qualitative research should not be assessed the same way as a quantitative research instead by the level of trustworthiness, as explained by Bell, Bryman and Harley (2019) with the four criteria *credibility*, *dependability*, *transferability*, and *confirmability* in order to examine validity and reliability:

Credibility - *parallels internal validity, how believable are the findings?* (Bell, Bryman and Harley, 2019). Interview participants of this paper all receive the possibility to comment and correct misinterpretations or misunderstandings from authors and contact this by email. A copy of the final draft will also be sent to each participant.

Transferability - *Parallels external validity. Do the findings apply to other contexts?* (Bell, Bryman and Harley, 2019) The findings in this report are in the context of textile industry supply chains and managerial aspects as described section 1.2 and 1.3, of course findings could be of use in industries with similar supply chain structures and environments, but are not part of the aim of this study as explained in delimitation section 1.4.

Dependability: *parallels reliability - are the findings likely to apply other times?* (Bell, Bryman and Harley, 2019) As this study is of cross sectional nature and involves elements such as emergent technologies as blockchain, and not a longitudinal study over time, the task of measuring reliability of this paper is not possible to do with accuracy, this may be more likely for the primary data collection. The secondary data collection is deemed more stable by the authors as it involves a more systematic review of literature, following the same process described in this paper will result in similar findings, therefore the overall *stability* of this paper is increased by the choice of a multimethod data collection. The authors choice to be as transparent as possible with the process could also increase reliability.

Confirmability - *researchers acted in good faith* (Bell, Bryman and Harley, 2019). The authors have to the best of their ability tried to be as transparent in the process and have no conflict of interest when writing this paper. Additionally, information gathered is presented in a traceable way to the best practical extent, in the data sections 4.0 and 5.0 but also in appendices. Of respect to participants wishing to remain anonymous, summaries without revealing information about the interviewees identities are presented (see appendix).

3.6 Limitations

As with all research our method has some limitations. We identified the following limitations in our chosen method:

Conducting our literature review a limitation could be biassed selectivity (Yin, 2003) meaning that the authors perceived search criteria could be biassed, and in turn lead to an incomplete selection of literature. Further the chosen search string for the literature review was designed to find highly relevant papers to the chosen scope of the thesis, however, there is a possibility that additional papers could have been found if the search string would have been less specific. The authors tried to mitigate this by snowballing and also several different search strings in order to get more accurate literature. Another is built in reporting bias (Yin, 2003) in other authors' work, a way to mitigate this is to increase the amount of reviewed articles.

The choice of semi structured interviews as a primary data source also involve limitations such as response bias, reflexivity (interviewee give what interviewer wants to hear) and inaccuracies due to poor recall. As this paper was written by two authors, one was in charge of note keeping and making sure to record the interviews. This is especially true for the first two interviews as they were not recorded, the rest were recorded by digital means and transcribed with an AI tool. Directly after all interviews the authors discussed the retrieved data in order to reduce risk of inaccuracies due to poor recall (Yin, 2003).

Maybe the most relevant limitation of this study is the sampling of interview candidates, authors applied judgement sampling. A limitation of this method is that generalizability can be questionable (Sekaran & Bougie, 2016) and not generalizable to entire populations. Also the sampling size was a limiting factor. The choice to use both literature review and interviews was a way to mitigate the sampling limitations in this study.

4 Data section, part 1: Literature review

This chapter presents an in depth review of the current literature on blockchain tracing in the textile industry. This chapter together with chapter 5 presents the results from our primary and secondary data collection. This chapter summarises the results from the conducted literature review from the three dimensions of Technological, Organisational and Environmental to explain adoption challenges to answer RQ1 and RQ2, and another heading called Blockchain in the textile industry aimed to answer RQ1.

4.1 The Environmental Context

Rusinek, Zhang and Radziwill (2018) explains that textile retailers that implement blockchain solutions early on will be more resilient to industry disruptions because they will be able to trace their entire supply chain. This in turn ensures compliance on the various levels and will put them in a favourable position toward competitors as more and more organisations are facing increasing pressure from new traceability legislation.

Further the authors explain that governments can actively manage environmental risks that arise from practices abroad that conflict with national policies. For example, chemicals that are banned in Europe are used in textile processing in foreign countries and then imported into the EU, causing the same environmental and human health problems the domestic policy is aiming to avoid (Rusinek, Zhang & Radziwill, 2018).

Pal and Yasar (2020) concluded that the textile and clothing manufacturing businesses today face significant volatility, uncertainty and complexity because of the highly dynamic operating environment. Customer buying patterns have changed, they are more informed, expect higher service levels, demand mobile commerce and at the same time expect lower prices. This results in a need for customer intelligence and different fulfilment models.

4.1.1 Competition aspect

The adaptation of a transparent and traceable supply chain may enhance an organisation's competitiveness, reputation, ability to recruit and promote its sustainable products for competitive advantage (Ahmed & MacCarthy, 2021). Pal and Yasar (2020) argue that special access to capital, natural resources, trained professionals or even market access are not enough for a fashion company in order to gain competitive advantage in the current global economy. Considering this, competitiveness is based on information flows, creating own distribution networks, also product design plays a very important role within the industry and traceability could be an additional edge and reliable factor for final customers(Ahmed & MacCarthy, 2021).

Wang et al (2020) that studied a circular blockchain enabled supply chain management approach found that the regeneration of clothing and reducing waste make organisations more competitive by enhancing resource efficiency, saving total costs, improving the organisation’s reputation, and minimising environmental impact.

Taking into account the low-cost players of the industry ElMessiry and ElMessiry (2018) found that many manufacturers compromise quality in order to become more cost competitive in the market. Additionally, they found that ineffective quality management in the supply chain of textile companies on average costs 14% of the sales compared to an average of 6,5% for companies in other industries. Companies now instead seek opportunities to reduce production costs without negatively affecting product yield or quality.

Further they explain that poor quality control in the supply chain can have bigger financial impacts than expected as in the case with Indian textile maker Welspun was called out by Target for mislabeling sheets and pillow cases as premium Egyptian cotton products, which resulted in the company shares collapsing (ElMessiry & ElMessiry, 2018).

In their paper they also explain the case of American giant Walmart using information technology to limit holding large inventory instead shifting the competitive advantage of suppliers from being mainly a question of production costs to a question of costs in combination with lead time and flexibility and quality (ElMessiry & ElMessiry, 2018).

Supply chain management platforms can use blockchain technology to disclose product information and in that way companies can earn competitive advantage in the market (Choi & Luo, 2019)

4.1.2 Government aspect

Government support has been identified by several studies to have an impact on how keen organisations are to implement technology such as blockchain tracing (Choi & Luo, 2019; Malik et al, 2020), but also how government can act as a barrier in some cases (Wang et al, 2020).

Choi and Luo (2019) found that government support is important for the use of blockchain in social welfare enhancing efforts, but also brings harm to the individual organisation implementing the solution as it could affect the supply chain profitability, as investing in such a solution requires a fixed cost and a variable operational cost. This can be mitigated by government sponsorship or a taxation scheme that incentives the use of the technology, creating a win-win situation where both companies and society can benefit. In spite of this, the only form of support currently offered by governments around the world is policies and regulations (see section 2.5).

However, governmental legislations and standards have been shown to be a major factor for traceability implementation in other sectors such as the food and pharmaceutical sector (Hader et al, 2022). There is reason to believe that it could have a similar effect in the textile sector, Wang et al (2020) found that governments of emerging economies can better fulfil their environmental and social responsibilities by applying international standards such as SA8000 (social accountability standard). There are currently no standards for either transparency, traceability or blockchain tracing but they are to be expected in the future (see section 2.5).

4.2 The organisational Context

The organisational context refers to the characteristics of the organisation that implements blockchain tracing. Various benefits exist but there are many organisational barriers that obstruct the adoption of blockchain. Some factors that affect the implementation are: organisational readiness, technical expertise, digital infrastructure, scalability issues, financial resources, legal and regulatory compliance, organisational resistance, performance expectancy (Min, 2019), standardisation and security of models (Lacity, 2018).

Moggi et al (2020) found that lack of ad hoc investments for maintenance and management, a scarce commitment by middle management, insufficient understanding by company members and lack of standard are organisational barriers for blockchain implementation. Another challenge is the state of blockchain tracing technology, which is in its early stages. This results in that there are no easy-to-use platforms available, therefore, companies have to rely on experts/consultants to implement it (Mougayar, 2016). An additional organisational challenge is the lack of standardisation when it comes to blockchain implementation. It

therefore is hard for managers and employees to know how to build the system, what information that they need and other choices. Currently, each company has to start from scratch. It is as one project manager in the paper of Caldarelli et al (2021) stated: “we still do not have a universal standard but… nobody does”.

Large textile actors will likely be harder to convince into implementing since their tendency to choose marginal changes increases with size. Small firms on the other hand, are more inclined to go through with more radical changes (Hockerts and Wustenhagen, 2010; Schaltegger et al., 2016; Kennedy et al., 2017).

4.3 The Technological context

Technological breakthroughs and other changes are happening more frequently than ever before. This has resulted in a wide array of options when it comes to technological solutions and the chosen products are usually selected based on their perceived benefits, perceived compatibility, and complexity (Malik et al, 2020). Blockchain tracing falls within this category and this chapter will focus on answering on how well this technology does within these three categories.

4.3.1 Perceived benefits

Blockchain tracing is a technology with breath and has many potential benefits when it is adopted across the supply chain that authors have studied (Rusinek et al, 2018; Kshetri, 2018; Jardim et al, 2021). Down below are some of the main ones. Traceability is one of the core benefits with blockchain tracing and it is frequently used to describe its potential. Maul et al (2017) emphasised that it is the technology's ability to keep a chronological record that is crucial for its traceability. It enables the ledger to keep track of changes, identifying mistakes and noticing attempts to tamper the records (Maul et al, 2017 ; Viriyasitavat & Hoonsopon, 2019).

The security of blockchain is another one of its benefits. It has become a major challenge in our modern society when businesses want to keep their information confidential, the internet and digitization has not made it easier. Kouhizadeh et al (2019a, 2019b) concluded that blockchain offers higher security than other online solutions. Similarly, Maull et al (2017) saw that the tamper-proof architecture of blockchain technology makes it a safe and attractive option. (Prevention of confidential information leaks). The technology is even more safe through the risk control that is built into the blockchain, where all parties need to accept specific touchpoints in the network for a transactions to occur (Wang et al, 2019)

BCT could enhance accountability and trust in supply chains; it can do so through its immutable record of data that can be shared between all supply chain actors (see figure 5)

(Battva & Norrman, 2021; Agrawal et al, 2021). Transparency is another common challenge in the textile industry that blockchain has potential to solve. The openness of the network enables the actors to provide their data in a secure medium where all participants can access a copy of the distributed ledger at any time (Viriyasitavat & Hoonsopon, 2019).

An especially interesting potential benefit with blockchain is that it enables the usage of autonomous smart contracts which are computerised systems that automatically execute certain terms of a contract if the conditions are met (Wang et al, 2019; Szabo, 1997). These contracts raise blockchain from a secure data storage platform to a platform that enables automatic execution of transactions (Xu et al, 2019). Some additional benefits to blockchain technology:

- Information sharing: Improved integration and sharing of information along the supply chain (Alexandris et al., 2018). This is crucial to enable a transparent and traceable textile industry.

- Increased understanding: Better consumer understanding of the whole supply chain (Rusinek et al., 2018) since blockchain could help the consumer to trace orders from upstream to downstream (Wang et al, 2020). It would enable customers to be flexible, making more conscious choices and choose brands that live up to their expectations (Wang et al, 2020). This could speed up the textile industry's transition to sustainability since it would be beneficial for the brands and actors that invest or have invested in more sustainable practices.

- Higher efficiency: Optimal resource distribution and effective resource sharing (Agrawal, Kalaiarasan, & Wiktorsson, 2020; Yu et al, 2020) as well as increased process speed and reduced inventory at production sites along the supply chain (Wang et al, 2020). This would reduce overproduction as well as lead times along the supply chain which would benefit all actors. It would also limit the bullwhip effect which can be explained as a demand disorder that travels upstream in a supply chain and causes overproduction at the actors in the early stages of the chain (Ahmed & MacCarty, 2021).[1]

- Improved data quality: Data quality can be improved, and demand volatility reduced (Cho & Luo, 2019) as well as improved and more exact measurement indicators for environmental, economic, and social sustainability (Wang et al, 2020). These qualities could eliminate uncertainties along the chain and thereby reduce the risks for scandals.

- Innovation: Innovation boost through the removal of third parties, the possible new applications and the open source software of blockchain (Hughes et al, 2019).

- Improved traceability, transparency, and quality of the textile production and the product (El Messiry & El Messiry, 2018; Longo et al, 2019). An example would be the ability to trace the material in a product from a garment back to its cradle.

Finally, Wang et al (2020) found several areas where blockchain technology could make a difference: Data management, Resource deployment, supplier selection and development, procurement, Production and operations, Materials management in the logistics process, Reverse logistics, Supply chain control, Green product management and Reusing waste across different circular supply chains. These various areas show the versatility of the technology and its potential.

4.3.2 Perceived compatibility

Another important dimension for technology implementation is the perceived compatibility with the blockchain tracing system and the organisation in question, that is what this section will focus on.

The architecture of the blockchain tracing system has an important effect on how efficient it is to store, process and distribute data (Pal & Yasar, 2020), it needs to fit within the organisational structure of the company that plans on using it. A well-functioning IT infrastructure at all actors in the supply chain is crucial in order for the blockchain system to be fully functional and therefore enable its users to trace all upstream organisations (Bonanni, 2018).

The interaction between actors in the chain is an important but often overlooked aspect that aids in ensuring security and trust within the supply chain (Agrawal et al, 2021). Monitoring systems at all levels of the supply chain is another important aspect since it affects the information integrity and the authentication of the chain (Kumar et al, 2017).

4.3.3 Perceived complexities

Last but not least, the perceived complexity of the blockchain tracing system is paramount of its application and usage (see 3.4 and figure 7). This subchapter will focus on this topic.

There is a built in trust into blockchain systems that is not necessarily reasonable. How can one trust the information that has been shared by the actors in a textile supply chain in a centralised system? This type of system could become so powerful by its access to data that an asymmetry between actors could be created. Additionally, the data can be compromised through bribery and then will the entire system fall as a result (Tian, 2016). Another way that

the data could be compromised is through cyber-attacks that could create issues with data manipulation, identity management and confidential information (Agrawal et al, 2018).

Many different actors see scalability as a large challenge for blockchain tracing (Kohad et al, 2020). These issues are even more significant within industries that utilise a lot of information such as the fashion industry. One scalability issue is the risk of the system to bug when more and more data is added (Hader et al, 2022). Other complexities:

- Resistance to change, Govindan and Hasanagic (2018), Pan et al. (2015) and Sternberg and Baruffaldi (2018) argue that organisations ,such as fashion brands, prefer to keep their current ways of working rather than adapt new approaches or technologies.

- Conflicts of interest (Lambert & Enz, 2017) between actors in supply chains or within organisations can slow down the process significantly. An example would be if one supply chain actor focuses on selling as many products as possible while another focuses on selling high quality products, the latter would be a lot more positive to a blockchain tracing system.

- Arm's length business relationships (Lambert & Enz, 2017). Many actors in supply chains act independently and have little to none influence on each other, this means that one actor in the chain can refuse to implement a blockchain tracing system or putting in certain information.

- Lack of alignment between the systems of different actors (Abeyratne & Monfared, 2016; Sternberg & Baruffaldi, 2018; Farooque et al., 2020). If an actor has multiple customers that all use different tracing solutions, it would require too much resources for them to implement all.

These are just a few of many complexities. For example, Dutta et al (2020) mentions several additional ones such as inadequate infrastructure, lack of blockchain understanding, data storage centres and maintenance costs, data ownership, lack of top management and organisational support, trust among the actors and trained technical staff. It is beneficial to name the most common complexities to create an awareness, however, their relevance will likely differ for different actors. The mentioned complexities therefore have a second purpose besides their identification, they induce an awareness of the challenges that can arise when implementing blockchain tracing and which allows actors to proactively solve them.

Additionally, there is a need for additional software and hardware in order for any of these applications to work. There have been a number of proposals on technology that can be

combined with blockchain tracing (Pigini & Conti, 2017; Agrawal et al, 2018; Agrawal et al, 2021; Kshetri, 2018; Pal & Yasar, 2020):

- Barcodes
- Radio Frequency Identification Devices (RFID) reader
- QR-code reader
- Wireless sensors
- Secure tags
- DNA markers
- Near field communication (NFC)
- Electronic product codes (EPC)

4.4 Blockchain tracing in textile supply chains

Further on, the literature also provides some valuable insights into how the entire supply chain needs to function. This is especially important in the textile industry and its supply chains since they are particularly complex compared to others (see section 2.1).

Agrawal et al (2021) concluded that in an ideal blockchain tracing solution, every actor would be able to be in several different "chains" simultaneously. Each of these would be separated and therefore have a separate ledger. In that way could the blockchain tracing solution work in the complex net of retailers, manufacturers and other sources further up in the supply chain. Another suggestion was made by Kumar et al (2017) who argued that a blockchain tracing solution should do more than just collect data and send out data. It should plan, gather, arrange, and exchange information on each level. Continuing on a similar idea, Agrawal et al (2021) found that an agreement between the actors is necessary in order to define the most essential information that all are willing to share, one reason is that many businesses still are reluctant to share their data on a public system.

In order to scale up the use of blockchain tracing in entire supply chains and the textile industry as a whole, Sharma et al (2018) concluded that there is a need for a common standard. The present state of blockchain tracing with different solutions, platforms and supply chain agreements, issues with interoperability is a very likely issue when scaling up (Agrawal et al, 2021; Malik et al, 2018). Another important aspect is the data collection and how farmers and field workers gather and transfer data into the blockchain tracing systems, doing so faster rather than later creates a lot of benefits such as identifying bottlenecks (ElMesseiry & ElMesseiry, 2018).

Recently, the COVID-19 pandemic has shown that blockchain tracing solutions needs to enable the entire network of supply chains in the fashion industry to interact and aid each other in their response to disruptions (WEF, 2020).

5 Data section, part 2: Interview study

In this chapter we present the results from our interview study presented in table 4 below. The columns in the table represent each theme that emerged from the thematic analysis of the primary data transcripts (see section 3.4). Each row represents findings from each participant respectively. For more background information on participants see appendix D, summaries of the two blockchain experts interviews are presented first and they are then followed by the four interviews with managers. The seven themes emerging from the interviews were deemed most relevant from the authors after transcribing and analysing the data. These are presented and coded as:

Perceived benefits (T) with BLT tracing technology and in which aspects these benefits are beneficial for organisations and managers.

Perceived challenges (T) with BLT tracing technology and identified challenges by participants.

Business goals (O) when implementing blockchain tracing, resource allocation and why organisations implement blockchain.

Supply chain integration (SC) insights identified by participants when implementing tracing systems vertically in supply chains.

Industry characteristics (E) opportunities and challenges identified by participants specific to the textile industry

Need for Transparency and Traceability (E) perceived need and perception of transparency and traceability.

Laws and regulation (E) insights regarding law and regulations in the field by participants.

Table 4: A table divided into seven themes in four categories that presents the result of our interview study (see section 5.0).

Participant	**Perceived benefits (T)**	**Perceived challenges (T)**	**Business goals (O)**	**Supply chain integration (SC)**	**Industry characteristics (E)**	**Need for Transparency and Traceability (E)**	**Laws and regulation (E)**
1	-Traceability -Automation -Creating trust -"Track things in real life" -Perfect accounting tool	-Many different tech solutions -No one has fully exploited the technology	Implementation: -Retailers take the decision and then sign the rest of the businesses.	-Complex task to integrate in whole supply chain	-Driven by retailer implementation	-See benefits of the use of BCT in textile industry	N/A
2	-Tool for transparency and traceability -High safety -The technology is not the big issue	- Create an own solution or use an existing one. -Stable systems that bugs can make users lose trust. -Blockchain trilemma -To track lost validator key	-Unique DLT solutions costs ten times as much in operating costs	-How to make the supplier use the solution?	N/A	-A way to increase transparency and traceability	N/A

3	-Tool to identify and make challenges in the supply chain visible -Information -Find out things about their supply chains that they did not know before using the tracing solution	-Data visualisation, to make data for managers more understandable by improving analytical functions. -The technology is not the limiting factor	-More brands starts to see the importance, and makes it a higher priority - Goal should be clear, to help brands be able to comply with their sustainability efforts.	-Need for standardisation - Suppliers should not feel victimised or that they are "overcontrolled". -Seen an increased engagement between suppliers and brands after implementation.	-Brands struggles to find ways to comply -Smaller brands have used BCT to differentiate themselves -Bigger brands starts to implement DLT -Seen more apparent benefits in the food industry compared to textile at the moment -About 50% of Standardisation is coming from business setting the tone.	- Need for companies to understand and track their supply chain transparency -Increased transparency enables the right decisions.	-Some laws exist and new ones are coming, pushing for more transparency. -Prohibiting buying from China - Local or regional -
4	-Increased transparency -Quality assurance	-Limiting overproduction -The bullwhip	-To be transparent needs to be a	--All actors need to work together	- Customers want information,	-A desire to know the origin of the	-Different types of external support is needed

	-Data is essential	effect	goal -Clear customer info -Identifying good resellers -Great product quality	-Better cooperation with suppliers	mainly on the garment and not its origin -Third-party factories	product -Good for the long term perspective Can you truly know if something is e.g. 100% organic?	
5	-Information stays forever -Risk aversing -Knowledge of materials origin -Being ahead of legislation	-Interoperability -Standardisation -Disclosure of data -Time consuming to implement	-Competitive advantage -Greenwashing	-”Can it work on a phone?” -Could be a reward/incentive -”Who pays the cost?” -Easier the more vertical aligned a business is -Bridging the digital gap -Creating trust between all actors	-Hundreds of DLT platforms -Many suppliers in the chain -Early in implementation	-The location of the company matters	-Differences in laws for big and small companies -NFRD -Governmental sponsorship is needed
6	-Validation of data from multiple data points and if those multiple data points	-Technology won't magically solve transparency.	-There needs to be a goal of wanting to achieve real	-It is about understanding behaviour at an	- *Competitive advantage* in the industry is based on	-Need to define what transparency and	- Many new legislation. - Problem for governments to

	are matched the transaction is trusted.	- Many different ERP -Interoperability -Requires a learning curve to utilise the system	transparency -Sharing risks with suppliers -A desire to know one's supply chain.	organisational and supplier level. - It is about understanding suppliers -Having a buy-in for real data reporting	secrets and the ability to deliver products to the customer. - Barrier to enter the industry is low - 85% of cotton from China - Greenwashing going on. - Commodity merchants, maybe not prioritise transparency	traceability is in the industry. -True transparency will change the way fashion operates, shift the risk profiles of each supply chain actor	enforce -New regulation coming at the US and EU level

6 Discussion

In this chapter the main findings of the literature review and interview study are analysed and discussed in relation to chapter two (theoretical background) by addressing the purpose of this paper and discussing research questions. Main findings are presented, but also research gaps and areas for further research. At the end of this chapter there is a summary of the findings.

6.1 Answering RQ1

Managers need to make decisions concerning their suppliers since the supply chain connects them on a business level (see section 2.1 & 2.2). Simultaneously, managers also need to progress toward meeting the UN SDGs as more and more external forces pressures them to do so to some extent, for example, EUs NFRD that require managers to provide information on social matters (see section 2.3, 2.4 & 2.5). Blockchain tracing is a relatively new technology that has potential of being useful and improving many areas, the textile industry is one of these. In this section, we combine our gathered data to answer RQ1: ***"How could blockchain tracing be a managerial tool in making decisions about suppliers and progressing towards meeting UN sustainability goals?".***

Benefits of Blockchain tracing

Blockchain tracing technology has been verified by multiple sources to possess potential for inducing a more transparent and traceable fashion industry (El Messiry & El Messiry, 2018; Longo et al, 2019; Agrawal et al, 2021; Maul et al, 2017 ;Viriyasitavat & Hoonsopon, 2019; participant 1,2,3,4,5 & 6). The information sharing, more detailed knowledge, and insight into their supply chain that this entails could be used to separate trustworthy suppliers from others, pinpoint bottlenecks and follow regulations (Alexandris et al., 2018; Choi & Luo, 2019; Perez et al, 2020; participant 4). An example of the technology's usefulness in a real world scenario was provided by participants 3: "*There is currently an US legislation that strives to combate forced labour and thereby prohibits retailers from purchasing cotton from Xinjiang in China, a region that produces 85% of the world's available cotton*."

However, the lack of transparency in textile supply chains makes it almost impossible to know the origin of cotton, and therefore makes it hard for retailers to comply with these regulations (participant 5 & 6). This indicates that there is a principal-agent problem, a conflict in the priorities between two parties (Grossman & Heart, 1983), where retailers are facing sustainability pressures from society while suppliers often are unaffected by such pressures and able to focus on their success (Rusinek et al, 2018). The increased visibility that a blockchain tracing solution could bring can thereby be used by managers to make better-informed decisions regarding their suppliers but also to help them mitigate risks, buy high-quality products (participant 4 & 5). This can help the progress toward SDG 12, more sustainable production patterns, can be achieved by managers by using the additional information to select the suppliers with the most sustainable practices. SDG 3, promote well-being, as well as SDG 8, forced labour, can be furthered through selecting suppliers that have neither slave labour nor underage workers.

It could also be used by customers that struggle with a similar issue, they have to rely on certifications or product information provided by retailers when they shop and have no way to check if this information is correct (participant 4). A blockchain tracing system could be designed in such a way so that it enables customers to walk into a physical clothing store, scan a QR code on a garment and then be able to track the products path from cradle to the store (Wang et al, 2020). This technology would thereby enable customers and managers to be flexible, make more conscious choices and to choose brands that live up to their expectations (Wang et al, 2020). The buying power of the customers could then speed up the textile industry's transition to sustainability since it would be beneficial for the brands and actors that invest or have invested in more sustainable practices. As a result it would help managers progress towards SDG 8 & SDG 12.

Another related benefit is the high security that the technology has been shown to have compared to other online solutions that are available today (participant 2; Kouhizadeh et al, 2019a; Kouhizadeh et al, 2019b; Maull et al, 2017). This is important since some actors might consider this data to be confidential (participant 3) and actors might choose to not use the system rather than taking the risk of adding the data to it. These security features could thereby induce more actors to trust the system and share more information which, as described in the previous paragraph, can aid managers in their decision making (Agrawal et al, 2021; participant 3). Another related benefit is that the immutable record of the ledger is kept forever as a common truth and that the validating process when entering data ensures that it is correct (participant 5). This can further eliminate a lot of challenges that exist in supply chains such as bribery, forgery and misinformation (Hader et al., 2021; Rusinek et al., 2018). The reduction of bribery could force suppliers to improve their businesses and live up to legislation, an example would be to pay their workers. Thereby can this further the progress toward SDG 8 as well as SDG 12.

On top of the improved information sharing, the technology has been shown to contribute to improved resource distribution and faster process speeds (Agrawal, Kalaiarasan, & Wiktorsson, 2020; Yu et al, 2020; Wang et al, 2020). This can result in higher efficiency in retailers' supply chains since it can limit the amount resources that are wasted in vain through overproduction, long lead times and the bullwhip effect (Ahmed & MacCarty, 2021; Hader et al, 2021; Wang et al, 2020; participant 4). Participant 1 agreed with this view and stated that a benefit with blockchain tracing is that it could be used to "Track things in real time". Adding to this, the smart contracts that are part of the technology enables it to automate certain processes (Wang et al, 2019; Szabo, 1997; Xu et al, 2019).

This ability to track materials, information and automate processes in a supply chain therefore has the potential to eliminate or reduce several cost elements that are part of textiles (see figure 1). For example, the cost for waste that makes up around 7% of textiles' final price and could potentially be reduced. ElMessiry and ElMessiry (2018) explain that unnecessary costs can make up around 40% of the end product value. Hence, blockchain tracing has the potential to reduce the costs for all actors in the supply chain and could potentially help managers improve their financial results and therefore progress towards SDG 8, economic growth. Since less waste would mean less resources that are taken from nature but also less waste that ends up on land, water and the air. Therefore could it also help managers in progressing toward SDG 13, climate action, SDG 14, life below water, and SDG 15, life on land.

A way to comply with laws and regulations

Blockchain tracing systems can also be a way for managers to ensure that they stay ahead of legislation (participant 5). This is important since laws and regulations can have a big impact on the textile industry (Hader et al, 2022). Recently, more and more regulations have aimed at improving businesses transparency and the traceability of their products (see section 2.5). Implementing a blockchain tracing system can provide managers with information on suppliers that they can use to make better proactive decisions regarding their operations in accordance with existing laws and regulations. These decisions could then further the competitiveness of the managers' organisations while competitors that are indifferent to the laws can lose their competitiveness.

Acting proactively towards new regulations could enable managers to become early adopters and place themselves on the forefront of transparency. This could give them a strong position to face future challenges and decisions as well as give them a head start if the technology becomes more widespread. Smith (2015) presents a concept called diffusion of innovation where users of new innovations increase slowly initially and later enter a period of rapid acceleration. Managers that stay informed on new developments of relevant laws &

regulations and have visibility over their supply chain though their blockchain tracing system can thereby be quick to implement changes to their supply chain.

Better understanding of supply chains

An additional way in which blockchain tracing systems could to aid managers and reach the SDGs is the strengthened relationships between the actors in the supply chain that the technology can induce (participant 4 & 5; Hader et al, 2021; Chen et al, 2021; Rusinek et al, 2018). This can help managers to realise issues at suppliers sooner and understand if a supplier is willing to improve their operations for the better or not. In its turn, this would help managers to find suppliers that are better partners in a supply chain context and willing to cooperate to progress towards the SDGs. This is particularly beneficial for the progress of SDG 12 since it allows managers to locate more serious suppliers and thereby establish a more sustainable supply chain.

Blockchain tracing allows managers to, as participant 3 stated, "Find out things about their supply chains that they did not know before using the tracing solution". The interview study showed that a majority of the participants saw the retailers as the actor at the centre of supply chains, the one responsible and driving change (participant 1,3,4,5 & 6). However, most of the written reports in the literature review placed retailers more equally to other actors as part of a more linear network (Hader et al, 2021; Ahmed & MacCarty, 2021; Perez et al, 2020; Chen et al, 2021; Wang et al, 2020; Choi & Luo, 2019; ElMessiry & ElMessiry, 2018).

This difference could indicate that managers are too focused on their respective company and risk treating their suppliers as workers rather than partners. A blockchain tracing system can then be used to illuminate the importance of suppliers. Recognizing this issue and the potential benefits of treating suppliers more equally (Lam & Lei, 2019) can result in improved trust, acceptance and interest of suppliers to change their ways to the best of their ability. Thereby can the retailer in question and the industry as a whole progress toward more sustainable practices. Due to the textile industry's history with bad working conditions, the impact of this characteristic is believed to have the largest impact on SDG 8, decent work. However, it is also believed to further the progress of SDG 12 since the suppliers attitude towards change can become more positive when they are given more power in their role as a supply chain actor.

Industry need for transparency and traceability

During the last century, the textile industry have grown to be so complex that it is extremely hard, in some cases impossible, for managers to keep track of all suppliers in their supply chains (participants 3,4,5 and 6; Hader et al, 2021; ElMessiry & ElMessiry, 2018). As a result, some retailers such as H&M & Babyghost (H&M Group, 2021b; Nasdaq, 2016) have

started to take responsibility for their supply chains but these organisations are a minority (Everledger, 2022; Fashion revolution, 2020). With this as a background, it is likely that the textile industry will be unable to reach UNs SDGs if no changes are made and if retailers do not try to implement the SDGs into their businesses. However, these issues have recently been moved into the spotlight and have induced an awareness that transparency and traceability are needed. Considering the characteristics of blockchain tracing mentioned above, it is a tool that has the potential to induce a more transparent textile industry with more traceable garments,a view supported by participants 1,2,3 and 6. This can in turn help the progress of the SDGs.

6.2 Answering RQ2

Both primary and secondary data findings found several challenges associated with implementation of blockchain tracing, in this section our combined and gathered data is analysed to answer RQ2: "***What are the challenges in applying blockchain tracing technology in a company's supply chain?"***

Technological challenges

As the field is still novel, there are several challenges as no one has fully exploited the technology yet (participant 1). Participants 2 and 3 indicated that these challenges do not lie within the technology but rather in the way it is used. An example is the challenge with the many different blockchain tracing solutions that exist today (Agrawal et al, 2021) therefore managers face the choice of developing a tailor made solution that can increase costs as unique DLT solutions can cost up ten times more in operating costs (Participant 2) or choose an existing tracing solution. The significance of this finding is unclear as there are no published papers to our knowledge on implementation costs associated with blockchain in a textile supply chain, further studies are required to establish better understanding of the operational costs of such a system and aid managers in making informed decisions. Hence we argue that the field is still in its early stages as adopted by innovators and early adopters as described by Rogers (1962) DoI theory.

Further, supplier data today is clustered within each company using different ERP systems (participants 4, 5 & 6), and these systems in turn need to deliver data and retrieve data to the tracing system. The interoperability of these systems could therefore be of concern in an implementation as well as further standardisation of these systems (participants 3,5 and 6) and have also been identified in literature (Malik et al, 2018). Hence the choice of tracing

solution should take into account not only ERP systems internally but also consider compatibility with supplier systems along the whole supply chain. Further explained by participant 5 that the implementation is still in its infancy, and brands are still struggling to shape their BCT systems (participant 3). Most fashion retailers that have started to implement BCT have done so through different solutions which have led to the existence of hundreds of different platforms for the technology (participant 5). However, the gathered data of this report show that the interviewed managers mentioned this challenge while only few reports did. Taking this into account one could therefore argue there is a need for standardisation within the industry going forward.

Regardless of which solution is implemented, an additional challenge could be one of stability, as many different systems connected to each other can create some malfunctions, as unstable systems and bugs can lead to losses of trust in the system by supply chain actors (participant 2). Managers could also benefit from understanding the blockchain trilemma (Ledger, 2022) as explained by participant 2 that there is a correlation between decentralisation, scalability and security. Therefore, the solution should take into account each specific case since they all face different challenges and have different requirements. An example would be if a company's critical information is going to be stored in these chains, then the level of security is of higher value than the scalability aspect or how many copies of the ledger that exist (decentralisation). Considering this, results from this paper indicate that this problem can be solved in supply chain management as private and consortium blockchains exist that have characteristics applicable for textile supply chain implementation (participants 1 & 2).

Concluding, the technological challenges are important as well as the benefits to understand when looking at implementation and to have an idea of how the technology could work in an organisation's specific environment as data suggests that implementing such a system could be a challenging task without awareness of technological challenges. Results from this study indicate that it needs to be part of a large business objective or goal, as technology can not solve transparency and traceability issues on its own (participant 6).

Industry characteristics

Pal and Yasar (2020) concluded that the textile and clothing manufacturing businesses today face significant volatility, uncertainty and complexity because of the highly dynamic operating environment. The results in this study indicate that textile industry supply chains are global, complex, multilevel and in many cases opaque (Agrawal et al, 2021; Rusinek et al, 2018;Melissa J, Zhang & Radziwill, 2018). Hence, these characteristics by itself could create a challenge to organisations that aim for increased transparency and traceability by the means of block chain tracing. As explained by (participant 5) that it is a complex task as there are

many suppliers in a textiles supply chain, this makes it harder for retailers or other actors further down in the chain to know exactly what is going on in the early stages and could explain why greenwashing has become a relatively common phenomenon (participant 6).

Results from this study indicate that there is also an increased demand for transparency data in the industry. During the last few years, customers have started to request more and more information about the products that they buy, even more so when it comes to online shopping (participant 4). Since the revenue of all actors in the chain depends on their consumers, the consumers can have a large influence and role in changing the industry as a whole. This claim was supported by participants 4, 5 and 6 who believed that the customers' requests for transparent and traceable products was driving the change. The textile industry is a highly competitive industry with low barriers of entry, this increases the importance of retailers competitive advantages (see section 2.1). As Pal and Yasar (2020), Ahmed and MacCarthy (2021) and Choi, Luo (2019) as well as participants 3,5 and 6 argue, competitive advantages in the industry include areas such as information flow and traceability which conclude that it could be a factor for final customers. Hence, this shows a need for new ways to make data available and meet new customers' expectations and a challenge that managers have to consider when implementing tracing systems.

Alignment with Business goals

Implementation of blockchain tracing solutions often starts with a decision at the brand or retailer level and the system is then further implemented at all upstream suppliers (participants 1,5,6). This view was not explicitly written in any of the reports but it was present indirectly by the different authors' focus on retailers as the main users of their suggested blockchain tracing solutions. A result of the data in this paper shows that in order to implement, there is a need to define the goal with the implementation of the tracing system and communicate why the system is needed within the organisation and upstream in the supply chain (participants 3, 4 and 6). One could argue that textile company managers need to define why they want increased transparency and traceability in their supply chain and allocate relevant resources in order to achieve this. Therefore a challenge is to define and make the increased need for traceability and traceability part of companies business goals.

Another challenge from participants 3,4,5 and 6 is that managers often struggle with what transparency actually means. One reason may be that this study was unable to find an industry wide definition of transparency. Creating clear sustainability goals and definition of transparency whether if they are part of a company CSR policy or defining what the effects organisations are aiming at achieving could aid in the implementation process.

Further, the size of the organisation could also prove a challenge in implementation. Several sources in academia show that large textile companies' tendencies to choose marginal changes

increases with size while small firms are more inclined to go through with more radical changes (Hockerts and Wustenhagen, 2010; Schaltegger et al., 2016; Kennedy et al., 2017), a view that participant (3) also shared stating that smaller companies use BCT to differentiate themselves, thereof using it as a business strategy. This emphasises the need for implementation to be a clear goal for the organisation in order to create a real impact and also provide the financial resources needed (Min, 2019).

Relevant questions that managers implementing these kinds of solutions could reflect about are when aligning with business goals are: What is the overall goal with increasing transparency? Is it from a marketing perspective? Is it to give customers better information? Is more transparency coherent with the company culture? Are fashion companies willing to share the risk with suppliers of what increased transparency actually means? (participants 5 & 6) or maybe there is a combination of several of these. As Sloan (2020) describes in her theories about strategic thinking how it is about focusing on the problem, suspending solutions and testing for the real problem.

Concluding, a challenge is to define what business goal organisations are trying to achieve by implementing BLT tracing in their organisation. As previously mentioned the technology itself won´t solve transparency and traceability issues, rather it is only an integral part of a larger strategy and therefore the clearer the business goal is within the organisation but also for stakeholders as suppliers it could mitigate some of the implementation challenges.

Lack of some governmental support

Several of the interview participants as well as multiple academic sources have mentioned the importance of governmental support for the implementation of blockchain tracing technology (Malik et al, 2019; Choi & Luo, 2019; participant 4; participant 5). Regulations have been shown to have had a large impact on the implementation of traceability solutions in other sectors (Hader et al, 2022). It can impact how prone different supply chain actors are to implement the technology (Malik et al, 2019). The findings indicate that regulation is putting some pressure on the industry but unexpectedly there seems to be little information of regulations coming in producing countries or other governmental sponsorship in these countries. Participant 5 stated that governmental sponsorship is needed and participant 4 believes that there is a need for more than one type of support, partially since there are large differences in the business environments that organisations operate in. Hence this creates a problem that the implementing actor, normally fashion brands or retailers need to solve and could create a significant issue especially further up the supply chain.

Supply chain challenges

The collected data of this report indicates that supply chain integration between all parties is a necessity for successful blockchain tracing implementation in supply chains (participants 1,3 & 6; ElMesseiry & ElMesseity,2018; Pal & Yasar, 2020). As previously mentioned the characteristics of the industry make these supply chains very complex with several actors that often are geographically scattered, therefore a substantial challenge is how these actors could collaborate in order to make a BCT system work.

The findings suggest that the relationship between actors appears to be a factor. Participant 5 argued that the implementation of blockchain tracing is easier the more vertically integrated a business is, when actors already know each other. In a similar way, Agrawal et al (2021) argue that the relations between the various actors in the chain need to reach a state of mutual understanding, trust and respect. Expanding on this, a way could be through an agreement between all parties on how their collaboration should look and what information the blockchain needs in order to achieve their defined business goals, a challenge though is if retailers and supply chain partner goals do not align.

Therefore a certain degree of trust must exist between actors involved in order for information sharing to take place. In addition, the actors need to trust the blockchain tracing system itself if they are to share information that they consider confidential (Agrawal et al, 2021). If not, there is a possibility that upstream suppliers feel victimised or overcontrolled and therefore lack motivation to implement the blockchain tracing system (participant 3).

This study suggests another challenge is how the data will be collected throughout the supply chain and inserted into the blockchain tracing system. Simplicity is important, especially when it comes to the actors that are the furthest up in the supply chain as many of these are located in developing countries and do not have much resources nor time to spend on putting in data into the system, that is why the information gathering and transfer into the blockchain benefits from being very simple or even automatic (ElMesseiry & ElMesseiry, 2018). Further understanding technological differences by bringing the digital gap (participant 5) the perceived complexity (see 4.3.3) has to be low as participant 5 mentioned arguing that it should work on a smartphone and be intuitive. However, even if the solution is simple, there still is a question whether or not a farmer or another supplier would take the extra time to put in the information in the system (participant 2).

Continuing on the theme, Participant (6) described that there needs to be some type of benefits for the actors that implement the technology, one suggestion was to give actors a reward or support if they implement the technology, and who should pay the price of implementing and cost of implementation and data entry?(participant 5). Participant 6 emphasising the need for buy in at supplier level. This report found no answer to this question

other than that it is a challenge. Further investigation on this topic is outside the scope of this thesis but it is an interesting area for further studies.

An interesting connection could be the combination of cryptocurrencies with supply chains, could there be a way to incentivize upstream suppliers? A way could be by rewarding data entry with cryptocurrency as seen in solutions such as solarcoin, where users creating solar energy are rewarded the cryptocurrency “Solar Coin”(SolarCoin, 2022) or the “Helium network”, a crypto currency network (Helium, 2022) rewarding individuals sharing data hotspots by geographic position and amount of data relayed through their nodes. This user created network has reached almost 900 000 hotspots at this time. The interesting aspect of such a solution is that the cost would be shared by all the users of the network.

Finally the findings in this paper indicates that the challenge with supply chain integration could be considered a main dimension in blockchain tracing implementation in the textile industry as it is complex, emphasises the need for mutual understanding between suppliers and is an area lacking in research.

6.3 Summary: Answering research questions

RQ 1: How could blockchain tracing be a tool managers can use when making decisions about suppliers and aid them in making better decisions toward meeting UN sustainability goals?

The characteristics of blockchain technology such as immutable distributed ledger, security and decentralisation could aid in creating a more transparent and traceable supply chain. In this paper we found that transparency and traceability is an important aspect in working towards UN sustainable goals. Adoption of a blockchain-based traceability system is one of the possible solutions to address these challenges and ensure seamless information sharing among supply chain partners.

Findings indicate that SDG 12 (“Ensure sustainable production and consumption patterns") to be the one goal where blockchain tracing has the most potential to be impactful. Especially in the textile industry that has a history of material waste, social injustices and environmental challenges. In short, there is a need for transparency and traceability in fashion supply chains if the industry as a whole shall live up to SDG 12 by 2030.

RQ 2: What are the challenges in applying blockchain tracing technology in a company’s supply chain?

As with any technological innovation there are challenges associated with the implementation of new technology. This paper highlights the complexity of these supply chains and the overall business environment, which is highly competitive due to low barriers of entry, concluding that there are several aspects that come into consideration when applying tracing solutions into a company's supply chain. The challenges include, internal aspects, supply chain integration, external factors and the ability to understand the technological aspect of the technology. The findings of challenges identified in this paper is summarised in a model (figure 9) that conclude:

- **Inside the organisation**: Business goals
- **External factors** such as Laws and regulations, governmental support, Industry characteristics, and standardisation (or lack thereof).
- **Supply Chain integration** challenges: Trust (between actors), collaboration, relationships, the cost and collection of data (how to incentivize data input).
- Understanding **technological aspects** benefits and challenges with the technology

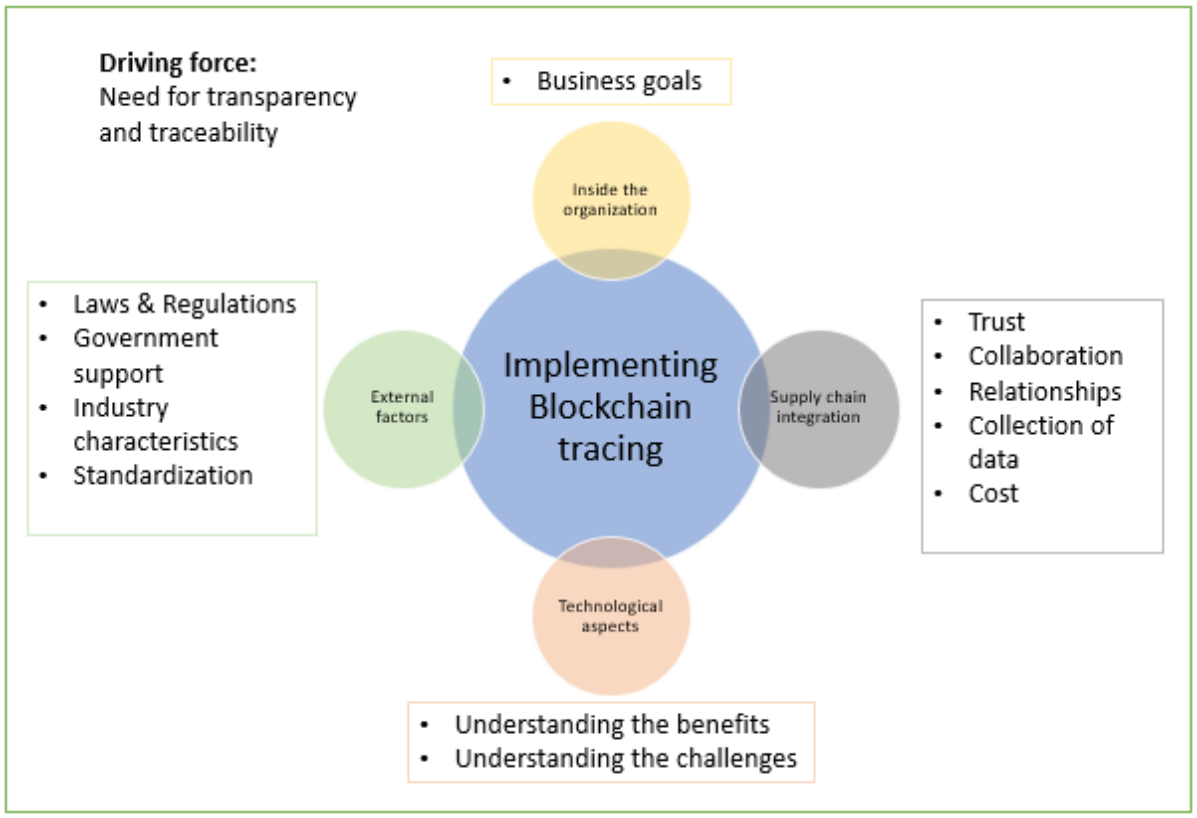

Figure 9 - Blockchain Tracing Implementation Model (BTIM) A model that describes the main aspect that needs to be taken into consideration when implementing blockchain tracing.

7 Conclusion

In this chapter, the key conclusions that emerged from the findings of this paper will be presented. Further research aim, practical implications, limitations of this study and future research identified in this study

7.1 Main conclusions

Blockchain tracing technology has been verified by multiple sources to possess potential for inducing a more transparent and traceable fashion industry. Implementing it, however, is quite a challenging task. The technology and the field as a whole is still in its early stages and provides little support to textile managers in businesses that want to invest in this technology. In addition, the results of this study show that there are more factors than just the organisation itself that are of importance for the implementation.

At the core of implementation of blockchain tracing are the characteristics of the textile industry, an industry that has grown to be so complex that it is hard in some cases to find out the origin of the materials in a garment. During the last decades, several large retailers understood the importance of finding out the answer to this and other questions regarding the supply chain and have started to take action on their own behalf. However, these organisations are a minority of the industry and the lack of regulations and standards have led to greenwashing that has made it hard for consumers to know which brands live up to their expectations. These issues have recently been moved into the spotlight of the industry and have induced an awareness that transparency and traceability are needed. This need can be viewed as the driving force behind the found development in the following paragraphs.

Laws and regulations have a big impact on the textile industry on a large scale since it is an indication to businesses and organisations on which direction future legislation will take. An indifference to these could lead to companies losing their competitive advantage and therefore market shares. It has been shown that laws and regulations have an effect on blockchain implementation in other industries and they are therefore likely to have a similar effect within textiles. Nevertheless, there are other ways in which the implementation could be furthered by external parties. It is important to note that all the external factors above are less efficient if

the implementation has no standard to be based upon. The lack of standard could lead to multiple issues and might obstruct the progress of blockchain tracing.

Nevertheless, the blockchain tracing technology has some highly interesting technological aspects. Our findings indicate that it could be used as a tool for transparency and traceability which might seem obvious since it was the aim but it did not necessarily have to be one of the findings. An additional benefit is the high security that the technology has been shown to have, higher than other online solutions that are available today. Another key feature of the technology, the immutable record that the ledger keeps is extremely beneficial in a supply chain context since it is kept forever and the process of entering data ensures that it is correct. This can eliminate a lot of challenges that exist in supply chains such as bribery, forgery and misinformation. Lastly, automation is another great characteristic of blockchain since some of its processes such as smart contracts (see section 2.6) can automate processes in the chain that currently are executed manually.

However, blockchain tracing is a technology just like all others and therefore also faces a lot of challenges. One of these is the hundreds of blockchain platforms that exist today and the various unique systems that most actors within textiles have. The findings show that interoperability is a challenge for this technology. Another challenge could be the stability that the system possesses might falter due to the huge amounts of data it needs to process when multiple chains are connected for multiple actors. Then there is also the challenge with the so-called blockchain trilemma, the correlation between decentralisation, scalability and security. Balancing these three aspects so that the characteristics suit all actors in the supply chain is a tremendous challenge since it is hard to come to an agreement with so many actors. It is important to note that the blockchain tracing technology will not magically solve any issues on its own. Businesses need to include transparency and traceability as a part of their business goals if they want to succeed in their efforts. This could also induce a competitive advantage, businesses that have the goal or the vision to embrace traceability and more open information flows. Having this data transparency as a goal has many benefits such as less waste and lagging time. The implementation of blockchain tracing technology needs a clear goal with the implementation, the company and its employees needs to know why they are doing this change. This could also eliminate issues such as managers not knowing what transparency means and what level of transparency they desire in their organisation.

Finally, the blockchain tracing technology does not work if only one actor uses it. All actors in the supply chain need to use it. Supply chain integration of the technology is therefore of uttermost importance for the success of the implementation. To begin, the improved communication between parties in the supply chain has shown to induce a more communal sense and better relations between all actors. The system is built on trust and it is therefore necessary to create it throughout the supply chain, trust in that the correct data is

implemented, that no one spreads confidential data outside the system and that all are treated equally. The research shows that another key point is how the data will be collected and transferred into this system since many actors have very limited resources and therefore are not able to spend too much time doing so. Additionally, there is the question on who should pay for the implementation? This needs to be agreed upon by all actors at an initial stage to avoid issues on a later stage. Lastly, as mentioned before, there needs to be a standardisation which supports a change towards interoperability between the many blockchain tracing systems that exist today and the countless ones that could exist in the future.

These lessons and insights into the implementation of blockchain tracing technology are aimed at textile managers that are in a position where they shall implement such a system in their organisation. As a way of simplifying this knowledge and making it more accessible, the authors of this report created a model for blockchain tracing implementation in the textile industry (see figure 9).

7.2 Research Aim

This paper aimed to create a high level overview and basic understanding of blockchain technology and how it could be of use in a textile industry context by the means of a literature review and an interview study with blockchain experts and managers involved in implementation processes. Finding common challenges associated when implementing blockchain tracing technology in textile industry companies supply chains by presenting a model that describes the main aspect that needs to be taken into consideration when implementing blockchain tracing in the textile industry.

7.3 Practical implications

This paper was intended to bring light to the potential and challenges of blockchain tracing in the textile industry. The findings and conclusion in this paper are aimed to give practical insights on technological benefits/challenges, and to understand factors inside and outside the organisation that affect implementation of BCT. Finally give an understanding of the complex task of integrating such a system throughout the supply chain. In conclusion, this paper presents an implementation model that can be used for industry professionals that are working with increasing transparency and traceability in order to work toward UN sustainable goals or other business goals in need of increased transparency. To our knowledge the first

implementation model for block chain tracing implementation in a textile context. Additionally this paper is intended to add knowledge to the field of blockchain tracing in the context of the textile industry, a field identified by the authors as one lacking in research.

7.4 Limitations

This paper was conducted during 10 weeks and is of limited scope, this is a clear limitation. The multimethod data collection used aimed at getting an accurate understanding of what implications and challenges are associated with the implementation of BCT in the textile industry to date. As BCT is an emergent technology that has gained traction during the last recent years and the cross sectional nature of this study, it is unclear how relevant these findings will be over time.

7.5 Future research

Writing this paper generated several questions that still remain unanswered by academia. As there are no larger case studies on blockchain tracing in the textile industry, there is a need for a more comprehensive case study on the topic as previously discussed by several researchers. Further research of interest could be how textile suppliers in developing countries adopt new technology as this is of importance when introducing solutions such as BLT that all actors in the supply chain adopt the solution in order to create an impact. Further research on how cryptocurrency could be used in conjunction with blockchain tracing in order to incentivize suppliers to use it. Finally there is lack of research on the topic from upstream suppliers viewpoint, as available research takes a retailer perspective. This could further aid implementation processes in the future and aid in more transparent supply chains.

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Appendix A - UNs SDG

This appendix includes the description of all UN SDGs.

Goal	Description
1	End poverty in all forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions
17	Strengthen the means of implementation and revitalize the global partnership for sustainable

	development

Appendix B - List of the papers studied in the literature review

No.	Authors
1	Agrawal et al (2021)
2	Ahmed & MacCarty (2021)
3	Caldarelli et al (2021)
4	Chan et al (2020)
5	Chen et al (2021)
6	Choi & Luo (2019)
7	Dutta et al (2020)
8	ElMessiry (2019)
9	ElMessiry & ElMessiry (2018)
10	Fu et al (2018)
11	Hader et al (2022)
12	Huynh (2022)
13	Lam & Lei (2019)
14	Pal & Yasar (2020)
15	Peréz et al (2020)
16	Rusinek et al (2018)
17	Wang et al (2020)

Appendix C - Interview participant list

Here we present a table of our interview study participants as part of our data collection.

Participant	Group	Position	Field	Duration (min)	Data	Country (place of work)
1	Blockchain expert	Software Engineer	Blockchain expert (since 2015)	60	Notes taken	Belgium
2	Blockchain expert	Senior secure computation expert	Cryptography expert (PHD)	60	Notes taken	Belgium
3	Manager	Project Manager	Blockchain tracing solutions supplier	60	Recorded	India
4	Manager	Founder and CMO	Textile e-commerce	50	Recorded	Egypt
5	Manager	Project Manager	Textile blockchain implementation	60	Recorded	Switzerland
6	Manager	COO (Manager)	Textile tracing solution supplier	60	Recorded	Netherlands

Appendix D - Summary of interviews

In this appendix we will summarise the interviews conducted during this study

Participant	1
Group	Blockchain expert
Position	Software Engineer

Participant 1 has worked with blockchain technology since 2015 doing blockchain R&D. He has been working with this technology since the beginning and sees many ways of how it could be used in different industries. He explained that no one has been able to fully exploit blockchain technology today and that the choice of technology in the case of distributed ledger technology is still "open". The participant also explained that he has not been working with projects directly related to the textile industry but he has insights of how blockchain has been used in other industries.

He further explained that the most common is enterprise blockchain technology, enterprise blockchain offers key features that make it possible for it to run on an enterprise scale as enterprises have a completely different requirement. He further explained that there is not one standard setup for blockchain.

Additionally he explained that blockchain, the main benefits compared to the traditional approaches are about traceability and automation. Things that are manually executed can be done so in a new valuable way, it is about creating trust and automating things. He could imagine that the supply chain also is extremely complex.

Moreover he explained the concept of private blockchains/application specific blockchain which is a blockchain set up for a specific purpose. If you want to track items for items that are owned by different parties, all of them need the same blockchain and create it together. People running these blockchains, most of the time a business takes the decision and then signs the rest of the businesses.

Finally he explained what blockchain is good at is not to enforce things but rather to track what is happening in real life. It can then be used to trace where the problem originated after it has been noticed, stating that blockchain is the perfect accounting tool as it is almost impossible to change previously recorded transactions in the ledger.

Participant	2
Group	Blockchain expert
Position	Senior Secure Computation Expert

Participant 2 is an expert in blockchain, a software engineer and holds a PHD in cryptography. He works at an R&D department working with blockchain on a day to day basis in a big global technological company. He has been working with cryptosystems since 2017.
On transparency and traceability he explained that blockchain amongst other DLTs are a way to increase transparency and traceability in supply chains. A big challenge according to participant 2 in implementing blockchain throughout a supply chain is how to make the supplier use the solution. Textile retailers can create their own solution or go together with other brands and create one. Additionally there is a cost involved for brands developing their own solution and operating these solutions can result in ten times the costs in engineering. Furthermore he emphasised the need of a working system as bugs and malfunctions can destroy the trust in the system, summarising that the technology itself is not the big challenge rather which tools to use and the implementation.

There are several open source solutions to build brand applications on, such as Hyperledger Fabric by IBM (Hyperledger, 2017) that could be used to track supply chains or the Corda consortium, a scalable, permissioned peer-to-peer (P2P) distributed ledger technology (DLT) platform that enables the building of applications for transparency and trust between different parties.

Additionally on the technological aspect the benefits of blockchain technology is that it is safe as it is validated by nodes (validators). The technology is also infinitely scalable, but you have tradeoffs. In a blockchain each block is based on the previous block. The tradeoff in such a system is called the *Blockchain trilemma (figure x)*, basically the tradeoff between decentralisation, scalability and security. The dilemma is to find a balance between these factors, for example increased security in the system can impact performance. Overall the technology is safe as the information is encrypted. There is a small risk for a 50+1 attack, meaning that someone could take control of more than 50% of the validators and in that case could validate transactions that are not real for example. But this risk is not very likely as it would require many different actors (validators) to conspire together.

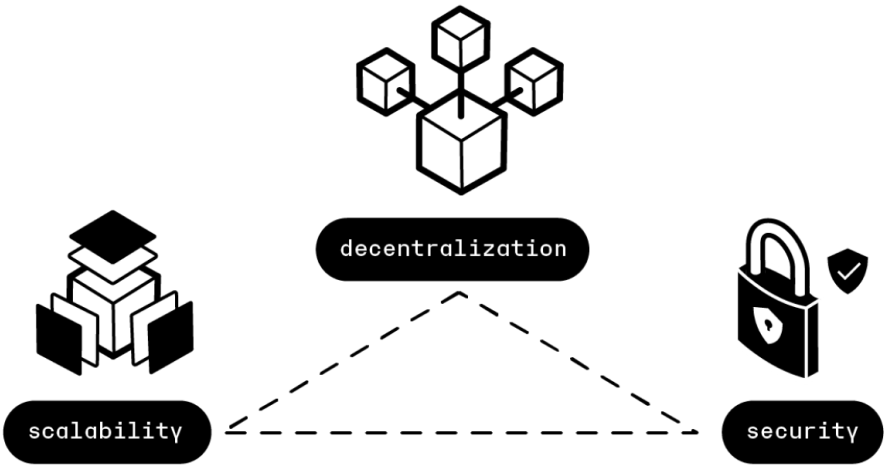

Figure X (Ledger, 2022)

Another risk is that a validator's private key gets compromised and used to validate bogus transactions, but all solutions today that want to be useful in practice have systems to counter lost or compromised keys.

A final statement from our participant is: ”As long as everyone redo everything from scratch, we will have problems. But if we build upon the work of others we can progress”.

Participant	3
Group	Manager
Position	Project manager - Blockchain tracing solutions supplier

Participant 3 works as a manager for a blockchain tracing solutions provider that has implemented tracing solutions for several customers in the fashion industry. He works as the head of development teams and has good insight on blockchain technology and implementation within the fashion industry. He explained that the initial approach they used at their organisation was to experiment with the technology and then analyse what happened afterwards.

Their organisation is active in the textile and food industry, explaining that the food industry has been a much better way to use blockchain since they can see the benefits much clearer. In the textile industry, they are still to see the benefits of their efforts but the company now focuses on the textile industry.

He explained that they work with tracking supply chains from raw materials to finished goods, explaining that new *laws and regulations* create new challenges for the textile industry, an example are new US regulations that forbids companies from buying certain materials and products in a specific province in China creating a need for companies to understand and track their supply chain in a transparent way. Many of these new laws are not on a global level rather local or regional. Most brands are now trying to figure out how to respond to these new regulations and they also expect these laws to mature in the future.

Further explaining that they are working with a brand that has 8 million transactions that they need to track, emphasising the size and complexity of the task. Many smaller brands have started to use this technology in order to differentiate themselves but now also bigger brands are starting to see the importance of *traceability* and *transparency* in their supply chains.

Additionally it is still early and there has been some pivoting in the area of tracing of supply chains but they see that a structure and standardisation is coming. This standardisation is driven by a combination of actors as it is still a young concept, new industry standards, certificates. An estimation from the participant is that 50-60% of the standardisation is coming from business setting the tone, the rest from interaction with individual customers and the rest from new laws and regulations.

Implementation of their blockchain tracking solutions takes approximately six weeks to onboard a brand and the suppliers, some projects have taken as long as two months explaining that the technology is not the limiting factor rather the aspect that it takes time for the suppliers to understand the volume of information that is needed. The approach they took to implement blockchain in supply chains is that they pick the most important projects that a customer's needs to make transparent and traceable and create a pilot project. Normally fashion brands start with the upcoming collections. When brands are onboard they can use the platform on a self-serve basis. An insight from these projects is that brands find out things about their supply chains that they didn´t know before using the tracing solution.

A challenge that they identified is that it is important not to get the suppliers in the supply chain to feel victimised or that they are being "overcontrolled". The goal should be clear that it is to help the brand in being able to comply with their sustainability efforts and that the increased transparency enables them to make the right decisions.

Another insight from participant 3 is that they have seen an increase of engagement between suppliers and brands after implementation.

Finally he explains that the next step they are looking at is to make data for managers more understandable by improving the platform's analytical functions, and they are working on using the data they already have to give managers insights so that they can identify risks in different projects when picking suppliers in the supply chain.

Participant	4
Group	Manager
Position	Founder and CMO

Participant 4 works as a Chief Marketing Officer and founder of an e-commerce fashion brand based in Egypt. They are at the moment of the interview an organisation of 65+ employees and produce their own products as well as sell products from external brands on their e-commerce platform. His responsibilities include marketing, but also overall operational management, but also overall business development decisions, production logistics, including such things as supply chain management.

Transparency is important for the brand as they want to be able to inform their customers where their products are from, and to provide information about material, composition and be transparent about which type of garment they are selling.

On *traceability* there is a challenge when it comes to external brands they sell, as they have several external brands, some are more honest than others. Some are more eager to disclose as much information as possible while other brands there is no certainty of where the garments have been sourced from. In their private label line they are more aware of where it is sourced. On a long term perspective these issues need to be solved , basically what factory is this garment made from? Who is this factory? These are things they are working on.

Further explaining that they are not where they which they would like to be when it comes to *transparency* and *traceability* and explaining that they operate in Egypt and the sustainability aspect is not the highest priority for their customers right now but seeing that especially the younger generation of customers are more environmentally concerned than previous generations and they need to work with more *transparency* to meet customer expectations, in that sense.

Another challenge in the industry is that it is easy to claim the use of organic cotton but companies are not really aware if this “organic cotton” is created at an organic weaver, it is basically a system of trust of what the supplier is saying. From a business perspective the *quality* of the product is important to trace and being able to source good producers, and it is not uncommon that quality differs from shipment to shipment from the same supplier.

The organisation is not currently using DLT to track their supply chain but they are aware of blockchain tracing and that it could be a solution for solving traceability and transparency issues. They are a tech heavy organisation and developed their own Enterprise Resource Planning Software (ERP), a software used throughout the business into one single, unified suite that takes care of everything the business needs from end to end. Here they store data about their products and the suppliers, meaning that they can trace to the supplier level, but

where the supplier's textile is woven is not always straightforward. A way to mitigate this is that they work with a smaller number of suppliers. *"The more data you have and if you have full transparency related to it, you can take a well-informed decision, knowing the consequences it entails, and this goes to the whole industry*".

From an e-commerce point of view, the more accurate data you have and can present is of value for the customer as they are not purchasing from a physical store, customers today are more informed and can give companies with more transparent data a competitive advantage, but not only about having the data is important but also how you can visualise it in a meaningful way.

Concluding, answering if he believes that blockchain could be implemented industry wide he believes that it is dependent on business priorities and companies environmental goals, if factories are held accountable for providing transparent information then the whole industry would become more transparent.

Participant	5
Group	Manager
Position	Project Manager

Participant 5 works at a major global organisation at an operational level on a *transparency* and *traceability* project regarding blockchain tracing implementation, the project involves 20 companies, with the goal of explaining how a traceability system could work in the textile industry. The project ranges from working with big fashion brands to smaller cotton farmers in remote areas. This participant's background is from management consulting, sustainability and supply chain management.

Explaining that one important factor of a *transparency* and *traceability* platform is user experience, if the underlying technology ends up in blockchain or something else is subordinated to the goal of creating a more *transparent supply chain.* The advantages with *blockchain* from a higher perspective is that, whatever you put in there stays there. It is incorruptible in that sense. So that creates a trace that, especially in terms of sustainability claims, stays there forever. Today's implementation depends if you use it to comply with legislation, or just because companies want to make some claims voluntarily.

Further explaining, the fact that it stays there forever, especially if it is publicly accessible, organisations don't really want to lie or say something that is wrong, because it can be scrutinized by governments, in theory, or by the public, like an independent investigative journalist goes into the blockchain five years from now and see that, company X says that they do a garment without slave labor or whatever, but actually the oppostite is true. Another challenge is that some brands don't want to disclose everything, if everything is made publicly available, one could in theory copy other brands' supply chains, something that brands have worked many years at developing, concluding that organisations need to decide what level of transparency they want to have.

In terms of risk management, with *blockchain tracing* one knows where things come from. And not knowing that it could be a risk, well, that is maybe okay sometimes. On the other hand, it could be a big risk in terms of supply chain disruptions, such as not having products delivered, it also protects organisations from the risk of having your final product done with suppliers that they are not completely aware of, or not really sure about, or can help companies comply with certain standards, etc that could end up in a reputational risk. Today, in some cases, it is a legal compliance risk. And which in the end turns into a financial risk. Either because organisations will get fined or because of consumers, you lose reputation. There's a lot of greenwashing going on at the moment. *Blockchain tracing* can help

companies in standing out from the crowd as they can back up their claims with a *traceability* solution.

Further participant 5 explains that another advantage of implementing early is that companies that have been experimenting with it can be part of the law making process such as the open consultation before a law is passed, and in that way help in shaping new regulation. The challenge with it is that there needs to be a system that also works for the smaller suppliers and not only for the wealthier suppliers and brands. Normally legislation being passed today has a revenue threshold for companies that are being affected by new laws. There is also a digital gap that needs to be addressed when working with smaller suppliers, they need support in order to implement.

Right now the participant doesn't see that there is only one big blockchain tracing solution that is going to be implemented by all suppliers and brands, rather many different solutions that are used by different organisations. Further emphasising the importance that platforms have a degree of *interoperability*. They are working on different API's (Application Programming Interface) in order to mitigate the interoperability problem.

Finally, the participant believes that that blockchain tracing has a future describing that blockchain tracing has been gaining momentum in the past three or four years

Participant	6
Group	Manager
Position	COO - Fabric tracing solutions supplier

Participant 6 works as a Chief Operating Officer at a fabric tracing solutions provider, and has been involved in the implementation of the solution at several textile companies. Their solution tracks garments from raw source to shelf, by using a physical unique component applied to the raw material that can be tracked and stored in an immutable database (Blockchain) through the entire supply chain. The participants' role in the organisation involves operation as well as parts of R&D and business development.

Transparency is about the output of trust. *Traceability* is the tool that creates trust that in turn leads to *transparency.* There is a lot of misconception about what the terms actually mean in the industry, and there is a need to define it better, explaining that just because you have a traceability solution or mapping solution doesn't necessarily mean that you are transparent. The fashion industry is not an industry with a vast amount of intellectual property such as other industries, the barrier to enter the industry is low. This means in a sense that the *competitive advantage* in the industry is based on secrets and the ability to deliver products to the customer. True transparency in that sense in the fashion industry will change the way fashion operates and will shift the risk profiles of each actor along the chain.

On blockchain a challenge is if there is going to be a trust in these technologies, as trust ultimately leads to transparency, but also a trust between actors is needed. Suppliers need to be ready to disclose the way they operate, in regard to raw materials, wages, working conditions or even financial information. An example is when the participant visited a supplier claiming to use organic cotton according to a certification, but once at the factory it turned out that the cotton used for producing the yarn was not organic, and that it basically was impossible to get that kind of organic cotton with that quality in that country.

Implementation requires efforts from all actors and the most important thing is “buy in”, what is in it for the individual actor? Many brands are good at marketing their traceability solution, but actually having no clue of what is going on in their supply chain. Technology won't magically solve transparency as people need to implement it in the supply chain.
Another challenge is that many companies have implemented different ERP solutions or CRM systems and there is a need for interoperability and there is a need for standardisation and governance. These software systems need to be connected, via APIs, into other legacy systems as ways to automate different processes. It is about understanding behaviour at an organisational and supplier level.

Further is the use of third party validators, some systems use this and they are important but there is a cost and integrity challenge, some third party validators have proven to be untrustworthy as well. Here the advantages of blockchain could be of use in validation of data from multiple data points and if those multiple data points are matched the transaction is trusted.

There is a learning curve in the organisations in implementing and to actually understand the complexity of how textile supply chains operate, and there is a need for understanding vertically of how suppliers' business environments look like.

There is new regulation coming at the US and EU level. There are already some regulations that for instance a US regulation prohibits companies from purchasing cotton from Xinjiang in China, due to forced labour concerns in this region. The problem is that due to the many levels in the supply chain, fashion brands cannot be sure if a supplier in Myanmar or Vietnam is not using fibre from China, and Xianjang produces 85% of the cotton that is used in garments around the world. Furthermore, explaining that brands do not make transparency data a real priority, are on a crash course to be out of business very soon. It is about intention and company culture.

Another challenge identified by the participant is that many cotton farmers sell to commodity merchants and these in turn work with all kinds of commodities. Cotton might me a small number of their entire business, therefore not prioritised. So in order to change behaviour in fashion there might be a need for change across industries.

Benefits of implementing tracing solutions for textile organisations are that you can already now prepare that you will be asked more questions in the future, but also for tracking quality, tracking goods and working conditions. The market will ultimately drive the outputs that are required by governments from a reporting and compliance perspective.

Participant 6 answered that blockchain tracing can help managers for sure and aid in making decisions from a commercial standpoint, such as quality, timing, availability and capacity. Answering the question if blockchain technology has a future in the fashion industry:
“Absolutely. I would say that, I'd reverse it, I'd say that the fashion industry has a future in blockchain technology”. Because without true transparency and without true risk sharing it is going to be an industry with constrained resources.

Appendix E - Research interview guide

Here we present the questions that were part of the interview study. As the interviews were conducted in a semi structured manner, the interviewers asked follow up questions and additional questions to this in order to get a better understanding or dig deeper into a topic.

Focus Area	**Number**	**Question example**
General	1	What is your role in the organisation and what tasks does it entail?
Transparency	2	What does transparency mean to you?
Transparency	3	How do textile companies work with transparency today?
Traceability	4	How do textile companies work with traceability today?
Transparency and Traceability	5	What are common challenges that textile companies have with traceability and transparency in their supply chains?
Perceived benefits(T)	6	Why do textile companies choose to implement blockchain?
Benefit and Challenges (T)	7	How is the implementation perceived by the employees at textile companies?
Organisational	8	How would you describe the organisational innovativeness in the textile companies that adapt blockchain tracing?
Organisational	9	How important is the management support for the implementation?
Competition (E)	10	Have many textile companies implemented or started to implement blockchain tracing?

Government support (E)	11	Have you or your textile customers received any support from any government?
Laws and regulation (E)	12	Are there any regulations that speeds up the implementation of blockchain tracing?
Supplier (E)	13	What is the most common reaction from the textile suppliers to the new blockchain solution?
Industry general (E)	14	How is the cooperation between textile companies when it comes to blockchain implementation?
Challenges (T)	15	Which challenges do you usually face when implementing blockchain technology?
General (Blockchain)	16	Could blockchain tracing be a tool managers use when making decisions about suppliers and aid them in making better decisions?
General (Blockchain)	17	Do you believe that blockchain tracing technology has a future in the fashion industry?